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Knowledge Spillovers, Entrepreneurial Ecosystems and the Geography of High Growth Firms Redux

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ABSTRACT

High-growth firms (HGFs) exist across most regions, yet some UK local authority districts (LADs) consistently outperform others in their prevalence. This study investigates why, focusing on knowledge spillovers and entrepreneurial ecosystems (EE) as drivers of HGF incidence. Replicating and extending Fotopoulos (2023), we analyse longitudinal data from 2009–2021, refining methods to address autocorrelation biases from overlapping periods. Our findings confirm persistent inter-regional differences in HGFs incidence rates, driven by robust human capital, creative industries, and business services, though evidence for knowledge spillovers remains weak, meriting further exploration. By offering longitudinal evidence from a high-quality EE context, we enrich debates on regional HGF persistence and the EE framework's utility, informing policies aiming to foster productive entrepreneurship.

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Keywords: entrepreneurial ecosystems, high growth firms, persistence, knowledge spillovers, regional development.

CONTENTS

1. INTRODUCTION

High-growth firms (HGFs) have attracted a lot of attention in the last two decades, both from academics and policy makers (Coad et al., 2014; Du & Temouri, 2015; Hart et al., 2020; Moreno & Coad, 2015; Storey 1994) and for good reasons. HGFs have been shown to contribute both disproportionally to job creation (Anyadike-Danes et al., 2015; Henrekson & Johansson, 2010) and positive productivity spillovers on other firms (Du & Vanino, 2021), establishing them as important contributor and catalyst for regional economic development. Unsurprisingly, such findings had influenced policy under the assumption that targeting firms with high-growth potential is more effective than providing support indiscriminately to all firms.

Yet, research has also highlighted the importance of the persistence of HGFs, i.e. how long these firms can sustain high performance, given the evident low persistence of such growth at the firm level (Moreno & Coad, 2015). That explains the shift of the focus from predicting HGFs to understanding how to foster an environment where firms can thrive and achieve high growth.[1]

High growth firms are present in almost all regions, yet some regions consistently show a higher incidence of HGFs than others (Li et al., 2016; Motoyama & Danley, 2012, Sleuwaegen & Ramboer, 2020). Here, by HGFs incidence, we mean the rate of occurrence of HGFs in a region over a period of time, and we further discuss the different metrics used in the literature and the implications this induces for the analysis. This disparity highlights a key challenge: identifying the factors that make some regions more successful in HGFs generation. A deeper understanding can inform the design of effective regional policies to foster entrepreneurial success. The Entrepreneurial Ecosystem (EE) framework (Leendertse, et al., 2022; Stam, 2015; Wurth et al., 2021) has become a leading analytical approach in this domain, focusing on identifying the conditions that enable productive entrepreneurship – often measured by the incidence of HGFs – and ultimately contribute to high-value creation outcomes.

However, the EE framework is not without its challenges. The 'broken clock' critique of Coad and Srhoj (2023) highlights a fundamental tension: if EE elements are assumed to be structural and slow changing, then a meaningful relationship between the EE and the incidence of HGFs at the regional level is only plausible if the regional incidence of HGFs is itself structural and persistent over time. Yet, empirical evidence on the regional persistence of HGFs remains scarce (Coad and Srhoj, 2023, Coad et al., 2025; Friesenbichler & Hölzl, 2020). Crucially,

[1] Unsurprisingly, given that the identification of potential HGFs before the high-growth episode is difficult and when achieved it can hardly be sustained, Hart et al. (2020) urged for a reorientation of the existing policy focus.

existing empirical studies linking EEs or other structural regional characteristics to HGFs are predominantly cross-sectional, which limits their ability to confirm or refute this perspective.

Fotopoulos (2023) is a notable departure from the prevailing approach by conducting a longitudinal study at regional level (local authority districts, LAD) in the UK aiming to identify factors influencing HGFs incidence. His findings suggest that 'interregional differences in HGF rates are persistent (at least in the short-to-medium run explored here) and explained by knowledge spillovers related to economic diversity as well as vertical relatedness' (Fotopoulos, 2023, p.1878). However, his conclusions rely on a methodological approach which may be inherently unsuitable for capturing the complex dynamics of regional HGFs incidence, thereby raising concerns about the robustness of the inferences drawn. Our main concern relates to the overlapping structure of the time periods used in Fotopoulos's (2023) study. Because of the construction of the HGFs variable[2], HGFs counts and incidence rates in overlapping periods are built, at least partially, on the same observations, hence imposing structural autocorrelation in the dependent variable which may well drive inference if left unaccounted for. This is a known in the literature issue and the reason why previous studies examining the persistence of HGFs make use of non-overlapping periods (Coad and Srhoj, 2023, Erhardt, 2021; Friesenbichler & Hölzl, 2020).

Given the importance of evidence of persistence in regional HGFs incidence, a key contribution of our paper is to offer insights grounded in more rigorous and robust methodological approaches. In particular, we adopt a battery of estimation methods to address the several issues that the structural autocorrelation imposed by the definition of the HGFs variable gives rise to in order to robustly identify the factors that affect regional HGFs generation. Using UK data from the ONS Business Demography data that span 2009-2021 and addressing methodological issues, we confirm that inter-regional differences were persistent over this period with a number of factors explaining this variation. We find strong evidence of the essential role of human capital and talent in explaining the success of regions to generate HGFs. We also find that regions with high shares of creative industries and business and professional services are associated with higher HGFs incidence. In contrast to Fotopoulos (2023), our results on knowledge spillovers are, however, less strong and call for additional investigation.

In effect, we contribute to the literature in three ways. First, we provide new insights about the regional determinants of HGFs incidence (Fotopoulos, 2023; Li et al., 2016; Sleuwaegen &

[2] Although discussed later in greater depth, indicatively, Fotopoulos (2023) uses HGFs incidence rates based on OECD-Eurostat definition of HGF where firms employing 10 employees or more at the beginning of the period are identified as high-growth if the average annual growth of employment over the three-years period is 20% or more.

Ramboer, 2020). Second, by answering to the call of Wurth et al., (2002) for longitudinal EE studies, we enrich the knowledge base of a new albeit crucial body of research on regional persistence of HGFs (Coad and Srjoj, 2023, Coad et al., 2025; Fotopoulos, 2023; Friesenbichler and Hölzl, 2020; Van Dijk et al., 2024) by providing evidence from the UK, a country with high quality EE. Third, by also answering the call of Bettis et al. (2016) and Davidson (2004), and, especially of Wurth et al., (2002) and Van Dijk et al., (2024), we also develop the replication studies to improve our 'statistical research knowledge' (Bettis et al., 2016, p. 257) in the vital area of entrepreneurship and management studies in EE.

The remainder of the paper is organised as follows. Section 2 overviews the recent debate on regional HGFs persistence, EE and the role of knowledge spillovers. Section 3 describes the data sources used in our empirical investigation and proceed to the analysis of regional HGFs persistence in the UK LAD regions. Section 4 discusses our methodological approach where we also explain how it addresses the issues associated with the Fotopoulos (2023) study. Section 5 contains our empirical results. Finally, Section 6 summarises and contains our concluding remarks.

2. BACKGROUND

There are three strands of literature that are directly related to our work. First, it is the literature on the regional persistence of HGFs. Then, and building on this literature, it is the Entrepreneurial Ecosystem framework and the, directly linked, 'broken clock' controversy. Finally, it is the literature on knowledge spillovers within a region. This section overviews each of these strands in turn providing effectively the theoretical background of our work.

Regional persistence of HGFs

At firm level, the research evidence clearly points to the low persistence of HGFs (Daunfeldt & Halvarsson, 2015; Hölzl, 2014; Moreno & Coad, 2015). In other words, firms that are classified HGFs at any one period are unlikely to repeat the high growth performance in the subsequent periods. The principal reason for this rather stylised fact seems to be the predominant role of randomness in determining the growth of any specific firm (Coad et al., 2013). However, because from a policy standpoint HGFs create a disproportionate number of jobs at regional and/or country level, recent studies call for analysis at aggregated level to get insights into HGFs incidence and regional persistence of HGFs shares, and their macro and local determinants (Coad & Srhoj, 2023; Friesenbichler & Hölzl, 2020; Hart et al., 2020; Moreno & Coad, 2015).

Previous studies measure regional HGF incidence (or prevalence) either as the number of HGFs in a region relative to the human population (Fotopoulos, 2023; Leendertse et al., 2022), or relative to the pool of potential HGFs, defined as firms with 10+ employees that existed at the beginning and were still active at the end of the three-year period (Coad & Srhoj, 2023; Coad et al., 2025; Friesenbichler & Hölzl, 2020). Consequently, the regional persistence of HGFs can then be viewed as the repeated and consistent incidence of HGFs ‘in a region over time’ (van Dijk et al., 2024). However, only a handful of empirical studies analysed explicitly HGFs persistence.

Interestingly, Friesenbichler and Hölzl (2020) contend that regional incidence of HGFs is ‘rather unrelated to the persistence of being a HGF at the firm level’ which is why they suggest that it may exhibit substantially more persistence than the HGFs themselves at firm level (Friesenbichler & Holzl, 2020, p.1586). Indeed, using information for NUTS-3 Austrian regions, they find moderate evidence of HGFs persistence over time and show that HGFs incidence is higher in regions with higher specialisation of industrial composition (related variety), while diversified sectoral composition (unrelated variety) does not play any significant role.

A small number of recent studies also find some evidence of HGFs persistence over time although in different settings. Fotopoulos (2023) finds that inter-regional differences of HGFs shares to active population over 2012-2017 in the UK Local Authority Districts (LADs) are persistent over time[3]. Coad et al. (2025) analysing HGFs prevalence in the NUTS-3 and NUTS-2 EU regions over the period 2008-2020 find a fairly strong regional persistence over time, which is not associated however with higher economic development and level of innovation of the region. Likewise, Van Dijk et al. (2024), using data from the Netherlands at the NUTS-2 and NUTS-3 levels, consistently find that regions with high HGFs incidence in one period are also likely to be those with high HGFs incidence in the following period(s), with the strength of the relationship weakening when the time lapse between periods increases.

In contrast, Coad and Srhoj (2023) analysing regional HGFs persistence in Croatia and Slovenia at NUTS-3 level, find no evidence of regional HGFs persistence (HGFs are defined using employment and turnover definitions) in Croatia, and only weak support for regional persistence in Slovenia when using employment HGFs definition, and stronger evidence when using turnover HGFs definition. Moreover, they find stronger evidence in support of industry-level persistence of HGFs compared to regional persistence and some indication of the influence of business cycle on HGFs persistence.

[3] This evidence is however based on analysis of overlapping periods.

Therefore, in sum, there seems to be mixed evidence on the persistence of HGFs at regional level requiring further investigation in different contexts. In this paper, we aim to contribute to building empirical evidence on this subject.

HGFs, Entrepreneurial Ecosystem (EE) and 'broken clock' controversy

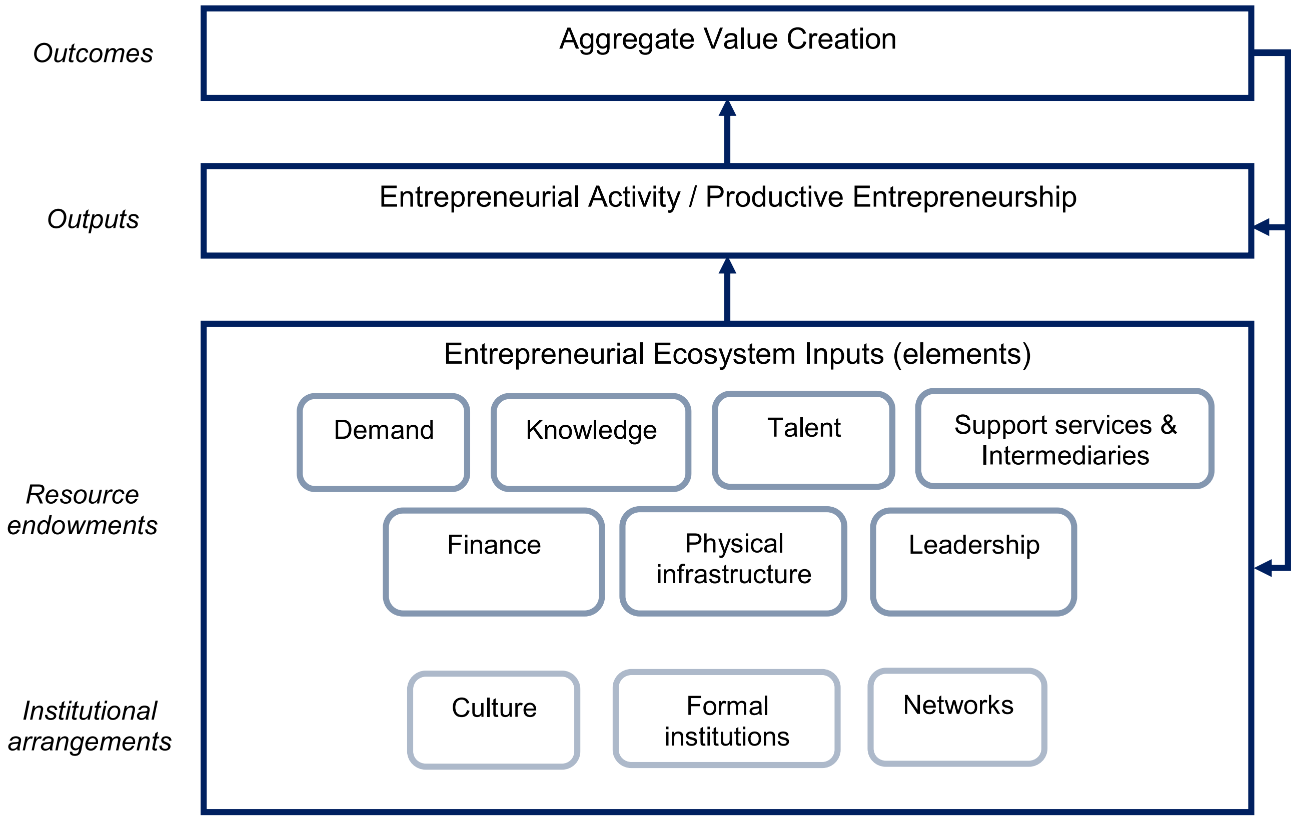
One reason why analysing regional persistence of HGFs is important, is that it spurred a theoretical controversy with important policy implications. Coad and Srhoj (2023) based on the empirical investigation of HGFs persistence formulate a 'broken clock' critique challenging the predominant Entrepreneurial Ecosystem (EE) framework:

'We observe there is negligible persistence in HGFs at the regional level. This is incongruous with the observation that there is high persistence in the inputs to an entrepreneurial ecosystem. The relationship between inputs and outputs is so noisy that we conclude that the entrepreneurial ecosystem approach, according to its most recent formulations (i.e. Leendertse et al., 2022) is not a useful approach for policymakers with regards to generating the main outputs of ecosystems, i.e. HGFs. We therefore formulate a "broken clock" critique of EE in its current formulation. A broken clock tells the correct time twice a day, but overall it is not useful for telling the time.' (Coad and Srhoj, 2023, p.17)

The Entrepreneurial Ecosystem (EE) is a relatively recent framework that quickly became popular not least because it marks a 'transition' towards 'entrepreneurial economy' as opposed to 'managerial economy' (Wurth et al., 2021) and explicitly emphasises the geographical context of entrepreneurial activity (Fritsch, 2024; Malecki, 2018; Sternberg, 2022). The EE has three core features: (1) it focuses predominantly on productive forms of entrepreneurship (or else ambitious i.e. growth-oriented and innovative forms) rather than on the entrepreneurial activity overall; (2) it emphasises the role of 'place' and territorially bounded external factors which may make an entrepreneur more 'successful' by acknowledging that the activity of 'entrepreneurship takes place in a community of interdependent actors' (Stam, 2015, p. 1761); (3) it allows for a plausible feedback loop in which on one hand productive entrepreneurship is considered as an output of the system, and on the other hand, the entrepreneur as the principal actor is the input 'feeding' the ecosystem alongside with other structural elements, such as finance and infrastructure (Stam, 2015; Wurth et al., 2021; see Fig1).

The EE literature considers several outputs of EE and their relationships with EE elements (Wurth et al., 2021): start-ups (Audretsch & Belitski, 2017), new ventures (Leendertse et al., 2022), opportunity and necessity-motivated entrepreneurial activity (Bosma & Sternberg, 2014), academic spin-offs (Franco-Leal et al., 2020; Prokop, 2021), social entrepreneurship (Harms & Groen, 2017). However, it is productive entrepreneurship – viewed as both EE output (entrepreneurial behaviour) and outcome (value creation) (Stam & van de Ven, 2021) – which has attracted a lot of attention both from the research community and policy-makers. This is also reflected by the fact that HGFs incidence is overwhelmingly the most frequently used proxy of productive entrepreneurship (Coad & Srhoj, 2023; Fotopoulos, 2023; Stam & van de Ven, 2021), along with innovative start-ups (van Dijk et al., 2024), entrepreneurial employees (Bosma et al., 2014; Stam, 2013), and unicorns (Leendertse et al., 2022).

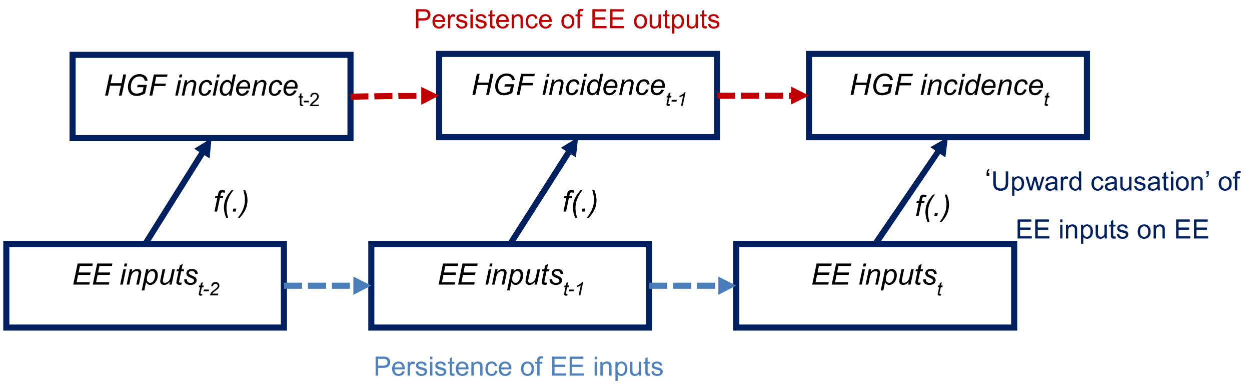
Fig. 1 EE: inputs, outputs and outcomes



Source: based on Stam (2015, p. 1765) and Stam & Van de Ven (2021, p.813)

The EE framework has received a number of critiques: absence of unified definition (Malecki, 2018), lack of strong theoretical foundations and insufficient differentiation from other research traditions, such as industrial clusters and regional innovation systems (Fritsch, 2024; Spigel and Harrison, 2017), focus on productive entrepreneurship and high-growth start-ups which leaves behind established and less well performing ventures (Fritsch, 2024), the predominantly static view of EE what is reflected in the lack of longitudinal studies (Malecki, 2018). While these debates are beyond the scope of the current paper whose primary concern is variation in HGFs incidence at regional level and its underlying factors, the recent 'broken clock' critique is at the core of our investigation. Coad and Srhoj (2023) pointed out that if the EE inputs (or elements, i.e. resource endowments and institutional arrangements, see Fig.1), are by nature slow changing and persistent, they should also lead to persistence of outputs, i.e. regional HGFs persistence (Fig.2); but when they examined Slovenia and Croatia, they found that to be untrue.

Fig. 2 The 'broken clock' critique: persistence of EE inputs and outputs



Source: based on Coad and Srhoj (2023, p.4)

Recent research has sparked valuable debate about the entrepreneurial ecosystem (EE) framework, prompting calls for theoretical refinement (Coad et al., 2025; Fritsch, 2024). One key issue is the use of HGFs incidence as an EE output. While EE studies often imply that high-quality EEs consistently produce higher HGFs incidence rates (van Dijk et al., 2024), Coad et al. (2025) challenge this by showing that more developed regions—presumed to have higher-quality EEs—do not exhibit greater HGF incidence or persistence. This suggests that HGFs incidence may be a flawed proxy for EE performance, a view reinforced by critiques of the Eurostat-OECD HGF definition (Coad et al., 2014; Daunfeldt et al., 2015) and concerns over an overreliance on a single metric (Hart et al., 2020, p. 3). We initially posited that low-quality or smaller EEs might show less HGF persistence due to vulnerability to external shocks (van Dijk et al., 2024), expecting a positive link between EE quality and persistence. However, Coad et al.'s (2025) findings indicate this relationship may not hold universally, possibly due to nonlinear dynamics (Leendertse et al., 2022) or unaccounted regional factors. This tension underscores the need for longitudinal studies to better understand EE inputs—such as stable institutional arrangements versus variable resource endowments—and their impact on HGF persistence over time.

HGFs and knowledge spillovers

The EE research suggests that different EE elements may have varying importance for different EE outputs (Wurth et al., 2021). Previous evidence from various research traditions has attracted attention to the singular importance of skills, knowledge production, knowledge spillovers and knowledge diffusion ('Knowledge', 'Networks', and 'Talents' elements in EE terms) for HGFs prevalence (Araki et al., 2024; Fotopoulos, 2023; Li et al., 2016; Motoyama, 2014; Sleuwaegen & Ramboer, 2020). Spigel (2020) highlights that co-location and proximity benefits for high growth are related to the efficiencies realised through the 'access to a specialised labour pool, the ability to capture knowledge spillovers from knowledge producers like universities or major firms, or the opportunity for radical innovation through serendipitous contact between diverse actors mediated by localized social network' (Spigel, 2020, p.32).

The intersection of EE and knowledge spillover theory of entrepreneurship (KSTE) (Audretsch, 1995) has become a burgeoning body of research within the field of entrepreneurship. This emerging strand of literature specifically focuses on the transmission of knowledge from actors within entrepreneurial ecosystems to entrepreneurial venture (Morris et al., 2023). Universities and other higher education institutions, and especially leading knowledge-intensive universities, are regarded as an essential element of high-quality EE: they produce cutting-edge knowledge, 'spill over' the knowledge via formal and informal networks, play an essential role in skills development via training, and also generate academic spin-outs, directly contributing to innovative entrepreneurial activity (Spigel, 2017, 2020). The role of agglomeration economies for innovation and growth has received an extensive attention from economics and economic geography scholars, with the debate focusing on which type of externalities are the most conducive to knowledge spillovers and thereby regional growth (Glaeser et al., 1992; Henderson et al., 1995). In essence, it was a question whether regional specialisation (Marshall's externalities) or regional diversification (Jacob's externalities) are the most important conduit of knowledge spillovers. Later, following the works of Frenken et al. (2007) and Boschma & Iammarino (2009), a more nuanced view of regional diversification has been suggested. It has been argued that Jacob's externalities capture two different effects, i.e. knowledge spillover effect and portfolio effect which should be distinguished (Frenken et al., 2007). Knowledge spillover effect occurs when two sectors are complementary and when the cognitive distance (in terms of skills and competences) between them is not too large so that effective communication and learning are facilitated (Boschma, 2005), i.e. they should be 'related' to a certain degree. Indeed, it is questionable how much knowledge can spill over from, for example, a farmer growing oats to a software development company, even when they are geographically close. The concept of 'related variety' therefore refers to 'sectors related in terms of shared or complimentary competences' with 'some degree of cognitive proximity' being necessary to 'ensure that effective communication and interactive learning take place, although not too extreme, to avoid cognitive lock-in' (Boschma & Iammarino, 2009, p. 293). Therefore, it is not regional diversification per se (when cognitive distance is too important, knowledge does not spill over from one industry to another), nor regional specialisation (when cognitive proximity is too important, there is less cross-fertilisation), but rather 'local specialisation in related variety'

(Boschma & Iammarino, 2009, p. 293) that drives knowledge spillovers, innovation and, ultimately growth.

Portfolio effect, on the contrary, comes from 'unrelated variety' covering sectors which do not necessarily share competences. The presence of unrelated sectors in the region allows to spread risk: when one sector is affected by sector-specific shock in demand, other unrelated sectors play a role of stabilisers at the regional level. Regions with high degree of unrelated variety have been shown to protect regions from growth in unemployment: redundant workers of an affected industry can find new job in unrelated sectors (Frenken et al., 2007).

In sum, it is expected that knowledge spillovers within the region are to occur predominantly in related sectors, and only to a limited extent in unrelated sectors. Additionally, Fotopoulos (2023) argues that related variety based on industrial classification may not reflect technological relatedness. It is possible that firms can be classified as unrelated while they are vertically related. This vertical relatedness can spur inter-sectoral knowledge spillovers leading to organic growth or acquisitive growth.

3. DATA

A key contribution of our work is the use of UK data enabling us to draw valuable insights into the variable construction and estimation methods by directly comparing our approach with that Fotopoulos (2023).[4] To facilitate this comparison, we adopt the general setup of his work including the data collection and variable construction both of which we have endeavoured to be as similar as it was possible. Table 1 provides summary statistics for all the variables involved and Table 6 in Annex summarises the variable description, data sources, geographic coverage, and time period. However, this section goes beyond replication; it details the construction of our dependent and independent variables while also illustrating the level of the regional persistence of HGFs embedded in our dataset.

[4] The appendix contains a detailed comparison of our inference with that of Fotopoulos (2023) when we restrict our sample to be identical to his. We are unable to perfectly recreate the data used in Fotopoulos (2023). It is acknowledged that imputation methods were explicitly reported by Fotopoulos (2023) for the "Institutions" variable (p. 12). Given the observed discrepancies between our dataset and that utilised in Fotopoulos (2023), it remains a possibility—though unconfirmed—that similar data imputation procedures may have been employed for other variables without explicit documentation. Readers should thus consider this factor when interpreting comparisons across datasets.

Table 1 Summary statistics

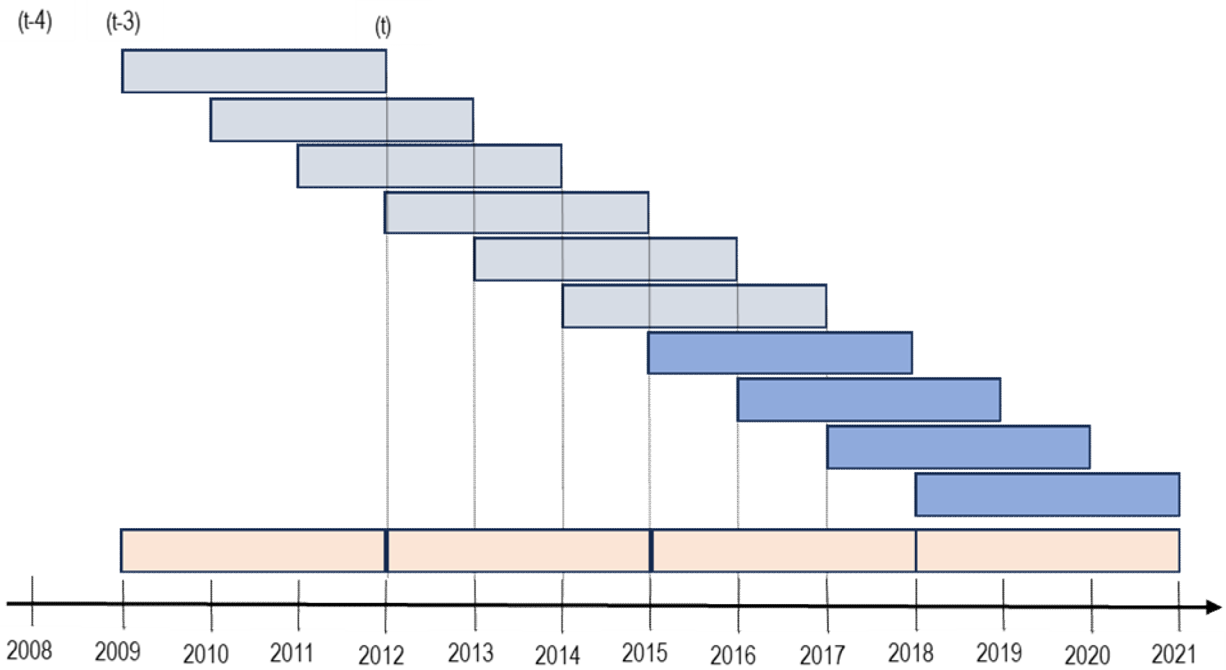
Variable name	N	mean	Min	max
HGFs count	3622	33.18	0.00	520.00
HGFR	3622	0.42	0.00	64.55
HGFR2	3622	0.05	0.00	0.13
UNIVERSITIES	3570	0.13	0.00	1.80
UNI_SPINOFFS	3881	0.09	0.00	2.71
UNI_PATENTS	3881	1.52	0.00	157.60
UNI_ENGAGEMENT	3881	0.43	0.00	5.34
RESEARCH_INCOME	3881	4.61	0.00	264.70
RVARIETY	3488	1.42	0.56	2.01
UVARIETY	3596	4.95	3.65	5.38
THEIL	3488	6.64	4.60	7.17
VRELATED	3596	66.47	12.95	79.11
INCUBATORS	3570	0.09	0.00	12.79
INNOUK_GRANTS	3422	12.74	0.00	19.40
INNOUK_APPL	3372	0.12	0.00	17.06
SCIENCE&ENGINEERS	3473	5.35	2.18	30.70
R&D_PERSONNEL	3050	0.12	0.02	1.15
BUSINESS_R&D	2856	39.83	1.09	1693.60
HUMAN_CAPITAL	3619	0.23	0.06	1.23
ESHIP_CULTURE	3910	13.67	9.10	18.40
BUSINESS_SERVICES	3775	0.13	0.02	0.56
CREATIVE	3775	0.03	0.00	0.17
SMALL_FIRMS	3740	0.97	0.92	1.00
GVA_GROWTH	3740	0.02	-0.20	0.34
VCAPITAL_PROJECTS	3910	1.06	0.08	7.67
VCAPITAL_INVESTMENT	3910	1.09	0.03	15.94
INSTITUTIONS	4040	0.07	0.03	1.00
POP_DENSITY	3310	3696.70	135.80	21438.40

Dependent variable

Our main dependent variable, HGFs incidence rate in the UK LAD regions is measured as the number of HGFs per 1,000 working age population (*HGFR*). The data on the number of HGFs in the region (*HGFs count*) comes from ONS Business Demography data, which ONS produces using the OECD-Eurostat definition of HGFs by employment. Specifically, a firm is identified as HGF if it has been growing by average annualised growth of at least 20% per year over three years, provided that (i) it has at least 10 employees in the beginning of the period (year *t-3*) and

(ii) is still active at the end of the period (year *t*). In practical terms, this means a firm is identified as HGF if its total growth in employment of at least 72.8% from year *(t-3)* to year *(t)*. In other words, the HGFs incidence rates refer to three-year overlapping periods.[5] Figure 3 illustrates this point.

Fig. 3 Growth periods studied



Note: the grey blocks indicate the data that Fotopoulos (2023) has examined; blue blocks indicate to the additional overlapping data that we include in our work; and the orange blocks indicate the data when adopting a 3-year frequency to ensure the presence of non-overlapping observations.

Source: authors

Fotopoulos's (2023) study covers the period from 2012 to 2017 and, although not explicitly stated, uses data from six overlapping periods within that timeframe[6]: firms registered as HGFs over the period 2009-2012, 2010-2013, 2011-2014, 2012-2015, 2013-2016, and 2014-2017. We extend our dataset to include the most recent years, increasing the number of overlapping periods to ten and to allow for the analysis of four consecutive non-overlapping periods: 2009-2012, 2012-2015, 2015-2018, 2018-2021.

[5] In anticipation of our Methodology, this overlapping nature of the HGFs incidence rates is what leads to correlation of observations by design which may invalidate inference about the persistence of HGFs incidence.
[6] In Fotopoulos (2023), the number of periods used ais not clearly described but can be inferred from the total number of observations (2268) and the number of LADs (380).

To allow for comparability with the original Fotopoulos (2023) study, we also use 1,000 working-age population as the denominator in HGFR. However, this definition, while also used in other studies (Leendertse et al., 2022), conflates firm-level data with population-level data, mixing two distinct dynamics, which is questionable. Other studies use an alternative HGF incidence metric by reporting the number of HGFs in the region relative to the number of firms satisfying criteria (i) and (ii) in the OECD HGF definition above—that is, by comparing HGF counts to the total pool of firms that potentially qualify as HGFs (Coad & Srhoj, 2023; Coad et al., 2025; Friesenbichler & Hölzl, 2020). This latter definition has the advantage of comparing like with like and ideally should be used in studies on regional HGF incidence. Therefore, we use the share of HGFs relative to the number of firms with 10+ employees existing in (t-3) and still surviving in (t) (HGFR2) as an alternative measure for the correlation analysis of regional HGF persistence.

Regional persistence of HGFs in the UK

Table 2 shows the Pearson and Spearman's rank correlation coefficients between LAD-level HGFs indicators (the count of HGFs based on employment criterion, the share of HGFs per 1,000 working age population (*HGFR*) and the share of HGFs per active firm with 10 or more employees (*HGFR2*)) for three pairs of consecutive non-overlapping periods. In all cases, we find consistently a positive highly significant relationship between HGFs incidence in one period and the period that follows. However, correlation coefficients are considerably higher for *HGFs counts* and *HGFR* compared to *HGFR2*. Moreover, Table 4 in Annex shows that the relationship remains highly positive and significant, although weakening over the time for HGFs as a share of LAD's firms' with 10 or more employees active at the end of the growth period (*HGFR2*), which means that regions with high incidence of HGFs in 2009 – 2012 are also likely to have high HGFs incidence rate in all the subsequent periods, even few years later. However, the rolling-average construction of the HGF incidence rates might explain this finding. We note that the correlation coefficients are considerably higher in overlapping periods for HGFR2 compared to non-overlapping periods. For example, the correlation of HGFR2 in the overlapping periods 2009-2012 and 2010-2013 is 0.668, while it drops to 0.404 for the consecutive non-overlapping periods 2009-2012 and 2012-2015. Intuitively, the higher correlation in overlapping periods compared to non-overlapping periods can be explained by the following analogy: consider a die that has been rolled four times. Each roll is random, but the sum of the first three rolls (rolls number 1, 2, and 3) is highly correlated with the sum of the last three rolls (rolls number 2, 3, and 4) due to the overlap (rolls 2 and 3 are included in both sums)[7]. The relationship is much more stable when HGFs incidence is measured as the number of HGFs per 1,000 working age inhabitants (Fotopoulos, 2023; Van Dijk et al., 2024), showing high correlation coefficients in both overlapping and non-overlapping periods (Table 5 in Annex). However, as discussed previously, this metric, by introducing another variable in the denominator, conflates two different dynamics: the evolution of HGF count and the evolution of population in the region.

Table 2 HGFs ratios correlations in consecutive periods

	HGFs count		*HGFR* HGFs per 1,000 working age pop.		*HGFR2* HGFs per active firm with 10+ employees	
	Pearson correlation [p-value]	Spearman correlation [p-value]	Pearson correlation [p-value]	Spearman correlation [p-value]	Pearson correlation [p-value]	Spearman correlation [p-value]
Periods:	(1)	(2)	(3)	(4)	(5)	(6)
2009-2012 & 2012-2015	0.960 [0.000]	0.886 [0.000]	0.999 [0.000]	0.661 [0.000]	0.404 [0.000]	0.361[0.000]
2012-2015 & 2015-2018	0.956 [0.000]	0.868 [0.000]	0.999 [0.000]	0.637 [0.000]	0.311 [0.000]	0.246[0.000]
2015-2018 & 2018-2021	0.967 [0.000]	0.852 [0.000]	0.999 [0.000]	0.608 [0.000]	0.352 [0.000]	0.301[0.000]

Note: p-values reported in the brackets

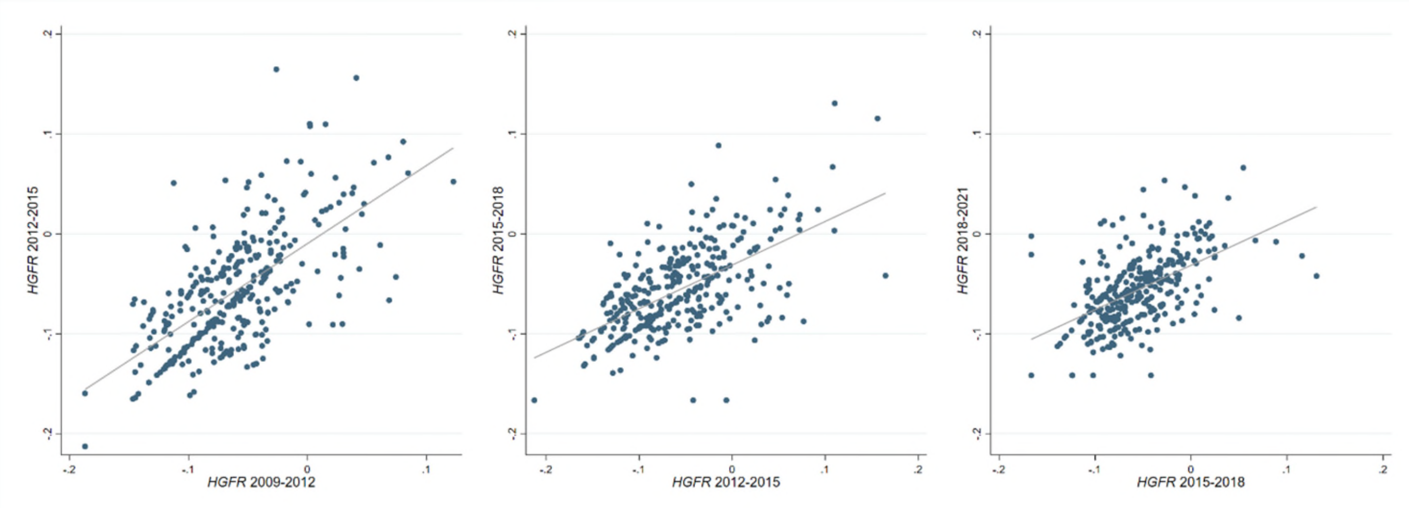
Fotopoulos (2023) stresses that “the between-region variation amounts to almost 98.3% of the total variation in HGFR” (Fotopoulos (2023), p. 1891), with between-years variation accounting for less than 1% of the total variation. Hence, he concludes that “the interregional differences in HGFR are time persistent over the 2012-2017 period” (Fotopoulos (2023), p. 1892). As mentioned before, this estimation was carried out on a sample with overlapping periods. When considering non-overlapping periods, we estimate that the between-region variation accounts for 95.9% of the total variation, a smaller but still very large share of HGFR variation. The between-periods (within-region) variation is estimated to account for 2.9%, and residual variation for 1.1% of the total variation.

In sum, we find evidence in support of regional persistence of HGFs incidence in the UK local authorities. This is also illustrated in Figures 4 and 5 which plot the incidence of HGFs measured as share to working age inhabitant (Fig.4) or to active firms with 10+ employees (Fig.5) in one period depending on the share in the previous period. If we take our results at face value, Van Dijk et al.’s (2024) view—that established EEs in larger or more developed regions support persistent HGF geographies—may explain why UK LADs show such patterns, and why Coad

[7] We thank the anonymous reviewer for suggesting this analogy. For a formal demonstration of why the overlapping data structure introduces bias into the analysis of regional HGF persistence, see Coad & Srhoj (2023, pp. 18-19).

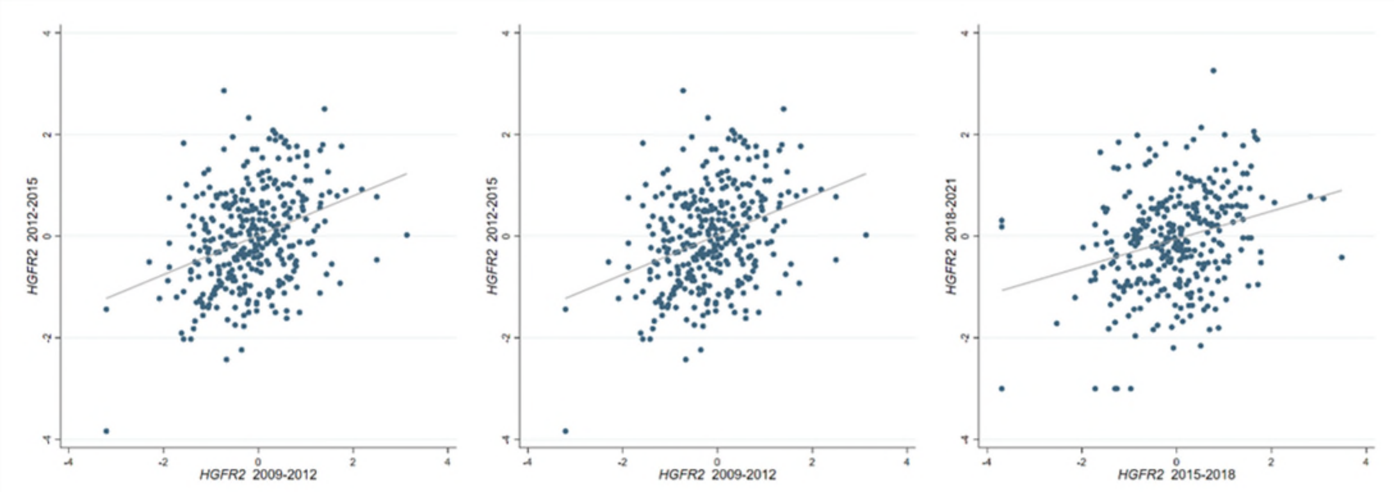
and Srhoj (2023) found insufficient human capital for HGF emergence in Croatia and Slovenia's smaller, less developed EEs. However, Coad et al. (2025) challenge this, showing higher HGF persistence in less developed EU regions, suggesting regional development alone doesn't dictate outcomes. Alternative explanations, such as business cycle fluctuations or variations in industry composition, could also drive these differences, warranting further investigation.

Fig. 4 Persistence of HGFs incidence rates (per 1,000 working age population) in consecutive non-overlapping periods



Note: for comparability across different periods, the rates were standardized so that each period mean = 0 and std deviation =1. London LADs, as outliers, were excluded from this graph to keep the scale (inclusion of London LAD's does not change the overall relationship though).
Source: authors

Fig. 5 Persistence of HGFs incidence rates (per active 10+ employee firm) in consecutive non-overlapping periods



Note: for comparability across different periods, the rates were standardized so that each period mean = 0 and std deviation =1. London LADs, as obvious outliers, were excluded from this graph.
Source: authors

Independent variables

Fotopoulos (2023) provides a comprehensive rationale for the selection of independent variables, based both on EE and KSTE literature and we refer the interested reader for more details. We are able to collect almost all the variables used in his study. However, we should point out that there have been several cases for which we could not construct the variables exactly as Fotopoulos (2023) did because it was either unclear in the paper or we could not access such data from the respective data sources.[8] In those cases, we had to resort to the best alternative that we could construct. Specifically, the UNI_PATENTS variable is defined as patent count weighted by regional GDP (bn £) to account for the size of the region instead of patent portfolio per academic staff member. For UNI_ENGAGEMENT and UNI_SPINOFFS variables, to handle zero values we used logarithm of (observed values plus 1) the number of research contracts with SMEs and the number of HE Institutions spinoffs. The same holds true for INNOUK_GRANTS. For the variables INCUBATOR[9] and UNIVERSITIES, the underlying data is location-based without time variation, therefore, instead of pure counts, we also weight the series by regional size (GDP, bn £).

4. METHODOLOGY

The use of overlapping observations in the construction of our dependent variable, the HGFs incidence rate, imposes structural autocorrelation which may well bias any inference about the significance of the factors that determine it. This is a well-known issue in the time-series literature where it was initially examined following the adoption of some rolling-average mechanism for the construction of variables or statistics. Consequently, a core aspect of our work is to ensure that we draw robust inference in the presence of such challenges. Given that we are also interested to ensure consistency with the Fotopoulos (2023) work, we proceed in two steps. First, we aim to replicate and update the Fotopoulos (2023) study by adopting the same setup. Then, in the second step, we extend the analysis and adopt an incremental approach by first identifying several possible sources of inference bias that the rolling average definition of HGFs and Fotopoulos (2023) setup may induce and then examining how inference

[8] We have tried to contact the author for the necessary clarifications, but we could not get any response. The lack of descriptive statistics in Fotopoulos (2023) was a key limiting factor for any differences that our paper might have from his. Moreover, the data officially published by ONS and other institutions is subject to updates to correct errors. We have collected our data through the summer 2024, and although we do not have direct indications, we cannot exclude the possibility that some of the data series have been updated.

[9] The data source on number of incubators provides cross-sectional time invariant data series for 2016, which, to the best of our knowledge, has not been updated since.

is affected by accounting for each of them. The remainder of this section first presents the main model and then elaborates on these two steps of our work.

The main model

Following Fotopoulos (2023), our main model is given by a special case of the random effects model that Mundlak (1978) originally proposed, and Bell and Jones (2014) and Bartels (2009) extended:

$$y_{rt} = \beta_0 + \beta_1(x_{rt} - \overline{x_r}) + \beta_2\overline{x_r} + \beta_3 z_r + (u_r - \varepsilon_{rt})$$

where our left hand-side variable is the number of HGF per 1,000 working age population in region (r) and at time (t). The right hand-side covariates are partitioned into those that capture the effects of the between $(x_{rt} - \overline{x_r})$ and within variation $(\overline{x_r})$, and those that capture time invariant effects. To ensure consistency with Fotopoulos (2023), we have kept the same six model variants which he selected on the grounds that partial correlations of the explanatory variables is conservatively kept well below multicollinearity alarming levels.

Replication and updated study

To make our subsequent extension results comparable with Fotopoulos (2023) study, we first replicate and update the original study. To do so, we endeavoured to collect all necessary data from ONS and various other sources and used the definitions provided in the paper to construct HGF incidence and EE variables. As aforementioned, despite our best efforts to have as a starting point the dataset identical to the one used in Fotopoulos (2023) study[10], some discrepancies may remain. Then we have updated the dataset to the most recent periods in order to increase the sample size which becomes essential for our ensuing analysis.

Consequently, there are three main results of the model variants that we need to compare, namely (i) those reported by Fotopoulos (2023) (ii) those that we could replicate with the data we have collected from the same data sources that span the same sample period (2012-2017, and (iii) those by expanding the data sample to the most recent years (2012-2021, see Figure 3). A comparison of (i) and (ii) would reveal discrepancies that should be attributed primarily to different variable construction methods and updates in the data series while a comparison of (ii) and (iii) would indicate the effect that the additional observations would have on the inference. The latter (iii) is then used later for determining the effect of the additional sources of bias that

[10] Unfortunately, we could not get the author's input for this step. Without detailed summary statistics and variables description tables in the original study to compare with, we cannot guarantee that that our initial dataset is identical to the one used by Fotopoulos (2023).

could be attributed to purely methodological choices. In anticipation of our results, there are some discrepancies between (i) and (ii) but (ii) and (iii) are almost identical suggesting that variable construction may play a role in drawing inference but updating the sample to the most recent observations does not.

Accounting for possible sources of inference distortions

As discussed above, the OECD HGF definition has a rolling nature, with a firm being registered as HGF at the end of three years period. Using overlapping periods (as in original, reproduced and updated discussed above) may lead to important estimation biases. Additionally, in Fotopoulos (2023), all EE variables were lagged by one or two years relative to time t (at the end of the three-year period), meaning that they can be at best considered as contemporaneous to the growth period rather than creating ex ante conditions for growth. For example, the 2012 HGFs incidence rates refer to firms growing over the period 2009-2012. Consequently, a 1- or 2-year lag cannot reflect the initial conditions where firms started to grow (continuing with the same example, the 2012 HGFs incidence rate would be linked to values of explanatory variables from 2011 or 2010, literally in between the 2009-2012 period). The second part of our work seeks to address the possible impact on inference that these assumptions may have. We contrast the results we have obtained from the Updated sample with those obtained when (i) we use a non-overlapping HGF incidence panel; (ii) we also account for possible simultaneity of the explanatory variables; (iii) we adopt an estimator that explicitly accounts for the presence of overlapping observations.

Specifically, in (i), we change the sampling frequency of our observations to three years, i.e. 2012 (growth period 2009-2012), 2015 (growth period 2012-2015), 2018 (growth period 2015-2018), 2021 (growth period 2018-2021, see Figure 3). In this way, we ensure that HGFR do not overlap with their previous values. As a result, the panel reduces in size – which explains why updating the sample to the most recent periods is important for inference – but it no longer suffers from the rolling average structure that the definition imposes. Hereafter, we call this sample Non-Overlapping (N-O).

In (ii), in addition to non-overlapping structure of the growth periods, we also ensure that explanatory variables are lagged accordingly so that they are not measuring contemporaneous effects: i.e. all explanatory variables are lagged by four years relative to time t. For example, for the HGFR observations 2012 (growth period 2009-2012), the corresponding EE variables will go back to 2008, i.e. prior the beginning of the growth period. Hereafter, we call this sample Non-Overlapping-with-Lag (N-O-L).

Finally, in (iii), we adapt the estimator of Britten-Jones et al (2011), that explicitly addresses the presence of overlapping observations, by transforming the time-varying variables of each panel in such a way so that the part of the autocorrelation in the error terms which is induced by the overlapping scheme is removed. We call this approach Britten-Jones (B-J) going forward. The method can also be modified to account for an unknown autocorrelation structure.

5. EMPIRICAL RESULTS

To facilitate comparisons and determine the effect of using different samples and/or methods, we present results in the same way as Fotopoulos (2023). Specifically, the first part is about the results of the 'within-between' random effect estimations (models (1) to (6)); the second part is about the results of the 'within-between' random effect estimations when focusing on the University related variables (models (7) to (10); and the third part is about the results of models (11) to (16) introducing R&D finance, and institutions variables (the multilevel analysis is used here to allow for the modelling of unobserved heterogeneity as well as to account for the possibility that the observations within each of the spatial levels considered are not independent). The full comparison tables are presented in Annex, Table 3 summarises the main findings across all models (1) to (16) and all approaches in a schematic way.

Replication study

Before focusing on the main results which seek to address potential biases, we first briefly discuss original, reproduced and updated estimations (Annex Tables 7, 8, and 9), which use the same methodology as in Fotopoulos (2023). Fotopoulos (2023) selected the different model permutations based on the grounds that partial correlations of the explanatory variables are conservatively kept well below multicollinearity alarming levels; but in our case we simply adopted his model specification - effectively making our tables directly comparable to his[11]. As in Fotopoulos (2023), along with estimation coefficients, we report continuous p-values and the Bayes factor which allows to judge the strength of evidence[12].

Overall, the differences observed between the original and the reproduced samples indicate that we were only partially successful in inferring the variable construction from what Fotopoulos (2023) presents in his paper. For instance, when looking at Table 7, reproduced and updated results are close to what Fotopoulos (2023) reports although there are some discrepancies.

[11] Tables 2, 4 and 6 in the original study.
[12] Typically, the Bayes Factor equal or higher than 100 means decisive evidence for H1, between 10 to 30 – very strong evidence for H1, 3 to 10 – substantial evidence, 1 to 3 – anecdotal evidence, and equal to 1 – no evidence.

Across all samples, cross-sectional variations in human capital (HUMAN_CAPITAL_BW), business and professional shares (BUSINESS_SERVICES_BW), relative importance of creative industries (CREATIVE_BW), growth rate of gross value-added (GVA_GROWTH_BW), Innovate UK applications (INNOUK_APPL_BW), and vertical relatedness (VERTICALLY_RELATED_BW) were consistently positive and statistically significant.

Original, reproduced and updated estimations show 'decisive' or 'strong' evidence of positive and significant influence of 'between' variation of human capital (HUMAN_CAPITAL_BW) and professional and business services shares (BUSINESS_SERVICES_BW) on HGF incidence. The evidence for creative industries employment share (CREATIVE_BW) and Innovate UK applications (INNOUK_APPL_BW) was 'moderate' (substantial) in original study, but 'decisive' in reproduced and updated samples. In contrast, the decisive evidence for positive influence of unrelated variety (UNRELATED_VARITY_BW) and entrepreneurship culture (ESHIP_CULTURE_BW) in original sample, was not confirmed, in reproduced and updated samples. Interestingly, INCUBATORS, which Fotopoulos (2023) found to have the largest effect size on HGFR, are insignificant in our estimations[13].

Furthermore, the differences between the reproduced and updated samples show that there is indeed an impact of using a larger dataset. Interestingly, however, the original and updated samples are much more similar to one another suggesting that basing our inference on the updated sample would make it directly comparable to that of Fotopoulos (2023).

Given that we cannot be sufficiently certain of replicating Fotopoulos's (2023) results identically, in what follows we use our updated sample estimations as a reference to compare with our alternative approaches and judge about the influence of potential biases on inference.

Addressing biases

Table 10 in Annex presents the results focusing on influence of knowledge spillovers and main EE variables[14] by allowing the comparison of Fotopoulos (2023) approach using our Updated (U) sample with alternative approaches we propose to address potential biases discussed above: Non-Overlapping (N-O), Non-Overlapping-with-Lag (N-O-L) and Britten-Jones (B-J) estimations. Overall, we do not find major differences in results between original Fotopoulos

[13] It must be emphasized, however, that we cannot definitively confirm that our INCUBATORS variable is identical to that used in Fotopoulos (2023). This is due to insufficient detailed information regarding its construction and the methodology employed to address the time-invariant nature of the underlying data.
[14] equivalent to Table 2 in original study

(2023) approach applied to the updated sample and our alternative methods, with a few nuances, however.

First, similarly to the original study, we find that the odds against the null hypothesis were higher for 'between' coefficients compared to 'within'. Regional differences in human capital (HUMAN_CAPITAL_BW), research grants applications (INNOUK_APLL_BW), importance of business and professional services (BUSINESS_SERVICES_BW) and of creative industries (CREATIVE_BW) in regional employment composition are consistently influential in variations of HGFs incidence rates across all approaches, with very high Bayes factors signifying 'decisive' evidence. Time variation of these variables, however, was not significant across all approaches, with the exception of HUMAN_CAPITAL_WI which was negative and significant for the updated sample and marginally significant for the N-O sample.

Second, we do not see dramatic changes in estimates when the overlapping issue is addressed (comparing U and N-O). In contrast, when addressing the simultaneity issue (comparing N-O and N-O-L), there are some important changes. Thus, the effect of research income generated by universities at LAD level (RESEARCH_INCOME_BW) was positive and highly significant ('decisive' evidence) in U and N-O results but it becomes non-significant in N-O-L regressions. It was also the case for the B-J estimation results. Interestingly, knowledge spillovers variables (THEIL_BW, VERTICALLY_RELATED_BW), non-significant or only marginally significant in N-O results, become significant when lagged properly. Related variety, which we expected to exert positive influence on HGF incidence based on the literature, and which came up as negative in U and N-O regressions, comes out as insignificant when simultaneity issue is addressed (N-O-L) and in B-J estimation.

Finally, B-J estimates are very close to N-O-L findings increasing the robustness of the findings and validating both ways to address overlapping issue.

Moving to the models focusing on the role of universities in the ecosystem to support HGF, Table 11 in Annex, in the same way as previously compares U, N-O, N-O-L and B-J estimates. Regarding the main variables of interest here, the evidence is mixed. Only university engagement with SMEs (UNI_ENGAGEMENT_BW) is consistently positively and significantly associated with HGF incidence, with the exception of B-J estimation where the coefficient is not significant. Regional variation in universities' entrepreneurial activity reflected in the number of university spinoffs (UNI_SPINOFFS_BW) is positive but only marginally significant in N-O-L sample. Contrary of original Fotopoulos (2023) findings, we do not find that other university-related measures are significant (UNIVERSITIES, UNI_PATENTS). Regarding other variables, as in the first set of results, human capital differences across regions (HUMAN_CAPITAL_BW) are consistently positive and significant across all approaches and models, but the results for vertical relatedness (VERTICALLY_RELATED_BW) and entrepreneurial culture (ESHIP_CULTURE_BW) are positive and significant only for B-J approach.

Finally, Table 12 in Annex shows the multilevel analysis results across four approaches focusing on knowledge creation (R&D), finance and institutional elements of EE. The results for regional differences in formal institutions (INSTITUTIONS_BW) are not significant in all but one approach – unexpectedly B-J estimate is negative and significant. The share of scientists and engineers in the workforce (SCIENTISTS&ENGENEERS_BW) is positively and significantly associated with HGFs incidence, across all approaches, except for B-J, with the coefficient and the evidence being the strongest when both overlapping and simultaneity issues are addressed. It is also the case for the share of R&D related personnel. Similarly to original study, Business R&D investment was found to be not significant in all approaches except for B-J where it was negative and significant. The regional differences in finance element of EE reflected in the number of venture capital projects (VCAPITAL_PROJECTS_BW) and the amount invested (VCAPITAL_INVESTMENT_BW) appear to be positively and significantly related to HGF incidence rates, again in all but B-J estimations where the coefficients are negative and significant.

In sum, we can highlight the following main findings schematically presented in Table 3 by comparing findings resulting from different approaches across all models: (i) as in Fotopoulos (2023), the evidence is more supportive of the role of between transformation of selected variables in explaining HGF incidence differences across UK LAD regions; (ii) the evidence is decisive for the following variables: human capital, share of business services an creative services, and InnovateUK applications; (iii) although the positive influence of overall diversification and unrelated variety is supported in our alternative approaches, the evidence is much less strong than in Fotopoulos (2023) study judging by Bayes factor; (iv) the key finding of Fotopoulos (2023) regarding the strong and positive influence of vertical relatedness cannot be confirmed as the evidence is mixed across different models; (v) Fotopoulos (2023) findings regarding the role of universities is confirmed only for a subset of variables (research income and universities engagement with SMEs) when overlapping issue is addressed.

Table 3 Summary of findings. The effect of EE inputs and knowledge spillovers on HGFs incidence (HGFR). "Within-between" random effects estimations across different samples and approaches.

	BETWEEN						WITHIN					
	Fotopoulos (2023) original	Reproduced	Updated	N-O	N-O-L	B-J	Fotopoulos (2023) original	Reproduced	Updated	N-O	N-O-L	B-J
HUMAN_CAPITAL	+***	+***	+***	+***	+***	+***	+*	ns	mixed	mixed	ns	ns
RVARIETY	-***	ns	-***	-**	ns	ns	ns	+**	ns	ns	ns	ns
UVARIETY	+***	+*	+***	+***	+**	ns	ns	ns	+*	+*	ns	ns
THEIL	+***	+***	ns	ns	+***	+***	ns	ns	+*	ns	ns	ns
VRELATED	+***	mixed	mixed	mixed	mixed	mixed	ns	ns	mixed	ns	ns	ns
UNIVERSITIES	+**	ns	ns	ns	ns	ns	ns	+***	+***	ns	ns	ns
UNI_SPINOFFS	+*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
UNI_PATENTS	+**	-*	-**	ns	ns	ns	+**	-**	-**	ns	ns	ns
UNI_ENGAGEMENT	+**	+***	+***	+***	+*	ns	ns	-**	ns	ns	ns	ns
RESEARCH_INCOME	+**	ns	+***	+***	ns	ns	ns	ns	-**	-***	ns	ns
SCIENCE&ENGINEERS	ns	+**	+***	+**	+***	-*	ns	-***	-***	+**	ns	ns
R&D_PERSONNEL	+***	+***	+***	+***	+***	ns	+*	ns	-**	ns	-**	ns
BUSINESS_R&D	ns	ns	ns	ns	ns	-***	-**	+*	ns	+***	-***	+***
INCUBATORS	+**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
INNOUK_GRANTS	+*	ns	ns	ns	ns	ns	ns	+**	ns	ns	ns	+**
INNOUK_APPL	+**	+***	+***	+***	+***	+***	+***	+***	ns	ns	+***	+***
ESHIP_CULTURE	+***	mixed	mixed	mixed	mixed	mixed	ns	mixed	mixed	ns	mixed	ns
SMALL_FIRMS	+***	-**	ns	ns	ns	-**	ns	+**	-***	-**	-***	-**
BUSINESS_SERVICES	+***	+***	+***	+***	+***	+***	+***	ns	ns	ns	ns	ns
CREATIVE	+**	+***	+***	+***	+***	+***	ns	ns	ns	ns	ns	ns
INSTITUTIONS	+*	ns	ns	ns	ns	-***	ns	ns	ns	+***	-***	-***
VCAPITAL_PROJECTS	+**	+**	+**	+***	+**	-***	ns	ns	ns	ns	ns	+*
VCAPITAL_INVESTMENT	+***	+**	+**	+***	+***	-***	ns	ns	-**	ns	-***	ns
GVA_GROWTH	+***	mixed	ns	ns	ns	ns	ns	mixed	mixed	ns	ns	mixed
POP_DENSITY	mixed	mixed	mixed	mixed	mixed	-***	mixed	mixed	mixed	mixed	mixed	mixed

Note: +*** indicates positive and significant relationship at 1% (at least, across all models), +** positive and significant at 5% (at least, across all models), +* positive and significant at 10% (at least, across all models); -*** negative and significant at 1% (at least, across all models), -** negative and significant at 5% (at least, across all models), -* negative and significant at 10% (at least, across all models); 'mixed' indicates that evidence is mixed across different models (sign and significance), 'ns' indicates that relationship is not significant (at least in one of the models).

6. DISCUSSION

This paper examines the incidence of high-growth firms (HGFs) across UK local authority districts (LADs) and explores the role of knowledge spillovers and other entrepreneurial ecosystem (EE) elements in explaining regional variations in HGF prevalence. Building on Fotopoulos (2023), we address key methodological challenges associated with the rolling nature of HGF definitions, which can introduce bias in estimating regional persistence. This issue is central to understanding the long-term dynamics of high-growth firms and has important implications for regional policy.

Regional HGF persistence

Even after addressing overlapping growth periods, we find evidence of regional HGF persistence at the LAD level in the UK, suggesting some local authorities consistently outperform others in generating HGFs*,* in contrast to the low persistence observed at the firm level. This aligns broadly with prior studies of regional HGF persistence in developed contexts (Coad et al., 2025; Friesenbichler & Hölzl, 2020; Van Dijk et al., 2024), though Coad et al. (2025) note higher persistence in less developed regions—a pattern not evident in our data, where developed LADs like London predominate. Our findings diverge from those in smaller emerging economies (Coad & Srhoj, 2024). Three key observations emerge from our analysis.

First, defining the appropriate spatial scale for regional HGF analysis is important. It remains unclear what would be the most appropriate geographical level to examine regional HGFs incidence. This relates to the discussion on the 'geographic reach' of EE and the challenges to identify spatial boundaries of EE (Fischer et al., 2022). The view that EE has administrative boundaries and that 'a region can be a county, a city, a state, a group of any type (e.g., a metropolitan area or a megaregion) or any definable geographic area that has a function of facilitating entrepreneurial activity (Qian et al., 2013, p. 562) may be overly simplistic, ignoring the relational complexity of the linkages between firms and other EE actors. Empirically, so far, to analyse HGFs at regional level, the majority of the studies used NUTS-2 or NUTS-3 regions, the level for which the data encompassing EE characteristics is more easily available. What level of granularity is right though? Coad & Srhoj (2024) argue that, in case of small countries like Slovenia and Croatia, NUTS2 regions do not capture heterogeneity of the geographic areas (there are only 2 NUTS2 regions in Slovenia and 4 regions in Croatia), and more granular NUTS-3 regions reflecting administrative units with separate budgets would be more appropriate. Van Dijk et al. (2024) suggest that the NUTS-3 level may be too fine-grained to detect HGFs persistence, particularly in sparsely populated regions, implying that larger or more developed regions should exhibit greater persistence (Van Dijk et al., 2024, p. 22). In contrast, Coad et al. (2025) find consistent HGFs persistence patterns across both NUTS-3 and NUTS-2 levels in EU regions, with less developed regions often showing higher incidence and persistence. Our analysis at the UK LAD level—akin to NUTS-3—reveals persistent HGFs patterns, suggesting that fine-grained scales can still capture persistence, though the link to regional development may vary by context. The advantage of this granular scale is that it captures differences in local governance of the regions. At the same time, arguably some EE elements may transcend local authorities' borders, with extra-local authorities' knowledge linkages in sharing being potentially not adequately captured by LAD measures. This may be potentially a reason why the results for knowledge spillovers in our estimations are not consistently stable across all specifications. Future studies should identify the optimal geographical level of analysis of regional HGFs persistence and EE characteristics.

Second, there may still be limitations in assessing persistence. While we have extended the time period of our analysis to 2009-2021, it covers only 4 non-overlapping periods. This may not be sufficient to draw any deterministic conclusions regarding persistency. Ideally, it would be valuable to track HGFs incidence over longer periods of time to better understand the dynamic: how slow is a slow change? As it has already been mentioned above, this also concerns the inputs of EE, with some elements of EE being more prone to high inertia compared to other more dynamic elements.

Finally, the choice of HGF incidence metrics matters. While our correlation results show positive and significant correlation of HGF incidence rates between subsequent periods, the strength of the correlation depends on how HGF incidence is measured. The correlation coefficients are much higher for HGFs count and HGFs to 1,000 working age population (measure used in Fotopoulos, 2023) compared to HGFs to active 10+ employees firms. The first rate depends on the population demographics of the region (i.e. supply of labour force), including its age structure, while the second is influenced by firm demographics, fluctuating with firms' entries and exits. Recent research on business dynamism demonstrates a relationship between population growth and firm demographics: declining population growth typically results in decreased firm entry and a shift in firm distribution towards older firms (Hopenhayn et al, 2022). However, these processes are complex and evolving over time. Therefore, the choice of the measure of HGF incidence is not without consequence and should be examined more in depth.

Knowledge spillovers, Entrepreneurial Ecosystems and HGFs incidence

In contrast with Fotopoulos (2023) original study, our findings on the influence of knowledge spillovers on HGFs incidence are less strong, depend on model specification, and hence call for caution in interpretation. While, overall, we do find that overall diversification measured by Theil index is positive, the evidence is strong only when both overlapping and simultaneity issues are addressed. Contrary to theoretical predictions (Boschma & Iammarino, 2009; Frenken et al., 2007), the results of our preferred models (N-O-L and B-J) do not show significant results for related variety. We also find mixed evidence for vertical relatedness, the sign and the strength of relationship depending on model specification. As mentioned previously, it may be due to the fact that LADs level is inappropriate spatial scale to capture industrial structure in the UK. Additionally, the knowledge spillovers variables were constructed using employment data, and hence capture knowledge embedded in people, as opposed to patented knowledge. Alternative measures using patent data may lead to more conclusive results. Therefore, our results do not allow us to completely endorse Fotopoulos' (2023) 'guidance on what policies should and shouldn't do when trying to increase local HGF rates. They should, for example, not try to encourage regional specialization.' (Fotopoulos, 2023, p. 1904).

Interestingly, our evidence for the positive role of InnovateUK grants applications is much more decisive than in Fotopoulos (2023). It is the number of applications rather than the amount of grants awarded which seem to play the role in our estimations, meaning that the effect is essentially due to the pool of innovators in the region and the signalling effect of InnovateUK grants. This is also confirmed by the strong positive influence of R&D personnel on HGF incidence.

Among other EE elements, the most robust evidence is for the role of human capital in explaining regional variations of HGF incidence rates which is also in line with the original study. The policy implication of this finding is that if regions were to choose what investment to prioritise it should be education and human capital. The strong evidence highlights the importance of business and professional services sector and of creative industries sector for HGFs incidence. It has been argued that creative industries and creative class contribute to culture of ideas, knowledge spillovers and flourishing entrepreneurial culture and activity, and have been empirically shown to attract productive entrepreneurship (Audretsch & Belitski, 2021). This speaks in favour of investments in social and cultural infrastructure to attract creative class to the regions.

Interestingly, contrary to Fotopoulos (2023), in most of our estimations we find negative and significant effect of population density on HGFs incidence. This, at first glance surprising finding, may indicate that it is not urbanisation per se that spurs high growth but rather agglomeration of qualified labour and support services. This is in line with previous findings by Frenken et al. (2007).

7. CONCLUSION

This study confirms that UK LADs exhibit persistent HGF incidence from 2009–2021, driven by human capital, creative industries, and business services, though knowledge spillovers play a less pronounced role than expected. By refining Fotopoulos's (2023) methods with non-overlapping periods, we offer robust evidence of regional HGF persistence, contrasting with firm-level volatility and aligning broadly with developed-context studies (Coad et al., 2025; Friesenbichler & Hölzl, 2020; Van Dijk et al., 2024). Unlike smaller emerging economies (Coad & Srhoj, 2023), the UK's established EE sustains HGFs geographies, though Coad et al.'s (2025) finding of persistence in less developed regions highlights context-specific variation. While developed LADs like London lead in incidence and GDP per capita, fully disentangling these from persistence exceeds our scope, meriting future research. Our longitudinal insights enrich EE debates, countering the "broken clock" critique in high-quality settings, and suggest policies targeting talent and key sectors to foster productive entrepreneurship. Further studies should probe knowledge spillovers' weak effects and alternative drivers like business cycles.

While our results suggest that UK regions indeed differ in their capacity to attract HGFs and these differences being persistent over the period of 10 years, the research of the underlying conditions behind this persistency should be further developed. It raises questions on the spatial scale, time scale, and the choice of EE variables. Picking winners at firm-level seems to be unpromising, but picking winners at regional level may prove to be equally challenging.

REFERENCES

Anyadike-Danes, M., Hart, M., & Du, J. (2015). Firm dynamics and job creation in the United Kingdom: 1998–2013. *International Small Business Journal, 33*(1), 12-27. doi:10.1177/0266242614552334

Araki, M. E., Bennett, D. L., & Wagner, G. A. (2024). Regional innovation networks & high-growth entrepreneurship. *Research Policy, 53*(1), 104900. doi:https://doi.org/10.1016/j.respol.2023.104900

Audretsch, D. B. (1995). *Innovation and industry evolution*: MIT Press.

Audretsch, D. B., & Belitski, M. (2017). Entrepreneurial ecosystems in cities: establishing the framework conditions. *The Journal of Technology Transfer, 42*(5), 1030-1051. doi:10.1007/s10961-016-9473-8

Audretsch, D. B., & Belitski, M. (2021). Towards an entrepreneurial ecosystem typology for regional economic development: the role of creative class and entrepreneurship. *Regional Studies*, *55*(4), 735–756. https://doi.org/10.1080/00343404.2020.1854711

Bartels, B. (2008). Beyond "fixed versus random effects": a framework for improving substantive and statistical analysis of panel, time-series cross-sectional, and multilevel data. *The Society for Political Methodology*, *9*, 1–43.

Bell, A., & Jones, K. (2015). Explaining fixed effects: Random effects modeling of time-series cross-sectional and panel data. *Political Science Research and Methods*, *3*(1), 133–153. https://doi.org/10.1017/psrm.2014.7

Bettis, R. A., Ethiraj, S., Gambardella, A., Helfat, C., & Mitchell, W. (2016). Creating repeatable cumulative knowledge in strategic management. *Strategic Management Journal, 37*(2), 257-261. doi:https://doi.org/10.1002/smj.2477

Bone, J., Gonzalez-Uribe, J., Haley, C., & Lahr, H. (2019). The impact of business accelerators and incubators in the UK. BEIS Research Paper Number 2019/009.

Boschma, R., & Iammarino, S. (2009). Related variety, trade linkages, and regional growth in Italy. *Economic geography, 85*(3), 289-311.

Boschma, R.A. (2005). Does geographical proximity favour innovation?. *Économie et institutions*, *6–7*, 111–128. https://doi.org/10.4000/ei.926

Bosma, N., & Sternberg, R. (2014). Entrepreneurship as an Urban Event? Empirical Evidence from European Cities. *Regional Studies, 48*(6), 1016-1033. doi:10.1080/00343404.2014.904041

Bosma, N., Stam, E., & Wennekers, S. (2014). Intrapreneurship versus entrepreneurship in high and low income countries. *Entrepreneurship, People And Organisations.*

Frontiers in European Entrepreneurship Research. Cheltenham: Edward Elgar, 94-115.

Britten-Jones, M., Neuberger, A., & Nolte, I. (2011). Improved inference in regression with overlapping observations. *Journal of Business Finance & Accounting*, *38*(5–6), 657–683. https://doi.org/10.1111/j.1468-5957.2011.02244.x

Coad, A., & Srhoj, S. (2023). Entrepreneurial ecosystems and regional persistence of high growth firms: A 'broken clock' critique. *Research Policy, 52*(6), 104762. doi:https://doi.org/10.1016/j.respol.2023.104762

Coad, A., Daunfeldt, S.-O., Hölzl, W., Johansson, D., & Nightingale, P. (2014). High-growth firms: introduction to the special section. *Industrial and Corporate Change, 23*(1), 91-112.

Coad, A., Domnick, C., Santoleri, P., & Srhoj, S. (2025). Regional incidence and persistence of high-growth firms: testing ideas from the entrepreneurial ecosystems literature. *Regional Studies*, 1–21. https://doi.org/10.1080/00343404.2024.2433498

Coad, A., Frankish, J., Roberts, R. G., & Storey, D. J. (2013). Growth paths and survival chances: An application of Gambler's Ruin theory. *Journal of Business Venturing, 28*(5), 615-632. doi:https://doi.org/10.1016/j.jbusvent.2012.06.002

Daunfeldt, S.-O., & Halvarsson, D. (2015). Are high-growth firms one-hit wonders? Evidence from Sweden. *Small Business Economics, 44*(2), 361-383. doi:10.1007/s11187-014-9599-8

Daunfeldt, S.-O., Johansson, D., & Halvarsson, D. (2015). Using the Eurostat-OECD definition of high-growth firms: a cautionary note. *Journal of Entrepreneurship and Public Policy, 4*(1), 50-56.

Davidsson, P. (2004). *Researching entrepreneurship*. Springer.

DCMS (2016). Creative industries economic estimates. Department of Culture, Media and Sport, UK Government. https://www.gov.uk/government/statistics/creative-industries-economic-estimates-january-2016

Du, J., & Temouri, Y. (2015). High-growth firms and productivity: evidence from the United Kingdom. *Small Business Economics, 44*(1), 123-143. doi:10.1007/s11187-014-9584-2

Du, J., & Vanino, E. (2021). Agglomeration externalities of fast-growth firms. *Regional Studies, 55*(2), 167-181. doi:10.1080/00343404.2020.1760234

Erhardt, E. C. (2021). Measuring the persistence of high firm growth: choices and consequences. *Small Business Economics, 56*(1), 451-478.

Fischer, B., Meissner, D., Vonortas, N., & Guerrero, M. (2022). Spatial features of entrepreneurial ecosystems. *Journal of Business Research*, *147*, 27-36. https://doi.org/10.1016/j.jbusres.2022.04.018

Fotopoulos, G. (2023). Knowledge Spillovers, Entrepreneurial Ecosystems and the Geography of High Growth Firms. *Entrepreneurship Theory and Practice, 47*(5), 1877-1914. doi:10.1177/10422587221111732

Franco-Leal, N., Camelo-Ordaz, C., Fernandez-Alles, M., & Sousa-Ginel, E. (2020). The Entrepreneurial Ecosystem: Actors and Performance in Different Stages of Evolution of Academic Spinoffs. *10*(2). doi:doi:10.1515/erj-2018-0228

Frenken, K., Van Oort, F., & Verburg, T. (2007). Related Variety, Unrelated Variety and Regional Economic Growth. *Regional Studies, 41*(5), 685-697. doi:10.1080/00343400601120296

Friesenbichler, K., & Hölzl, W. (2020). High-growth firm shares in Austrian regions: the role of economic structures. *Regional Studies, 54*(11), 1585-1595.

Fritsch, M. (2024). *Struggling with entrepreneurial ecosystems* (No. 2024-007). Jena Economic Research Papers.

Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., & Shleifer, A. (1992). Growth in cities. *Journal of political economy, 100*(6), 1126-1152

Harms, R., & Groen, A. (2017). Loosen up? Cultural tightness and national entrepreneurial activity. *Technological Forecasting and Social Change, 121*, 196-204. doi:https://doi.org/10.1016/j.techfore.2016.04.013

Hart, M., Prashar, N., & Ri, A. (2020). From the Cabinet of Curiosities: The misdirection of research and policy debates on small firm growth. *International Small Business Journal, 39*(1), 3-17. doi:10.1177/0266242620951718

Henderson, V., Kuncoro, A., & Turner, M. (1995). Industrial development in cities. *Journal of political economy, 103*(5), 1067-1090.

Henrekson, M., & Johansson, D. (2008). Competencies and Institutions Fostering High-growth Firms. *Foundations and Trends® in Entrepreneurship, 5*(1), 1-80. doi:10.1561/0300000026

Henrekson, M., & Johansson, D. (2010). Gazelles as job creators: a survey and interpretation of the evidence. *Small Business Economics, 35*(2), 227-244. doi:10.1007/s11187-009-9172-z

Hölzl, W. (2014). Persistence, survival, and growth: a closer look at 20 years of fast-growing firms in Austria. *Industrial and Corporate Change, 23*(1), 199-231. doi:10.1093/icc/dtt054

Hopenhayn, H., Neira, J., & Singhania, R. (2022). From population growth to firm demographics: Implications for concentration, entrepreneurship and the labor share. *Econometrica*, *90*(4), 1879-1914. https://doi.org/10.3982/ECTA18012

Leendertse, J., Schrijvers, M., & Stam, E. (2022). Measure Twice, Cut Once: Entrepreneurial Ecosystem Metrics. *Research Policy, 51*(9), 104336. doi:https://doi.org/10.1016/j.respol.2021.104336

Li, M., Goetz, S. J., Partridge, M., & Fleming, D. A. (2016). Location determinants of high-growth firms. *Entrepreneurship & Regional Development, 28*(1-2), 97-125. doi:10.1080/08985626.2015.1109003

Malecki, E. J. (2018). Entrepreneurship and entrepreneurial ecosystems. *Geography Compass, 12*(3), e12359. doi:https://doi.org/10.1111/gec3.12359

Moreno, F., & Coad, A. (2015). *High-Growth Firms: Stylized Facts and Conflicting Results*. Retrieved from https://EconPapers.repec.org/RePEc:sru:ssewps:2015-05

Morris, A. K., Fiedler, A., & Audretsch, D. B. (2023). Enablers of knowledge spillover entrepreneurship in entrepreneurial ecosystems: synthesis and future directions. *The Journal of Technology Transfer*, 1-25.

Motoyama, Y. (2014). The state-level geographic analysis of high-growth companies. *Journal of Small Business & Entrepreneurship, 27*(2), 213-227. doi:10.1080/08276331.2015.1012795

Motoyama, Y., & Danley, B. (2012). An analysis of the geography of entrepreneurship: Understanding the geographic trends of Inc. 500 companies over thirty years at the State and Metropolitan levels. *Available at SSRN 2145480*.

Mundlak, Y. (1978). On the pooling of Time Series and Cross Section Data. *Econometrica*, *46*(1), 69–85. https://doi.org/10.2307/1913646

Prokop, D. (2021). University entrepreneurial ecosystems and spinoff companies: Configurations, developments and outcomes. *Technovation*, *107*(2021), 102286, 1–14. https://doi.org/10.1016/j.technovation.2021.102286

Qian, H., Acs, Z. J., & Stough, R. R. (2013). Regional systems of entrepreneurship: the nexus of human capital, knowledge and new firm formation. *Journal of economic geography*, *13*(4), 559-587.

Sleuwaegen, L., & Ramboer, S. (2020). Regional competitiveness and high growth firms in the EU: the creativity premium. *Applied Economics, 52*(22), 2325-2338. doi:10.1080/00036846.2019.1686454

Spigel, B. (2020). *Entrepreneurial Ecosystems: Theory, Practice and Futures*. Cheltenham, UK: Edward Elgar Publishing.

Spigel, B., & Harrison, R. (2018). Toward a process theory of entrepreneurial ecosystems. *Strategic Entrepreneurship Journal, 12*(1), 151-168. doi:https://doi.org/10.1002/sej.1268

Stam, E. (2013). Knowledge and entrepreneurial employees: a country-level analysis. *Small Business Economics, 41*(4), 887-898. doi:10.1007/s11187-013-9511-y

Stam, E. (2015). Entrepreneurial Ecosystems and Regional Policy: A Sympathetic Critique. *European Planning Studies, 23*(9), 1759-1769. doi:10.1080/09654313.2015.1061484

Stam, E., & van de Ven, A. (2021). Entrepreneurial ecosystem elements. *Small Business Economics, 56*(2), 809-832. doi:10.1007/s11187-019-00270-6

Sternberg, R. (2022). Entrepreneurship and geography—some thoughts about a complex relationship. *The Annals of Regional Science, 69*(3), 559-584. doi:10.1007/s00168-021-01091-w

Storey, D.J. (1994). *Understanding the small business sector*. London: International Thomson Business Press.

van Dijk, J., Leendertse, J., Stam, E., & van Rijnsoever, F. (2024). The entrepreneurial ecosystem clock keeps on ticking–Regional persistence of high-growth firms. USE Research Institute, 2024.

Wurth, B., Stam, E., & Spigel, B. (2021). Toward an Entrepreneurial Ecosystem Research Program. *Entrepreneurship Theory and Practice, 46*(3), 729-778. doi:10.1177/1042258721998948

ANNEX

Table 4 HGFs per active firm with 10+ employees (*HGFR2*): Pearson correlation coefficients

Period	2009-2012	2010-2013	2011-2014	2012-2015	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020	2018-2021
2009-2012	1									
2010-2013	0.668	1								
	0.000									
2011-2014	0.518	0.642	1							
	0.000	0.000								
2012-2015	0.404	0.428	0.489	1						
	0.000	0.000	0.000							
2013-2016	0.319	0.289	0.291	0.526	1					
	0.000	0.000	0.000	0.000						
2014-2017	0.255	0.228	0.145	0.400	0.629	1				
	0.000	0.000	0.005	0.000	0.000					
2015-2018	0.300	0.283	0.208	0.311	0.501	0.633	1			
	0.000	0.000	0.000	0.000	0.000	0.000				
2016-2019	0.377	0.322	0.207	0.250	0.327	0.397	0.623	1		
	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
2017-2020	0.370	0.351	0.243	0.262	0.296	0.357	0.531	0.682	1	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
2018-2021	0.369	0.354	0.313	0.272	0.302	0.244	0.352	0.449	0.629	1
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Note: p-values reported below coefficient; grey-shaded area shows correlation coefficients for overlapping periods.

Table 5 HGFs per 1,000 working age population: Pearson correlation coefficients

	2009-2012	2010-2013	2011-2014	2012-2015	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020	2018-2021
2009-2012	1									
2010-2013	0.999	1								
	0.000									
2011-2014	0.999	0.999	1							
	0.000	0.000								
2012-2015	0.999	0.999	0.999	1						
	0.000	0.000	0.000							
2013-2016	0.999	0.999	0.999	0.999	1					
	0.000	0.000	0.000	0.000						
2014-2017	0.999	0.999	0.998	0.999	1.000	1				
	0.000	0.000	0.000	0.000	0.000					
2015-2018	0.999	0.999	0.999	0.999	0.999	1.000	1			
	0.000	0.000	0.000	0.000	0.000	0.000				
2016-2019	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1		
	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
2017-2020	0.999	0.999	0.998	0.999	0.999	0.999	1.000	1.000	1	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
2018-2021	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	1.000	1
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Note: p-values reported below coefficient; grey-shaded area shows correlation coefficients for overlapping periods.

Table 6 Variables description

Variable	Description and measurement	Source	Geographical level	Period of data availability
HGFs count	Number of HGFs (OECD employment definition)	ONS Business Demography	LAD	2012-2021*
HGFR	Number of HGFs per 1,000 working age population, computed using HGFs count and working age population	ONS Business Demography, Nomis	LAD	2012-2021*
HGFR2	Number of HGFs divided by the number of active (survived) firms with 10+ employees: computed using HGFs count and number of firms who were present in (t-3) with 10+ employees and who survived in year (t)	ONS Business Demography	LAD	2012-2021*
UNIVERSITIES	Number of HE Institutions to GDP(bn£) of the region	Higher Education and community Interaction (HEBCI) survey	LAD	2008-2021
UNI_SPINOFFS	Number of HE Institutions spinoffs, log (observed value+1)	HEBCI	LAD	2009-2021
UNI_PATENTS	Cumulated number of patents to GDP(bn£) of the region	HEBCI	LAD	2009-2021
UNI_ENGAGEMENT	Number of research contracts with SMEs, log (observed value+1)	HEBCI	LAD	2009-2021
RESEARCH_INCOME	Total Research Income of universities, mn £	HEBCI	LAD	2009-2021
RVARIETY	Related Variety, based on employment data constructed using Frenken et al.(2007) methodology. Related sectors refer to different 4-digit SIC classification within the same 2-digit industry group	Nomis, BRES	LAD	2008-2021
UVARIETY	Unrelated Variety, based on employment data constructed using Frenken et al.(2007) methodology	Nomis, BRES	LAD	2008-2021
THEIL	Theil Index, calculated as a sum of RVARIETY and UVARIETY	Nomis, BRES	LAD	2008-2021
VRELATED	Vertically related	ONS United Kingdom Input-Output Analytical Tables (2017); and Employment data from Nomis, BRES	LAD	2010-2021
INCUBATORS	Number of incubators/accelerators to GDP(bn £) of the region	https://ian.centreforentrepreneurs.org/ <downloaded in Mai 2024>	LAD	time invariant
INNOUK_GRANTS	Amount of grants awarded, log (observed value+1)	Innovate UK	LAD	2008-2021
INNOUK_APPL	Grant applications per 1,000 working age population	Innovate UK	LAD	2008-2021

SCIENCE&ENGINEERS	% of working age population (aged 16-64) who are scientists and engineers	Eurostat, Business Enterprise Research and Development (BERD) survey	NUTS2	2008-2019
R&D_PERSONNEL	% of working age population (aged 16-64) who are R&D personnel	Eurostat, BERD	NUTS2	2008-2019
BUSINESS_R&D	Business sector R&D expense (% to GDP (mn))	Eurostat, BERD	NUTS2	2008-2019
HUMAN_CAPITAL	% of working age population (aged 16-64) with NVQ4+	Nomis, Annual Population Survey (APS)	LAD	2008-2021
ESHIP_CULTURE	% of working age population (aged 16-64) who are self employed	Nomis, APS	LAD	2008-2021
BUSINESS_SERVICES	Employment share in Professional and Business services sector (to total employment in the region). See Bone et al. (2019) for SIC codes	Nomis, Business Register and Employment Survey (BRES)	LAD	2008-2021
CREATIVE	Employment share in Creative industries (to total employment in the region). See DCMS (2016) for creative industries definition	Nomis, BRES	LAD	2008-2021
SMALL_FIRMS	Share of micro and small firms to total number of firms	Nomis, BRES	LAD	2008-2021
GVA_GROWTH	Growth rate of GVA per capita	Nomis, Regional Accounts	LAD	2008-2021
VCAPITAL_PROJECTS	Total equity investment (nbr of companies)	BVCA Reports on Investment Activity	NUTS1	2008-2021
VCAPITAL_INVESTMENT	Total equity investment (mn £)	BVCA Reports on Investment Activity	NUTS1	2008-2021
INSTITUTIONS	Quality of governance index	Charron et al., 2019	NUTS1	Data available for 2010, 2012, 2017, missing years imputed
POP_DENSITY	Nbr of people per sq km	ONS, Lin to confirm	LAD	2011-2021

Note: * Year refers to the end of the growth period, i.e. 2012 refers to growth period 2009-2012, 2021 – to growth period 2018-2021.
Source: authors

Table 7 ‘Within-between’ Random Effects Estimations: comparison of original Fotopoulos (2023), reproduced and updated estimations.

Variable	Estimation	(1)	(2)	(3)	(4)	(5)	(6)
HUMAN_CAPITAL_BW	original	0.004 (0.0000) 3195.36	0.003 (0.0036) 18.33		0.003 (0.0004) 125.82		
HUMAN_CAPITAL_BW	reproduced	0.049 (0.0000) >3196	0.050 (0.0000) >3196		0.044 (0.0000) >3196		
HUMAN_CAPITAL_BW	updated	0.055 (0.0000) >3196	0.067 (0.0000) >3196		0.060 (0.0000) >3196		
RESEARCH_INCOME_BW	original	0.007 (0.0363) 3.06				0.009 (0.0096) 8.25	0.009 (0.0116) 7.11
RESEARCH_INCOME_BW	reproduced	0.007 (0.2992) 1.02				0.005 (0.4424) 1.02	0.000 (0.9722) 13.44
RESEARCH_INCOME_BW	updated	0.081 (0.0000) >3196				0.083 (0.0000) >3196	0.077 (0.0000) >3196
INNOUK_APPL_BW	original			0.823 (0.0304) 3.46			
INNOUK_APPL_BW	reproduced			0.028 (0.0000) >3196			
INNOUK_APPL_BW	updated			0.091 (0.0000) >3196			
INNOUK_GRANTS_BW	original				0.003 (0.0163) 5.48		
INNOUK_GRANTS_BW	reproduced				0.006 (0.2747) 1.04		
INNOUK_GRANTS_BW	updated				0.005 (0.6455) 1.30		
THEIL_BW	original	0.065 (0.0001) 316.25	0.049 (0.0087) 8.88				
THEIL_BW	reproduced	0.013 (0.0060) 11.94	0.013 (0.0041) 16.37				
THEIL_BW	updated	0.006 (0.4054) 1.01	0.012 (0.1717) 1.22				
UNRELATED_VARIETY_BW	original					0.171 (0.0000) >3196	
UNRELATED_VARIETY_BW	reproduced					0.009 (0.0722) 1.94	
UNRELATED_VARIETY_BW	updated					0.023 (0.0019) 31.59	
RELATED_VARIETY_BW	original					-0.113 (0.0062) 11.75	
RELATED_VARIETY_BW	reproduced					-0.003 (0.5500) 1.12	
RELATED_VARIETY_BW	updated					-0.027 (0.0003) 168.78	
VERTICALLY_RELATED_BW	original			0.420 (0.0000) >3196	0.503 (0.0000) >3196		0.650 (0.0000) >3196
VERTICALLY_RELATED_BW	reproduced			0.015 (0.0025) 24.17	0.010 (0.0613) 2.15		0.015 (0.0011) 47.71
VERTICALLY_RELATED_BW	updated			0.020 (0.0118) 7.04	0.024 (0.0166) 5.41		0.006 (0.3532) 1.00
INCUBATORS_BW	original		0.057 (0.0101) 7.91				
INCUBATORS_BW	reproduced		-0.004 (0.7293) 1.60				
INCUBATORS_BW	updated		0.005 (0.5514) 1.12				
BUSINESS_SERVICES_BW	original					1.063 (0.0000) >3196	
BUSINESS_SERVICES_BW	reproduced					0.044 (0.0000) >3196	
BUSINESS_SERVICES_BW	updated					0.030 (0.0000) 803.58	
CREATIVE_BW	original						0.068 (0.0164) 5.45
CREATIVE_BW	reproduced						0.055 (0.0000) >3196
CREATIVE_BW	updated						0.064 (0.0000) >3196
SMALL_FIRMS_BW	original						2.191 (0.0002) 198.55
SMALL_FIRMS_BW	reproduced						-0.012 (0.0290) 3.58
SMALL_FIRMS_BW	updated						0.011 (0.1248) 1.42
ESHIP_CULTURE_BW	original	0.011 (0.0000) 1177.48	0.011 (0.0000) 3195.36	0.012 (0.0000) >3196	0.009 (0.0000) >3196	0.015 (0.0000) >3196	
ESHIP_CULTURE_BW	reproduced	0.008 (0.1469) 1.31	0.006 (0.2690) 1.04	0.019 (0.0003) 158.85	0.008 (0.1555) 1.27	0.017 (0.0017) 34.19	
ESHIP_CULTURE_BW	updated	0.013 (0.1078) 1.53	-0.007 (0.4911) 1.05	0.011 (0.1992) 1.14	-0.006 (0.5434) 1.11	0.033 (0.0000) 1450.15	
GVA_GROWTH_BW	original	3.598 (0.0001) 296.12	3.055 (0.0000) >3196	2.560 (0.0000) 3195.36	2.883 (0.0006) 89.12	2.703 (0.0013) 43.73	3.490 (0.0003) 142.86
GVA_GROWTH_BW	reproduced	0.004 (0.3955) 1.00	0.004 (0.3850) 1.00	0.006 (0.2600) 1.05	0.004 (0.4171) 1.01	0.007 (0.1481) 1.30	0.001 (0.9010) 3.92

Table 7 ‘Within-between’ Random Effects Estimations: comparison of original Fotopoulos (2023), reproduced and updated estimations. (continued)

GVA_GROWTH_BW	updated	0.035 (0.0000) >3196	0.045 (0.0000) >3196	0.035 (0.0000) >3196	0.045 (0.0000) >3196	0.037 (0.0000) >3196	0.024 (0.0003) 154.05
POP_DENSITY_BW	original	0.015 (0.0664) 2.04	-0.002 (0.6589)	0.017 (0.0055) 12.89	0.016 (0.0692) 1.99	0.015 (0.0549) 2.31	0.020 (0.0261) 3.87
POP_DENSITY_BW	reproduced	-0.045 (0.0000) >3196	-0.041 (0.0000) >3196	-0.034 (0.0000) >3196	-0.046 (0.0000) >3196	-0.046 (0.0000) >3196	-0.049 (0.0000) >3196
POP_DENSITY_BW	updated	-0.018 (0.0163) 5.48	0.025 (0.0072) 10.33	0.031 (0.0000) >3196	0.023 (0.0059) 12.08	-0.001 (0.8798) 3.26	-0.012 (0.0845) 1.76
HUMAN_CAPITAL_WI	original	0.001 (0.0696) 1.98	0.001 (-0.0548) 2.31		0.001 (0.0834) 1.78		
HUMAN_CAPITAL_WI	reproduced	0.008 (0.0014) 39.97	0.008 (0.0013) 41.77		0.008 (0.0010) 54.29		
HUMAN_CAPITAL_WI	updated	-0.007 (0.0000) >3196	-0.007 (0.0000) >3196		-0.007 (0.0000) 2930.63		
RESEARCH_INCOME_WI	original	0.000 (0.8876)				0.001 (0.7721)	0.001 (0.8424)
RESEARCH_INCOME_WI	reproduced	0.001 (0.6494) 1.31				0.001 (0.6264) 1.26	0.002 (0.5493) 1.12
RESEARCH_INCOME_WI	updated	-0.005 (0.0065) 11.20				-0.004 (0.0100) 7.98	-0.005 (0.0011) 47.76
INNOUK_APPL_WI	original			0.141 (0.0025) 24.24			
INNOUK_APPL_WI	reproduced			0.007 (0.0059) 12.10			
INNOUK_APPL_WI	updated			0.002 (0.3157) 1.01			
INNOUK_GRANTS_WI	original				0.000 (0.5166)		
INNOUK_GRANTS_WI	reproduced				0.005 (0.0177) 5.15		
INNOUK_GRANTS_WI	updated				-0.001 (0.3196) 1.01		
THEIL_WI	original	-0.024 (0.5239)	-0.023 (0.5447)				
THEIL_WI	reproduced	0.000 (0.9437) 6.72	0.000 (0.9713) 12.99				
THEIL_WI	updated	0.002 (0.0897) 1.70	0.003 (0.0683) 2.01				
UNRELATED_VARIETY_WI	original					-0.052 (0.3083) 1.01	
UNRELATED_VARIETY_WI	reproduced					0.002 (0.4247) 1.01	
UNRELATED_VARIETY_WI	updated					0.003 (0.0636) 2.10	
RELATED_VARIETY_WI	original					0.041 (0.4306)	
RELATED_VARIETY_WI	reproduced					0.004 (0.0409) 2.81	
RELATED_VARIETY_WI	updated					0.000 (0.7730) 1.85	
VERTICALLY_RELATED_WI	original			0.010 (0.9049)	-0.013 (0.8735)		0.013 (0.8738)
VERTICALLY_RELATED_WI	reproduced			-0.001 (0.6921) 1.44	-0.001 (0.5520) 1.12		-0.001 (0.6801) 1.40
VERTICALLY_RELATED_WI	updated			-0.005 (0.0003) 165.80	-0.004 (0.0019) 30.68		-0.004 (0.0027) 23.30
INCUBATORS_WI	original		-0.005 (0.4273)				
INCUBATORS_WI	reproduced		0.016 (0.3567) 1.00				
INCUBATORS_WI	updated		0.004 (0.4640) 1.03				
BUSINESS_SERVICES_WI	original					0.374 (0.0063) 11.51	
BUSINESS_SERVICES_WI	reproduced					0.002 (0.4613) 1.03	
BUSINESS_SERVICES_WI	updated					-0.001 (0.5480) 1.12	
CREATIVE_WI	original						-0.067 (0.7457)
CREATIVE_WI	reproduced						-0.003 (0.2120) 1.12
CREATIVE_WI	updated						-0.001 (0.4984) 1.06
SMALL_FIRMS_WI	original						1.070 (0.2363) 1.08
SMALL_FIRMS_WI	reproduced						0.006 (0.0235) 4.17
SMALL_FIRMS_WI	updated						-0.008 (0.0000) >3196
ESHIP_CULTURE_WI	original	0.000 (0.7600)	0.000 (0.7842)	0.000 (0.6981)	0.000 (0.7608)	0.000 (0.7460)	
ESHIP_CULTURE_WI	reproduced	0.005 (0.0357) 3.09	0.006 (0.0271) 3.76	0.005 (0.0404) 2.84	0.005 (0.0394) 2.89	0.006 (0.0304) 3.47	
ESHIP_CULTURE_WI	updated	0.001 (0.7134) 1.53	0.001 (0.5407) 1.11	0.000 (0.8882) 3.49	0.001 (0.4280) 1.01	0.000 (0.8748) 3.14	
GVA_GROWTH_WI	original	0.243 (0.1058) 1.55	0.236 (0.1101) 1.51	0.285 (0.0483) 2.51	0.245 (0.1099) 1.52	0.246 (0.0855) 1.75	0.307 (0.0291) 3.58

Table 7 'Within-between' Random Effects Estimations: comparison of original Fotopoulos (2023), reproduced and updated estimations. (continued)

GVA_GROWTH_WI	reproduced	0.000 (0.9426) 6.60	0.000 (0.9666) 11.20	0.000 (0.9242) 5.05	0.000 (0.9838) 22.83	0.000 (0.9468) 7.10	0.001 (0.6536) 1.32
GVA_GROWTH_WI	updated	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196
POP_DENSITY_WI	original	-0.035 (0.3882)	0.004 (0.9318)	-0.041 (0.3046) 1.02	-0.035 (0.3870)	-0.041 (0.3018) 1.02	-0.040 (0.3525) 1.00
POP_DENSITY_WI	reproduced	-0.004 (0.5235) 1.09	-0.003 (0.6369) 1.28	-0.002 (0.7780) 1.88	-0.005 (0.4442) 1.02	0.001 (0.8400) 2.51	0.003 (0.5992) 1.20
POP_DENSITY_WI	updated	-0.006 (0.0004) 118.37	-0.006 (0.0005) 94.23	-0.008 (0.0000) >3196	-0.006 (0.0005) 103.44	-0.008 (0.0000) >3196	-0.005 (0.0050) 13.88
CONSTANT	original	-0.474 (0.0011) 47.62	-0.318 (0.0094) 8.35	-0.115 (0.0068) 10.83	-0.209 (0.0036) 18.00	-0.710 (0.0000) 399.42	-2.187 (0.0003) 151.17
CONSTANT	reproduced	-0.244 (0.0709) 1.96	-0.250 (0.0658) 2.06	-0.101 (0.2511) 1.06	-0.068 (0.4094) 1.01	-0.149 (0.3274) 1.01	1.119 (0.0241) 4.10
CONSTANT	updated	-0.250 (0.2119) 1.12	-0.353 (0.1763) 1.20	-0.332 (0.0219) 4.40	-0.419 (0.0090) 8.66	-0.621 (0.0058) 12.32	-0.974 (0.1504) 1.29
N	original	2268	2268	2268	2268	2268	2268
N	reproduced	1387	1387	1387	1387	1387	1387
N	updated	2684	2684	2684	2684	2684	2684
R2 between	original	0.2951	0.5142	0.4538	0.3302	0.3867	0.2871
R2 between	reproduced	0.3382	0.3345	0.239	0.3405	0.3471	0.3724
R2 between	updated	0.4924	0.3086	0.4812	0.3274	0.5007	0.5252
R2 overall	original	0.2577	0.4485	0.3963	0.2882	0.3375	0.2504
R2 overall	reproduced	0.2459	0.2445	0.1756	0.2442	0.25	0.2637
R2 overall	updated	0.2983	0.2115	0.2868	0.2186	0.2946	0.3189
rho	original	0.7643	0.6902	0.7208	0.7199	0.7433	0.768
rho	reproduced	0.5172	0.5187	0.5498	0.5133	0.5215	0.487
rho	updated	0.7167	0.8214	0.7836	0.8162	0.7206	0.7187

Note: Each column shows the results of original Fotopoulos (2023) estimations along with estimations performed on two different samples (reproduced and updated). For ease of comparison, the results are grouped by variable of interest, with between effects in the top part and within effects in the bottom part of the table. Coefficient reported (p-values in Parentheses) Bayes Factor Bounds (BFB).

Table 8 'Within-between' Random Effects Estimations, university-related variables: comparison of original Fotopoulos (2023), reproduced and updated estimations.

Variable	Estimation	(7)	(8)	(9)	(10)
HUMAN_CAPITAL_BW	original		0.003 (0.0007) 76.11	0.003 (0.0004) 120.17	
HUMAN_CAPITAL_BW	reproduced		1.465 (0.0000) >3196	1.442 (0.0000) >3196	
HUMAN_CAPITAL_BW	updated		1.567 (0.0000) >3196	1.563 (0.0000) >3196	
VERTICALLY_RELATED_BW	original	0.553 (0.0000) >3196	0.585 (0.0000) >3196	0.538 (0.0000) >3196	0.586 (0.0000) >3196
VERTICALLY_RELATED_BW	reproduced	-0.061 (0.5052) 1.07	-0.110 (0.1023) 1.58	-0.277 (0.0001) 368.60	-0.143 (0.1393) 1.34
VERTICALLY_RELATED_BW	updated	-0.032 (0.8043) 2.10	-0.147 (0.0072) 10.38	-0.317 (0.0000) >3196	-0.114 (0.4062) 1.01
GVA_GROWTH_BW	original	3.005 (0.0000) >3196	2.736 (0.0006) 78.16	3.094 (0.0004) 122.93	3.233 (0.0001) 630.72
GVA_GROWTH_BW	reproduced	0.387 (0.0000) 1472.68	0.137 (0.0376) 2.98	0.154 (0.0189) 4.90	0.402 (0.0000) >3196
GVA_GROWTH_BW	updated	0.363 (0.0031) 20.60	0.136 (0.0102) 7.87	0.138 (0.0099) 8.05	0.370 (0.0022) 26.99
ESHIP_CULTURE_BW	original	0.015 (0.0000) >3196	0.009 (0.0000) >3196	0.011 (0.0000) 3195.36	0.015 (0.0000) >3196
ESHIP_CULTURE_BW	reproduced	0.258 (0.0094) 8.38	-0.299 (0.0001) 357.94	-0.166 (0.0331) 3.26	0.323 (0.0013) 41.48
ESHIP_CULTURE_BW	updated	0.249 (0.0817) 1.80	-0.334 (0.0000) >3196	-0.204 (0.0027) 23.30	0.311 (0.0324) 3.31
UNIVERSITIES_BW	original	0.078 (0.0158) 5.61			
UNIVERSITIES_BW	reproduced	-0.160 (0.1159) 1.47			
UNIVERSITIES_BW	updated	-0.149 (0.3061) 1.02			
UNI_PATENTS_BW	original		0.325 (0.0268) 3.79		
UNI_PATENTS_BW	reproduced		-0.149 (0.0965) 1.63		
UNI_PATENTS_BW	updated		-0.103 (0.0497) 2.47		
UNI_ENGAGEMENT_BW	original			0.022 (0.0213) 4.49	
UNI_ENGAGEMENT_BW	reproduced			0.344 (0.0000) 776.67	
UNI_ENGAGEMENT_BW	updated			0.383 (0.0000) >3196	
UNI_SPINOFFS_BW	original				0.135 (0.0688) 2.00
UNI_SPINOFFS_BW	reproduced				0.175 (0.1230) 1.43
UNI_SPINOFFS_BW	updated				0.158 (0.3223) 1.01
POP_DENSITY_BW	original	0.009 (0.0154) 5.71	0.014 (0.1016) 1.58	0.014 (0.0707) 1.96	0.016 (0.0046) 14.76
POP_DENSITY_BW	reproduced	0.339 (0.0017) 33.18	-0.276 (0.0011) 48.56	-0.534 (0.0000) >3196	0.154 (0.1848) 1.18
POP_DENSITY_BW	updated	0.180 (0.2123) 1.12	-0.430 (0.0000) >3196	-0.705 (0.0000) >3196	-0.005 (0.9716) 13.13
HUMAN_CAPITAL_WI	original		0.001 (0.0733) 1.92	0.001 (0.0789) 1.84	

Table 8 'Within-between' Random Effects Estimations, university-related variables: comparison of original Fotopoulos (2023), reproduced and updated estimations. (continued)

Variable	Estimation	(7)	(8)	(9)	(10)
HUMAN_CAPITAL_WI	reproduced		0.005 (0.6145) 1.23	0.008 (0.4413) 1.02	
HUMAN_CAPITAL_WI	updated		0.071 (0.0000) >3196	0.078 (0.0000) >3196	
VERTICALLY_RELATED_WI	original	0.016 (0.8499)	-0.007 (-0.9267)	-0.009 (0.9082)	0.020 (0.8097)
VERTICALLY_RELATED_WI	reproduced	0.005 (0.3728) 1.00	0.005 (0.4902) 1.05	0.005 (0.4838) 1.05	0.004 (0.4619) 1.03
VERTICALLY_RELATED_WI	updated	0.012 (0.1518) 1.29	0.003 (0.7792) 1.89	0.002 (0.8552) 2.75	0.007 (0.4150) 1.01
GVA_GROWTH_WI	original	0.328 (0.0184) 5.00	0.232 (0.1191) 1.45	0.253 (0.0925) 1.67	0.332 (0.0168) 5.35
GVA_GROWTH_WI	reproduced	-0.006 (0.4231) 1.01	-0.011 (0.1973) 1.15	-0.011 (0.1884) 1.17	-0.011 (0.1327) 1.37
GVA_GROWTH_WI	updated	0.008 (0.3193) 1.01	0.003 (0.7926) 2.00	0.003 (0.7741) 1.86	0.003 (0.7028) 1.48
ESHIP_CULTURE_WI	original	0.000 (0.8213)	0.000 (0.7651)	0.000 (0.7705)	0.000 (0.7963)
ESHIP_CULTURE_WI	reproduced	-0.043 (0.0000) >3196	-0.047 (0.0000) >3196	-0.045 (0.0000) >3196	-0.052 (0.0000) >3196
ESHIP_CULTURE_WI	updated	0.021 (0.0104) 7.72	0.028 (0.0131) 6.49	0.028 (0.0114) 7.20	0.018 (0.0318) 3.36
UNIVERSITIES_WI	original	0.017 (0.2290) 1.09			
UNIVERSITIES_WI	reproduced	0.063 (0.0000) >3196			
UNIVERSITIES_WI	updated	0.063 (0.0000) >3196			
UNI_PATENTS_WI	original		0.369 (0.0368) 3.03		
UNI_PATENTS_WI	reproduced		-0.019 (0.0287) 3.61		
UNI_PATENTS_WI	updated		-0.026 (0.0291) 3.57		
UNI_ENGAGEMENT_WI	original			-0.001 (0.8707)	
UNI_ENGAGEMENT_WI	reproduced			-0.018 (0.0122) 6.82	
UNI_ENGAGEMENT_WI	updated			-0.002 (0.8518) 2.69	
UNI_SPINOFFS_WI	original				-0.007 (0.2582) 1.05
UNI_SPINOFFS_WI	reproduced				0.002 (0.7833) 1.92
UNI_SPINOFFS_WI	updated				-0.005 (0.5238) 1.09
POP_DENSITY_WI	original	-0.029 (0.4822)	-0.029 (0.4495)	-0.035 (0.3927)	-0.031 (0.4511)
POP_DENSITY_WI	reproduced	0.240 (0.0000) >3196	0.207 (0.0000) >3196	0.204 (0.0000) >3196	0.221 (0.0000) >3196
POP_DENSITY_WI	updated	0.182 (0.0000) >3196	0.118 (0.0000) >3196	0.114 (0.0000) >3196	0.165 (0.0000) >3196
CONSTANT	original	-0.171 (0.0008) 65.91	-0.204 (0.0041) 16.39	-0.216 (0.0039) 17.11	-0.185 (0.0068) 10.81
CONSTANT	reproduced	-1.946 (0.2276) 1.09	0.341 (0.7698) 1.83	2.010 (0.0926) 1.67	-1.129 (0.4974) 1.06
CONSTANT	updated	-2.179 (0.3442) 1.00	1.002 (0.3070) 1.01	2.733 (0.0083) 9.24	-1.338 (0.5723) 1.15
N	original	2268	2268	2268	2268
N	reproduced	1596	1596	1596	1596
N	updated	3028	3028	3028	3028
R2 between	original	0.485	0.3421	0.3457	0.3892
R2 between	reproduced	0.0049	0.2723	0.282	0.0066
R2 between	updated	0.0159	0.2693	0.2787	0.0158
R2 overall	original	0.4224	0.299	0.3017	0.3391
R2 overall	reproduced	0.0059	0.2275	0.2337	0.0072
R2 overall	updated	0.0177	0.1658	0.1697	0.0172
rho	original	0.7082	0.749	0.7466	0.7415
rho	reproduced	0.983	0.9491	0.9492	0.9822
rho	updated	0.959	0.6829	0.7047	0.9585

Note: Each column shows the results of original Fotopoulos (2023) estimations along with estimations performed on two different samples (reproduced and updated). For ease of comparison, the results are grouped by variable of interest, with between effects in the top part and within effects in the bottom part of the table. Coefficient (p-values in Parentheses) Bayes Factor Bounds (BFB).

Table 9 Multilevel analysis results: comparison of original Fotopoulos (2023), reproduced and updated estimations

Variable	Estimation	(11)	(12)	(13)	(14)	(15)	(16)
HUMAN_CAPITAL_BW	original		0.003 (0.0036) 18.37				
HUMAN_CAPITAL_BW	reproduced		1.205 (0.0000) >3196				
HUMAN_CAPITAL_BW	updated		1.156 (0.0000) >3196				
VERTICALLY_RELATED_BW	original	0.636 (0.0000) >3196	0.542 (0.0000) >3196	0.644 (0.0000) >3196	0.635 (0.0000) >3196	0.620 (0.0000) >3196	0.595 (0.0000) >3196
VERTICALLY_RELATED_BW	reproduced	-0.164 (0.2435) 1.07	-0.192 (0.0924) 1.67	-0.278 (0.1463) 1.31	-0.068 (0.6012) 1.20	-0.057 (0.6561) 1.33	-0.069 (0.5969) 1.19
VERTICALLY_RELATED_BW	updated	-0.139 (0.2937) 1.02	-0.206 (0.0546) 2.32	-0.256 (0.1584) 1.26	-0.046 (0.7124) 1.52	-0.038 (0.7552) 1.74	-0.046 (0.7127) 1.52
GVA_GROWTH_BW	original	2.447 (0.0004) 132.09	2.093 (0.0014) 40.98	2.473 (0.0003) 151.17	2.960 (0.0001) 630.72	3.036 (0.0000) 1177.48	3.209 (0.0000) 3195.36
GVA_GROWTH_BW	reproduced	0.382 (0.0040) 16.54	-0.001 (0.9906) 39.46	0.386 (0.0039) 16.97	0.387 (0.0023) 26.44	0.384 (0.0024) 24.98	0.386 (0.0026) 23.85
GVA_GROWTH_BW	updated	0.332 (0.0056) 12.76	0.008 (0.9394) 6.26	0.333 (0.0058) 12.36	0.338 (0.0036) 18.27	0.337 (0.0036) 18.14	0.337 (0.0039) 16.91
ESHIP_CULTURE_BW	original	0.009 (0.0005) 93.56	0.006 (0.0225) 4.31	0.009 (0.0003) 142.86	0.010 (0.0001) 278.54	0.009 (0.0008) 68.17	0.009 (0.0006) 85.11
ESHIP_CULTURE_BW	reproduced	0.297 (0.0394) 2.89	-0.185 (0.1662) 1.23	0.275 (0.0570) 2.25	0.215 (0.1058) 1.55	0.027 (0.8724) 3.09	0.402 (0.0068) 10.86
ESHIP_CULTURE_BW	updated	0.268 (0.0527) 2.37	-0.178 (0.1624) 1.25	0.248 (0.0750) 1.89	0.186 (0.1505) 1.29	0.025 (0.8821) 3.32	0.362 (0.0103) 7.82
SCIENTISTS&ENGINEERS_BW	original	0.010 (0.3962)					
SCIENTISTS&ENGINEERS_BW	reproduced	0.364 (0.0148) 5.90					
SCIENTISTS&ENGINEERS_BW	updated	0.376 (0.0089) 8.74					
R&D_PERSONNEL_BW	original		0.079 (0.0000) >3196				
R&D_PERSONNEL_BW	reproduced		0.528 (0.0000) >3196				
R&D_PERSONNEL_BW	updated		0.514 (0.0000) >3196				
BUSINESS_R&D_BW	original			0.005 (0.7794)			
BUSINESS_R&D_BW	reproduced			-0.315 (0.1309) 1.38			
BUSINESS_R&D_BW	updated			-0.324 (0.1037) 1.57			
VCAPITAL_PROJECTS_BW	original				0.035 (0.0331) 3.26		
VCAPITAL_PROJECTS_BW	reproduced				0.286 (0.0232) 4.22		
VCAPITAL_PROJECTS_BW	updated				0.245 (0.0414) 2.79		
VCAPITAL_INVESTMENT_BW	original					0.034 (0.0007) 72.34	
VCAPITAL_INVESTMENT_BW	reproduced					0.390 (0.0121) 6.87	
VCAPITAL_INVESTMENT_BW	updated					0.332 (0.0239) 4.12	
INSTITUTIONS_BW	original						0.162 (0.0702) 1.97
INSTITUTIONS_BW	reproduced						0.143 (0.3618) 1.00
INSTITUTIONS_BW	updated						0.123 (0.4232) 1.01
POP_DENSITY_BW	original	0.021 (0.0000) 3195.36	0.013 (0.0013) 42.86	0.022 (0.0000) >3196			
POP_DENSITY_BW	reproduced	0.049 (0.7357) 1.63	-0.522 (0.0000) 920.39	0.108 (0.4578) 1.03			
POP_DENSITY_BW	updated	-0.053 (0.6802) 1.40	-0.510 (0.0000) >3196	0.005 (0.9722) 13.41			
HUMAN_CAPITAL_WI	original		0.001 (0.0304) 3.47				
HUMAN_CAPITAL_WI	reproduced		0.035 (0.0000) >3196				
HUMAN_CAPITAL_WI	updated		0.023 (0.0000) >3196				
VERTICALLY_RELATED_WI	original	0.003 (0.9680)	-0.009 (0.9111)	0.013 (0.8675)	0.000 (0.9959)	0.016 (0.8381)	-0.008 (0.9171)
VERTICALLY_RELATED_WI	reproduced	0.004 (0.3905) 1.00	0.003 (0.4117) 1.01	0.004 (0.3753) 1.00	0.011 (0.0453) 2.62	0.011 (0.0480) 2.52	0.011 (0.0439) 2.68
VERTICALLY_RELATED_WI	updated	0.004 (0.2474) 1.06	0.004 (0.2572) 1.05	0.004 (0.2661) 1.04	0.007 (0.0787) 1.84	0.007 (0.0857) 1.75	0.007 (0.0776) 1.86
GVA_GROWTH_WI	original	0.283 (0.0227) 4.28	0.145 (0.2737) 1.04	0.380 (0.0016) 34.80	0.277 (0.0211) 4.51	0.324 (0.0065) 11.24	0.244 (0.0577) 2.24
GVA_GROWTH_WI	reproduced	-0.007 (0.1109) 1.51	-0.008 (0.0535) 2.35	-0.007 (0.0815) 1.80	-0.007 (0.2018) 1.14	-0.007 (0.2097) 1.12	-0.007 (0.2062) 1.13

Table 9 Multilevel analysis results: comparison of original Fotopoulos (2023), reproduced and updated estimations (continued)

Variable	Estimation	(11)	(12)	(13)	(14)	(15)	(16)
GVA_GROWTH_WI	updated	-0.001 (0.7581) 1.75	-0.002 (0.5463) 1.11	-0.001 (0.6522) 1.32	-0.002 (0.6026) 1.21	-0.002 (0.6057) 1.21	-0.002 (0.6021) 1.20
ESHIP_CULTURE_WI	original	0.000 (0.6503)	0.000 (0.7104)	0.000 (0.6864)	0.000 (0.5917)	0.000 (0.5930)	0.000 (0.5504)
ESHIP_CULTURE_WI	reproduced	-0.032 (0.0000) >3196	-0.040 (0.0000) >3196	-0.040 (0.0000) >3196	0.003 (0.6066) 1.21	0.003 (0.5116) 1.07	0.002 (0.7623) 1.78
ESHIP_CULTURE_WI	updated	-0.024 (0.0000) >3196	-0.032 (0.0000) >3196	-0.030 (0.0000) >3196	0.001 (0.8664) 2.96	0.002 (0.6963) 1.46	0.001 (0.8812) 3.30
SCIENTISTS&ENGINNERS _WI	original	0.003 (0.1421) 1.33					
SCIENTISTS&ENGINNERS _WI	reproduced	-0.015 (0.0084) 9.12					
SCIENTISTS&ENGINNERS _WI	updated	-0.018 (0.0000) >3196					
R&D_PERSONNEL_WI	original		0.027 (0.0618) 2.14				
R&D_PERSONNEL_WI	reproduced		-0.004 (0.2681) 1.04				
R&D_PERSONNEL_WI	updated		-0.008 (0.0128) 6.61				
BUSINESS_R&D_WI	original			-0.016 (0.0301) 3.49			
BUSINESS_R&D_WI	reproduced			0.011 (0.0597) 2.19			
BUSINESS_R&D_WI	updated			-0.001 (0.8559) 2.76			
VCAPITAL_PROJECTS_WI	original				-0.005 (0.3118) 1.01		
VCAPITAL_PROJECTS_WI	reproduced				-0.003 (0.6883) 1.43		
VCAPITAL_PROJECTS_WI	updated				-0.002 (0.6695) 1.37		
VCAPITAL_INVESTMENT_ WI	original					0.002 (0.2814) 1.03	
VCAPITAL_INVESTMENT_ WI	reproduced					-0.010 (0.1779) 1.20	
VCAPITAL_INVESTMENT_ WI	updated					-0.010 (0.0455) 2.62	
INSTITUTIONS_WI	original						0.014 (0.2516) 1.06
INSTITUTIONS_WI	reproduced						0.013 (0.4285) 1.01
INSTITUTIONS_WI	updated						0.001 (0.7943) 2.01
POP_DENSITY_WI	original	-0.034 (0.0853) 1.75	-0.035 (0.0712) 1.96	-0.029 (0.1359) 1.36			
POP_DENSITY_WI	reproduced	0.160 (0.0000) >3196	0.148 (0.0000) >3196	0.157 (0.0000) >3196			
POP_DENSITY_WI	updated	0.104 (0.0000) >3196	0.095 (0.0000) >3196	0.100 (0.0000) >3196			
CONSTANT	original	-0.211 (0.0608) 2.16	-0.215 (0.0000) >3196	-0.129 (0.0121) 6.89	-0.221 (0.0016) 36.29	-0.189 (0.0002) 215.96	-0.215 (0.0046) 14.91
CONSTANT	reproduced	-0.982 (0.6896) 1.44	1.612 (0.4348) 1.02	2.043 (0.5635) 1.14	-1.556 (0.4966) 1.06	0.006 (0.9982) 199.28	-3.139 (0.2012) 1.14
CONSTANT	updated	-0.953 (0.6835) 1.41	1.877 (0.3367) 1.00	2.144 (0.5256) 1.09	-1.521 (0.4911) 1.05	-0.158 (0.9467) 7.10	-3.036 (0.1968) 1.15
N	original	2268	2236	2268	2268	2268	2268
N	reproduced	1682	1682	1682	1682	1682	1682
N	updated	2271	2271	2271	2271	2271	2271
BIC	original	-4240.2	-4169.28	-4245.6	-4186	-4188.4	-4190.6
BIC	reproduced	725.2964	607.7714	732.2273	1352.8558	1349.8704	1356.8192
BIC	updated	188.2159	84.1327	213.8838	690.5104	685.6241	694.1406
Error variance	original	0.005	0.005	0.005	0.005	0.005	0.005
Error variance	reproduced	0.1568	0.1551	0.157	0.1993	0.1992	0.1993
Error variance	updated	0.1504	0.1501	0.1513	0.1723	0.1721	0.1723
ICC_LADS	original	0.8164	0.7646	0.817	0.8106	0.8079	0.8116
ICC_LADS	reproduced	0.9952	0.9934	0.9953	0.9917	0.9917	0.9918
ICC_LADS	updated	0.9954	0.9934	0.9954	0.9936	0.9936	0.9937
ICC_NUTS1	original	NA	NA	NA	0.0126	0.0004	0.0188
ICC_NUTS1	reproduced				0	0	0
ICC_NUTS1	updated				0	0	0
ICC_NUTS2	original	0.2995	0.1346	0.3002	NA	NA	NA
ICC_NUTS2	reproduced	0	0	0			

Table 9 Multilevel analysis results: comparison of original Fotopoulos (2023), reproduced and updated estimations (continued)

Variable	Estimation	(11)	(12)	(13)	(14)	(15)	(16)
ICC_NUTS2	updated	0	0	0			
LAD (intercept variance)	original	0.0142	0.0135	0.0142	0.0212	0.0212	0.0212
LAD (intercept variance)	reproduced	5.1477	3.6286	5.2062	4.7572	4.7347	4.8265
LAD (intercept variance)	updated	4.8782	3.3935	4.936	4.6351	4.615	4.6891
NUTS1 (intercept variance)	original	NA	NA	NA	0.0003	0	0.0005
NUTS1 (intercept variance)	reproduced				0	0	0
NUTS1 (intercept variance)	updated				0	0	0
NUTS2 (intercept variance)	original	0.0082	0.0029	0.0082	NA	NA	NA
NUTS2 (intercept variance)	reproduced	0	0	0			
NUTS2 (intercept variance)	updated	0	0	0			
Log-likelihood	original	2174.19	2146.34	2176.86	2139.37	2140.54	2141.68
Log-likelihood	reproduced	-310.654	-244.4638	-314.1195	-631.8615	-630.3688	-633.8431
Log-likelihood	updated	-40.0121	19.7574	-52.8461	-298.8873	-296.4442	-300.7024
Wald chi2	original	113.02	211.68	114.71	100.492	115.429	97.3851
Wald chi2	reproduced	860.0901	1030.1394	850.9817	26.1891	29.282	21.9665
Wald chi2	updated	619.5741	765.514	587.1328	21.7976	26.7753	17.9798

Note: Each column shows the results of original Fotopoulos (2023) estimations along with estimations performed on two different samples (reproduced and updated). For ease of comparison, the results are grouped by variable of interest, with between effects in the top part and within effects in the bottom part of the table. Coefficients reported (p-values in Parentheses) Bayes Factor Bounds (BFB).

Table 10 'Within-between' Random Effects Estimations: comparison of U, N-O, N-O-L and B-J estimations.

Variable	Estimation	(1)	(2)	(3)	(4)	(5)	(6)
HUMAN_CAPITAL_BW	U	0.055 (0.0000) >3196	0.067 (0.0000) >3196		0.060 (0.0000) >3196		
HUMAN_CAPITAL_BW	N-O	0.054 (0.0000) >3196	0.061 (0.0000) >3196		0.055 (0.0000) >3196		
HUMAN_CAPITAL_BW	N-O-L	0.047 (0.0000) >3196	0.048 (0.0000) >3196		0.044 (0.0000) >3196		
HUMAN_CAPITAL_BW	B-J	0.058 (0.0000) >3196	0.058 (0.0000) >3196		0.050 (0.0000) >3196		
RESEARCH_INCOME_BW	U	0.081 (0.0000) >3196				0.083 (0.0000) >3196	0.077 (0.0000) >3196
RESEARCH_INCOME_BW	N-O	0.051 (0.0000) >3196				0.056 (0.0000) >3196	0.049 (0.0000) >3196
RESEARCH_INCOME_BW	N-O-L	0.009 (0.0805) 1.81				0.008 (0.1702) 1.22	0.002 (0.6659) 1.36
RESEARCH_INCOME_BW	B-J	0.002 (0.7860) 1.94				0.000 (0.9843) 23.66	-0.006 (0.3521) 1.00
INNOUK_APPL_BW	U			0.091 (0.0000) >3196			
INNOUK_APPL_BW	N-O			0.066 (0.0000) >3196			
INNOUK_APPL_BW	N-O-L			0.028 (0.0000) >3196			
INNOUK_APPL_BW	B-J			0.032 (0.0000) >3196			
INNOUK_GRANTS_BW	U				0.005 (0.6455) 1.30		
INNOUK_GRANTS_BW	N-O				0.005 (0.5388) 1.10		
INNOUK_GRANTS_BW	N-O-L				0.002 (0.6409) 1.29		
INNOUK_GRANTS_BW	B-J				0.008 (0.2640) 1.05		
THEIL_BW	U	0.006 (0.4054) 1.01	0.012 (0.1717) 1.22				
THEIL_BW	N-O	0.008 (0.2303) 1.09	0.012 (0.0860) 1.74				
THEIL_BW	N-O-L	0.012 (0.0044) 15.51	0.013 (0.0023) 26.08				
THEIL_BW	B-J	0.019 (0.0003) 153.61	0.019 (0.0003) 158.72				
UNRELATED_VARIETY_BW	U					0.023 (0.0019) 31.59	
UNRELATED_VARIETY_BW	N-O					0.019 (0.0070) 10.56	
UNRELATED_VARIETY_BW	N-O-L					0.011 (0.0277) 3.70	
UNRELATED_VARIETY_BW	B-J					0.007 (0.2748) 1.04	
RELATED_VARIETY_BW	U					-0.027 (0.0003) 168.78	
RELATED_VARIETY_BW	N-O					-0.018 (0.0104) 7.75	
RELATED_VARIETY_BW	N-O-L					0.000 (0.9956) 83.56	
RELATED_VARIETY_BW	B-J					0.002 (0.6800) 1.40	
VERTICALLY_RELATED_BW	U			0.020 (0.0118) 7.04	0.024 (0.0166) 5.41		0.006 (0.3532) 1.00
VERTICALLY_RELATED_BW	N-O			0.015 (0.0214) 4.47	0.015 (0.0518) 2.40		0.007 (0.2526) 1.06
VERTICALLY_RELATED_BW	N-O-L			0.015 (0.0010) 55.86	0.013 (0.0033) 19.54		0.016 (0.0004) 122.01
VERTICALLY_RELATED_BW	B-J			0.010 (0.0983) 1.61	0.010 (0.1065) 1.54		0.017 (0.0060) 12.04
INCUBATORS_BW	U		0.005 (0.5514) 1.12				
INCUBATORS_BW	N-O		0.011 (0.4323) 1.01				
INCUBATORS_BW	N-O-L		-0.004 (0.6402) 1.29				
INCUBATORS_BW	B-J		-0.010 (0.4407) 1.02				
BUSINESS_SERVICES_BW	U					0.030 (0.0000) 803.58	
BUSINESS_SERVICES_BW	N-O					0.029 (0.0001) 615.52	
BUSINESS_SERVICES_BW	N-O-L					0.035 (0.0000) >3196	
BUSINESS_SERVICES_BW	B-J					0.042 (0.0000) >3196	
CREATIVE_BW	U						0.064 (0.0000) >3196

Table 10 'Within-between' Random Effects Estimations: comparison of U, N-O, N-O-L and B-J estimations. (continued)

Variable	Estimation	(1)	(2)	(3)	(4)	(5)	(6)
CREATIVE_BW	N-O						0.060 (0.0000) >3196
CREATIVE_BW	N-O-L						0.044 (0.0000) >3196
CREATIVE_BW	B-J						0.050 (0.0000) >3196
SMALL_FIRMS_BW	U						0.011 (0.1248) 1.42
SMALL_FIRMS_BW	N-O						0.005 (0.4243) 1.01
SMALL_FIRMS_BW	N-O-L						-0.008 (0.1164) 1.47
SMALL_FIRMS_BW	B-J						-0.014 (0.0276) 3.71
ESHIP_CULTURE_BW	U	0.013 (0.1078) 1.53	-0.007 (0.4911) 1.05	0.011 (0.1992) 1.14	-0.006 (0.5434) 1.11	0.033 (0.0000) 1450.15	
ESHIP_CULTURE_BW	N-O	0.012 (0.1065) 1.54	0.001 (0.8912) 3.58	0.015 (0.0308) 3.43	0.000 (0.9537) 8.14	0.030 (0.0000) 690.57	
ESHIP_CULTURE_BW	N-O-L	0.010 (0.0463) 2.59	0.007 (0.1622) 1.25	0.020 (0.0000) 1725.72	0.007 (0.1224) 1.43	0.018 (0.0002) 215.30	
ESHIP_CULTURE_BW	B-J	0.003 (0.5759) 1.16	0.002 (0.7671) 1.81	0.019 (0.0006) 89.03	0.005 (0.3859) 1.00	0.015 (0.0118) 7.00	
GVA_GROWTH_BW	U	0.035 (0.0000) >3196	0.045 (0.0000) >3196	0.035 (0.0000) >3196	0.045 (0.0000) >3196	0.037 (0.0000) >3196	0.024 (0.0003) 154.05
GVA_GROWTH_BW	N-O	0.024 (0.0001) 456.66	0.029 (0.0000) 1180.06	0.026 (0.0000) 819.11	0.029 (0.0000) 2589.43	0.029 (0.0000) >3196	0.017 (0.0064) 11.41
GVA_GROWTH_BW	N-O-L	0.012 (0.0081) 9.45	0.012 (0.0076) 9.97	0.015 (0.0011) 49.68	0.012 (0.0078) 9.71	0.013 (0.0050) 13.90	0.009 (0.0574) 2.24
GVA_GROWTH_BW	B-J	0.003 (0.5657) 1.14	0.003 (0.5892) 1.18	0.012 (0.0501) 2.45	0.005 (0.3830) 1.00	0.005 (0.4229) 1.01	0.005 (0.3961) 1.00
POP_DENSITY_BW	U	-0.018 (0.0163) 5.48	0.025 (0.0072) 10.33	0.031 (0.0000) >3196	0.023 (0.0059) 12.08	-0.001 (0.8798) 3.26	-0.012 (0.0845) 1.76
POP_DENSITY_BW	N-O	-0.026 (0.0004) 107.70	-0.005 (0.5633) 1.14	0.012 (0.0774) 1.86	-0.003 (0.6460) 1.30	-0.009 (0.2872) 1.03	-0.020 (0.0045) 15.04
POP_DENSITY_BW	N-O-L	-0.042 (0.0000) >3196	-0.037 (0.0000) >3196	-0.032 (0.0000) >3196	-0.040 (0.0000) >3196	-0.044 (0.0000) >3196	-0.045 (0.0000) >3196
POP_DENSITY_BW	B-J	-0.045 (0.0000) >3196	-0.043 (0.0000) >3196	-0.033 (0.0000) 864.35	-0.049 (0.0000) >3196	-0.047 (0.0000) >3196	-0.052 (0.0000) >3196
HUMAN_CAPITAL_WI	U	-0.007 (0.0000) >3196	-0.007 (0.0000) >3196		-0.007 (0.0000) 2930.63		
HUMAN_CAPITAL_WI	N-O	-0.008 (0.0047) 14.49	-0.009 (0.0036) 18.10		-0.008 (0.0053) 13.35		
HUMAN_CAPITAL_WI	N-O-L	-0.006 (0.0866) 1.74	-0.006 (0.0774) 1.86		-0.006 (0.0708) 1.96		
HUMAN_CAPITAL_WI	B-J	0.005 (0.1483) 1.30	0.005 (0.1977) 1.15		0.006 (0.1113) 1.51		
RESEARCH_INCOME_WI	U	-0.005 (0.0065) 11.20				-0.004 (0.0100) 7.98	-0.005 (0.0011) 47.76
RESEARCH_INCOME_WI	N-O	-0.007 (0.0086) 8.95				-0.007 (0.0092) 8.52	-0.008 (0.0032) 19.90
RESEARCH_INCOME_WI	N-O-L	0.004 (0.3085) 1.01				0.003 (0.3646) 1.00	0.003 (0.3572) 1.00
RESEARCH_INCOME_WI	B-J	0.006 (0.0661) 2.05				0.006 (0.0656) 2.06	0.005 (0.1180) 1.46
INNOUK_APPL_WI	U			0.002 (0.3157) 1.01			
INNOUK_APPL_WI	N-O			0.004 (0.1097) 1.52			
INNOUK_APPL_WI	N-O-L			0.012 (0.0001) 373.03			
INNOUK_APPL_WI	B-J			0.012 (0.0000) 1462.41			
INNOUK_GRANTS_WI	U				-0.001 (0.3196) 1.01		
INNOUK_GRANTS_WI	N-O				0.000 (0.9902) 37.70		
INNOUK_GRANTS_WI	N-O-L				-0.001 (0.8815) 3.31		
INNOUK_GRANTS_WI	B-J				0.005 (0.0366) 3.04		
THEIL_WI	U	0.002 (0.0897) 1.70	0.003 (0.0683) 2.01				
THEIL_WI	N-O	0.003 (0.3034) 1.02	0.004 (0.1992) 1.14				
THEIL_WI	N-O-L	-0.004 (0.2502) 1.06	-0.004 (0.2337) 1.08				
THEIL_WI	B-J	0.003 (0.4579) 1.03	0.003 (0.5414) 1.11				
UNRELATED_VARIETY_WI	U					0.003 (0.0636) 2.10	
UNRELATED_VARIETY_WI	N-O					0.005 (0.0842) 1.77	

Table 10 'Within-between' Random Effects Estimations: comparison of U, N-O, N-O-L and B-J estimations. (continued)

Variable	Estimation	(1)	(2)	(3)	(4)	(5)	(6)
UNRELATED_VARIETY_WI	N-O-L					-0.002 (0.6127) 1.23	
UNRELATED_VARIETY_WI	B-J					0.001 (0.7739) 1.85	
RELATED_VARIETY_WI	U					0.000 (0.7730) 1.85	
RELATED_VARIETY_WI	N-O					0.000 (0.9192) 4.75	
RELATED_VARIETY_WI	N-O-L					-0.003 (0.3927) 1.00	
RELATED_VARIETY_WI	B-J					0.003 (0.2521) 1.06	
VERTICALLY_RELATED_WI	U			-0.005 (0.0003) 165.80	-0.004 (0.0019) 30.68		-0.004 (0.0027) 23.30
VERTICALLY_RELATED_WI	N-O			-0.004 (0.0824) 1.79	-0.004 (0.1066) 1.54		-0.005 (0.0603) 2.17
VERTICALLY_RELATED_WI	N-O-L			0.003 (0.3195) 1.01	0.002 (0.4701) 1.04		0.003 (0.3028) 1.02
VERTICALLY_RELATED_WI	B-J			-0.005 (0.0675) 2.02	-0.003 (0.2043) 1.13		-0.003 (0.2600) 1.05
INCUBATORS_WI	U		0.004 (0.4640) 1.03				
INCUBATORS_WI	N-O		0.007 (0.5370) 1.10				
INCUBATORS_WI	N-O-L		-0.012 (0.4896) 1.05				
INCUBATORS_WI	B-J		0.007 (0.8788) 3.24				
BUSINESS_SERVICES_WI	U					-0.001 (0.5480) 1.12	
BUSINESS_SERVICES_WI	N-O					0.001 (0.5744) 1.16	
BUSINESS_SERVICES_WI	N-O-L					0.000 (0.9620) 9.87	
BUSINESS_SERVICES_WI	B-J					-0.004 (0.2443) 1.07	
CREATIVE_WI	U						-0.001 (0.4984) 1.06
CREATIVE_WI	N-O						-0.003 (0.1654) 1.24
CREATIVE_WI	N-O-L						-0.001 (0.8426) 2.55
CREATIVE_WI	B-J						0.001 (0.8252) 2.32
SMALL_FIRMS_WI	U						-0.008 (0.0000) >3196
SMALL_FIRMS_WI	N-O						-0.006 (0.0216) 4.44
SMALL_FIRMS_WI	N-O-L						-0.011 (0.0057) 12.53
SMALL_FIRMS_WI	B-J						-0.010 (0.0176) 5.17
ESHIP_CULTURE_WI	U	0.001 (0.7134) 1.53	0.001 (0.5407) 1.11	0.000 (0.8882) 3.49	0.001 (0.4280) 1.01	0.000 (0.8748) 3.14	
ESHIP_CULTURE_WI	N-O	-0.006 (0.0186) 4.96	-0.008 (0.0033) 19.53	-0.008 (0.0028) 22.32	-0.007 (0.0102) 7.83	-0.007 (0.0053) 13.16	
ESHIP_CULTURE_WI	N-O-L	0.002 (0.6000) 1.20	0.003 (0.5269) 1.09	-0.001 (0.8994) 3.86	0.002 (0.5831) 1.17	0.004 (0.2831) 1.03	
ESHIP_CULTURE_WI	B-J	-0.007 (0.0429) 2.72	-0.007 (0.0439) 2.68	-0.009 (0.0096) 8.27	-0.007 (0.0339) 3.21	-0.007 (0.0455) 2.62	
GVA_GROWTH_WI	U	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196	0.007 (0.0000) >3196
GVA_GROWTH_WI	N-O	0.021 (0.0000) >3196	0.022 (0.0000) >3196	0.023 (0.0000) >3196	0.022 (0.0000) >3196	0.023 (0.0000) >3196	0.023 (0.0000) >3196
GVA_GROWTH_WI	N-O-L	-0.004 (0.2975) 1.02	-0.004 (0.3090) 1.01	-0.005 (0.1773) 1.20	-0.003 (0.4178) 1.01	-0.005 (0.1248) 1.42	-0.003 (0.4407) 1.02
GVA_GROWTH_WI	B-J	-0.002 (0.6036) 1.21	-0.002 (0.6012) 1.20	-0.003 (0.3067) 1.01	-0.002 (0.5498) 1.12	-0.001 (0.6579) 1.34	-0.002 (0.5789) 1.16
POP_DENSITY_WI	U	-0.006 (0.0004) 118.37	-0.006 (0.0005) 94.23	-0.008 (0.0000) >3196	-0.006 (0.0005) 103.44	-0.008 (0.0000) >3196	-0.005 (0.0050) 13.88
POP_DENSITY_WI	N-O	0.031 (0.0000) >3196	0.039 (0.0000) >3196	0.026 (0.0000) >3196	0.038 (0.0000) >3196	0.023 (0.0000) >3196	0.026 (0.0000) >3196
POP_DENSITY_WI	N-O-L	-0.019 (0.0018) 32.52	-0.022 (0.0005) 99.54	-0.024 (0.0000) 1306.83	-0.020 (0.0007) 76.24	-0.023 (0.0001) 416.80	-0.010 (0.0763) 1.87
POP_DENSITY_WI	B-J	-0.070 (0.0000) >3196	-0.072 (0.0000) >3196	-0.073 (0.0000) >3196	-0.073 (0.0000) >3196	-0.066 (0.0000) >3196	-0.067 (0.0000) >3196
CONSTANT	U	-0.250 (0.2119) 1.12	-0.353 (0.1763) 1.20	-0.332 (0.0219) 4.40	-0.419 (0.0090) 8.66	-0.621 (0.0058) 12.32	-0.974 (0.1504) 1.29
CONSTANT	N-O	-0.246 (0.1851) 1.18	-0.322 (0.1169) 1.47	-0.226 (0.0632) 2.11	-0.250 (0.0485) 2.51	-0.519 (0.0172) 5.26	-0.434 (0.4947) 1.06
CONSTANT	N-O-L	-0.270 (0.0286) 3.62	-0.279 (0.0254) 3.95	-0.139 (0.0780) 1.85	-0.146 (0.0795) 1.83	-0.238 (0.1021) 1.58	0.758 (0.1181) 1.46
CONSTANT	B-J	-0.425 (0.0069) 10.76	-0.416 (0.0086) 8.95	-0.058 (0.6154) 1.23	-0.105 (0.3379) 1.00	-0.108 (0.5654) 1.14	1.261 (0.0288) 3.61
N	B-J	1639	1639	1639	1639	1639	1639
N	N-O	956	956	956	956	956	956

Table 10 ‘Within-between’ Random Effects Estimations: comparison of U, N-O, N-O-L and B-J estimations. (continued)

Variable	Estimation	(1)	(2)	(3)	(4)	(5)	(6)
N	N-O-L	673	673	673	673	673	673
N	U	2684	2684	2684	2684	2684	2684
R2 between	B-J	0.455	0.4563	0.3128	0.4252	0.3908	0.416
R2 between	N-O	0.6219	0.5514	0.5923	0.5543	0.5826	0.6224
R2 between	N-O-L	0.4096	0.4007	0.3158	0.3997	0.3456	0.3454
R2 between	U	0.4924	0.3086	0.4812	0.3274	0.5007	0.5252
R2 overall	B-J	0.2895	0.2895	0.2072	0.2718	0.2504	0.2655
R2 overall	N-O	0.374	0.3558	0.3414	0.3552	0.331	0.3645
R2 overall	N-O-L	0.3046	0.299	0.2555	0.2975	0.2594	0.2697
R2 overall	U	0.2983	0.2115	0.2868	0.2186	0.2946	0.3189
rho	B-J	0.4291	0.432	0.4786	0.4354	0.4626	0.4419
rho	N-O	0.6396	0.6891	0.6736	0.6857	0.6724	0.6405
rho	N-O-L	0.2544	0.2593	0.3042	0.2578	0.2952	0.2915
rho	U	0.7167	0.8214	0.7836	0.8162	0.7206	0.7187

Note: Each column shows the results of estimations performed on the sample with extended time period using four different approaches: estimation equivalent to Fotopoulos (2023) study with overlapping periods (updated), estimation which uses non-overlapping periods only (N-O), estimation which uses non-overlapping periods and all explanatory variables are lagged by four years relative to time t (N-O-L), estimation using alternative Britten-Jones et al (2011) estimator (B-J). For ease of comparison, the results are grouped by variable of interest, with between effects in the top part and within effects in the bottom part of the table. Coefficients reported (p-values in Parentheses) Bayes Factor Bounds (BFB).

Table 11 ‘Within-between’ Random Effects Estimations, university-related variables: comparison of U, N-O, N-O-L and B-J estimations.

Variable	Estimation	(7)	(8)	(9)	(10)
HUMAN_CAPITAL_BW	U		1.567 (0.0000) >3196	1.563 (0.0000) >3196	
HUMAN_CAPITAL_BW	N-O		1.213 (0.0000) >3196	1.204 (0.0000) >3196	
HUMAN_CAPITAL_BW	N-O-L		3.918 (0.0000) >3196	3.775 (0.0000) >3196	
HUMAN_CAPITAL_BW	B-J		0.057 (0.0000) >3196	0.058 (0.0000) >3196	
VERTICALLY_RELATED_BW	U	-0.032 (0.8043) 2.10	-0.147 (0.0072) 10.38	-0.317 (0.0000) >3196	-0.114 (0.4062) 1.01
VERTICALLY_RELATED_BW	N-O	-0.013 (0.8915) 3.59	-0.108 (0.0818) 1.80	-0.239 (0.0005) 104.04	-0.088 (0.3787) 1.00
VERTICALLY_RELATED_BW	N-O-L	-1.174 (0.0081) 9.39	-0.804 (0.0258) 3.90	-1.181 (0.0011) 47.94	-1.491 (0.0015) 37.58
VERTICALLY_RELATED_BW	B-J	0.021 (0.0000) 1477.77	0.012 (0.0036) 18.20	0.013 (0.0039) 17.15	0.018 (0.0003) 139.73
GVA_GROWTH_BW	U	0.363 (0.0031) 20.60	0.136 (0.0102) 7.87	0.138 (0.0099) 8.05	0.370 (0.0022) 26.99
GVA_GROWTH_BW	N-O	0.276 (0.0021) 28.05	0.109 (0.0682) 2.01	0.113 (0.0554) 2.29	0.291 (0.0010) 53.87
GVA_GROWTH_BW	N-O-L	2.004 (0.0000) 2105.97	0.827 (0.0292) 3.56	0.920 (0.0149) 5.86	2.017 (0.0000) 3107.17
GVA_GROWTH_BW	B-J	0.008 (0.1426) 1.32	0.005 (0.2476) 1.06	0.005 (0.2490) 1.06	0.008 (0.1147) 1.48
ESHIP_CULTURE_BW	U	0.249 (0.0817) 1.80	-0.334 (0.0000) >3196	-0.204 (0.0027) 23.30	0.311 (0.0324) 3.31
ESHIP_CULTURE_BW	N-O	0.189 (0.0706) 1.97	-0.251 (0.0006) 81.79	-0.151 (0.0459) 2.60	0.248 (0.0195) 4.80
ESHIP_CULTURE_BW	N-O-L	0.880 (0.0685) 2.00	-0.746 (0.0894) 1.70	-0.410 (0.3379) 1.00	1.215 (0.0139) 6.20
ESHIP_CULTURE_BW	B-J	0.019 (0.0006) 85.57	0.006 (0.1996) 1.14	0.005 (0.2714) 1.04	0.021 (0.0001) 334.49
UNIVERSITIES_BW	U	-0.149 (0.3061) 1.02			
UNIVERSITIES_BW	N-O	-0.150 (0.1602) 1.25			
UNIVERSITIES_BW	N-O-L	-0.255 (0.5643) 1.14			
UNIVERSITIES_BW	B-J	-0.008 (0.1821) 1.19			
UNI_PATENTS_BW	U		-0.103 (0.0497) 2.47		
UNI_PATENTS_BW	N-O		-0.074 (0.2015) 1.14		
UNI_PATENTS_BW	N-O-L		-0.211 (0.6269) 1.26		
UNI_PATENTS_BW	B-J		0.003 (0.6178) 1.24		
UNI_ENGAGEMENT_BW	U			0.383 (0.0000) >3196	
UNI_ENGAGEMENT_BW	N-O			0.299 (0.0002) 229.98	
UNI_ENGAGEMENT_BW	N-O-L			0.698 (0.0629) 2.11	
UNI_ENGAGEMENT_BW	B-J			-0.001 (0.8737) 3.12	
UNI_SPINOFFS_BW	U				0.158 (0.3223) 1.01
UNI_SPINOFFS_BW	N-O				0.145 (0.2152) 1.11
UNI_SPINOFFS_BW	N-O-L				0.997 (0.0598) 2.18

Table 11 'Within-between' Random Effects Estimations, university-related variables: comparison of U, N-O, N-O-L and B-J estimations. (continued)

Variable	Estimation	(7)	(8)	(9)	(10)
UNI_SPINOFFS_BW	B-J				0.003 (0.6094) 1.22
POP_DENSITY_BW	U	0.180 (0.2123) 1.12	-0.430 (0.0000) >3196	-0.705 (0.0000) >3196	-0.005 (0.9716) 13.13
POP_DENSITY_BW	N-O	0.194 (0.0668) 2.04	-0.286 (0.0001) 412.40	-0.491 (0.0000) >3196	0.038 (0.7358) 1.63
POP_DENSITY_BW	N-O-L	0.050 (0.9196) 4.77	-1.710 (0.0007) 72.00	-2.069 (0.0000) >3196	-0.524 (0.3615) 1.00
POP_DENSITY_BW	B-J	-0.038 (0.0000) 1629.61	-0.052 (0.0000) >3196	-0.050 (0.0000) >3196	-0.045 (0.0000) >3196
HUMAN_CAPITAL_WI	U		0.071 (0.0000) >3196	0.078 (0.0000) >3196	
HUMAN_CAPITAL_WI	N-O		-0.007 (0.1401) 1.34	-0.007 (0.1449) 1.31	
HUMAN_CAPITAL_WI	N-O-L		-0.040 (0.2740) 1.04	-0.043 (0.2470) 1.07	
HUMAN_CAPITAL_WI	B-J		0.001 (0.6966) 1.46	0.001 (0.7057) 1.50	
VERTICALLY_RELATED_WI	U	0.012 (0.1518) 1.29	0.003 (0.7792) 1.89	0.002 (0.8552) 2.75	0.007 (0.4150) 1.01
VERTICALLY_RELATED_WI	N-O	-0.003 (0.2840) 1.03	-0.003 (0.4723) 1.04	-0.003 (0.4718) 1.04	-0.003 (0.3040) 1.02
VERTICALLY_RELATED_WI	N-O-L	0.000 (0.9589) 9.14	0.002 (0.9194) 4.76	0.000 (0.9812) 19.72	0.000 (0.9792) 17.88
VERTICALLY_RELATED_WI	B-J	-0.001 (0.7368) 1.63	-0.001 (0.7429) 1.67	-0.001 (0.7465) 1.69	-0.001 (0.7368) 1.63
GVA_GROWTH_WI	U	0.008 (0.3193) 1.01	0.003 (0.7926) 2.00	0.003 (0.7741) 1.86	0.003 (0.7028) 1.48
GVA_GROWTH_WI	N-O	0.016 (0.0000) >3196	0.013 (0.0023) 26.35	0.013 (0.0020) 29.41	0.015 (0.0000) >3196
GVA_GROWTH_WI	N-O-L	0.003 (0.7313) 1.61	0.003 (0.8393) 2.50	0.005 (0.7782) 1.89	0.002 (0.7626) 1.78
GVA_GROWTH_WI	B-J	0.000 (0.9737) 14.19	0.000 (0.9130) 4.43	0.000 (0.9104) 4.30	0.000 (0.8825) 3.33
ESHIP_CULTURE_WI	U	0.021 (0.0104) 7.72	0.028 (0.0131) 6.49	0.028 (0.0114) 7.20	0.018 (0.0318) 3.36
ESHIP_CULTURE_WI	N-O	0.017 (0.0000) >3196	0.020 (0.0001) 277.89	0.019 (0.0002) 254.68	0.018 (0.0000) >3196
ESHIP_CULTURE_WI	N-O-L	0.019 (0.0557) 2.29	0.039 (0.0735) 1.92	0.035 (0.1081) 1.53	0.017 (0.0638) 2.10
ESHIP_CULTURE_WI	B-J	-0.007 (0.0430) 2.72	-0.008 (0.0191) 4.87	-0.008 (0.0179) 5.11	-0.007 (0.0432) 2.71
UNIVERSITIES_WI	U	0.063 (0.0000) >3196			
UNIVERSITIES_WI	N-O	-0.002 (0.6731) 1.38			
UNIVERSITIES_WI	N-O-L	0.003 (0.6215) 1.24			
UNIVERSITIES_WI	B-J	0.006 (0.4078) 1.01			
UNI_PATENTS_WI	U		-0.026 (0.0291) 3.57		
UNI_PATENTS_WI	N-O		0.001 (0.7722) 1.84		
UNI_PATENTS_WI	N-O-L		0.018 (0.3651) 1.00		
UNI_PATENTS_WI	B-J		-0.001 (0.7353) 1.63		
UNI_ENGAGEMENT_WI	U			-0.002 (0.8518) 2.69	
UNI_ENGAGEMENT_WI	N-O			0.003 (0.4806) 1.04	
UNI_ENGAGEMENT_WI	N-O-L			0.008 (0.6138) 1.23	
UNI_ENGAGEMENT_WI	B-J			0.000 (0.9909) 40.63	
UNI_SPINOFFS_WI	U				-0.005 (0.5238) 1.09
UNI_SPINOFFS_WI	N-O				0.000 (0.9230) 4.98
UNI_SPINOFFS_WI	N-O-L				0.001 (0.8918) 3.60
UNI_SPINOFFS_WI	B-J				0.001 (0.6291) 1.26
POP_DENSITY_WI	U	0.182 (0.0000) >3196	0.118 (0.0000) >3196	0.114 (0.0000) >3196	0.165 (0.0000) >3196
POP_DENSITY_WI	N-O	-0.006 (0.2578) 1.05	-0.010 (0.1630) 1.24	-0.010 (0.1361) 1.36	-0.005 (0.2829) 1.03
POP_DENSITY_WI	N-O-L	-0.082 (0.0000) >3196	-0.118 (0.0042) 16.13	-0.106 (0.0066) 11.11	-0.082 (0.0000) >3196
POP_DENSITY_WI	B-J	-0.105 (0.0000) >3196	-0.100 (0.0000) >3196	-0.101 (0.0000) >3196	-0.109 (0.0000) >3196
CONSTANT	U	-2.179 (0.3442) 1.00	1.002 (0.3070) 1.01	2.733 (0.0083) 9.24	-1.338 (0.5723) 1.15
CONSTANT	N-O	-1.826 (0.2789) 1.03	0.635 (0.5684) 1.15	1.971 (0.0866) 1.74	-1.098 (0.5254) 1.09
CONSTANT	N-O-L	13.149 (0.1335) 1.37	10.903 (0.0946) 1.65	15.328 (0.0178) 5.13	16.841 (0.0501) 2.45
CONSTANT	B-J	-0.176 (0.0358) 3.09	-0.087 (0.2174) 1.11	-0.095 (0.1974) 1.15	-0.155 (0.0711) 1.96
N	B-J	2750	2750	2750	2750
N	N-O	1083	1083	1083	1083
N	N-O-L	236	236	236	236
N	U	3028	3028	3028	3028
R2 between	B-J	0.1938	0.4157	0.415	0.1891
R2 between	N-O	0.0588	0.3356	0.3467	0.0575
R2 between	N-O-L	0.1593	0.3964	0.4043	0.1746
R2 between	U	0.0159	0.2693	0.2787	0.0158
R2 overall	B-J	0.127	0.2581	0.2578	0.1239
R2 overall	N-O	0.0345	0.1522	0.1547	0.0334
R2 overall	N-O-L	0.0732	0.2149	0.2159	0.0801
R2 overall	U	0.0177	0.1658	0.1697	0.0172
rho	B-J	0.5077	0.4084	0.4095	0.5065
rho	N-O	0.9973	0.9878	0.9881	0.9972
rho	N-O-L	0.9993	0.9937	0.9937	0.9993
rho	U	0.959	0.6829	0.7047	0.9585

Note: Each column shows the results of estimations performed on the sample with extended time period using four different approaches: estimation equivalent to Fotopoulos (2023) study with overlapping periods (updated), estimation which uses non-overlapping periods only (N-O), estimation which uses non-overlapping periods and all explanatory variables are lagged by four years relative to time t (N-O-L), estimation using alternative Britten-Jones et al (2011) estimator (B-J). For ease of comparison, the results are grouped by variable of interest, with between effects in the top part and within effects in the bottom part of the table. Coefficients reported (p-values in Parentheses) Bayes Factor Bounds (BFB).

Table 12 Multilevel analysis results comparison of U, N-O, N-O-L and B-J estimations

Variable	Estimation	(11)	(12)	(13)	(14)	(15)	(16)
HUMAN_CAPITAL_BW	U		1.156 (0.0000) >3196				
HUMAN_CAPITAL_BW	N-O		1.000 (0.0000) >3196				
HUMAN_CAPITAL_BW	N-O-L		0.793 (0.0001) 644.46				
HUMAN_CAPITAL_BW	B-J		0.054 (0.0000) >3196				
VERTICALLY_RELATED_BW	U	-0.139 (0.2937) 1.02	-0.206 (0.0546) 2.32	-0.256 (0.1584) 1.26	-0.046 (0.7124) 1.52	-0.038 (0.7552) 1.74	-0.046 (0.7127) 1.52
VERTICALLY_RELATED_BW	N-O	-0.164 (0.1784) 1.20	-0.214 (0.0255) 3.93	-0.240 (0.1493) 1.30	-0.066 (0.5690) 1.15	-0.055 (0.6360) 1.28	-0.064 (0.5873) 1.18
VERTICALLY_RELATED_BW	N-O-L	-0.279 (0.1374) 1.35	-0.355 (0.0259) 3.89	-0.400 (0.1131) 1.49	-0.130 (0.4752) 1.04	-0.115 (0.5255) 1.09	-0.141 (0.4477) 1.02
VERTICALLY_RELATED_BW	B-J	0.022 (0.0000) >3196	0.013 (0.0046) 14.87	0.003 (0.6848) 1.42	0.016 (0.0017) 34.49	0.015 (0.0021) 28.71	0.016 (0.0016) 35.42
GVA_GROWTH_BW	U	0.332 (0.0056) 12.76	0.008 (0.9394) 6.26	0.333 (0.0058) 12.36	0.338 (0.0036) 18.27	0.337 (0.0036) 18.14	0.337 (0.0039) 16.91
GVA_GROWTH_BW	N-O	0.385 (0.0011) 50.13	0.050 (0.6112) 1.22	0.380 (0.0014) 40.78	0.398 (0.0007) 72.90	0.400 (0.0006) 80.93	0.377 (0.0014) 39.04
GVA_GROWTH_BW	N-O-L	0.455 (0.0124) 6.77	0.028 (0.8667) 2.97	0.443 (0.0157) 5.64	0.461 (0.0127) 6.62	0.472 (0.0104) 7.74	0.469 (0.0121) 6.89
GVA_GROWTH_BW	B-J	0.010 (0.0465) 2.58	0.007 (0.1086) 1.53	0.010 (0.0408) 2.82	0.009 (0.0870) 1.73	0.009 (0.0782) 1.85	0.010 (0.0521) 2.39
ESHIP_CULTURE_BW	U	0.268 (0.0527) 2.37	-0.178 (0.1624) 1.25	0.248 (0.0750) 1.89	0.186 (0.1505) 1.29	0.025 (0.8821) 3.32	0.362 (0.0103) 7.82
ESHIP_CULTURE_BW	N-O	0.275 (0.0290) 3.58	-0.119 (0.2892) 1.03	0.248 (0.0505) 2.44	0.240 (0.0467) 2.57	0.028 (0.8544) 2.74	0.416 (0.0031) 20.45
ESHIP_CULTURE_BW	N-O-L	0.401 (0.0376) 2.98	0.116 (0.5327) 1.10	0.357 (0.0656) 2.06	0.362 (0.0530) 2.36	0.000 (0.9987) 273.80	0.686 (0.0025) 24.26
ESHIP_CULTURE_BW	B-J	0.018 (0.0185) 4.98	0.004 (0.5995) 1.20	0.018 (0.0194) 4.81	0.018 (0.0096) 8.24	0.034 (0.0004) 133.57	0.001 (0.9205) 4.83
SCIENTISTS&ENGINEERS_BW	U	0.376 (0.0089) 8.74					
SCIENTISTS&ENGINEERS_BW	N-O	0.323 (0.0133) 6.40					
SCIENTISTS&ENGINEERS_BW	N-O-L	0.540 (0.0070) 10.56					
SCIENTISTS&ENGINEERS_BW	B-J	-0.013 (0.0669) 2.03					
R&D_PERSONNEL_BW	U		0.514 (0.0000) >3196				
R&D_PERSONNEL_BW	N-O		0.637 (0.0000) >3196				
R&D_PERSONNEL_BW	N-O-L		1.294 (0.0000) >3196				
R&D_PERSONNEL_BW	B-J		0.001 (0.9326) 5.65				
BUSINESS_R&D_BW	U			-0.324 (0.1037) 1.57			
BUSINESS_R&D_BW	N-O			-0.249 (0.1704) 1.22			
BUSINESS_R&D_BW	N-O-L			-0.407 (0.1384) 1.34			
BUSINESS_R&D_BW	B-J			-0.025 (0.0005) 98.68			
VCAPITAL_PROJECTS_BW	U				0.245 (0.0414) 2.79		
VCAPITAL_PROJECTS_BW	N-O				0.323 (0.0065) 11.29		
VCAPITAL_PROJECTS_BW	N-O-L				0.463 (0.0119) 6.98		
VCAPITAL_PROJECTS_BW	B-J				-0.026 (0.0005) 93.03		
VCAPITAL_INVESTMENT_BW	U					0.332 (0.0239) 4.12	
VCAPITAL_INVESTMENT_BW	N-O					0.454 (0.0022) 27.40	
VCAPITAL_INVESTMENT_BW	N-O-L					0.704 (0.0027) 22.73	
VCAPITAL_INVESTMENT_BW	B-J					-0.034 (0.0019) 30.28	
INSTITUTIONS_BW	U						0.123 (0.4232) 1.01
INSTITUTIONS_BW	N-O						0.146 (0.3012) 1.02
INSTITUTIONS_BW	N-O-L						0.336 (0.1411) 1.33
INSTITUTIONS_BW	B-J						-0.027 (0.0036) 18.15
POP_DENSITY_BW	U	-0.053 (0.6802) 1.40	-0.510 (0.0000) >3196	0.005 (0.9722) 13.41			
POP_DENSITY_BW	N-O	0.119 (0.3821) 1.00	-0.439 (0.0001) 310.12	0.173 (0.2139) 1.12			
POP_DENSITY_BW	N-O-L	0.097 (0.6427) 1.29	-0.579 (0.0024) 25.51	0.188 (0.3773) 1.00			
POP_DENSITY_BW	B-J	-0.041 (0.0000) >3196	-0.046 (0.0000) >3196	-0.056 (0.0000) >3196			
HUMAN_CAPITAL_WI	U		0.023 (0.0000) >3196				
HUMAN_CAPITAL_WI	N-O		0.004 (0.2993) 1.02				
HUMAN_CAPITAL_WI	N-O-L		-0.005 (0.2057) 1.13				
HUMAN_CAPITAL_WI	B-J		0.008 (0.0795) 1.83				

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Table 12 Multilevel analysis results comparison of U, N-O, N-O-L and B-J estimations (continued)

Variable	Estimation	(11)	(12)	(13)	(14)	(15)	(16)
VERTICALLY_RELATED_WI	U	0.004 (0.2474) 1.06	0.004 (0.2572) 1.05	0.004 (0.2661) 1.04	0.007 (0.0787) 1.84	0.007 (0.0857) 1.75	0.007 (0.0776) 1.86
VERTICALLY_RELATED_WI	N-O	-0.002 (0.4354) 1.02	-0.003 (0.3682) 1.00	-0.002 (0.4089) 1.01	-0.001 (0.6209) 1.24	-0.001 (0.6092) 1.22	-0.002 (0.4482) 1.02
VERTICALLY_RELATED_WI	N-O-L	0.003 (0.2712) 1.04	0.004 (0.2244) 1.10	0.003 (0.2539) 1.06	0.002 (0.5837) 1.17	0.002 (0.4297) 1.01	0.003 (0.3404) 1.00
VERTICALLY_RELATED_WI	B-J	0.000 (0.8647) 2.93	-0.001 (0.8412) 2.53	0.000 (0.8721) 3.08	-0.001 (0.7850) 1.94	-0.001 (0.8365) 2.46	-0.001 (0.8308) 2.39
GVA_GROWTH_WI	U	-0.001 (0.7581) 1.75	-0.002 (0.5463) 1.11	-0.001 (0.6522) 1.32	-0.002 (0.6026) 1.21	-0.002 (0.6057) 1.21	-0.002 (0.6021) 1.20
GVA_GROWTH_WI	N-O	0.004 (0.1887) 1.17	0.004 (0.1967) 1.15	0.005 (0.1326) 1.37	0.005 (0.0936) 1.66	0.005 (0.1192) 1.45	0.006 (0.0666) 2.04
GVA_GROWTH_WI	N-O-L	-0.001 (0.7436) 1.67	-0.001 (0.7661) 1.80	-0.002 (0.6208) 1.24	-0.003 (0.3324) 1.00	-0.005 (0.1590) 1.26	-0.004 (0.2284) 1.09
GVA_GROWTH_WI	B-J	-0.003 (0.2374) 1.08	-0.004 (0.1841) 1.18	-0.002 (0.3984) 1.00	-0.004 (0.1907) 1.16	-0.004 (0.1649) 1.24	-0.004 (0.1785) 1.20
ESHIP_CULTURE_WI	U	-0.024 (0.0000) >3196	-0.032 (0.0000) >3196	-0.030 (0.0000) >3196	0.001 (0.8664) 2.96	0.002 (0.6963) 1.46	0.001 (0.8812) 3.30
ESHIP_CULTURE_WI	N-O	0.002 (0.5536) 1.12	0.004 (0.2215) 1.10	0.000 (0.9382) 6.14	0.013 (0.0000) 1528.68	0.013 (0.0000) >3196	0.008 (0.0186) 4.97
ESHIP_CULTURE_WI	N-O-L	0.009 (0.0336) 3.23	0.007 (0.0527) 2.37	0.012 (0.0047) 14.60	-0.011 (0.0014) 38.82	-0.008 (0.0086) 8.99	0.000 (0.9595) 9.27
ESHIP_CULTURE_WI	B-J	0.006 (0.0667) 2.04	0.005 (0.1168) 1.47	0.002 (0.6030) 1.21	0.004 (0.1629) 1.24	0.005 (0.1542) 1.28	0.005 (0.1118) 1.50
SCIENTISTS&ENGINNERS_WI	U	-0.018 (0.0000) >3196					
SCIENTISTS&ENGINNERS_WI	N-O	0.007 (0.0487) 2.50					
SCIENTISTS&ENGINNERS_WI	N-O-L	-0.006 (0.1075) 1.53					
SCIENTISTS&ENGINNERS_WI	B-J	-0.003 (0.6086) 1.22					
R&D_PERSONNEL_WI	U		-0.008 (0.0128) 6.61				
R&D_PERSONNEL_WI	N-O		0.002 (0.2540) 1.06				
R&D_PERSONNEL_WI	N-O-L		-0.005 (0.0283) 3.64				
R&D_PERSONNEL_WI	B-J		-0.002 (0.3942) 1.00				
BUSINESS_R&D_WI	U			-0.001 (0.8559) 2.76			
BUSINESS_R&D_WI	N-O			0.007 (0.0027) 23.06			
BUSINESS_R&D_WI	N-O-L			-0.008 (0.0034) 19.28			
BUSINESS_R&D_WI	B-J			0.025 (0.0000) >3196			
VCAPITAL_PROJECTS_WI	U				-0.002 (0.6695) 1.37		
VCAPITAL_PROJECTS_WI	N-O				0.000 (0.9531) 8.03		
VCAPITAL_PROJECTS_WI	N-O-L				-0.006 (0.1578) 1.26		
VCAPITAL_PROJECTS_WI	B-J				0.004 (0.0984) 1.61		
VCAPITAL_INVESTMENT_WI	U					-0.010 (0.0455) 2.62	
VCAPITAL_INVESTMENT_WI	N-O					-0.007 (0.1974) 1.15	
VCAPITAL_INVESTMENT_WI	N-O-L					-0.016 (0.0001) 672.99	
VCAPITAL_INVESTMENT_WI	B-J					0.000 (0.9837) 22.76	
INSTITUTIONS_WI	U						0.001 (0.7943) 2.01
INSTITUTIONS_WI	N-O						0.014 (0.0048) 14.38
INSTITUTIONS_WI	N-O-L						-0.020 (0.0000) >3196
INSTITUTIONS_WI	B-J						-0.048 (0.0001) 279.48
POP_DENSITY_WI	U	0.104 (0.0000) >3196	0.095 (0.0000) >3196	0.100 (0.0000) >3196			
POP_DENSITY_WI	N-O	0.021 (0.0002) 234.56	0.021 (0.0001) 276.95	0.023 (0.0000) 863.62			
POP_DENSITY_WI	N-O-L	-0.043 (0.0000) >3196	-0.041 (0.0000) >3196	-0.044 (0.0000) >3196			
POP_DENSITY_WI	B-J	-0.022 (0.1276) 1.40	-0.022 (0.1151) 1.48	-0.042 (0.0038) 17.22			
CONSTANT	U	-0.953 (0.6835) 1.41	1.877 (0.3367) 1.00	2.144 (0.5256) 1.09	-1.521 (0.4911) 1.05	-0.158 (0.9467) 7.10	-3.036 (0.1968) 1.15
CONSTANT	N-O	-0.892 (0.6750) 1.39	1.625 (0.3446) 1.00	1.425 (0.6437) 1.30	-1.870 (0.3630) 1.00	-0.122 (0.9554) 8.44	-3.348 (0.1346) 1.36
CONSTANT	N-O-L	-0.455 (0.8868) 3.45	2.007 (0.4720) 1.04	3.242 (0.4806) 1.04	-2.082 (0.5095) 1.07	0.828 (0.8051) 2.11	-4.941 (0.1541) 1.28
CONSTANT	B-J	-0.161 (0.1044) 1.56	-0.064 (0.4706) 1.04	0.184 (0.1668) 1.23	-0.108 (0.2684) 1.04	-0.246 (0.0247) 4.03	0.061 (0.6339) 1.27
NUTS1 (intercept variance)	U				0	0	0
NUTS1 (intercept variance)	N-O				0	0	0
NUTS1 (intercept variance)	N-O-L				0	0	0
NUTS1 (intercept variance)	B-J				0	0	0
NUTS2 (intercept variance)	U	0	0	0			
NUTS2 (intercept variance)	N-O	0	0	0			
NUTS2 (intercept variance)	N-O-L	0	0	0			
NUTS2 (intercept variance)	B-J	0	0	0			

Table 12 Multilevel analysis results comparison of U, N-O, N-O-L and B-J estimations (continued)

Variable	Estimation	(11)	(12)	(13)	(14)	(15)	(16)
LAD (intercept variance)	U	0	0	0	0	0	0
LAD (intercept variance)	N-O	3.8295	2.4933	3.8915	3.7767	3.7481	3.8593
LAD (intercept variance)	N-O-L	9.0634	6.9269	9.2165	9.3855	9.2884	9.5265
LAD (intercept variance)	B-J	4.8782	3.3935	4.936	4.6351	4.615	4.6891
Error variance	U	0.2303	0.2242	0.2319	0.2443	0.2438	0.2445
Error variance	N-O	0.0712	0.0712	0.0709	0.073	0.0729	0.0725
Error variance	N-O-L	0.077	0.0768	0.0766	0.0806	0.0796	0.0791
Error variance	B-J	0.1504	0.1501	0.1513	0.1723	0.1721	0.1723
ICC_NUTS1	U				0	0	0
ICC_NUTS1	N-O				0	0	0
ICC_NUTS1	N-O-L				0	0	0
ICC_NUTS1	B-J				0	0	0
ICC_NUTS2	U	0	0	0			
ICC_NUTS2	N-O	0	0	0			
ICC_NUTS2	N-O-L	0	0	0			
ICC_NUTS2	B-J	0	0	0			
ICC_LADS	U	0	0	0	0	0	0
ICC_LADS	N-O	0.9987	0.998	0.9987	0.9986	0.9986	0.9986
ICC_LADS	N-O-L	0.9993	0.9991	0.9994	0.9993	0.9993	0.9993
ICC_LADS	B-J	0.9954	0.9934	0.9954	0.9936	0.9936	0.9937
N		1999	1999	1999	1999	1999	1999
N		834	834	834	834	834	834
N		834	834	834	834	834	834
N		2271	2271	2271	2271	2271	2271
BIC	U	-91.4746	-183.4153	-63.0989	129.5558	121.8448	132.1324
BIC	N-O	264.1932	154.0207	263.3867	273.7767	269.9325	272.2778
BIC	N-O-L	597.6131	530.4663	596.5937	644.2106	627.6122	627.9376
BIC	B-J	188.2159	84.1327	213.8838	690.5104	685.6241	694.1406
Log-likelihood	U	98.9401	152.5109	84.7523	-19.1755	-15.32	-20.4638
Log-likelihood	N-O	-85.013	-23.2005	-84.6097	-96.5309	-94.6089	-95.7815
Log-likelihood	N-O-L	-251.7229	-211.4233	-251.2132	-281.7479	-273.4487	-273.6114
Log-likelihood	B-J	-40.0121	19.7574	-52.8461	-298.8873	-296.4442	-300.7024
Wald chi2	U	269.0261	393.9034	237.059	16.2338	24.0225	13.6379
Wald chi2	N-O	81.7318	246.7263	82.9	56.6783	60.8169	58.2415
Wald chi2	N-O-L	97.9293	199.1932	99.2872	33.2328	50.5923	50.2557
Wald chi2	B-J	619.5741	765.514	587.1328	21.7976	26.7753	17.9798

Note: Each column shows the results of estimations performed on the sample with extended time period using four different approaches: estimation equivalent to Fotopoulos (2023) study with overlapping periods (updated), estimation which uses non-overlapping periods only (N-O), estimation which uses non-overlapping periods and all explanatory variables are lagged by four years relative to time t (N-O-L), estimation using alternative Britten-Jones et al (2011) estimator (B-J). For ease of comparison, the results are grouped by variable of interest, with between effects in the top part and within effects in the bottom part of the table. Coefficients reported (p-values in Parentheses) Bayes Factor Bounds (BFB).

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