

Business Research Methodologies and the need for Economies of Scale in the Business Research Process: Harnessing the Innovation Opportunities of Novel Technologies and Technological Change

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DOI: 10.34190/JBRM.17.3.007

Abstract: Theory and evidence suggests that returns to research and research and development are currently declining. This paper seeks to identify patterns in the use of business research methodologies in certain of the latest articles published at the forefront of the field of business research innovation, from its leading journal. This literature is used to identify the current front line of business research methodologies at the forefront of the field. Propositions are derived from novel theory, and are critically juxtaposed against identified topics and methodologies in these articles. In so doing, the conceptual distance of the front line of empirical research in the field from the radical front line of theory in the broader field is quantified. Methodological implications are discussed and recommendations are made for the development of a future research agenda.

Keywords: Research methodology; Innovation; Technology; Technological change; Management; Crowdsourcing

1. Introduction

Global growth in volumes of goods and services- produced using a given amount of labour and capital- has over time fundamentally determined growth in human living standards (Fabina and Wright, 2013). For example, the world's gross domestic product (GDP) has risen over 20-fold since 1850, globally transforming standards of living (Stewart, 2018). This rise in our standards of living has therefore been ascribed to technical progress, measured as total factor productivity- the contribution to growth of how effectively we combine given amounts of labour and capital. The productivity of an economy is therefore derived from how efficiently and effectively it combines its endowments of labour and capital, to "produce valuable goods and services" (Fabina and Wright, 2013:1). According to this perspective, it is business- the innovative production of goods and services that are then consumed- that drives growth in human living standards by combining labour and capital more effectively over time. Accordingly, business research methods are therefore of particular importance as they provide knowledge that supports this process. Knowledge of the extent to which the business knowledge creation process is over time becoming more effective- whether the knowledge creation process demonstrates economies of scale in knowledge production- is therefore important.

Certain theory predicts the importance of business research methods to growth, by way of technological progress (how well we combine labour and capital). Examples of this theory include Romer's (1990) endogenous growth theory and Weitzman's (1998) recombinant innovation theory. According to Romer (1990), the ways that resources are combined and recombined can be likened to 'recipes', that others can use to increase their productivity, at no additional cost- this knowledge is non-rivalrous in production. Using knowledge developed by someone else does not reduce the original knowledge. Knowledge creation should therefore exhibit economies of scale. Similarly, Weitzman's (1998) theory predicts that even with resource scarcity, growth should occur, as ideas can be combined and recombined in unlimited ways. Businesses are key to this process, as they contribute to growth, and productivity growth- increasing standards of living, but this process is to some extent dependent on whether business research methods reflect these theoretical predictions. This paper seeks to investigate the extent to which business research methodologies are aligned with the principles of theory that predicts that they should, where appropriate, demonstrate economies of scale.

A focus on improving the responsiveness of research methodologies is especially important at this time.

Economically, the world is facing a problem of slowing productivity growth, representing a "productivity puzzle," with important implications for the living standards of the world's populations (Haldane, 2017:2):

At this point, it is customary to wheel out the following, now rather over-used Paul Krugman quote: “productivity isn’t everything, but in the long run it is almost everything.” Despite its over-use, this quote does have one important virtue, something not to be taken lightly in this post-fact, post-truth world: it is empirically verifiable and appears to be factually accurate.

The global slowdown in productivity growth is particularly important, for a number of reasons. First, it has implications for world development, including those related to the divergence of economic growth between advanced and emergent economies. The rate of growth of productivity has dramatically reduced in almost all advanced economies since 2003 (Fabina and Wright, 2013). Second, it highlights the Solow (1987:36) paradox, whereby “what everyone feels to have been a technological revolution, a drastic change in our productivity lives, has been accompanied everywhere, including Japan, by a slowing-down of productivity growth, not by a step up” and you “can see the computer age everywhere but in the productivity statistics.” This paradox suggests that, notwithstanding the technological advances associated with what has been termed the ‘Fourth Industrial Revolution’ (Schwab, 2017), productivity growth seems to have been limited to Internet-related activities, as the behavioural impact of innovations introduced by Google and others have yet to be felt in economic terms (Byrne, Fernald and Reinsdorf, 2016). Information technology (IT) has not been found to increase output even in IT-intensive industries, challenging certain assumptions of the technological-discontinuity perspective (Acemoglu, Autor, Dorn, Hansen and Price, 2014).

Contributing to this body of literature, this paper seeks to (i) understand the key topic areas at the forefront of business research, and then to (ii) derive certain theoretical propositions from the literature. These theoretical propositions are then juxtaposed against the topics and methodologies of certain topics identified in the first stage. The sample to which this process is applied consists of published work at the forefront of the world’s field of business knowledge innovation (the study of how research itself is researched and innovated). A purposive sample of latest 2018 and 2019 published articles from the world’s foremost business/economics journal in the field is used, namely Research Policy, to provide an analysis of the current state of the field, and of its specific topics and methodologies.

The first objective of this paper is therefore to interrogate the state of the art in contemporary methodology in the field of business research innovation, from its top journal, and to identify the core topics of research that characterise the field at this time. The second objective of the paper is to derive propositions from the broader theoretical literature, and to test patterns in this methodological evidence against these theoretical propositions developed here. These propositions are derived on the basis of a novel synthesis of theory.

The first research question posed in this paper is therefore: What are the ‘front line’ cross-sectional patterns in topics and methodologies currently published at the forefront of the field of business knowledge innovation? The second research question is: How do these patterns in topics and methodologies conform to the front line of theory in this area? The novel contribution of this paper is therefore its interrogation of this methodological literature and its derivation of a conceptual measure of the distance between these methodologies and novel theoretical propositions that reflect the forefront of innovative thinking at this time. The paper proceeds as follows. First, the methodology of the paper is outlined, in Section 2. Section 3 provides a discussion framed by the first research question, and Section 4 provides the same, related to the second research question. Section 5 then concludes.

2. Methodology

In performing reviews, it is important to follow a systematic process, so as to develop evidence-informed management knowledge (Tranfield, Denyer and Smart, 2003). To do so, as discussed, this project sought to review a comprehensive and purposive sample of the latest articles of two volumes (2018 and 2019) of the foremost journal in the field of business-related research innovation. These 25 articles are taken to reflect a broad cross-section of the topics and methodologies at the forefront of the field. To answer the first research question, a detailed analysis of the research designs, methodological approaches and statistical and econometric techniques applied in these studies is used as the basis for the discussions here. This is undertaken in Section 3. A broad categorisation of the research topics of these articles is provided, together with their methods. On the basis of this categorisation, four clusters of topics are identified, namely those related to technological development across international boundaries, silo-based versus multidisciplinary research, the role of policy in research, and novel technologies applied to research methodologies.

After their derivation, in order to answer the second research question these different topics are juxtaposed against principles associated with the two propositions, and assessed as to the extent that they reflect these principles. This portion of the analysis is reported in Section 4. One of the three sub-categories of Theme 1, namely research into research itself in the form of reflexive research on international collaboration networks, is taken to reflect principles associated with these propositions. Theme 3, which relates to the role of policy, and who makes the rules of research, also accords strongly with the propositions. Theme 4 relates to the application of novel technologies to the research process itself, and is considered to be the third and final topic area in this body of literature that aligns with the principles of the propositions. In the following sections an overview of this literature is provided. This overview is followed by a case review of these three topic areas, which are synthesised to develop core themes of a proposed research agenda for future research that focuses on the improvement of the research process itself.

3. The state of the art at this current time

This section reports on the findings of the analysis that seek to answer the first research question: What are the core themes that characterise this sample of literature? Analysis that answers the second research question is reported and discussed in Section 4.

A cross-sectional review of these articles reveals four clusters of topics, namely (i) technological development across international boundaries, (ii) silo-based versus multidisciplinary research; (iii) the role of policy, and (iv) novel technologies applied to research methodologies. These are each briefly discussed as follows.

3.1 Theme 1: Technological development across international boundaries

The papers in this category seem to use research designs that take advantage of the large data necessary for country-level analysis. For example, Jin (2019) uses research conference proceedings published by the International Electric Vehicle Symposium (EVS) from 1990 to 2009. His sample includes 24 symposia, 5092 scientists, 2864 papers and 8714 scientist-year observations. Dominguez Lacasa et al. (2019) use a statistical framework based on patent indicators as a measure of technological upgrading for BRICS economies for the period 1980-2015. They investigate patterns in the technological development of BRICS countries. Research on the dynamism of exporting firms and how they upgrade their exported portfolio of exports (Castellani and Fassio, 2019) demonstrates the continued importance of exports in this body of literature. Castellani and Fassio (2019) use a sample of over 14 000 Swedish manufacturing firms, comprising the years 2001-2012.

Linking to issues of convergence versus divergence for the 'North' (advanced economies) versus the 'South' (emerging economies) a study in the sample investigates the drivers of growth, integrating the Schumpeterian perspective of technical and structural change with the Keynesian approach to effective demand and balance-of-payment constraint (Cimoli, Pereima and Porcile, 2019). Using a modelling approach, Cimoli et al. (2019) make comparisons between Argentina, which abandoned active industrial policy in the 1970s, Brazil, which followed in the 1980s, and Korea, which continued with it. They highlight the importance of exports in mitigating divergence and enabling convergence between emerging and advanced economies. Although these studies are peripherally relevant to the two propositions, they do not explicitly exhibit a concern with radically improving the efficiencies and effectiveness of the research process itself, or a concern with developing economies of scale in the research process itself. Within the broad theme of technological development across international boundaries, three subordinate themes seem to stand out. These are now discussed as follows.

3.1.1 *The technological frontier and technological development*

According to research in the EU context, across the years 2000-2015, there has been considerable heterogeneity in R&D intensity for firms within the same sector, as variation in R&D intensities largely does not decrease over time for these firms (Coad, 2019). This connects to the broader literature that suggests that the puzzle of the global productivity slowdown (Haldane, 2017) may relate more to divergence between firms rather than divergence of remuneration within them (OECD, 2015), with important implications for debates on societal inequality, as well as the ability of firms to keep up with the technological frontier, and not fall back from it.

Coad (2019) uses microdata from the EU Industrial R&D Investment Scoreboard, developing an unbalanced panel data set for the period 2000-2015. His research design and findings may be particularly important as they relate to the problem of fat tails in the distribution of firms, according to their productivity, whereby most

firms are well behind the technological frontier, reflecting inadequate diffusion of knowledge (OECD, 2015; Haldane, 2017). Coad's study, however, seems to peripherally relate to the two propositions, demonstrating only a second order association, notwithstanding the importance of the topic.

Grillitsch et al. (2019) use longitudinal Swedish linked-employer-employee micro-data, of 1 034 734 individual observations of 225 063 firms, based on employee educational and job occupations in firms. This employer-employee occupational data is merged with business registry and financial indicator data to create a panel dataset for the period 2004-2011. The identification of how three different knowledge types contribute to growth in small and medium-sized firms, and the research design applied here provides important insights for further research seeking to radically improve the efficiency and effectiveness of the research process itself (Proposition 1) and how to enable economies of scale in the research process (Proposition 2). Further research should extend work on these knowledge types and how they can be applied to generate economies of scale in the discovery process.

Another study in this category tests differences in the skills base of the circular economy, differentiating between the skills and educational endowments associated with human capital requirements (Burger *et al.*, 2019). The importance of the circular economy relates to changing of the 'end-of-life' mentality of production toward renewable (environment-friendly) forms of product disposal. This study reflects an environmental focus that is shared with other studies included here (Burlinson, Giulietti and Battisti, 2018, Conti *et al.*, 2018, Helveston *et al.*, 2019, Jin, 2019, Wallace and Ràfols, 2018). Although its focus is on environmental aspects of research innovation, it is not taken to accord with the two principles it is tested against here.

Conti et al. (2018) also study the field of renewable energy sources in terms of trends in patent citations. They investigate the extent to which the EU innovation system in the field of renewable energy sources is fragmented, finding that increasing renewable energy sources patent citation patterns are similar post-2000 to those of 3D and robotics research but differ from those of IT and biotechnology, which have decreased (Conti *et al.*, 2018). Whereas these two studies may not reflect the vision of the two propositions, they offer important insights into technology upgrading in relation to environmentally important areas of research innovation. It bears noting that the changes in the patterns of citations for IT and biotechnology may have important implications for how broader patterns in research production are changing.

Overall, this stream of literature, related as it is to the technological frontier and technological development, does not seem to be at the forefront of research into systematic changes in the discovery process itself. A gap seems to exist here, in that technological development may have an important role to play in the attainment of real time research capability.

3.1.2 Collaboration networks across borders

Country borders remain an important constraint to the diffusion of innovation. In light of this overarching constraint to knowledge diffusion, certain of these 'latest' papers relate to the way firms enter into different country markets. An example is the case of automotive firms and their entry into Spain after it joined the European Union (EU) (Barroso, Giarratana and Pasquini, 2019), the consequences for domestic innovation of foreign firms entering into the Chinese plug-in electric vehicle market using the official joint venture regime (Helveston *et al.*, 2019), and cross-border international research collaborations (IRCs) themselves as research topic (Chen, Zhang and Fu, 2019).

Another example relates to the Chinese context, a study of firms engaged in the development of plug-in electric vehicles, finding firms to be more successful in their experimentation if they are independent of the official joint venture regime that requires foreign firms to partner (with equity restrictions) with local firms, in that this joint venture regime constrains the diffusion of technologies from foreign to local firms (Helveston *et al.*, 2019). Local firms (and not those that join joint ventures with foreign firms) that are independent of these joint ventures typically undertake extensive experimentation across infrastructure, core system, subsystem, and component levels of the plug-in electric vehicle technology platform. Foreign firms seem, therefore, to hold back their latest technologies in these joint ventures (Helveston *et al.*, 2019). By showing certain boundary constraints to innovation diffusion across countries, and particularly the role of the state as a constraint to this diffusion by virtue of its policies, this study seems to develop important insights into enabling conditions for research improvement.

Joint ventures offer important opportunities for international knowledge sharing, but also for risk mitigation.

Joint ventures, as a form of governance in R&D outsourcing alliances, have been shown to reduce the chances of negative share price spillovers from a partner's biopharmaceutical safety crisis, but to increase the intensity of the spillover costs if they do occur (Diestre, 2018). Diestre (2018) uses data on 296 R&D outsourcing alliances (involving 145 different firms, 64% of these pharmaceutical firms and 36% of these biotechnology firms) in the biopharmaceutical industry, across the years 2000-2009. The methods and design of this study, and its findings, are taken to only peripherally relate to the propositions, however, and are taken to represent second order relationships, at best. What seems to be evident from this discussion is the way that borders might constrain knowledge sharing. Future research might explore the extent to which these boundaries are holding back research progression toward developing economies of scale in research.

3.1.3 *Research into research itself: Reflexive research on international collaboration networks*

An important topic area in innovation studies is research into research practice itself, or reflexive research, as it relates to international research collaborations. This is the primary domain expected to meet the predictions of the propositions developed here. An example of this type of research into international research collaboration uses co-citation network analysis, main path analysis, and bibliographic coupling analysis, together with qualitative review (Chen, Zhang and Fu, 2019). Although falling within the first theme, 'technological development across international borders,' this example is discussed further in Section 4, as a specific example of work that accords with the two propositions derived here.

3.2 Theme 2: Silo-based versus multidisciplinary research: implications for societal contributions

Longstanding debates have considered the costs of engaging in Mode 1 knowledge creation (a single-discipline research focus) at the expense of Mode 2 (research that adopts multidisciplinary frameworks, particularly when seeking to tackle societally important research problems) (Gibbons, Limoges, Nowotny, Schwartzman, Scott and Trow 2002). Recent work in this area includes an analysis of the influence of multidisciplinary work (cognitive openness) and higher numbers of collaborations (structural openness) on the citation counts of individual researchers (Belkhouja and Yoon, 2018). This concern with the gap between research and practice is also echoed in another study that stresses the importance of management regimes in steering research toward Mode 1 outcomes at the expense of those of Mode 2 (Amara, Olmos-Peñuela and Fernández-de-Lucio, 2019). These studies seem to highlight the importance of multidisciplinary work for knowledge creation.

Although this topic area peripherally accords with the vision of increasing the efficiencies and effectiveness of research (Proposition 1), it does not explicitly reference the development of economies of scale in the research process itself (Proposition 2).

3.3 Theme 3: The role of policy: who makes the rules of research?

Centralised priority setting processes can be problematic, as they can be "vulnerable to capture by particular interests or incumbent institutions," even as there is a need for the explicit prioritization of certain research, but this requires the incorporation of inclusive stakeholder perspectives (Wallace and Råfols, 2018). This theme, relating to who makes the rules of research, is discussed in Section 4, which is reserved for the discussion of themes and work within themes that directly accord with the two propositions.

3.4 Theme 4: Novel technologies applied to research methodologies

Callaghan (2015) stresses the importance of novel methodologies like crowdsourcing that can radically increase the economies of scale attainable in research. Using such methodologies can allow a researcher to access not only large volumes of data, but also analysis. The fourth theme identified in this literature relates to how novel technologies are applied to improve research methodologies. Studies in this topic area are also discussed in the following section, as work that accords directly with these propositions.

4. Topic areas that accord with the Propositions

In this section, propositions are derived, in order to juxtapose them against the topic areas of the literature in the sample. These theoretical propositions are drawn from certain novel theoretical literature, and ideas that seem to suggest how radical improvements can be made to the business research methodologies so that research can be performed more effectively and efficiently (at much lower cost). These propositions represent the theoretical arguments of this paper. Literature points to longstanding theoretical models, such as those of

Kortum (1997) and Segerstrom (1997), and, more recently, Jones (2009) that produce different theoretical rationales for what might be described as the ‘burden of knowledge effect.’ According to Jones (2009), this effect describes the mechanisms through which returns to investments in research are declining across contexts. These theoretical models broadly predict that it is increasingly difficult to achieve breakthroughs in research over time. These theoretical predictions have been borne out by empirical evidence (for a more detailed commentary on this evidence, see Cowen, 2011). Indeed, according to Gordon (2016: 2), our “best measure of the pace of innovation and technical progress is total factor productivity (hereafter TFP), a measure of how quickly output is growing relative to the growth of labor and capital inputs,” yet “TFP grew after 1970 at barely a third the rate achieved between 1920 and 1970. “

Others have cautioned that technological advances herald a ‘second machine age’ in which technology no longer merely complements human activity (the ‘first machine age’) but is now increasingly replacing it, and that new forms of market dominance by technologically-enabled firms are increasing inequality as the median earnings of firms draw away from median individual wages (Brynjolfsson and McAfee, 2014).

Technological proliferation is increasingly posing serious risks to human societies, contributing to almost unimaginable uncertainties (Vinge, 1993; Bostrom, 2014; Tegmark, 2017). Indeed, there is an urgent need for responsible innovation (Stilgoe, Owen and Macnaghten, 2013), as well as technology safety research to improve our ability to manage threats associated with artificial intelligence (AI), biotechnology, geoengineering, nanotechnology (Baum, 2015), dual-use research of concern, and a host of others (see Callaghan, 2018). As argued by Callaghan (2018), the rapid pace of technology development will perhaps carry on, unabated, across the world, irrespective of most legislative or other attempts to slow it. If so, then the only way to outpace the growth of technological knowledge is through more efficient (quicker) and effective (rigorous and radically innovative) research methodologies, and capabilities. On the basis of this literature, Proposition 1 is derived, *that research methods in the field of research innovation should reflect a concern with radically improving the efficiencies and effectiveness of the research process itself.*

Societally important research problems are not limited to much vaunted threats such as societal conflict, global pandemics of avian influenza, climate change, antibiotic resistance (Wallace and Ràfols, 2018), or the global productivity growth slowdown (Haldane, 2017), but also relate to the threats posed by increases in knowledge itself, and technological proliferation (Bostrom, 2014; Tegmark, 2017). *Yet, with a slowdown in the efficiency and effectiveness of the research system itself*, reflected in declining returns to investments in research (Kortum, 1997; Segerstrom, 1997; Cowen, 2011; Gordon, 2016), we might be headed for trouble, as these societal threats may be rapidly outpacing our research into how to safely manage them. Thus, research with a focus on research itself, and how to improve its efficiency and effectiveness, may be of increasing importance.

It is suggested here that it is perhaps only through a re-calibration of our understanding of the methodological requirements needed to outpace these threats that we might not become their victims. It is therefore perhaps only through developing economies of scale in our methodological capabilities that we can generate knowledge quickly enough to rein in these rapidly developing threats (Callaghan, 2018). Proposition 2 is therefore offered here, *that research methods in the field of research innovation should reflect a concern with the development of economies of scale in the research process itself.*

These propositions are novel in that they seek to place notions of innovation in the research process itself at the heart of what should be the literature on the study of business research itself, and its methodologies. In doing so, they challenge certain longstanding assumptions about the prioritisation of objectives in the study of research and its methodologies, in that the topic of these propositions has been largely absent in the innovation literature. Prior to the discussion of the juxtaposition of these theoretical propositions against the topic areas identified above, it is necessary to expand on the logics that underlie the derivation of these propositions, and their societal importance.

4.1 Societal importance of research process improvement

The novelty of these propositions is in the way they challenge longstanding assumptions about how research itself should be conducted, and its accountability to societal stakeholders. Under conditions whereby slow research processes have seemingly come to act as a proxy for quality, such thinking may disadvantage the most powerless in human societies. For example, in pharmaceutical innovation the high fixed cost investments

necessary for drug and vaccine development can lead to the prioritisation of the needs of wealthy markets (Callaghan, 2019).

Examples of the costs of ineffective or inefficient (slow) research include the costs of failing to solve problems such as societal conflict, global pandemics such as avian influenza, climate change, antibiotic resistance (Wallace and Ràfols, 2018), the global productivity growth slowdown (Haldane, 2017), inequality in the outcomes of the research process (Callaghan, 2019), and certain threats posed by increases in knowledge itself (Bostrom, 2014; Tegmark, 2017).

Probabilistic innovation theory (PIT) predicts that we might currently face states of innovation failure, where in certain instances closed modes of research and powerful monopolies dominate knowledge creation and its transmission to socially important outputs (Callaghan, 2018). This theory suggests that the current research system may primarily be top down rather than emergent in its focus, whereby research funding and the scientific review process prioritise incremental research.

Incremental research is less risky for gatekeepers to publish, in contrast to novel ideas that have yet to gain acceptance. This accords with Kuhn's (1970) descriptions of normal science, whereby ideas that do not conform with an accepted paradigm may initially be rejected, until they accumulate sufficiently to overturn the paradigm, replacing it with a new one. PIT predicts that the current mode of science itself is insufficiently innovative, failing to solve societally important problems through the discovery of novel facts (Lakatos, 1978).

According to Lakatos (1978), science differs from pseudoscience in that the latter fails to generate novel facts, and degenerates over time due to this failure. PIT predicts that under the current mode of science, societal research benefit ratios (SBRs) are too small. Propositions 1 and 2 effectively relate to how SBRs can be increased.

A SBR can, for example, take the form of a ratio of the number of people that are affected by a societally important problem, as the denominator, and the number of people (appropriately) researching to solve the problem as the numerator. This ratio can be expressed using any form of resources, not only human researchers. Although it is an imprecise measure, the SBR serves as a useful heuristic, as it highlights the current state of science, where the relationships between investments in societally important research problems and their successful outcomes seem to largely be uncertain, whereby the chances of attaining problem solving breakthroughs cannot be estimated.

The problem of small SBRs is perhaps of particular importance if we are experiencing a slowdown in the efficiency and effectiveness of the research system itself (Kortum, 1997; Segerstrom, 1997; Cowen, 2011; Jones, 2009; Gordon, 2016). According to this literature, this slowdown is evident in the way that breakthrough discoveries are not being made at the rate at which investments in research and additional researchers are being made globally. PIT suggests that these increases are simply not increasing SBR numerators sufficiently, for the following reasons.

The scientific research system may largely be *geared toward incremental and not radical research*. Research funding may favour research that can assure funders that a contribution will be made, and incremental contributions suit this process. Incremental contributions can be predicted- they are not fundamentally uncertain. Success in these ventures may be dependent on the ability of a proposed research project to articulate the path dependencies that will lead to beneficial outcomes. Yet, once the low hanging fruit is picked by this incremental system, however, making progress using incremental methodologies will produce diminishing returns.

4.2 Beyond path dependency thinking

Given the rise of societally important research problems that are as yet unsolved (Wallace & Ràfols, 2018), there is a need to provoke discussions about how the scientific research process can improve its ability to produce societally important breakthroughs. If we assume that we cannot identify the path dependencies *a priori* that relate current knowledge creation to future breakthroughs that are fundamentally new to the world (in the spirit of what Lakatos (1978) describes as novel facts), then we need a (supplementary) mode of science that can attain these breakthroughs *without (not dependent upon) knowledge of these path dependencies*. This requires a reconceptualisation of the scientific process, as one that can 'capture' breakthroughs when there is

no way to know, a priori, what these breakthroughs are, or the path dependent processes needed to achieve them. How, then, might this be done?

According to the logics of PIT, there is but one way in which this path dependency paradox can be solved. This is by bridging this gap, not through a direct linkage, but through changing the mode of science itself, or supplementing the current incremental mode with one that is explicitly concerned with achieving breakthroughs. By unfolding the problem space (making its front line understandable and accessible) and by populating it with very large numbers of solvers, or resources, PIT suggests that the probability of solving a complex problem (like those found in biomedicine), can be increased. Novel technologies have given rise to methodologies such as those applied by sites like InnoCentive, which allow those seeking solutions to scientific problems to put these problems online, for solvers across the world to solve.

PIT predicts that, as technologies drive down the costs of unfolding problem spaces and of populating them with large numbers of the appropriate solvers, radical cost and time efficiencies can contribute to more balanced SBRs. In other words, economies of scale will increase in the research process itself. Investments in the research process will result in more effective and efficient research outputs.

Importantly, what is seemingly unique in the predictions of PIT is the prediction that a threshold point will ultimately be reached, *at which the relationship between investments in the research process and its breakthrough outcomes switches from one of uncertainty to one of risk*. In other words, whereas under the current mode of science there is no probabilistic relationship between these investments and their uncertain breakthroughs (there are no path activities toward the breakthrough that can be identified prior to the discovery), in the probabilistic mode, a probabilistic relationship now exists, which, like risk, can be calculated, in terms of its probabilities. Research that accords with Proposition 1 will focus on improving the effectiveness and efficiency of the research process itself. If the SBR is considered using resource costs, it could take the form of total resources invested in solving an important societal problem as the numerator and the total resource costs of the problem to society as the denominator. In this case, any improvements in the research process would increase the effectiveness of the numerator, so as to increase its weighting. Similarly, if economies of scale are achieved in the research process itself, then this would suggest that the resources invested in the numerator will be leveraged to have more of a problem-solving contribution.

Yet, with a current slowdown in the efficiency and effectiveness of the research system itself, reflected in declining returns to investments in research (Kortum, 1997; Segerstrom, 1997; Cowen, 2011; Gordon, 2016), we might be headed for trouble, as the proliferation of societal threats might outpace our ability to produce knowledge of how to safely manage them. Thus, research with a focus on research itself, and how to improve its efficiency and effectiveness, is therefore of increasing importance.

4.3 Themes specifically in accordance with propositions

In this section, certain themes and topics are discussed in relation to the extent to which they accord with the two propositions derived here. Table 1 outlines the themes and sub-themes identified in Section 3. The three topic areas that accord with the propositions are highlighted in grey. In this table, Theme 1 relates to technological development across international boundaries. Although its first two sub-themes are only peripherally related to the issues highlighted by the propositions, the third sub-theme directly relates to these issues. Similarly, Theme 2 does not directly relate to the primary issues associated with the propositions.

Themes 3 and 4 do, however. A case review now follows, of these three topic areas, in which the discussions are synthesised to develop core themes for a proposed future research agenda related to the improvement of the research process itself. Each topic area is now discussed in turn.

Table 1: Categories of themes in the sample

Overarching themes	Theme 1: Technological development across international boundaries	Theme 2: Silo-based versus multidisciplinary research: implications for societal contributions	Theme 3: The role of policy: who makes the rules of research?	Theme 4: Novel technologies applied to research methodologies
Subordinate theme	Sub-theme 1. The technological frontier and technological development			
Subordinate theme	Sub-theme 2. Collaboration networks across borders			
Subordinate theme	Sub-theme 3. Research into research itself: Reflexive research on international collaboration networks			

4.4 Theme 1: Technological development across international borders: Sub-theme 3. Research into research itself in the form of reflexive research on international collaboration networks

International research collaboration itself, “has been increasingly important as an emerging area of innovation studies” (Chen et al., 2019, 149). Chen et al. (2019) provide a systematic and comprehensive overview of international collaboration research literature (IRC), offering important insights into how research collaboration can improve the effectiveness and efficiencies of research by applying collaborative methodologies. They review the intellectual base, primary research trajectories, and intellectual communities of the IRC field and its literature, across the years 1957-2015.

What methodologies are applied by Chen et al. (2019) to do this? They use co-citation network analysis, main path analysis, and bibliographic coupling analysis with with CiteSpace, Pajek and Gephi software.

How do their findings accord with the propositions? They demonstrate that IRC research has progressed across three phases: an emergence phase (1957-1991), of emergent growth, a fermentation phase (1992-2005) of deepening research, and a take-off phase (2006-2015), of rapidly expanding research. Chen et al.’s (2019) study offers a useful indicator of research increase across boundaries and reflects the essence of what drives the logics behind these propositions: the investigation of research processes themselves. The development of collaborative methodologies seems to be a promising avenue for further research into how to enable economies of scale in the research process.

4.5 Theme 3: The role of policy and who makes the rules of research

In their study of global threats to human populations, with a focus on avian influenza, Wallace and Ràfols (2018) use a mixed method analysis, triangulating evidence from interviews, bibliometrics, funding statistics, and appropriate literature. They find that the landscape of public avian influenza research is not driven directly by expectations of societal outcomes, or by direct societal needs. It is shaped instead by institutional drivers, including (i) pharmaceutical industry priorities, (ii) publishing and public research funding pressures, and (iii) the mandates of science-based policy and/or public health organisations. Key to attaining economies of scale in the research process itself is knowledge of potential constraints to societally important research production, and their study offers useful insights into the realpolitik that underlies the research system itself.

Another study in this topic area relates to how government participative loans influence the growth of entrepreneurial ventures (Bertoni, Martí and Reverte, 2019). Bertoni et al. (2019) studied 512 entrepreneurial ventures that received a participant loan from a Spanish government agency, across the period 2005-2011.

The find, on the basis of propensity score matching, that recipient firms had higher employment and sales. This article demonstrates the importance of state support for entrepreneurial ventures, and highlights the importance of decisions about which firms or which innovation states should or should not support. This study highlights the issue that policy and the issue of who makes the rules of research is a critical factor in ensuring societally important research.

Wallace and Ràfols (2018, 1975) therefore stress the importance of the management of the research system itself, to increase its responsiveness to societally important threats, including those such as climate change, malaria or antibiotic resistance, which require rapid responses. Similarly, Callaghan (2015; 2016; 2017; 2018; 2019) argues for the development of near real time research capability, which is particularly important in disaster research response, where catastrophic events require a research response, but the data required for this is typically only available after the onset of the catastrophe.

4.6 Theme 4: Novel technologies applied to research methodologies

Crowdsourcing, as a methodology, is an important source of innovation for firms, but the attraction of solvers is found to be a function of a seeker's knowledge of the problem domain as well as the status of the seeker (Pollok, Lüttgens and Piller, 2019). Knowledge of the conditions under which a firm shifts from closed to open innovation (Bahemia, Sillince and Vanhaverbeke, 2018) is therefore an important contribution to this topic area.

Pollok et al. (2019) analyse 637 crowdsourcing projects, hosted by NineSigma, using requests for proposals (RFP) as their unit of analysis. They create a unique dataset of project-level data with information about each crowdsourcing project hosted by NineSigma, for the five-year period from 2009 to 2014. Their data includes 238 seeker firms with 889 RFPs.

In another example of this topic area, Bahemia et al. (2018) offer an analysis of a radical innovation project at Jaguar (UK). Their focus on radical innovation has certain useful insights for those interested in applying them to the research process itself.

Another paper that accords with these propositions is a study investigating relationships between societal trust and open innovation (Brockman, Khurana and Zhong, 2018). Brockman et al. (2018) use panel data on co-owned patents across 29 countries, finding that firms with higher levels of trust are able to produce a higher level of joint output. Their analysis offers evidence that suggests that trust is key to enabling improved collaborations in research production. All the studies in this theme accord with the vision of Propositions 1 and 2, as open innovation offers the potential to not only radically improve the efficiencies and effectiveness of the research process, but also to attain economies of scale.

Although all the publications in the sample are arguably peripherally related to the propositions derived here, a future research agenda seeking to build on these propositions, and to test them empirically, should include the following core themes: (i) Reflexive research, such as that which applies knowledge creation tracking methodologies to explicitly measure how knowledge creation proceeds differently in different disciplines, and how multidisciplinary can be improved over time. (ii) Research into the structural impediments that face societally important research should expand, particularly into how and who makes the decisions that prioritise one stream of research over another, on a global, regional, country, and within-country basis. (iii) Research into how novel methodologies, such as crowdsourcing, can be developed to achieve economies of scale in research across contexts, is particularly important. If future research can take its direction from these three topic areas, a future research agenda might emerge to support the attainment of societally important research outcomes in a way that is increasingly responsive to the productivity needs of human societies.

Finally, a specific example of how the mechanisms described by these themes can act together may be useful. Not all business research methods are suited to processes that can attain economies of scale. Silo research has its place, as Mode 1 knowledge creation. However, most businesses exist in an economic system, and demonstrate system properties. If Mode 1 knowledge is not circulated and if research is not conducted at the levels of business systems, knowledge will not be created optimally. An explosion of information, enabled by big data and novel technologies, offers us both opportunities and threats. Novel business methodologies such as crowdsourcing may be better suited to the opportunities offered by this information explosion. Indeed, it is perhaps only methodologies (such as, but not limited to, crowdsourcing) that can enable economies of scale in

knowledge creation that can take advantage of the exponential increase in information and data opportunities we seem to currently be experiencing.

5. Conclusion

This paper had two objectives. The first was to provide a broad outline of current business research and its methodologies. The second was to derive theoretical propositions from the front line of novel theoretical literature that suggest ways in which the production of societally important research can be improved. Using Romer's (1990) and Weitzman's (1998) theoretical frameworks, it was argued that business research methods are key to improving productivity growth- thereby increasing human standards of living over time. Two theoretical propositions were derived, which were juxtaposed against the topic areas identified as comprising this body of literature at this time. These propositions may be particularly important because theory suggests that certain societal threats are increasing in their probabilities of occurrence, while scientific breakthroughs are becoming harder to come by, a phenomenon described in the economics literature as the burden of knowledge effect. Findings suggest that although certain business research methodologies are moving in this direction (conforming to the methodological vision of the propositions), the majority of the papers are not.

This paper frames this problem (of a failure to explicitly focus on how to improve the business research process itself) as a methodological one, suggesting that research into the improvement of our methodologies that can allow us to outpace the growth in certain societal threats is becoming increasingly important.

6. Implications and Recommendations

Given agreement about the dangers of the burden of knowledge effect, and the declining ability of research to address growing societal dangers, business research should interrogate the reasons for why the study of the research process itself (and its methodological frameworks) has not become an overriding priority in this field. Two important implications derive from these results. First, if business research methods are key to enabling productivity increases, they therefore contribute to human development, and the improvement of human living standards over time. It seems that only a fraction of current publications at this time at the forefront of the field are taking advantage of methodologies that make it possible to obtain economies of scale in the research process itself. If the use of such methodologies is following a technology S-curve, then they might be in the early stages of its progression. Highlighting this progression might be useful, to increase awareness of how economies of scale can be more effectively enabled in business research methodologies.

Second, given evidence of the burden of knowledge effect, and its predictions that it is becoming harder to achieve breakthroughs in business research- and thereby to improve productivity- the attainment of economies of scale in business research methodologies may be becoming increasingly important.

Further research may urgently be needed to interrogate the methodological issues raised in this paper, in order to generate business knowledge more quickly and more effectively, without compromising quality in the research process while doing this.

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