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To Be or Not to Be: The Entrepreneur in Neo-Schumpeterian Growth Theory

Magnus Henrekson, Dan Johansson and Johan Karlsson

Research Institute of Industrial Economics
P.O. Box 55665
SE-102 15 Stockholm, Sweden
info@ifn.se
www.ifn.se

To Be or Not to Be: The Entrepreneur in Neo-Schumpeterian Growth Theory*

Magnus Henrekson[a] Dan Johansson[b] Johan Karlsson[c]

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Abstract: Based on a review of 700+ peer-reviewed articles since 1990, identified using text mining methodology and supervised machine learning, we analyze how neo-Schumpeterian growth theorists relate to the entrepreneur-centered view of Schumpeter (1934) and the entrepreneurless framework of Schumpeter (1942). The literature leans heavily towards Schumpeter (1942); innovation returns are modeled as following an *ex ante* known probability distribution. By assuming that innovation outcomes are (probabilistically) deterministic, the entrepreneur becomes redundant. Abstracting from genuine uncertainty, implies that central issues regarding the economic function of the entrepreneur are overlooked such as the roles of proprietary resources, skills, and profits.

Keywords: creative destruction; economic growth; entrepreneur; innovation; judgment; Knightian uncertainty

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[a] Research Institute of Industrial Economics (IFN), Stockholm, Sweden
Email: magnus.henrekson@ifn.se (corresponding author)

[b] Örebro University School of Business, Örebro, Sweden,
E-mail: dan.johansson@oru.se

[c] Centre for Family Entrepreneurship and Ownership (CeFEO), Jönköping International Business School, Jönköping, Sweden
E-mail: johan.karlsson@ju.se

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1 Introduction

> *What is the problem we wish to solve when we try to construct a rational economic order? […] If we possess all the relevant information, […] and if we command complete knowledge of available means, the problem which remains is purely one of logic. This, however, is emphatically not the economic problem which society faces. And the economic calculus which we have developed to solve this logical problem […] does not yet provide an answer to it.* (Hayek 1945)

The advent of sustained economic growth that began some two centuries ago has been crucial for the dramatic increase in human welfare compared to earlier periods in the history of our species. Understanding the causes of economic growth is therefore of enormous value. The first generation of modern mainstream growth models showed that the accumulation of factors of production could explain only a small part of growth (Solow 1957). This triggered the development of endogenous growth models in the 1980s, which added human capital accumulation and knowledge capital to the models. By assuming that some knowledge was nonrival and nonexcludable, the explanatory power was greatly increased.[1] Nevertheless, the models lacked an agent that combined and applied the new knowledge with other factors of production to generate growth. In short, the models were entrepreneurless.[2]

The first major step to introduce the entrepreneur into mainstream models of aggregate economic growth was neo-Schumpeterian growth theory, which first appeared in the early 1990s.[3] This line of economic inquiry is called "Schumpeterian" because it incorporates the process that Schumpeter (1942) termed "creative destruction," i.e., the process by which new innovations challenge and—if successful—replace existing economic structures, into a new breed of endogenous growth models.[4]

However, Schumpeter took two divergent views on the entrepreneur during his career. In earlier conceptualizations, Schumpeter (1934) considered the entrepreneur to be the *primus*

[1] Seminal articles include Romer (1986, 1990) and Lucas (1988).
[2] Schmitz (1989) is arguably an exception. In his theoretical contribution, he posits that the mechanism that drives growth consists of entrepreneurs who imitate other firms, which results in greater competition, more innovation, and a higher rate of growth.
[3] The entrepreneur held a prominent role in economics for a long time. Increased formalization of mainstream theory in the 1930s made the entrepreneur disappear from the dominant paradigm based on general equilibrium theory (Barreto 1989; Hébert and Link 2007). In a well-known parable, Baumol (1968) compared leaving out the entrepreneur from the theory of the firm to leaving out the Prince of Denmark from *Hamlet*. Excessive emphasis on mathematical analysis also negatively affects the study of entrepreneurship in business schools, particularly in the U.S. (Stewart 2022).
[4] Neo-Schumpeterian growth theory is based on general equilibrium methodology and applies formal models to capture the link between vertical technological change and economic growth. In the models, economic growth is generated by the introduction of new and superior technologies—innovations—and the subsequent displacement of old and inferior technologies. Growth specifically results from the destruction of rents generated by old products and processes through the introduction of new, more valuable ones (e.g., Acemoglu 2009).

motor of innovation-based growth by carrying out *discontinuous* innovations.[5] Later in life, Schumpeter (1942) predicted that entrepreneurs would become redundant as innovations became routinized and carried out by large corporations. Following Phillips (1971), these two opposing views of innovative activities are customarily referred to as Schumpeter Mark I and Mark II, respectively (e.g., Nelson and Winter 1982; Malerba and Orsenigo 1996).

Hence, creative destruction, according to Schumpeter, can be modeled either with the entrepreneur at the center of analysis or with the individual entrepreneur having a marginal role or being altogether absent. These two conceptualizations have vastly different implications for theory and policy. However, although comparative discussions on entrepreneurial definitions and their implications for research and policy have a long history in related fields, such discussions have been largely absent among neo-Schumpeterian growth theorists.

The aim of this article is to analyze how entrepreneurship is represented and conceptualized in neo-Schumpeterian growth theory. We do this by analyzing the content of 714 peer-reviewed articles on neo-Schumpeterian growth published over the period 1990–2020. The articles are identified through text mining of relevant articles and supervised machine learning. The analysis distinguishes between highly influential articles in the field ("core articles"), reviews, and other articles. In addition, two textbooks by seminal authors are analyzed.[6] First, the use of key terminology and references to formative literature, e.g., Schumpeter (1934), are examined quantitatively. Then, the use of the term "entrepreneur" is studied and categorized relative to Schumpeter Mark I and II.

Previous reviews of the literature on neo-Schumpeterian growth (Dinopoulos and Şener 2007; Bogliacino 2014; Shabnam 2014; Block et al. 2017) have taken entrepreneurial concepts as given and have not addressed the fundamentals of the underlying theory. Other studies have challenged the theoretical foundation of neo-Schumpeterian growth theory (Nelson 1997, 1998; Bianchi and Henrekson 2005; Acs and Sanders 2013; Johansson and Malm 2017). However, these studies have been limited in their empirical scope; they have not provided exhaustive evidence on what the literature *does* include.

[5] Schumpeter (1934) used the term "discontinuous" to denote the introduction of innovations transforming industries, whereas currently the terms "disruptive" and "radical" are mostly used. We use them interchangeably.
[6] Modern macroeconomics is heterogenous and encompasses a variety of topics and theories, including the study of economic growth. Subsequently, to identify eligible textbooks to complement existing review articles, we searched *Google Scholar*, *Scopus*, and the *Web of Science* for books that include variations of the term "macroecon" along with either "creative destruction," "Schumpeter," or "vertical innovation". We then selected those books that contained sections dedicated to neo-Schumpeterian growth theory that aspired to give an exhaustive account of the field. This process resulted in the identification of two textbooks: Acemoglu (2009) and Aghion and Howitt (2009), which are also written by the most influential researchers in the field.

Research in the Schumpeterian tradition since its inception has been prolific; there are several strands of literature inspired by Schumpeter's work such as the literature on national innovation systems (e.g., Lundvall 2012; Edquist 2013) and entrepreneurial ecosystems (e.g., O'Connor et al. 2018; Wurth et al. 2022). Meanwhile, although highly regarded and enriching on their own merits, each of these literatures lie outside the core of mainstream economics. Within the mainstream, Schumpeterian arguments are predominantly framed in the neo-Schumpeterian tradition highlighted in our paper.[7] In turn, this means that the neo-Schumpeterian tradition constitutes one of the dominant channels for disseminating ideas on entrepreneurship from economics more generally to policy makers, graduate students, and the general public (Aghion et al. 2015b). In our view, this provides a strong motivation for conducting an in-depth analysis of this literature. Moreover, in contrast to the rival Schumpeterian literatures, all mainstream endogenous growth models are based on the existence of an economic equilibrium and optimization. Hence, based on the political and scholarly impact of the literature as well as for the sake of logical clarity, the current article is strictly limited to the domain of neo-Schumpeterian growth.[8]

We contribute to the literature in at least two ways. First, we provide the first large-scale empirical study connecting the description of the entrepreneurial function in neo-Schumpeterian growth theory to its Schumpeterian antecedents. Second, we position the literature relative to Schumpeter's work, thus highlighting the limitations of current discussions and pointing to potential areas of future development.

We find that the literature leans more towards Schumpeter Mark II than towards Schumpeter Mark I. For instance, the literature refers to Schumpeter (1942) more often than Schumpeter (1934) and it does not relate to the key Schumpeter Mark I concept of "new combinations". A critical aspect is that innovative ventures are modeled as processes whose return is determined by an *ex ante* known probability distribution, which greatly curtails the literature's potential for providing causal guidance regarding the economic processes that precede innovation and the processes that influence its outcome. Moreover, the literature is shown to heavily emphasize routine over disruptive innovation, which is inferred to be a direct consequence of its conceptualization of the innovation process. Hence, the neo-Schumpeterian

[7] This is also reflected in its scholarly impact (Aghion et al. 2015a).

[8] A popular approach is to restrict analyses to top journals in a field or to limit the population based on keywords and abstracts, which results in a wider range across fields or concepts (e.g., Lohwasser et al. 2022; Radu-Lefebvre et al. 2021; Lampe et al. 2020). In contrast, and although focused on one discipline, the current analysis imposes no restrictions on the scope of analysis, the journals considered, or where matches may be found in the text. As a result, its scope is much greater than most conventional literature analyses.

entrepreneur may be described as a routine decision-maker who pursues business opportunities based on exogenous and *ex ante* given parameters. This modeling of innovative activities renders the entrepreneur—as presented in Schumpeter Mark I—redundant in discussions of neo-Schumpeterian growth. The literature thus abstracts from the role of non-routinized entrepreneurial decision-making in ventures that contain elements of genuine uncertainty, i.e., non-calculable risk. Genuine uncertainty is central to understanding the economic role of the entrepreneur, particularly his or her key role in the introduction of disruptive innovations. Thereby, the literature is also lacking in its ability to explain what economic conditions that promote radical technological shifts and, as a corollary, in identifying policy measures that foster radical innovation.[9]

Our findings highlight what is arguably a fundamental limitation of the current discourse. Given that researchers subscribe to the notion that innovations are, at least partly, associated with genuine uncertainty, this implies that extant neo-Schumpeterian growth models run the risk of providing misleading guidance to policymakers who would like to stimulate economic growth. In particular, in cases where it emanates from the introduction of disruptive innovations.

A potential objection to our examination is that neo-Schumpeterian growth models seek to explain and predict the historical macroevolution of the economy, and at the aggregate level, it may be fair to abstract from the genuine uncertainty of innovative activity at the micro level.[10] However, we argue that a causal understanding is necessary to inform us of how to stimulate future economic growth. This is likely to be particularly important for economies at the technological frontier, where the relationship between R&D output and economic growth is far from unequivocal and where there are only minor opportunities for improvements to basic institutional quality. The development of modern growth theory may itself serve as an illustrative example: Departing from modelling growth as exogenous, knowledge and creative destruction were endogenized to strengthen the models' explanatory power and to identify

[9] This shortcoming of endogenous growth theory (including Aghion and Howitt 1992) was pointed out already almost three decades ago by the doyen of mainstream growth theory, Robert Solow (1994, p. 52), who asserted that "if 'Knightian uncertainty' shows up …, then appropriate analytical techniques are lacking." Solow's article was a contribution to the *Journal of Economic Perspective's* symposium on the new growth theory.

[10] The Institute for New Economic Thinking (INET) launched the research program Knightian Uncertainty Economics (KUE) in 2019. It builds on the premise that macroeconomic outcomes cannot be adequately modelled and policy advice risks being misleading as long as one abstracts from Knightian uncertainty. See Frydman and Phelps (2013) and Frydman et al. (2019), who analyze this issue with respect to outcomes at business cycle frequencies. But if the modelling of Knightian uncertainty is essential at that frequency, its inclusion is also likely to be essential at lower frequencies such as the long-term aggregate growth rate.

additional economic policy tools. The current analysis can be regarded as a further step in that process.

To extend and enrich the discussion beyond routinized innovation, our study suggests that the literature could draw on insights from extant discussions of genuine uncertainty and its key role in entrepreneurial activity. We believe that the discussion could benefit from incorporating ideas from the entrepreneurship literature that has so far developed parallel to neo-Schumpeterian growth theory, notably Knight (1921) and the subsequent literature emphasizing the role of uncertainty-bearing and judgmental decision-making (e.g., Foss and Klein 2012). A fundamental idea in this tradition is the experimental character of the economy caused by uncertainty. The need for policy to provide favorable incentives for novelty and adaptability is therefore stressed to a greater extent than in the mainstream literature. Among other things, this includes a focus on diversity in skills, different forms of finance, and free access and flow of knowledge (e.g., Henrekson and Johansson 2009; Elert et al. 2019; Sanders et al. 2020). By incorporating aspects like these, we may gain a deeper understanding of entrepreneurship, innovation, and, ultimately, economic growth as an endogenous process.

The rest of the paper is organized as follows. Section 2 discusses Schumpeter's two concepts of entrepreneurship. Section 3 presents the study's data and method, and Section 4 presents the results. Section 5 offers a concluding discussion. Appendix A describes the process and search terminology to identify the neo-Schumpeterian growth literature, and Appendix B reports the core article that the identification process is based on. A complete list of identified articles is presented in Appendix C.

2 The Schumpeterian entrepreneur

Schumpeter first laid out his theory of the economic function of the entrepreneur in German in 1911, but it took until 1934 before the work was available in English. In Schumpeter (1934), he sets out to identify the causal mechanisms that connect innovative activity to economic growth. He posits that economic growth cannot be adequately explained by increases in factors of production; in his view, long-run growth also involves *change* in the sense that the factors of production are repurposed in new and more valuable ways, i.e., what he refers to as economic development. Such repurposing of existing resources—the creation of "new combinations"—is carried out by the *entrepreneur*, who, consequently, is conceptualized as the *primus motor* of innovation-based growth. Since economic change is seen as an endogenous process driven by the creativity and actions of individual actors, the ability of the individual entrepreneur becomes

central.[11] Since entrepreneurial skill is a scarce resource, it was identified as a bottleneck in innovative processes (Acs and Sanders 2013).

Schumpeter (1934) reasoned that new ideas are only economically relevant if they are put to economic use, and the entrepreneur is seen as the primary link between new ideas and their market introduction in the form of valuable commodities. The entrepreneur identifies the potential economic uses of new ideas and realizes their economic value through commercialization, and new firm entry provides an important channel for entrants to introduce radically new ideas and to challenge existing economic structures.

New combinations translate into economic development through a three-step process. The first step involves the conception of a novel idea, a new combination, which Schumpeter referred to as an *invention*. Once a novel and potentially profitable invention has been identified, the second step consists of identifying its potential economic uses and realizing its economic value by introducing it to the market, which is referred to as carrying out an *innovation*. When an economic use of a new combination has been identified, the third step of the process consists of spreading the innovation in the economy, which Schumpeter referred to as *dissemination*. If successful, the new innovations and their dissemination give rise to creative destruction manifested in structural change that alters the composition of the economy.

In describing this process, Schumpeter (1934) was careful to distinguish the role of inventors—actors who conceive new inventions—from those who identify and realize their economic value—*entrepreneurs*. This distinction is essential because it illustrates the assertion that economic change requires, in addition to novel ideas, the ability to commercialize them. This view is commonly referred to as Schumpeter Mark I.

Schumpeter defined innovation more broadly than what is typically referred to by the term in everyday language as well as in economic analysis, where innovation is most commonly thought of as emanating from R&D. However, Schumpeter maintained that this definition was too narrow and argued that innovations did not have to be of scientific origin. Rather, he envisioned innovations as taking five principal forms: the introduction of new products, the introduction of new methods of production, the opening of new markets, the conquest of new sources of supply, and new methods of organizing a firm or industry.

Later in life (Schumpeter 1942), he argued that the innovative activity of individual entrepreneurs would be gradually phased out and replaced by routinized R&D processes in

[11] In line with this, Schumpeter (1934) argued that economic development should be confined to changes arising from within the economic system on the initiative of the economic actors and not "forced upon it from without" (p. 63).

large corporations—a view customarily referred to as Schumpeter Mark II.[12] A notable aspect of the thesis is that its primary intent was not to account for the process of creative destruction but rather to provide detail on the workings of socialism. Schumpeter predicted that increased routinization of innovation would lead to the disappearance of the entrepreneurial class, which, in turn, would pave the way for a structural shift towards socialism in the West.

Innovative activity may thus be modeled either as having the individual entrepreneur at the center of analysis or as a process in which the entrepreneur is marginalized or even absent. The choice of conceptualization has far-reaching implications for how one understands the workings of the economic system and the impact of economic policy. Schumpeter Mark II, with its emphasis on large corporations and central planning, lends support to the idea of interventionism and active industrial policy to stimulate economic growth.[13] In contrast, Schumpeter Mark I's focus on individual entrepreneurs and non-routinized innovation speaks in favor of a decentralized market economy.[14]

Although Schumpeter's work has influenced subsequent economic thought, a shortcoming is that it largely abstracts from the roles of risk and uncertainty in economic growth. Therefore, researchers have recently begun to show increasing interest in the work of Knight (1921), who likewise argued that entrepreneurial profit is a product of innovative entrepreneurship. He thereby extended our understanding of profit and, by extension, our understanding of the nature and economic role of entrepreneurship.[15] Importantly, Knight made a distinction between risk and uncertainty: risk is probabilistically quantifiable, while uncertainty is not. Thus, Knight refers to uncertainty as events about which we know so little that we are unable to assign any probabilities. This is customarily termed Knightian uncertainty or genuine uncertainty.[16]

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[12] This thought experiment has yet to become reality (Acs and Audretsch 1988; Henrekson and Johansson 2010; Coad et al. 2014; Acs et al. 2017; Parker 2018).

[13] In recent years, this view has gained traction following the publication of Mariana Mazzucato's book *The Entrepreneurial State* (Mazzucato 2013) and her subsequent writings. For a harsh critique of her analysis, see the many contributions in Wennberg and Sandström (2022).

[14] The difference in policy implications between Schumpeter Mark I and Mark II can be exemplified by considering two distinct approaches to government in the innovation systems literature. One approach, the literature on national innovation systems, largely abstracts from Knightian uncertainty, which subsequently yields implications leaning towards interventionist policy (e.g., Edquist 2013; Nelson 1993). In contrast, other writings, e.g., the entrepreneurial (eco)systems approach, position Knightian uncertainty as central, and therefore arrive at results leaning towards limited government interventionism (e.g., Holcombe 2007; Nooteboom and Stam 2008). The former approach is in line with Schumpeter Mark II, while the latter is in line with Schumpeter Mark I (e.g., Acs et al. 2014; Stam 2015).

[15] It is noteworthy that Knight is influenced by Schumpeter; he makes a number of references to Schumpeter (1911). By contrast, Schumpeter does not refer to Knight (1921) in either his 1934 or 1942 book. One reason could be that Schumpeter believed risk was not part of the entrepreneurial function (1934, p. 137): "The entrepreneur is never the risk bearer … Risk-taking is in no case an element of the entrepreneurial function."

[16] Recently, a third dimension—radical uncertainty—has been added to the distinction between risk and uncertainty (Hébert and Link 2007, p. 346): "Risk refers to the situation where the probability distribution of possible outcomes is calculable and known. Uncertainty refers to a situation where the possible outcomes are

Building on the concepts of risk and uncertainty, Knight stipulated that entrepreneurial actions are inherently uncertain because they involve the creation of new combinations. Therefore, the outcomes of these actions cannot be known *ex ante*. Based on this premise, he argued that entrepreneurial profit cannot persist in competitive markets unless the expected value of innovative activity is also, at least in part, subjective because it would otherwise be absorbed through price adjustments of inputs in the innovation process. Consequently, the Knightian entrepreneurs differ in skill, which is expressed in terms of differences in their ability to make subjective assessments of the viability of innovative ventures, which Knight referred to as *judgment*.

Given the conception of risk as the outcome of calculable events, Knight was also of the opinion that risk should be seen as an ordinary cost, not as a residual of the returns on innovative activity. Therefore, it should not be understood as part of entrepreneurial profit; entrepreneurial profit should only be seen as the residual returns of innovative activity *given* risk, which he denoted "pure profit". Hence, in the Knightian tradition, entrepreneurial profit refers to bearing the uncertainty associated with the introduction of new ideas and where he saw the pursuit of such profit opportunities as one of the key mechanisms in explaining long-run economic growth.

In contrast to Schumpeter Mark I, who asserted that employees could also fulfill the entrepreneurial function, Knight argued that entrepreneurship was inextricably linked to ownership. He based his view on three arguments. First, given that owners hold the ultimate decision-making rights, Knight inferred that owners ultimately decide whether to pursue innovation activities, including any decision to delegate this task. Second, owners are the residual claimants of the return on innovative activity; as their resources are invested, they are the ultimate bearers of uncertainty.[17] Third, given that entrepreneurial activity is inherently uncertain, the value of entrepreneurship is also uncertain; hence, the role of ownership becomes central to understanding entrepreneurial incentives. By virtue of these three arguments, Knight suggested that unlike other factor inputs, remuneration for entrepreneurial activities cannot be determined *ex ante*, not even in a probabilistic sense, due to the inherent uncertainty associated with entrepreneurial activity. Therefore, to foster innovation and establish a "price" on entrepreneurship services in the face of uncertainty, the entrepreneur must hold a residual claim

identifiable, but the probability distribution of outcomes is unknown. Radical uncertainty refers to a situation in which the possible outcomes of a given event are unknown and unknowable." This resembles the saying "known knowns, known unknowns and unknown unknowns". For the purpose of this study, however, it is sufficient to distinguish between risk and uncertainty.

[17] According to Knight this implies that all entrepreneurs are owners, but not all owners are entrepreneurs.

on profits, i.e., be made an owner. Hence, in the Knightian conceptualization, entrepreneurial profit and ownership serve the role of both providing incentives for entrepreneurship and a contractual solution for the pricing of the entrepreneurial function.

Another framework complementary to Schumpeter's view is provided by Kirzner (1973). In contrast to Schumpeter, Kirzner envisioned the role of the entrepreneur as the actor who *restores* equilibrium by identifying existing arbitrage opportunities.[18] Moreover, he described entrepreneurship as a process of alertness and discovery, where entrepreneurs pursue objectively known arbitrage opportunities under competition.

Related to the Knightian and Kirznerian discussions on the nature of entrepreneurial activity, a strand of contemporary research studies the epistemological underpinnings of entrepreneurship by distinguishing between discovered and created business opportunities (e.g., Venkataraman 2003; Alvarez and Barney 2010; Leyden and Link 2015). Discovered opportunities are exogenously existing opportunities whose intrinsic value can be objectively assessed by actors *ex ante*. In contrast, created opportunities are endogenously created by entrepreneurs based on their subjective valuations and cognitive abilities, and the market value of these opportunities is continuously realized by the entrepreneurs through a process of trial-and-error whereby their intrinsic value only becomes manifest *ex post*. In practice, it is probably not a question of either or; arguably, innovations typically include elements both of discovery and creation.

The distinction between discovered and created opportunities provides a framework for understanding both the nature of business opportunities and the entrepreneurial skills needed to pursue them. By applying the concepts of discovered and created business opportunities, it is possible to gain insight regarding the position of the neo-Schumpeterian entrepreneur relative to the frameworks of Schumpeter Mark I and II. Specifically, when prospective innovative ventures are assumed to be completely or mostly based on discovered opportunities, i.e., when ventures are generally modeled as taking calculable risks, theory inadvertently assigns a central role to routinized investments and calculated risk preferences in firms for determining innovation and economic growth, which is in line with Schumpeter Mark II. In contrast, when innovative ventures are assumed to be completely or mostly based on created opportunities, i.e., when opportunities are generally modeled as genuinely uncertain, theory assigns a central

[18] Despite differences in their theoretical approaches, Kirzner explicitly envisioned his entrepreneurial framework as complementary to that of Schumpeter (e.g., Kirzner 2009).

role to the non-routinized decision-making of individual entrepreneurs, which is in line with Schumpeter Mark I.[19]

3 Method and data

3.1 Identifying the population

We follow Aghion and Howitt (2009) and Acemoglu (2009) and date the conception of neo-Schumpeterian growth theory to 1990 based on the publication of Segerstrom et al. (1990) and Aghion and Howitt (1990). As a result, our investigation is confined to peer-reviewed articles published between 1990 and 2020.

To identify the field, a number of influential—or core—articles were reviewed to capture relevant terminology. The selection was based on the reviews by Acemoglu (2009), Aghion and Howitt (2009), Aghion et al. (2015a), and Akcigit and Nicholas (2019).[20] This yielded an initial dataset of 44 publications (listed in Appendix B). Next, the content of these articles was analyzed to capture pervasive terminology across the articles by using text mining tools; see Appendix A.[21] As shown in Figure 1, the most common terms and phrases across the identified core articles are, for example, competition, productivity, and technological change. A striking feature of Figure 1 is the absence of the terms "entrepreneur" and/or "entrepreneurship".

Figure 1 here

Once the core terminology across articles was identified, combinations of key terms and auxiliary terminology were selected based on within-article co-occurrences. The resulting search strings were then inserted into *Google Scholar*, *Scopus*, and the *Web of Science*. The initial search process yielded a total of 40,388, unique results.[22] By means of a stepwise iterative procedure detailed in Appendix A, we arrive at a final population of 714 peer-reviewed articles featuring neo-Schumpeterian growth models. A complete list of identified articles is presented in Appendix C.

3.2 Text analysis

Once the literature was identified, all peer-reviewed articles were manually surveyed to review their conceptualizations of the entrepreneur. Moreover, to characterize the literature, all articles were subjected to a word search for terms related to the work of Schumpeter as well as the complementary work of Knight (1921) and Kirzner (1973). To capture terminology related to

[19] Although not further elaborated in this paper, there exists a number of suggestions to synthesize different views of the entrepreneurial function, e.g., Casson (1982, p. 20), Hébert and Link (1989, p. 47), Wennekers and Thurik (1999, p. 46–47), Carlsson et al. (2013, p. 914), and Henrekson and Stenkula (2016, p. 71)).
[20] For the selection of textbooks, see footnote 6.
[21] In this exercise, generic words and phrases have been omitted based on an extensive third-party dictionary.
[22] These results were also cross-referenced against articles that cite core literature.

all of the above works, articles were searched for the occurrence of the terms "entrepreneur" and "innovation". Next, to capture terminology related to Schumpeterian discussions, articles were also searched for the terms "creative destruction," "new combinations," "invention," "inventor," and "innovator". Moreover, to capture discussions by Knight (1921) and Kirzner (1973), articles were searched for the terms "alertness," "genuine uncertainty," and "judgment".[23] Finally, articles were searched for direct references to Schumpeter (1934, 1942), Knight (1921) and Kirzner (1973). To manage inconsistencies in formulations across texts, all search strings were applied using *n*-gram approximate or "fuzzy" string matching (e.g., Pfeifer et al. 1996).

3.3. Qualitative analysis

To capture the conceptual nature of the literature and how it is positioned relative to Schumpeter Mark I and Mark II, a qualitative review was undertaken. This process departed from two key differences in the Schumpeterian characterizations of the value-creating process, namely the role of the entrepreneur in capturing the value of new ideas—active in Mark I, versus passive or superfluous in Mark II—and the type of innovative activity that is emphasized—non-routinized in Mark I versus routinized in Mark II. Accordingly, the scope and focus of the review were limited to these areas of inquiry.[24] This required, in turn, operationalization of the involved constructs and their domains. To capture discussions on the nature of innovation relative to the Schumpeterian debate, two factors were considered: 1) the conceptualization of the investment decisions that precede innovation, and 2) the representation of new technologies relative to existing ones, i.e., the composition of creative destruction. Similarly, to capture relevant discussions on the economic role of the entrepreneur, the literature was surveyed for statements and assumptions that explicitly connect the actions of entrepreneurs to innovative outcomes.[25]

The qualitative analysis was thereafter conducted in three steps. First, all three topics were surveyed using open coding (e.g., Blair 2015). As such, this initial coding procedure sought to identify distinct subsets of theoretical and methodological traditions against which the literature's orientation could be understood. Next, to more closely relate these findings to the Schumpeterian discussion, the respective outcomes were categorized in terms of: 1) Whether

[23] Results for "genuine uncertainty" also encompass the terms "radical uncertainty" and "Knightian uncertainty". Searches for terminology related to Schumpeter (1934, 1942), Knight (1921) and Kirzner (1973) are restricted to text bodies to capture only explicit mentions of these concepts. In practice, this does not affect the results.

[24] This follows the logic of a restricted literature review in that it is designed to capture discussions within a fixed domain.

[25] This also encompasses the person or entity that fulfils the entrepreneurial function of inducing innovation. This is sometimes referred to as "an innovator," or simply "a firm".

or not innovative outcomes were represented as having an *ex ante* objective value, i.e., as being routinized, versus non-routinized; 2) whether potential innovation outcomes were characterized as being incremental or non-incremental, i.e., "step-by-step," versus radical innovation;[26] 3) whether the entrepreneur was conceptualized as playing an active role throughout the value-creating process, or whether parts of this role could be performed by other agents, i.e., the entrepreneur as the *primus motor*, versus the entrepreneur as a partially or wholly substitutable actor.

4 Results

In this section, the use of entrepreneurship constructs in neo-Schumpeterian growth research is analyzed and positioned relative to Schumpeter Mark I and Mark II. First, article contents are surveyed for terminology use and literature references related to Schumpeter (1934, 1942) and the complementary frameworks of Knight (1921) and Kirzner (1973). Then, theoretical conceptualizations of the entrepreneur and his/her roles in innovative activity are qualitatively reviewed across articles.

4.1 Descriptive results

Table 1 presents the use of Schumpeterian terminology related to Schumpeter (1934, 1942) as well as the complementary frameworks of Knight (1921) and Kirzner (1973). In addition, the table reports the number and share of articles that include direct citations to Schumpeter (1934, 1942), Knight (1921) and Kirzner (1973). In an effort to capture seminal discussions in the literature, the results are presented across the categories "core articles," "review articles and textbooks," and "other articles."

The table reports that 31 percent of all articles mention the term "entrepreneur," whereas almost all include the term "innovation."[27] Rather than using the term "entrepreneur," the literature is found to use the term "innovator," which appears in half of all articles.[28] This usage is likely to result from the terminology used in early papers, such as Aghion and Howitt (1992), to denote actors that pursue innovative activity.[29] Notably, the term "entrepreneur" does not appear in either of the seminal articles of Segerstrom et al. (1990) or Aghion and Howitt (1992). Grossman and Helpman (1991) include the term but use it as a synonym to innovation-based firms. It was not until later that the term became pervasive in the literature. Other early

[26] This relates closely to discussions on the routinization of innovation, i.e., whether it constitutes an incremental change of known concepts, or whether it constitutes a significant deviation from the current knowledge stock.
[27] The remaining articles use the term "technology" rather than "innovation" to discuss innovation-driven growth.
[28] The two terms are weakly complementary; approximately 20 percent of the articles use both "entrepreneur" and "innovator".
[29] This exclusion is in congruence with the notion that the entrepreneur is not the innovator, i.e., in line with Schumpeter Mark II.

contributions are represented around the genesis of the literature, such as Boyer (1991) or Cheng and Dinopoulos (1992).[30] However, it would take until the mid-2000s for the first emergence of this term in an article that spurred a significant number of subsequent studies (i.e., Aghion et al. 2005).

Table 1 here

The concepts of "invention" and "inventor," which are central to the Schumpeterian discussion, are found in approximately one-third and one-fourth, respectively, of all articles. In this case too, it could be noted that the early articles do not contain these terms, while only one review article does. Moreover, the few references made to "new combinations" use the term only to position the presented discussions relative to Schumpeterian terminology, whereas none apply the concept to the analysis (Stein 1997; Olsson 2000, 2005; Albaladejo and Martínez-García 2015; Murakami 2017).[31]

Next, by studying references to Schumpeter (1934) and (1942) [Schumpeter Mark I and Mark II], the results in Table 1 again suggest that the literature primarily relies on the work of Schumpeter Mark II. The two works are cited in 3 and 13 percent of articles, respectively.[32] Moreover, most core articles make no reference to Schumpeter (1934), including the early articles by Segerstrom et al. (1990) and Grossman and Helpman (1991). This strengthens the conjecture that neo-Schumpeterian growth theory is primarily oriented towards Schumpeter Mark II.[33]

There are three observations that stand out in Table 1. First, given the large difference in the share of articles that include the term "innovation" compared to the terms "entrepreneur" and "innovator," the focus of neo-Schumpeterian analyses is primarily innovation per se and not the actor(s) who conduct(s) it. This implies reliance on Schumpeter Mark II rather than Schumpeter Mark I. Since the latter views the innovator-entrepreneur as the *persona causa* of

[30] A single statement on "firms or entrepreneurs" is also made by Grossman and Helpman (1994). However, this statement is not expanded upon.

[31] Curiously, prominent articles published in top economics journals that are contemporary with neo-Schumpeterian growth discussions have actually taken steps to introduce new combinations in models of economic growth (e.g., Weitzman 1998). However, these propositions have seemingly not been implemented in the neo-Schumpeterian tradition.

[32] The relatively low proportion of articles that cite any of Schumpeter's works is notable as it suggests that the literature only weakly draws on the original Schumpeterian literature. Instead, we find that it primarily refers to seminal contributions in the neo-Schumpeterian field itself, as well as related endogenous growth models, e.g., Romer (1990), Segerstrom et al. (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992). As such, the current literature can be seen as the latest step in the development of economic mainstream growth theory, starting with exogenous growth, carrying over to endogenous growth, and now neo-Schumpeterian growth; see, e.g., Acemoglu (2009).

[33] This is also true for the recent work by Aghion et al. (2021).

innovation-based growth, the exclusion of these terms indicates that Schumpeter Mark I is not applied.

Second, turning to the frameworks of Knight (1921) and Kirzner (1973), the literature frequently refers to the concepts of "risk" and "uncertainty". However, a qualitative analysis suggests that these terms are used interchangeably rather than denoting two separate constructs. Similarly, only approximately one percent of all articles include discussions using the key Knightian concepts "genuine uncertainty," "Knightian uncertainty," "radical uncertainty," "true uncertainty," and "judgment," and no articles include the Kirznerian concept of "alertness". Finally, Knight (1921) is only cited in two articles.[34] Kirzner (1973) is cited in one single article, Sanders and Weitzel (2012), who also apply Kirzner's framework in their modeling. Given the small number of occurrences, these observations strongly suggest that the overall neo-Schumpeterian literature to date has not incorporated insights from Knight (1921) or Kirzner (1973).[35]

4.2 Conceptual analysis

By examining the prevalence of key terms and references related to the formative literature—Schumpeter (1934), Schumpeter (1942), Knight (1921), and Kirzner (1973)—on entrepreneurship, the analysis in Section 4.1 offers a preliminary understanding of the orientation of neo-Schumpeterian analyses relative to Schumpeter Mark I and Mark II. We will now proceed to a qualitative assessment of the literature by reviewing the boundaries of entrepreneurial conceptualizations across articles.

In reviewing the literature's orientation relative to Schumpeter Mark I and Mark II, we depart from their different characterizations of the value-creating process through the representation of innovative activity and the economic function of the entrepreneur. A prominent finding made during the initial open coding procedure is the high degree of homogeneity in the field's conceptual foundations.[36] First, the entrepreneurial function in neo-Schumpeterian growth theory is found to be exclusively modeled as an agent that pursues R&D

[34] These are Cantner et al. (2009) and Heertje (1995). Cantner et al. only mention Knight (1921) as a seminal contribution. Heertje explicitly recognizes limitations in its theoretical neo-Schumpeterian framework with respect to the omission of genuine uncertainty.

[35] In line with Kirzner (1973), the literature includes some discussions on entrepreneurial opportunity. However, most of these discussions are not clearly positioned relatively to the entrepreneur and its role in identifying opportunities, but rather the emergence of business opportunities as a result of, for example, recessions (e.g., Aghion and Saint-Paul 1998; Caballero and Hammour 2005; Aghion et al. 2009; Pardo 2016). Upon examination, two articles are found to include notions of business opportunities that are comparable to the Kirznerian formulation (Olsson 2005; Sanders and Weitzel 2012).

[36] This homogeneity concerns the formal assumptions posed by models which, in turn, have direct consequences for the subsequent analyses.

investments in search of *ex ante* calculable monopoly rents (e.g., Aghion et al. 2015b). The entrepreneur is thus conceptualized as a decision-making agent in an intermediate sector firm that is responsible for allocating firm resources between two activities: production and R&D. As such, this conceptualization is silent about the role of the entrepreneur within the firm, i.e., whether the role can be fulfilled by a manager or whether it refers to the owner(s) of a firm. A second characteristic of the literature is the conceptualization of innovation outcomes. Throughout the literature, it is assumed that returns on innovation investments follow an *ex ante* and objectively known probability distribution. The expected costs and returns of innovations are thus objectively calculable, and the value and economic uses of innovations are known once a new product or technology has been developed. Hence, the innovation concept is reminiscent of the concept of discovered opportunities.[37]

This assumption may be motivated by a quest for theoretical parsimony, which admittedly is both a common and necessary practice in economic modelling.[38] However, this particular simplification comes at a significant cost to causal interpretability. Specifically, by assuming that entrepreneurial decision-making follows an implicit distribution, the literature is effectively applying a form of backward induction, where behavior is assumed to follow a deterministic pattern that is observable *ex post.* Although this may be sufficient to explain historical growth rates, it hampers our understanding of the growth process. This makes it less likely to be helpful in advising us on how to *induce* innovation and growth through a proper design of policy instruments. A richer conceptualization of the innovation process would benefit the debate by highlighting additional relevant points of inquiry, such as the macroeconomic role of ownership compositions (Andersson et al. 2018).

By depicting the entrepreneur as an actor whose economic function is to invest in calculable outcomes, the role of the neo-Schumpeterian entrepreneur is relegated to the role of a routine decision-maker in pursuit of discoverable business opportunities.[39] This implies that neo-Schumpeterian economic modeling closely resembles the entrepreneurless growth process of Schumpeter Mark II rather than the entrepreneur-centered view of Schumpeter Mark I. In fact, despite being referred to as "Schumpeterian," the current literature is arguably more reminiscent

[37] In a supplementary analysis, we find zero occurrences of the terms "discovered opportunities" and "created opportunities".

[38] The specific focus on R&D as opposed to the entrepreneurial process is, in turn, likely to have been influenced by the comparability and availability of data on R&D output, i.e., patents.

[39] This implies that the neo-Schumpeterian entrepreneur could possibly be understood as a Kirznerian entrepreneur. Along these lines, Gries and Naudé (2010) augment the Lewis (1954) model of structural change—one of the workhorses in modern development economics—with an entrepreneur who engages in incremental innovations and Kirznerian entrepreneurship. However, the neo-Schumpeterian literature draws no parallels to this discussion.

of models on variety-expansion (e.g., Romer 1990), which do not include an entrepreneur. Owing to this theoretical affinity, the two literatures are often cited in tandem, and there have been theoretical efforts to bridge the gap between them (e.g., Futagami and Ohkusa 2003; Madsen 2008; Bondarev and Greiner 2019).[40] As such, the current framework can be understood as primarily following a tradition of describing incremental quality improvements of established products or services where the potential payoffs on investments are partly or wholly calculable, i.e., what neo-Schumpeterians commonly refer to as "quality ladders".[41]

Moreover, when the profitability of R&D investments is modeled as being probabilistically deterministic, the innovation process becomes of subordinate interest, which explains why the literature does not elaborate on the different stages of the innovation process: invention, innovation, and dissemination, i.e., the processes that connect the conception of a new idea to its subsequent market introduction and dissemination in the economy.[42] It also explains why the literature delves less than related research into the importance of "agent heterogeneity" for successfully carrying out the different phases of the innovation process, i.e., the need for economic actors such as entrepreneurs and firms with different skills.[43] Likewise, discussions of different types of innovations and their relative importance are largely absent. This constitutes yet another departure from Schumpeter.

Given the above discussion, it is inferred that the neo-Schumpeterian framework in its current state is likely to be *ineffective* in providing causal insights regarding the process of innovation and entrepreneurship, and in particular in cases where innovative outcomes are non-routinized and non-calculable, i.e., in cases where they contain elements of Knightian uncertainty. In turn, Knightian uncertainty is likely to be particularly central to forming an understanding of the antecedents of disruptive innovations and entrepreneurship (Assink 2006; Naar et al. 2019). To the extent that researchers subscribe to the notion that both incremental and disruptive innovations are important for providing *causal* explanations to modern economic development, this implies a need for a different conceptualization of innovation-driven growth. Growth results both from radical and incremental innovation and their relative contribution

[40] In fact, the similarity between the neo-Schumpeterian and variety-based frameworks is even delineated in Grossman and Helpman (1994).

[41] These types of incremental innovations, that can be understood as taking place once a scientific paradigm has been established, have also been referred to as "puzzle-solving" or "mopping-up" operations (Olsson 2000; 2005).

[42] Again, this is likely to be based on a rationale of theoretical parsimony that is shared with other formal endogenous growth models, such as variety-expansion, where the different stages are collapsed into one simultaneous step of invention, innovation, and dissemination.

[43] Taking stock on Schumpeter (1934), the recent literature on governance and entrepreneurship elaborates on the actors with different but complementary competencies required to generate rapid economic development, e.g., Johansson (2010); Elert and Henrekson (2021); Wurth et al. (2022).

varies across countries, sectors, and years; a model that focuses solely on either incremental or radical innovation will only capture part of the story.

A causally informative model of endogenous growth under genuine uncertainty must incorporate the fact that many—perhaps most—innovations are undertaken without full information on their potential value, meaning that they lack strictly objective benefits against which their costs can be weighed. Instead, innovation can be expected to be wholly or partly pursued based on the *subjective* valuations and judgment-based decisions of individual entrepreneurs (e.g., Bylund and Packard 2021). Hence, given elements of genuine uncertainty, entrepreneurs cannot solely rely on objective knowledge regarding the final economic uses of ideas to determine their expected economic value (cf. Boettke 1997). Instead, they must retain an active role in identifying the economic uses of innovations and appropriating their economic value, as the entrepreneur of Schumpeter Mark I. This implies that the focus of analysis is directed towards the process of invention, innovation, and dissemination. In contrast, neo-Schumpeterian growth models—like their variety-expanding kins—make no distinction between the invention and innovation stages and then assume instant diffusion.

At the same time, introducing incalculability and subjectivity into the economic models does *not* imply that innovation outcomes are driven solely by chance and subjectivity. On the contrary, several determinants of innovation success can likely be incorporated to increase both the causal interpretability and predictive power of existing frameworks. Notably, Knight (1921) stresses the central role of the knowledge, experience, and innate abilities of entrepreneurs in the selection and outcome of disruptive innovations, i.e., what he refers to as "judgment".[44] For example, it is likely that the tacit knowledge gained from past experiences of creating and exploiting innovations is a core element of entrepreneurial acumen. In this area, initial steps have been taken to include the concept in theoretical models (Aghion and Howitt 1998; Mukoyama 2003; Thoenig and Verdier 2003; Haruyama 2009) and empirical operationalizations of tacit knowledge have been presented in the microeconomic literature (e.g., Balconi et al. 2007). However, the concept has seemingly failed to gain a wider traction in the neo-Schumpeterian growth literature. This absence is, in turn, notable given the significant role attributed to tacit knowledge in the wider literature on entrepreneurship and innovation (Gertler 2003; Pérez-Luño et al. 2019).[45]

[44] A general point made in the literature emphasizing genuine uncertainty is that even though entrepreneurial efforts are rife with uncertainty, chance favors the prepared mind—or economy (e.g., Wurth et al. 2022).

[45] There is a parallel—and more prevalent—discussion on the effects of "learning-by-doing". However, although this discussion partially accounts for intangible knowledge accumulation, it does not provide a meaningful distinction regarding the transferability of attained knowledge, i.e., tacit versus codified knowledge.

Similarly, a superior ability to act, adapt, and learn may explain why some entrepreneurs consistently maintain a competitive advantage over time (Alvarez and Busenitz 2001; Alvarez and Barney 2010). Along these lines, a handful of neo-Schumpeterian contributions have sought to capture heterogeneity of innate abilities across entrepreneurs (Lloyd-Ellis and Bernhardt 2000; Michelacci 2003; Acemoglu et al. 2006; Dohse and Ott 2014). However, the discussion has not gained significant traction over time.[46] Again, this stands in contrast to the attention that entrepreneurial skill and adaptive abilities have received in the wider entrepreneurship field (e.g., Baker and Nelson 2005; Eshima and Anderson 2017).

Moreover, performance and profits may derive from the ability of founding entrepreneurs to build efficient organizational structures that are capable of sustaining competitive advantages through continuous innovation and adaption to changed circumstances (cf. Penrose 1959; Alvarez and Busenitz 2001). This involves forming a team of competent co-workers with complementary skills and providing them with incentives to work towards a common goal (e.g., Elert and Henrekson 2021; Wurth et al. 2022). One contractual solution to accomplish this is to offer stock options to key personnel, thus giving them future ownership stakes in the firms (e.g., Gompers and Lerner 2001; Bengtsson and Hand 2013; Henrekson and Sanandaji 2018). The concepts of managerial and organizational innovations are briefly alluded to in the literature (e.g., Martimont and Verdier 2000; Francois and Lloyd-Ellis 2003), but the subjects have not been thoroughly explored in theory. Instead, organizational innovations are typically housed under the wider umbrella of process innovations, where the literature has an explicit focus on patentable processes, while core non-patentable concepts such as managerial structures and their intangible components remain elusive.

In line with Knight (1921), entrepreneurship under uncertainty also emphasizes that ownership is intertwined with entrepreneurship and that remuneration to entrepreneurs—pure profit—emerges from bearing uncertainty as a residual claimant. In contrast, in the absence of uncertainty, ownership itself is unnecessary because any actor can simply contractually achieve the required control over assets and obtain the foreseen returns (Foss et al. 2021). As such, the incorporation of uncertainty may also help to motivate *why* there is a need for a private sector in neo-Schumpeterian models, which is not necessary in extant models where innovation follows directly from R&D investments. In fact, the ideas of standardized innovation and

[46] A notable contribution is Cozzi and Spinesi (2006), who connect the prevalence of entrepreneurial skill to the creation of new markets. However, the focus of their discussion is not skill per se but rather the appropriability of intellectual property, i.e., industrial espionage. Other models posit a distinction between "skilled" and "unskilled" individuals, where skilled individuals become entrepreneurs and unskilled individuals become workers. Although an adjacent discussion, this does not account for heterogeneity of outcomes among entrepreneurs.

economies of scale were what led Schumpeter (1942) to his prediction that the government (or rather what he called "laborism") would eventually replace the entrepreneur as the *primus motor* of the economy.[47] Finally, genuine uncertainty may enlighten our causal understanding of business failure among previously successful entrepreneurs because they can never fully anticipate the value of a novel idea.

Despite criticism from prominent economists (Nelson 1997, 1998; Bianchi and Henrekson 2005; Acs and Sanders 2013), another notable finding is that the conceptual limitations of the neo-Schumpeterian entrepreneur have not been addressed so far within the literature. In fact, during the literature review process, no instances of critical reflections concerning alternative entrepreneurial constructs were identified. At the same time, recent neo-Schumpeterian work explicitly acknowledges the disparity between core measures of R&D (patent output) and economic growth (Aghion et al. 2019). This may signal an increasing awareness in the literature that its workhorse models are currently lacking key elements. Another dimension is the fact that all endogenous growth models after Romer (1986) are supply driven. Gries and Naudé (2021) offer an endogenous growth model specification that is demand driven—illustrating that demand constraints can create fundamental doubt as to how much of potential production (supply) can be sold in the market, leading in turn to reduced entrepreneurial effort and investment.[48] This is yet another dimension that may be relevant for further exploration by neo-Schumpeterian growth theory.

A potential objection to our examination is that neo-Schumpeterian growth models seek to explain and predict the macroevolution of the economy, and at the aggregate level, it may be fair to abstract from the genuine uncertainty of innovative outcomes at the micro level. Although the validity of this assertion is debatable per se (Frydman et al. 2019), this line of reasoning is also likely to be debatable in this specific context in at least two respects. First, given that economics seeks to explain the *causes* of economic growth, a deeper causal understanding is required. Second, economists aspire to provide reliable policy advice and the adequacy and precision of policy proposals hinge on a good causal understanding of the growth process and its microeconomic foundations. Furthermore, given that endogenous growth

[47] See Swedberg (1997, p. 118–119) for further details on Schumpeter's articles in the last two years of his life, where he claims that laborism will be "the last stage of capitalism". At that stage "most things will be considered "from the viewpoint of the vested interests of the trade unions" and the "political class" will be "the exponent of the labor class".

[48] Their model may also be relevant for the findings of declining innovation measured by R&D productivity (Bloom et al. 2020). This is another finding in the neo-Schumpeterian growth literature that has been explained by, for instance, technological distance and reduced R&D spillovers because of specialization as the size of the market increases (Peretto and Smulders 2002).

models—both neo-Schumpeterian and variety-expansion models—make an explicit point of being grounded in microeconomic fundamentals, the argument that it is fair to abstract from the micro level becomes contradictory. In fact, this is at odds with the literature's own perception and goal of capturing fundamental causes of growth (Acemoglu 2009, p. 19).

The above points are likely to be particularly relevant for economies at the technological frontier, such as the U.S. and Western Europe, where the causal effect of R&D on economic growth is weak (Aghion et al. 2019; Bloom et al. 2020) and where there are only marginal opportunities for improvements to basic institutional quality such as enabling free entry, securing property rights, or increasing accessibility to higher education.

A broader understanding of the growth process may lead research onto previously unexplored paths that will increase its explanatory power. For instance, the existence of substantial information problems caused by genuine uncertainty may help explain the global predominance of family ownership of firms (Andersson et al. 2018). This is likely to have significant macroeconomic implications as family firms have been found to systematically deviate from the standard assumptions of firm behavior. Hence, by better understanding the interplay between entrepreneurship, ownership, firm organization, and innovation, growth theory may be augmented in ways that enhances both its predictive power and usefulness for policy analysis and guidance.

So, *why* do current neo-Schumpeterian models not incorporate genuine uncertainty? The explanation is likely linked to the theoretical and methodological approach of the literature and, specifically, to the prevalence of equilibrium modeling in the field (Hébert and Link 2007). Equilibrium is fundamentally incompatible with genuine uncertainty; this suggests a need for a more pluralistic methodological approach (Hébert and Link 2007). In the presence of uncertainty, an equilibrium or "optimum" output of innovative activities cannot be objectively defined. Hence, to yield a richer and more inclusive theory of entrepreneurship and economic growth, a more inclusive approach to economic theory and methodology is needed.

Finally, despite the presented criticism, it is worth emphasizing that in comparison to its neoclassical predecessors, the contributions of neo-Schumpeterian growth models are one step towards a more realistic conceptualization of the economic growth process. In effect, neo-Schumpeterian growth models have reintroduced the notion of an entrepreneur to the core of mainstream economics, and the neo-Schumpeterian literature has contributed to an increased focus on economic history to further our understanding of how institutions and policy enable or impede economic growth.

5 Concluding remarks

This study explores the position of the neo-Schumpeterian entrepreneur relative to Schumpeter Mark I and II, i.e., Schumpeter (1934), where the entrepreneur is the *persona causa* of innovation and economic growth, and Schumpeter (1942), where the entrepreneur becomes superfluous. This is accomplished by quantitatively reviewing the terminology applied in neo-Schumpeterian growth theory and by qualitatively reviewing neo-Schumpeterian conceptualizations of entrepreneurship and innovation. The analysis is based on more than 700 peer-reviewed articles on neo-Schumpeterian growth published from 1990 to 2020.

By quantitatively analyzing the literature, we find that less than one-third of all articles include the term "entrepreneur". Moreover, a mere one percent mention Schumpeter's key concept "new combinations," and then only to position their discussion relative to Schumpeterian terminology. Our analysis of the reference lists shows that less than one-twentieth of articles include references to Schumpeter (1934) and about one tenth to Schumpeter (1942). Rather, the literature adheres closely to its roots in endogenous growth theory, which abstracts from the Schumpeterian entrepreneur. Similarly, Frank Knight and Israel Kirzner, who, together with Schumpeter, are the most important scholarly pioneers in terms of influence on contemporary entrepreneurship research, are absent from the examined literature.[49] Only three out of 714 articles mention either Knight or Kirzner, and only two of these discuss implications for entrepreneurial decision-making. As a corollary, the related concepts of judgment, genuine uncertainty, and alertness are not discussed.

Our qualitative analysis of the literature's conceptualizations of entrepreneurship and innovation reveals two common themes. First, the neo-Schumpeterian entrepreneur is defined based on his/her role as an undertaker of innovative investments, notably in terms of R&D. Second, the outcome of innovative activity is assumed to follow an implicit probability distribution that is observable *ex post*, while simultaneously modelling it as if it was objectively known *ex ante*. Hence, the expected costs and benefits of innovative ventures are assumed to be *ex ante* calculable.

By assuming that the expected value of innovative activity is fully calculable, the economic role of the neo-Schumpeterian entrepreneur is reduced to that of a routine decision-maker. As a result, the disruptive role of the Schumpeter Mark I entrepreneur becomes redundant, i.e., in congruence with the prediction of Schumpeter Mark II. This conclusion is strengthened by the

[49] One single paper out of 714 cites Knight and recognizes the limitations of using *ex ante* calculable risk rather than genuine uncertainty to conceptualize potential innovation outcomes: Heertje (1995). Two papers cite either Knight or Kirzner as seminal contributions: Cantner et al. (2009) and Sanders and Weitzel (2012), respectively.

fact that references to Schumpeter (1934) are rare and that the articles do not use the terminology associated with Schumpeter's early work, including the concept of "new combinations".

When innovations are modeled as discovered opportunities whose expected value is exogenously given, analysis of the value-creating process becomes unnecessary. This includes the different stages of the innovation process, i.e., the processes that connect the conception of a new idea to its subsequent introduction and market dissemination. This abstracts from the distinction between the inventive and entrepreneurial functions, which is a further digression from Schumpeter Mark I. Relatedly, the assumption that the value of a given innovation is objectively and *ex ante* calculable may partially explain the seeming lack of diversity in terms of how innovative ventures are currently modeled. As a result, other types of innovations discussed in Schumpeter (1934), such as the creation of new or improved organizational structures with the ability to generate and exploit innovations through time, become less relevant. This also explains why discussions of ownership and the nature of entrepreneurial skills are so scarce.

In contrast to the neo-Schumpeterian conceptualization of the innovation process, a key component of the innovation process under uncertainty consists of the value generation process undertaken by entrepreneurs in the absence of calculable outcomes. In this process, the value of a new idea is endogenously imputed based on the subjective valuation of the entrepreneur and, over time, through its dissemination in the marketplace.

By assuming that returns on innovative activity are *ex ante* calculable, the neo-Schumpeterian conceptualization of economic growth is effectively disregarding key economic antecedents that are a pervasive characteristic of economic life. Hence, by re-introducing the entrepreneur into mainstream growth models, neo-Schumpeterian growth theorists also need to address theoretical and methodological issues that have hitherto remained underexplored, such as the entrepreneurial function as bearing uncertainty and the appropriateness of equilibrium modeling for analyzing economic growth as an innovation process.

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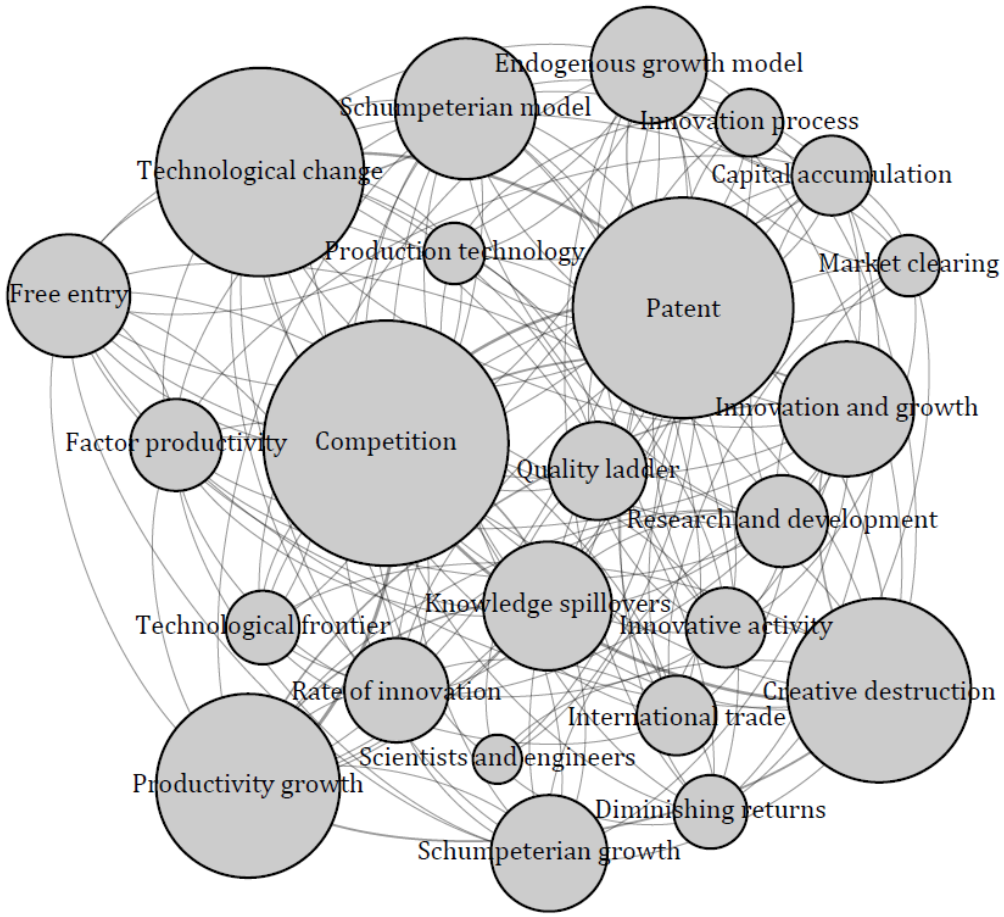
Figure 1. Co-occurrence of the most common terminology across core articles on neo-Schumpeterian growth, 1990–2020.



Note: Results of co-occurrence analysis of article terminology. The 30 most common phrases and words in neo-Schumpeterian growth articles, measured in terms of article occurrences. Articles were selected based on the reviews of Acemoglu (2009), Aghion and Howitt (2009), Aghion et al. (2015a) and Akcigit and Nicholas (2019). Search terms were separated from generic macroeconomic terms, such as "steady state" and "general equilibrium". The terminology was harmonized to account for different connotations and weighted by number of article occurrences. "Schumpeterian model" encompasses the phrase "Schumpeterian growth model"; "Technological change" encompasses the phrase "Technical change"; "Factor productivity" encompasses the phrase "Total factor productivity".

Table 1. The number and share (%) of peer-reviewed articles and textbooks that include direct citations and terminology related to Schumpeter Mark I and II, Knight (1921), and Kirzner (1973), 1990–2020.

	(1) Core articles		(2) Review articles and textbooks		(3) Other articles		(4) Total	
	Number	Share	Number	Share	Number	Share	Number	Share
Key terminology								
Creative destruction	26	59	4	100	291	44	321	45
Entrepreneur	15	34	3	75	205	31	223	31
Innovation	44	100	4	100	626	94	674	94
Innovator	28	64	3	75	324	49	355	50
Invention	17	39	3	75	226	34	246	34
Inventor	17	39	3	75	169	25	189	26
New combination	1	2	0	0	6	1	7	1
Uncertainty	17	39	2	50	173	26	192	27
Risk	22	50	3	75	350	53	375	53
Genuine uncertainty	0	0	0	0	8	1	8	1
Judgment	0	0	0	0	3	0.5	3	0.4
Alertness	0	0	0	0	0	0	0	0
Literature references								
Schumpeter (1934)	2	4	2	50	21	3	23	3
Schumpeter (1942)	7	16	3	75	87	13	96	13
Knight (1921)	0	0	0	0	2	0.3	2	0.3
Kirzner (1973)	0	0	0	0	1	0.2	1	0.1
Total number of included works	44	6	4	1	666	93	714	100

Note: The category "genuine uncertainty" also encompasses the terms "Knightian uncertainty," "true uncertainty" and "radical uncertainty". See Appendix A for "Core articles". "Review articles" are Aghion et al. (2015a) and Akcigit and Nicholas (2019). "Textbooks" are Acemoglu (2009) and Aghion and Howitt (2009). "Other articles" are listed in Appendix C. The terms "entrepreneur" and "innovator" are weakly complementary: approximately 20 percent of articles use both terms.

Appendix A: Identification process and search terminology

To identify the neo-Schumpeterian literature, a set of 44 core articles was selected based on the reviews of Acemoglu (2009), Aghion and Howitt (2009), Aghion et al. (2015a) and Akcigit and Nicholas (2019). Once identified, all articles were subjected to text mining analysis in which the frequencies of different word combinations were analyzed across articles, covering all combinations consisting of up to five words. In this study, an extensive dictionary of generic English phrases was utilized to omit irrelevant entries, such as "this study shows".

Once the core terminology across articles was identified, co-occurrences related to each of the identified terms were extracted to capture auxiliary terminology. By analyzing co-occurrences, we found that the identified terminology is strongly interrelated. Moreover, most articles use similar auxiliary terminology, such as "growth rate," "economic growth," "technological change," and "steady state" (the resulting search strings are presented in Table A1). This high degree of overlap of terminology suggests that the selected articles emanate from the same literature. Once core and auxiliary terminologies were identified, the resulting words and phrases were combined to build search strings to be used in bibliometric databases.

After extracting the most frequently used terminology across influential articles as identified by seminal authors in the field, the resulting search strings were inserted into *Google Scholar*, *Scopus*, and the *Web of Science*. The initial search process yielded a total of 40,388 unique results.[50] All publications without a timestamp were excluded due to difficulties in determining their publication date (3,552 observations, nine percent), and all non-English publications were omitted (4,045 observations, 10 percent).

By applying the above constraints, an initial dataset was obtained consisting of 32,791 papers, including 11,243 peer-reviewed articles (34 percent), 3,305 working papers (11 percent), 3,527 discussion papers (11 percent), 158 policy papers (0.5 percent), 1,017 doctoral theses (3 percent) and 13,541 works published outside official academic series, such as preliminary drafts and reports (41 percent). We included unpublished works to account for publication bias (Cooper et al. 1997; Lipsey and Wilson 2001).[51]

Despite efforts to refine search strings, the obtained data were still likely to contain inconsistencies. Specifically, terminology used in the neo-Schumpeterian growth literature

[50] These results were also cross-referenced against articles that cite core literature.
[51] To ensure text legibility, all articles were processed using text recognition algorithms, so-called Optical Character Recognition (OCR).

is also used in related endogenous growth models as well as in Austrian and evolutionary economics. Therefore, to accurately identify the target literature, all articles were subjected to text analyses using supervised machine learning. All article texts were decomposed using a bag-of-words approach and categorized using a random forest algorithm (e.g., Breiman 2001).[52] To provide an initial training set, a random subsample constituting ten percent of the full dataset was drawn, and observations were stratified by their year of publication. Articles were then categorized as follows:[53]

$$Population_i = \begin{cases} 1 \; if \; article \; i \; \in target \; population \\ 0 \; if \; article \; i \; \notin target \; population \end{cases}. \quad (1)$$

The random forest algorithm was trained by growing trees based on the terminology use of each article in the training set. Random forest classifiers are likely to be biased towards the majority class in the training set. Therefore, to facilitate accurate identification of the intended literature, the training dataset was balanced using random undersampling.[54] This was then estimated with the following model:

$$h(Population_i, \Theta_k), \quad s.t. \; \text{argmin} \; [1 - \textstyle\sum_{M=1}^{2}(p_M^2)], \quad (2)$$

where $[1 - \sum_{M=1}^{2}(p_M^2)]$ is the Gini impurity of each tree and $[\Theta_k]$ is a set of $k = 5{,}000$ independently and identically distributed random vectors drawn on the absolute frequencies of j distinct words across a random sample of $\sqrt{N}$ observations. Next, the algorithm was trained to identify the intended literature, and the resulting framework was used to classify observations across the full population based on the majority ruling across decision trees.

Finally, once the initial algorithm was trained and a prediction was produced, all observations that fell above the prediction threshold were manually reviewed in an iterative process, after which the previous steps were once again executed. This process was

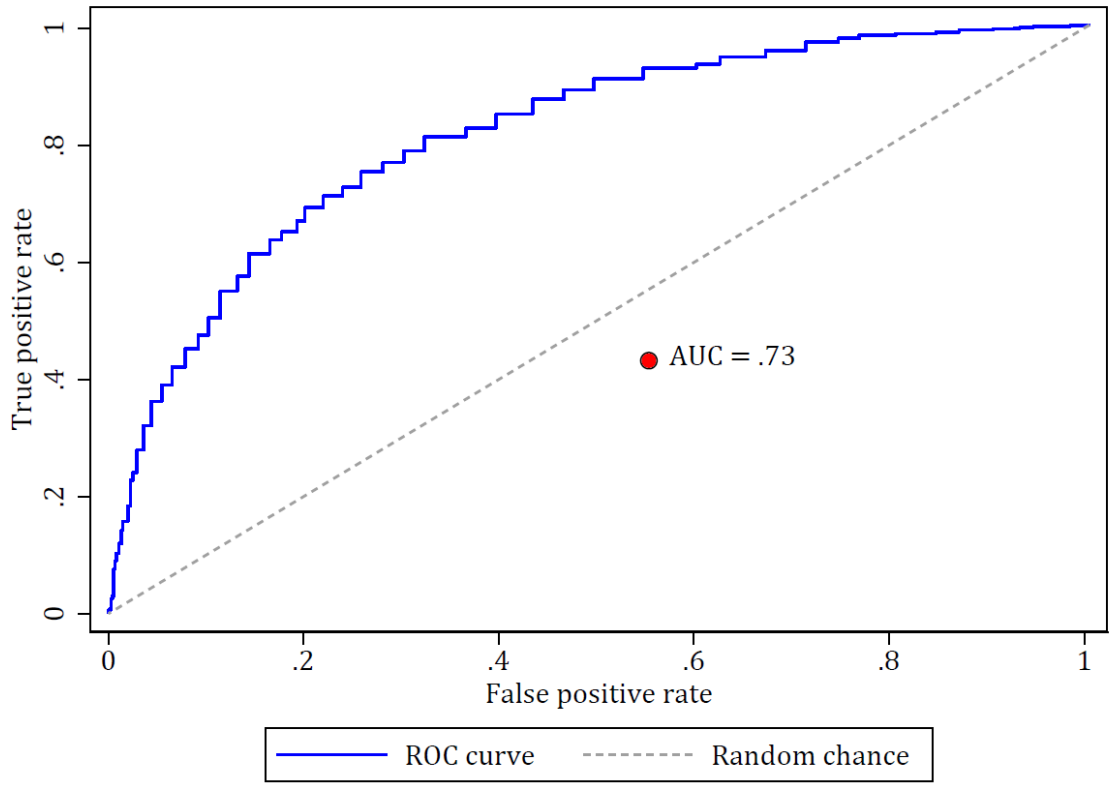
[52] Bag-of-words refers to the process of decomposing texts and counting the number of instances of each distinct word represented within them.

[53] By neo-Schumpeterian, we specifically refer to macro-level theory and empirics that depart from equilibrium methodology and focus on vertical innovation or vertical technological progress as the vehicle that drives economic growth. This process results in the displacement of past revenue streams or resources. As such, this distinction is in congruence with the descriptions provided by top scholars in the field, e.g., Aghion et al. (2015a,b), Aghion and Howitt (2009), and Acemoglu (2009).

[54] Competing techniques include cost-sensitive learning, random oversampling and synthetic minority oversampling (SMOTE). Cost sensitivity has been found to yield similar or even lower accuracy to that of undersampling, whereas it significantly increases computational requirements; random oversampling and SMOTE have been found to yield lower performance in sparse data (Weiss et al. 2007; Blagus and Lusa 2013).

repeated until no additional documents were identified by the algorithm. The performance of the final algorithm was gauged using 50-fold cross validation with *k*-fold cross-validation, which is a conventional metric for evaluating the performance of machine learning algorithms (e.g., Hastie et al. 2001).[55] In this process, all quantiles of the data were systematically cycled through and excluded from the training set. It was then used to test the predictive accuracy of the algorithm based on predictions yielded from the remaining $k - 1$ quantiles at all q distinct voting scores. In equivalence to the main process, these models were tested using $k = 5{,}000$ trees.[56] The outcome of this process is presented in the form of a receiver operating characteristic curve (ROC) in Figure B1 below.

Figure B1. Receiver operating characteristic curve for the derived machine learning algorithm relative to identification through random chance.



[55] *k*-fold cross validation can be applied to any set of k groups where $k \leq N$. In this regard, the choice of subsections to be tested follows an assessment of the tradeoff between computational bias, which asymptotically decreases in k, versus the computational resources needed to carry out the analysis. In this regard, $k = 50$ was chosen as a feasible intermediate point between the two.

[56] Random forest classifiers have strongly diminishing returns on computing additional trees. In a supplementary analysis, the number of trees was drastically increased. This analysis revealed that the corresponding AUC score increased only by half a percent. Hence, the presented results are likely to be an accurate representation of the main model in this regard.

By studying the results of the applied strategy, an area under the curve (a so-called AUC score) of 0.73 is obtained. The above-described strategy yielded a final population of 714 peer-reviewed articles featuring neo-Schumpeterian growth models. The process of manually reviewing the literature suggested a small number of false positives in each iteration. These articles were primarily in the fields of evolutionary or Austrian economics. A few articles analyzed related microeconomic models and variety-based endogenous growth models.[57] To test for the presence of false negatives in the extrapolated data, a random sample of negative outcomes was drawn. No false negatives were identified, which suggests that the algorithm yielded a reliable identification of the observed outcomes.[58] A complete list of the identified articles is presented in Appendix C. Table A1 presents the derived search terminology and gross number of results for each term and database.

[57] A recurrent issue for the derived algorithm is also difficulty in distinguishing between peer-reviewed articles and working papers.

[58] To obtain representativeness, a random sample of 1,700 observations (approximately 10 percent of negative responses) was drawn from the population.

Table A1. Applied search terminology divided across bibliometric sources, number of gross publications.

Search string(s):		Sources:	Years	No. of publications, gross[Ψ]
Mandatory (all terms)	Optional (any term)			
"Creative destruction," "Endogenous growth"	"Growth rate," "Economic growth," "Technological change," "Growth model," "Productivity growth," "Aghion and Howitt," "Growth rates," "Steady state," "Production function," "Marginal cost," "Schumpeter," "Grossman and Helpman," "Endogenous technological change," "Knowledge spillovers"	*Google Scholar*	1990–2020	7,630
"Endogenous growth model," "General equilibrium"	"Creative destruction," "Aghion and Howitt," "Schumpeterian model," "Grossman and Helpman"	*Google Scholar*	1990–2020	6,940
"Schumpeterian growth"	"Aghion and Howitt," "General equilibrium," "Grossman and Helpman"	*Google Scholar*	1990–2020	3,070
"Quality ladder*"	"Endogenous growth," "Schumpeterian model," "General equilibrium"	*Google Scholar*	1990–2020	2,690

"Technological change," "Creative destruction," "Endogenous growth"	"Aghion and Howitt," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Knowledge spillover"	*Google Scholar*	1990–2020	5,960
"Knowledge spillovers," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Endogenous technological change," "Free entry," "Global economy"	*Google Scholar*	1990–2020	5,870
"Productivity growth," "Creative destruction," "Endogenous growth"	"Aghion and Howitt," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Free entry"	*Google Scholar*	1990–2020	4,790
"Rate of innovation," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Steady state," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Free entry"	*Google Scholar*	1990–2020	1,880

"Quality improvement," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Steady state," "Schumpeterian model," "General equilibrium," "Knowledge spillovers," "Grossman and Helpman," "Endogenous technological change"	*Google Scholar*	1990–2020	1,150
"Schumpeter*," "Endogenous," "Innovat*," "Equilibrium," "Aghion," "Howitt"	"Leapfrogging," "Step-by-step," "Competition"	*Google Scholar*	1990–2020	41
"Schumpeter"	"Aghion," "Howitt," "Segerstrom," "Grossman," "Helpman," "Dinopoulos," "Akcigit," "Madsen," "Trajtenberg"	*Google Scholar*	1990–2020	20,900
"Endogenous growth," "Schumpeter*"	"Leapfrogging," "Step-by-step," "Quality ladder," "Creative destruction," "Innovation"	*Google Scholar*	1990–2020	14,900
"Schumpeterian wave*," "Endogenous growth"		*Google Scholar*	1990–2020	24
"Creative destruction," "Endogenous growth"		*Google Scholar*	1990–2020	13,400
"Quality ladder*," "Endogenous growth"		*Google Scholar*	1990–2020	2,100
"Step-by-step," "Endogenous growth," "Innovation"		*Google Scholar*	1990–2020	2,210
"Endogenous growth" "Innovation"	"Leap frogging," "Leap-frogging"	*Google Scholar*	1990–2020	1,240

"Endogenous growth," "Innovation"	"Neck-to-neck," "Neck to neck," "Neck by neck," "Neck-by-neck"	*Google Scholar*	1990–2020	103
"Knowledge production function," "Endogenous growth"		*Google Scholar*	1990–2020	1,900
"Schumpeterian," "Differentiation"	"Vertical product*," "Vertical and horizontal product"	*Google Scholar*	1990–2020	1,480
"Endogenous growth," "Differentiation"	"Vertical product*," "Vertical and horizontal product"	*Google Scholar*	1990–2020	523
"Endogenous growth," "Patent race*"		*Google Scholar*	1990–2020	600
"Endogenous growth," "Vertical innovation"		*Google Scholar*	1990–2020	650
"Endogenous growth"	"Patent ladder," "Technology ladder"	*Google Scholar*	1990–2020	265
"Creative destruction," "Endogenous growth"	"Growth rate," "Economic growth," "Technological change," "Growth model," "Productivity growth," "Aghion and Howitt," "Growth rates," "Steady state," "Production function," "Marginal cost," "Schumpeter," "Grossman and Helpman," "Endogenous technological change," "Knowledge spillovers"	*Web of Science*	1990–2020	35
"Endogenous growth model"	"Creative destruction," "Aghion and Howitt," "Schumpeterian model," "Grossman and Helpman"	*Web of Science*	1990–2020	22

"Schumpeterian growth"	"Aghion and Howitt," "General equilibrium," "Grossman and Helpman"	*Web of Science*	1990–2020	14
"Quality ladder*"	"Endogenous growth," "Schumpeterian model," "General equilibrium"	*Web of Science*	1990–2020	60
"Technological change," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Steady state," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Knowledge spillovers," "Global economy"	*Web of Science*	1990–2020	11
"Knowledge spillovers," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Endogenous technological change," "Free entry," "Global economy"	*Web of Science*	1990–2020	2
"Productivity growth," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Knowledge spillovers," "Free entry"	*Web of Science*	1990–2020	5
"Rate of innovation," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Steady state," "Schumpeterian model," "General equilibrium," "Grossman and Helpman," "Free entry"	*Web of Science*	1990–2020	1

"Quality improvement," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Steady state," "Schumpeterian model," "General equilibrium," "Knowledge spillovers," "Grossman and Helpman," "Endogenous technological change"	*Web of Science*	1990–2020	1
"Schumpeter*," "Endogenous," "Innovat*," "Equilibrium," "Aghion," "Howitt"	"Leapfrogging," "Step-by-step," "Competition"	*Web of Science*	1990–2020	1
"Schumpeter"	"Aghion," "Howitt," "Segerstrom," "Grossman," "Helpman," "Dinopoulos," "Akcigit," "Madsen," Trajtenberg	*Web of Science*	1990–2020	9
"Endogenous growth," "Schumpeter*"	"Leapfrogging," "Step-by-step," "Quality ladder," "Creative destruction," "Innovation"	*Web of Science*	1990–2020	17
"Schumpeterian wave*," "Endogenous growth"		*Web of Science*	1990–2020	0
"Creative destruction," "Endogenous growth"		*Web of Science*	1990–2020	43
"Quality ladder*," "Endogenous growth"		*Web of Science*	1990–2020	53
"Step-by-step," "Endogenous growth"	"Innovation"	*Web of Science*	1990–2020	2
"Endogenous growth," "Innovation"	"Leap frogging," "Leap-frogging"	*Web of Science*	1990–2020	3

"Endogenous growth," "Innovation"	"Neck-to-neck," "Neck to neck," "Neck by neck," "Neck-by-neck"	*Web of Science*	1990–2020	0
"Knowledge production function," "Endogenous growth"		*Web of Science*	1990–2020	12
"Schumpeterian," "Differentiation"	"Vertical product*," "Vertical and horizontal product"	*Web of Science*	1990–2020	0
"Endogenous growth," "Differentiation"	"Vertical product*," "Vertical and horizontal product"	*Web of Science*	1990–2020	0
"Endogenous growth," "Patent race*"		*Web of Science*	1990–2020	4
"Endogenous growth," "Vertical innovation"		*Web of Science*	1990–2020	14
"Endogenous growth"	"Patent ladder," "Technology ladder"	*Web of Science*	1990–2020	0
"Creative destruction," "Endogenous growth"	"Growth rate," "Economic growth," "Technological change," "Growth model," "Productivity growth," "Aghion and Howitt," "Growth rates," "Steady state," "Production function," "Marginal cost," "Schumpeter," "Grossman and Helpman," "Endogenous technological change," "Knowledge spillovers"	*Scopus*	1990–2020	2,391
"Endogenous growth model"	"Creative destruction," "Aghion and Howitt," "Schumpeterian model," "Grossman and Helpman"	*Scopus*	1990–2020	867

“Schumpeterian growth”	“Aghion and Howitt,” “General equilibrium,” “Grossman and Helpman”	*Scopus*	1990–2020	192
“Quality ladder*”	“Endogenous growth,” “Schumpeterian model,” “General equilibrium”	*Scopus*	1990–2020	906
“Technological change,” “Creative destruction”	“Endogenous growth,” “Aghion and Howitt,” “Steady state,” “Schumpeterian model,” “General equilibrium,” “Grossman and Helpman,” “Knowledge spillovers,” “Global economy”	*Scopus*	1990–2020	3,084
“Knowledge spillovers,” “Creative destruction”	“Endogenous growth,” “Aghion and Howitt,” “Schumpeterian model,” “General equilibrium,” “Grossman and Helpman,” “Endogenous technological change,” “Free entry,” “Global economy”	*Scopus*	1990–2020	1,018
“Productivity growth,” “Creative destruction”	“Endogenous growth,” “Aghion and Howitt,” “Schumpeterian model,” “General equilibrium,” “Grossman and Helpman,” “Knowledge spillovers,” “Free entry”	*Scopus*	1990–2020	1,439
“Rate of innovation,” “Creative destruction”	“Endogenous growth,” “Aghion and Howitt,” “Steady state,” “Schumpeterian model,” “General equilibrium,” “Grossman and Helpman,” “Free entry”	*Scopus*	1990–2020	67

"Quality improvement," "Creative destruction"	"Endogenous growth," "Aghion and Howitt," "Steady state," "Schumpeterian model," "General equilibrium," "Knowledge spillovers," "Grossman and Helpman," "Endogenous technological change"	*Scopus*	1990–2020	61
"Schumpeter*," "Endogenous," "Innovat*," "Equilibrium," "Aghion," "Howitt"	"Leapfrogging," "Step-by-step," "Competition"	*Scopus*	1990–2020	623
"Schumpeter"	"Aghion," "Howitt," "Segerstrom," "Grossman," "Helpman," "Dinopoulos," "Akcigit," "Madsen," Trajtenberg	*Scopus*	1990–2020	8,416
"Endogenous growth," "Schumpeter*"	"Leapfrogging," "Step-by-step," "Quality ladder," "Creative destruction," "Innovation"	*Scopus*	1990–2020	2,494
"Schumpeterian wave*," "Endogenous growth"		*Scopus*	1990–2020	7
"Creative destruction," "Endogenous growth"		*Scopus*	1990–2020	2,423
"Quality ladder*," "Endogenous growth"		*Scopus*	1990–2020	742
"Step-by-step," "Endogenous growth"	"Innovation"	*Scopus*	1990–2020	227
"Endogenous growth," "Innovation"	"Leap frogging," "Leap-frogging"	*Scopus*	1990–2020	6

"Endogenous growth," "Innovation"	"Neck-to-neck," "Neck to neck," "Neck by neck," "Neck-by-neck"	*Scopus*	1990–2020	0
"Knowledge production function," "Endogenous growth"		*Scopus*	1990–2020	287
"Schumpeterian," "Differentiation"	"Vertical product*," "Vertical and horizontal product"	*Scopus*	1990–2020	49
"Endogenous growth," "Differentiation"	"Vertical product*," "Vertical and horizontal product"	*Scopus*	1990–2020	42
"Endogenous growth," "Patent race*"		*Scopus*	1990–2020	75
"Endogenous growth," "Vertical innovation"		*Scopus*	1990–2020	104
"Endogenous growth"	"Patent ladder," "Technology ladder"	*Scopus*	1990–2020	6

Note: Search strings and results, per database across the period of 1990–2020. Search strings were used across *Google Scholar*, *Scopus* and *Web of Science*.
Ψ The gross number of publications in *Google Scholar* constitutes an approximation as returned when imputing each search string in the search engine. Consequently, search terms yielding returns of more than 1,000 are rounded off to the closest 10^{th} multiplier. In the identification process itself, the complete set of results is accounted for by compiling all individual search hits returned from *Google Scholar*. In a second stage, all publications containing non-English titles are removed, along with all publications that lack a time stamp.
"*" Indicates the use of wildcards.

Appendix B: Core articles

Acemoglu, D., & Akcigit, U. (2006). State-dependent intellectual property rights policy. NBER Working Paper No. 12775. Cambridge, MA: National Bureau of Economic Research.

Acemoglu, D., & Akcigit, U. (2012). Intellectual property rights policy, competition, and innovation. *Journal of the European Economic Association, 10*(1), 1–42.

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Appendix C: Complete list of identified articles

Acemoglu, D. (1998). Why do new technologies complement skills? Directed technical change and wage inequality. *Quarterly Journal of Economics*, *113*(4), 1055–1089. doi:10.1162/003355398555838

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