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**PROCESS AND VARIANCE RESEARCH: INTEGRATING RESEARCH ON  
UNIVERSITY SPINOFF EVOLUTION**

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## **PROCESS AND VARIANCE RESEARCH: INTEGRATING RESEARCH ON UNIVERSITY SPINOFF EVOLUTION**

### **Abstract**

University spinoffs (USOs) are firms created to commercialize research outcomes or innovative technologies developed by university members. This paper adopts a systematic literature review approach for exploring the trajectory of the USO research field. It categorizes the literature based on two perspectives: the *process* of *how* USOs develop and *what* factors can explain the *variance* of USO development; the paper critically examines the USO literature through these two lenses. By integrating these two perspectives and examining 120 peer-reviewed journal articles published between 1987 and 2022, we develop a comprehensive model of USO development. The paper contributes to the extant literature on academic entrepreneurship by contending that while the “how” and “what” questions pose unique challenges for USO scholars, they cannot be separated because the process and variance models are complementary and important in advancing research on USOs. As such, we explore and identify specific factors that affect each of the distinct phases of the USO development at the institutional, organizational, and individual levels of analysis which form the basis for a rich future research agenda.

Keywords: University spinoffs, variance perspective, process perspective, integrated framework, research commercialization.

## 1. Introduction

University spinoffs (USOs) are defined as ventures formed by university members to transfer research outcomes, technologies, knowledge, and skills created in the university to society (Dorner et al., 2017). It is important to study USOs as they can potentially create wealth for the university, and play an essential role in socioeconomic growth at the regional level by creating a market for business opportunities that generate employment, technological development, and infrastructure growth (Pattnaik and Pandey, 2014). Government policies, notably in developed countries, place considerable importance on the commercialization of research from universities (Kenney and Patton, 2011) to build an entrepreneurial culture and excel in innovation and technology that substantially affects the economy (OECD, 2019). It is imperative to study USOs, as regardless of the university and government support they avail of, they tend to have a gradual growth rate compared to the average startup (Fini et al., 2017). It has been acknowledged in current research that the number of USOs has increased sharply in the past two decades (Prokop, 2021), yet only a small percentage of them developed into large firms (OECD, 1998; Calvo et al., 2013; Abootorabi et al., 2021; Prokon, 2021). Indeed, studies show that the majority of university spinoffs continue to remain small and are more related with lifestyle firms (Ivanycheva et al., 2023) rather than high-growth ventures (Clarysse et al., 2007; Fernández-López et al., 2020; Grimaldi et al., 2011; Harrison and Leitch, 2010; Mustar et al., 2008; Rodríguez-Gulías et al., 2016). For instance, a recent study conducted by Peter Jelfs & Helen Lawton Smith (2022) that compares the survival rates of USOs formed by universities in the UK's West Midlands region between 1983 and 2013 support the claim that the growth rate of USOs were found to be significantly lower. Multiple other studies provide evidence of USOs growing poorly (Fernández-López et al., 2020; Rodríguez-Gulías et al., 2016; Mustar et al., 2008) and often sinking into the 'living-dead' phenomenon and fail (Mathisen, 2019). Mustar et al. (2008) find that 75% of the European USOs lack growth and

survive only 6 years after birth (Mustar et al., 2008). Rodríguez-Gulías et al., (2016) and Fernández-López et al. (2020) report that 1 out of 4 USOs have poor growth and fail. Research comparing different countries in this matter is also scarce (Clarysse et al., 2011).

Yet, the growing importance of these firms requires an evaluation of the factors impacting the USOs' survival whose growth and success depends to a large extent on the regional, national and international innovation capacity and the interactions among the multiple stakeholders that can potentially support the USOs (Calvo et al., 2013). In particular, several researchers have explored the factors leading to this slow growth (Su and Sohn, 2015), which can be attributed to the intervention of distinct stakeholders with different goals (Mustar et al., 2006), legitimacy (François and Philippart, 2019a), failed attempts to obtain resources (Zahra and Nielsen, 2002), not meeting a minimum threshold of economic viability (Ucbasaran et al., 2013), lack of institutional, human, financial, and commercial resources (Rodeiro Pazos et al., 2012), obstructive university policies (Mustar and Wright, 2010; Rasmussen et al., 2015; Shane, 2004), an incompetent knowledge transfer office (Algieri et al., 2013), and the quality of academic staff and financial support (Gómez Gras et al., 2008). The relevance of these factors, however, likely varies at different stages of the USO lifecycle. Thus, understanding the reasons and factors behind this slow growth by exploring the process of USO development is crucial for academics, practitioners, and policymakers (Skute, 2019; Fini et al. 2018; Sandström et al. 2018). The growing body of literature on USOs so far has enhanced our knowledge regarding the factors that enable and inhibit USO formation (Rasmussen et al., 2015; François and Philippart, 2019a; Prokon, 2021) but has not specifically investigated how those enabling and inhibiting factors vary along the USO development process. Thus, multiple scholars in the existing USO literature have called for an investigation into the USO evolution by studying both process and variance aspects of USOs (Aaboen et al., 2016; Berbegal-

Mirabent et al., 2015; Diáñez-González and Camelo-Ordaz, 2019; Ferretti et al., 2019; Hayter, 2016b; Huynh et al., 2017; Rasmussen, 2011).

The overarching aim of this paper is to investigate and identify specific factors impacting the distinct phases of USOs compared to other spinoffs not linked to universities. Our research progresses the study on the survival of USOs and identifies factors to be employed by the university, government and the USOs to support the survival of USOs (Helm and Mouroner, 2007). This study integrates insights from process and variance perspective research on USOs to answer the following research questions: a) How does the USO process unfold? and b) What factors affect each phase of the process as it unfolds? To answer these questions, we conduct a systematic literature review (SLR) on USOs by examining 120 articles published in peer-reviewed journals during the period 1987–2022. Important insights emerge from our work which offer important future research directions that are shared in the concluding section of the literature review.

To begin with we found previous studies focusing on early stage of USOs and exploring factors impacting its inception and overlooked the later stages of development (Rasmussen et al., 2015; Mustar et al., 2008; Rodríguez-Gulías et al., 2016), which are key for the USO's growth. This has resulted in an incomplete picture of USO development and a lack of understanding about “how” and “why” USOs experience slow growth or fail. Thus, an overarching view of USOs is needed that focuses not only on the early stage, but also on later stages of growth and maturity to understand better the development of USOs. Our study specifically identifies and distinguishes the factors that impact each of the distinct phases of the USO development process. In this review we find that while varied factors matter at distinct stages of the USO development, the supportive policies and programs in the institutional environment such as government programs remain key for the USO's success in each stage of development. Also, the USO development process is characterized by the constant broadening

of multiple actors and interactions, which poses important challenges on how to manage potential frictions and conflicts over time. Second, we identified that there is an overreliance on variance studies that mainly focus on “what” factors (independent variables) affect USO outcomes (dependent variables) (Rasmussen et al., 2015; François and Philippart, 2019a; Prokon, 2021; Rodríguez-Gulías et al., 2016). While variance studies are critical, they can limit our knowledge about “how” subtle factors enable or inhibit USO outcomes during different stages. To build a comprehensive understanding of these factors during different stages of the USO development, an integration with process studies is needed to explore the sequence of events that leads to USO outcomes, which is the main contribution of this study.

## **2. Methodology**

### *2.1. Literature Search*

We employed a multi-step protocol to identify and select the most pertinent articles for our systematic literature review (SLR). In the first step, we searched the Scopus and Web of Science databases' core collections using search terms such as "University spin-off\*" OR "Academic spin-off\*" OR "University spinoff\*" OR "Academic spinoff\*" OR "University spin off\*" OR "Academic spin off\*" OR "Research commercial\*" OR "Technology commercial\*" OR "Knowledge commercial\*". Including terms like "science" in search queries for reviewing USOs broadens the search scope, but it also yielded results related to scientific research and fields unrelated to the specific focus on spinoffs which were deleted. We limited the search to English-language journal articles published between 1987 and 2022, as the first article on USOs was published by Doutriaux (1987) according to Scopus and Web of Science.

The initial search yielded 3,691 articles, which were reduced to 3,074 after deleting duplicates. In the next step, we narrowed our focus to journals (depicted in figure A2) relevant to management, business, entrepreneurship, education, and innovation, and excluded 1,478 articles from journals in other areas, such as biology, molecular science, chemistry, and cancer

research. This screening step left us with 1,596 articles. By excluding journals with an impact factor of 2 or less, in a subsequent step, we excluded 1,197 articles, leaving us with 399 articles from high-impact journals. We used this approach to consolidate and strengthen the analysis with quality research outputs, as adopted by previous scholars (Lei and Sun, 2020; Myers and Kahn, 2021; Tranfield et al., 2003).

The next step involved screening the titles, abstracts, and keywords of the remaining 399 articles and excluding 221 that did not directly relate to USOs, such as those examining the link between networks and technological changes (Funk and Owen-Smith, 2017) or the importance of proof-of-concept centers (Bradley et al., 2013). In the final screening step, we reviewed the outstanding 178 articles in greater detail, and excluded 58 that did not focus on variance or process research of USOs. We excluded papers that, for example, investigated the relationship between business models and internationalization (Guercini and Milanesi, 2019) and studies that adopted a perspective other than variance or process, such as a system view aiming at understanding the effect of USOs on the economy or comparing the proposals of USOs (De Coster and Butler, 2005). Figure A.1 depicts the literature search and selection process.

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## 2.2. Coding

To analyse the content of the final sample of 120 selected studies, we followed a systematic coding process that included the following steps: coding for general information, coding to distinguish process vs. variance studies, and coding for and integrating insights from process and variance studies. First, we coded all articles for general article information, including author name(s), publication year, journal name, and manuscript title. In this step we also



analysed the research question of each study, the theoretical framework adopted, the research methods used, the sample size employed in empirical studies, the key findings, and the country context.

In a second step, we coded whether the study adopted a variance or process perspective. In line with previous research (Clarysse et al., 2005), we defined and coded process studies as those that investigated the sequence of events that lead to USO outcomes, such as their creation or success. To do so, we identify discrete stages of the process. For example, we coded as process studies those that defined the progression of stages involved in the USO process or conceptualized process-related theories or frameworks (Clarysse and Moray, 2004; Ndonzuau et al., 2002; Vohora et al., 2004). Process research often supports qualitative descriptions and evaluations of the evolving nature of the phenomena of relevance (Van de Ven and Poole 2005, Wolfe 1994). Such explanations involve explaining change as constantly being generated through emergent actions or as a sequence of phase.

We found that while process studies identify varying numbers and types of stages, the USO development process identified in those studies can be characterized by the following common three stages: First, the early phase of the USO is conceptualized as the period from idea or technology development until a new entity/firm is formed to commercialize the idea/technology. Second, the growth phase immediately follows USO formation and focuses on expanding the USO in terms of, for example, sales. Third, the success stage occurs when the USO develops to become an established firm, which usually means it has passed critical junctures and survived at least five years. (Prokop, 2019; Jelfs & Smith, 2022) Therefore, the eighteen process studies in our sample provided the underlying three stages of early stage, growth stage, and success stage along which to analyse and categorize variance studies.

Variance studies were defined as those studies that explored the effect of several factors on various USO outcomes. Variance research generally encompasses quantitative, survey-

based methods (Burton-Jones and Straub 2006). Measures are carefully developed to ensure their validity and reliability, thereby providing an objective base upon which to make assumptions (Lee 1999). Thus, the findings of variance studies, in contrast to process studies, describe the likelihood or magnitude of a relationship between independent (i.e., factors) and dependent variables (i.e., outcomes). We coded all variance studies for three distinct aspects.

First, we clustered variance studies along the three USO development stages by identifying the USO development stage(s) and associated outcome(s) a particular study was investigating. Dependent variables of the USO early-stage studies included entrepreneurial intention and orientation, speed and occurrence of new venture creation; outcomes associated with the growth stage included growth, entrepreneurial orientation, performance, efficiency, and the outcome of the success stage included innovativeness performance and internationalization.

Second, we extracted from each study the factors that affected the respective USO outcome(s) during a particular development stage, for example, how the prior experience of the founder and/or university resources affect USO in their early stage. Except for six studies that investigated the effect of one factor on more than one stage, all other variance studies investigated outcomes associated with one particular stage of the USO development process. In our sample, we classified and reported factors on three levels of analysis: individual, organizational, and institutional. We coded factors such as prior industry or start-up experience of academics/founders as individual factors, university resources or size as organizational factors, and things such as government policy as institutional factors. We elaborate on all the factors that we found in the literature in more detail in our findings section and illustrate them in figure A.3. Third, we coded whether the effect of the factor on the outcome was positive or negative, i.e., whether the factor was enabling or inhibiting the outcome. For example, in Ferretti et al. (2019)'s study we coded the engagement of parent universities and the presence

of academics on the board as factors, USO performance as the outcome, and the effect as positive.

In a last step, we integrated insights from all studies by combining and clustering the findings of the variance studies along the three common stages of the USO development process. Interweaving insights from process and variance studies in this way allows to generate an integrative framework that illustrates our current knowledge on inhibiting or enabling factors on distinct levels of analysis and, most importantly, along the USO development process. As illustrated in figure A.3 the integrative framework not only shows what is important at each distinct stage of USO development, but also where our current knowledge is limited.

Before reporting the detailed content analysis from our review, we provide the following descriptive information about our literature organization. Research methodologies vary between process and variance studies, thus while process studies exclusively adopt qualitative methods such as case studies, variance studies mainly rely on quantitative methods such as surveys, although qualitative and mixed methods are also adopted in variance studies. Finally, while studies are distributed across eighteen journals, the majority were published in three journals: *Technovation* (studies) *Research Policy* (studies), and *Journal of Technology Transfer* (studies) as represented in figure A.2.

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### **3. Content Analysis**

From this extensive content analysis, we propose an integrated framework that combines the findings from the variance and process research methodologies as summarized in Figure A.3. The integrative framework combines the process and variance aspects of the USO

phenomenon and presents factors at the institutional, organizational, and individual levels that affect USOs at the early, growth, and success stages.

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### *3.1. Review of Process Perspective Studies*

This section reviews the 15% (18 of 120) of studies that investigated USOs from a process perspective. Some of the early studies on the USO process examined how a new venture is formed from a parent university (Carayannis et al., 1998). Carayannis et al. (1998) investigated the USO creation process and identified two factors that are essential for the process to unfold: (1) an entrepreneur who originates from the parent firm and (2) the technology which is the basis for the creation of the spinoff. Doutriaux (1987), on the other hand, explored the growth pattern of entrepreneurial firms and identified that the process is less efficient with the university as a parent.

Four studies investigated how the process unfolds and adopted stage models to examine the progression of the USO through the distinct stages of creation and growth (Boh et al., 2016; Clarysse and Moray, 2004; Ndonzuau et al., 2002; Vohora et al., 2004). The studies identified varying numbers and types of stages. For example, Ndonzuau et al. (2002) identified four critical sequential phases: (1) creating ideas from research, (2) deciding on the venture from the ideas, (3) forming the spinoff, and (4) creating economic value from the venture. Clarysse and Moray (2004) also used a four-stage model to examine how the entrepreneurial team evolves over the distinct stages. They argued that understanding how the USO process unfolds requires an understanding of how the individuals involved develop as the process occurs. The stages identified in the study are: (1) the idea phase, (2) the pre-startup phase, (3) the startup phase, and (4) the post-startup phase (Clarysse and Moray, 2004). The authors found that the

growth of the entrepreneurial team and the champion role is distinctly related to the stages of the USO, and that the success of the USO is more likely if the founding team consents to the need for a more experienced CEO during the process (Clarysse and Moray, 2004). Drawing on previous studies on stage-based models and the resource-based view literature, Vohora et al. (2004) identified five phases through which USOs develop in a non-linear way: (1) the research phase, (2) the opportunity phase, (3) the reorganization phase, (4) the reorientation phase, and (5) the high sustainable growth phase. By analysing the intervals between the five phases of the USO process, Vohora et al. (2004) identified that USOs come across "critical junctures" that must be traversed to go from one phase of development to the next. The authors found four critical junctures: (1) opportunity recognition, (2) entrepreneurial commitment, (3) venture credibility, and (4) venture sustainability.

Further on, Boh et al. (2016) identified six stages of USO development: (1) idea generation, (2) the decision to commercialize, (3) prototype generation and establishment of commercial and technical viability, (4) founding team formation, (5) strategy and determination of the commercialization process, and (6) fundraising to sustain activities. But later consolidated and identified that USOs follow four pathways of growth that differ depending on whether the USO is founded by faculty members, experienced entrepreneurs, Ph.D./post-doctoral students, or business students (Boh et al., 2016). Van Geenhuizen and Soetanto (2009) added to the theory of the stage-based model of USO development to discover that the potential to overcome obstacles to development decreases after the fourth year of inception.

Some process studies propose theoretical arguments to explain the development of USOs. For example, Rasmussen (2011) proposed using different process theories to study the spinoff process at different development stages. For example, the teleological theory is helpful in analyzing individual roles and motives in the preliminary stages of a spinoff, while the

dialectical approach can be used to examine the relationship between the USO and the parent university after launch. Lifecycle theory is useful for studying business development in the later spinoff stage, and evolutionary theory can be used to explain how macro-level events influence the USO process, whereas François and Philippart (2019a) found that obtaining legitimacy from one stakeholder does not necessarily guarantee the agreement of another, and this may lead to early USO failure. Therefore, it is important to study the unique requirements of each phase of USO development.

Prominently, Wright et al. (2012a) developed a conceptual framework of resource orchestration for USO growth, investigating the different resources needed at distinct stages to overcome critical junctures, while Rasmussen and Borch (2010) and Rasmussen et al. (2011) identified the different capabilities and competencies that are required at separate times, such as creating new paths of action, balancing academic and commercial interests, and integrating novel resources. Hesse and Sternberg (2017) matched the willingness of academic entrepreneurs to the ability of USOs to grow and found that most USOs either lack entrepreneurial growth intentions or are impeded by personal characteristics or external factors.

Overall, we can determine that dynamic capabilities are crucial for USO development, as they allow for the integration, building, and reconfiguration of competencies to address rapidly changing environments. We recognize the importance of dynamic capabilities, in agreement with Messina et al. (2022a), who argue that the micro-foundation perspective of dynamic capabilities can help analyse USO operations, sub-processes, and actions. Prokop (2021) too supports this by developing an academic theory of spinoff development that incorporates concepts of RBV, managerial theory, transactional cost theory, knowledge-based theory, and dynamic capabilities. The academic spinoff theory is a comprehensive theory which aims to understand how the academic spinoff comes into existence, how it grows, and why it is unique from other ventures, by analyzing this phenomenon through the plurality of

perspectives of these different concepts (Prokop, 2021). Some other scholars, such as Thomas et al. (2020), developed a process model depicting pre-formation entrepreneurial capabilities with which science-based USOs are endowed for success. Corner and Wu (2012) further explored dynamic capabilities by identifying the idiosyncratic nature of dynamic entrepreneurial capabilities and their potential to offer a source of firm heterogeneity and competitive advantage. To conclude, Neves and Franco (2018) studied the barriers to spinoff creation and found that different perceptions of barriers could be solved through an internal strategy within the university.

In summary, USOs evolve through distinct stages in their development, and each stage involves distinct factors for USOs to attain legitimacy, pass critical junctures, and thus succeed. However, it is unclear which factors are most important during each stage of USO development. Therefore, in the next section of the review, variance-based studies are analyzed to determine which factors affect USO outcomes during distinct stages. Based on our review, we will distinguish three USO development stages: the early stage, the growth stage and the success stage (see Table B.1).

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### *3.2. Review of Variance Perspective Studies*

In this section we present the findings from our content analysis of variance studies (102 of 120 studies). Variance studies are commonly conducted to investigate the determinants that affect USO outcomes such as establishment, growth, and performance. These determinants, also known as independent or explanatory variables, can either enable or inhibit the success of USOs. Some commonly studied determinants include funding availability, technological innovation, entrepreneurial orientation, and regulatory environments (Colombo & Piva, 2012).

Understanding the impact of these determinants on USO outcomes can help policymakers, university administrators, and entrepreneurs make more informed decisions and create more supportive environments for USOs to thrive (see Table B.2).

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***Factors impacting the early stage:*** Variance research has mainly investigated the factors that affect the early stage of spinoff creation (69 of 102 studies). *Institutional-level factors* that affect early-stage of spinoff creation have been examined in eighteen of the studies sampled. For example, national policies, university schemes, university regulations, and other government commercialization policies (Åstebro et al., 2012; Fini et al., 2020; Gilsing et al., 2010; Goldfarb and Henrekson, 2003; Kroll and Liefner, 2008; Lawton Smith, 2006; Lockett et al., 2005; Mustar and Wright, 2010; O'Shea et al., 2007; Rasmussen and Sørheim, 2012; Shane, 2004; Swamidass, 2013) can foster spinoffs by cultivating an entrepreneurial ecosystem in the economy, which positively affects academics' entrepreneurial intentions (Guerrero and Urbano, 2014). The level of government funding (Jung and Kim, 2018), public seed funding (Ayoub et al., 2017), industry R&D revenues (Swamidass, 2013) and venture capital munificence (Kroll and Liefner, 2008) are also significant predictors of technology transfer offices (TTO) performance in spinoff creation (Powers and McDougall, 2005). However, Son et al. (2019) finds that research funding from industry has a negative effect on spinoff formation and a positive effect on license agreements and licensing income, whereas Swamidass (2013) proposed a theoretical model based on the investment risk perspective whereby the policies and actions of universities can reduce the risk faced by investors. Baldini (2010) studied the context and suggests that if a university is located within a fertile regional economy this can play a vital role in nurturing productive universities.



Guerrero and Urbano (2014) used knowledge spillover theory combined with planned behaviour theory to investigate how entrepreneurial university policies become motivational factors. Furthermore, legislative changes in the institutional framework to increase the creation of USOs positively affect the number of spinoffs created, but negatively affect their quality (Fini et al., 2017). Fini et al. (2017) adopted institutional theory to study the effect of these legislative changes on creating spinoffs. Finally, government support services and programs that are available to the university assist with spinoff creation (Fini et al., 2011; Gómez Gras et al., 2008; O'Shea et al., 2005). University networks or ties with industry and their strength, size, and density are essential enablers in the early formative years (Diáñez-González and Camelo-Ordaz, 2019; Huynh et al., 2017; Pérez Pérez and Sánchez, 2003; Rasmussen et al., 2015; Soetanto and Van Geenhuizen, 2015).

At the *organizational level* (36 studies), several factors have been identified that affect the preliminary stages of USOs. The university (Ferretti et al., 2019) and its resources are the primary factors affecting USO outcomes during these initial stages. From our analysis we note that TTOs have been found to be a significant structural enabler of spinoffs. The presence and efficiency of TTOs (Fini et al., 2011; Huyghe et al., 2014; Lee and Jung, 2021; Markman et al., 2005; O’Gorman et al., 2008), as well as their size (Horta et al., 2016; Iacobucci et al., 2021), have been studied as enablers to facilitate the establishment of USOs. Berbegal-Mirabent et al. (2015) combined the resource-based view, transaction cost economics, and a normative framework to study spinoff establishment and indicated that support programs, prior experience, and financial resources are necessary factors in spinoff establishment. Other enablers of spinoff establishment include TTOs’ support programs and services (Berbegal-Mirabent et al., 2015; Fernández-Alles et al., 2015; Hayter, 2016b; Nosella and Grimaldi, 2009), number, skill, dedication, and prior experience of TTO staff (Algieri et al., 2013; Berbegal-Mirabent et al., 2015; Gómez Gras et al., 2008; Nosella and Grimaldi, 2009;

Ramaciotti and Rizzo, 2015), and financial resources available to TTOs (Algieri et al., 2013; Berbegal-Mirabent et al., 2015; O'Shea et al., 2005). As an impacting factor, it was found that the TTOs' age led to contradictory results. For example, Powers and McDougall (2005) found that TTOs' age acts as an enabler of spinoff establishment, but Algieri et al. (2013) did not support this finding.

In addition to TTOs, the university prestige, culture, and size (Houweling and Wolff, 2020) are significant enablers of creating spinoffs (Horta et al., 2016). The presence of a university research park or science center, along with their age and their proximity to the university, positively affects the establishment of spinoffs (Gómez Gras et al., 2008; Hebllich and Slavtchev, 2014; Link and Scott, 2005; Steffensen et al., 2000). In addition, university resources such as a science and engineering knowledge base (Karnani, 2013; O'Shea et al., 2007), human capital (Hayter et al., 2017), financial resources, and prestige (Rizzo, 2015) enable spinoff generation.

While universities are crucial in enabling USOs, hostile departments can hinder the spinoff development process (Rasmussen et al., 2014). This research was supported by Meoli and Vismara (2016), who argued that although considerable support from the university is required to facilitate spinoff activities, some USOs were established serendipitously despite administrative bureaucracy and insufficient administrative support. Some other scholars found some supporting and contradictory factors. It was found that enabling factors that lead to the establishment of spinoffs and affect the early stages include a set minimum limit on university faculty involvement in spinoff capital (Muscio et al, 2016), leadership and the commitment of the university towards commercialization (O'Shea et al., 2007), industry R&D revenue and venture capital munificence (Powers and McDougall, 2005), prior experience in innovation (Epure et al., 2016), and a university board with more entrepreneurs (Meoli et al., 2019). Rasmussen and Wright (2015) supported the claim that the central university management and

students indirectly create spinoffs, whereas academics play a direct role. By adopting an entrepreneurship competency framework, Rasmussen, and Wright (2015) found that academics play a direct and key role in the development of entrepreneurial competencies related to the opportunity refinement, resource acquisition, and championing that is needed to establish new ventures (see Table B.3).

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Finally, *Individual-level factors* in the variance studies (22 studies) were mostly related to the entrepreneurial intentions of the academic or researcher. Critical enablers of the academic founder's entrepreneurial intention (Prodan and Drnovsek, 2010) include personal benefits such as academic awards, enhancement of academic positions, and financial rewards (Fini et al., 2009), and individual motivating factors such as entrepreneurial self-efficacy, perceived role models, and inventor ownership (Kenney and Patton, 2011). Prodan and Drnovsek (2010) adopted social cognitive theory to study academic spinoffs across varied cultures and found that the individual academic enablers that lead to spinoff creation include the type of research in which the academic is involved (e.g., joint research) (Krabel and Mueller, 2009; Prodan and Drnovsek, 2010), the number of years spent at an educational institution, and the patents owned by the academic (Landry et al., 2006; Prodan and Drnovsek, 2010). However, cooperating with industry did not significantly affect the academic's entrepreneurial intention (Prodan and Drnovsek, 2010). Academic staff quality or excellence was found to be a significant predictor of technology transfer performance and spinoff creation (Gómez Gras et al., 2008; O'Shea et al., 2005; Powers and McDougall, 2005). Other essential enablers of spinoff creation include prior start-up experience or industry experience and knowledge assets in the technical field (Krabel and Mueller, 2009; Landry et al., 2006; Villani

et al., 2018), the academic's business and social connections (Hayter, 2016a; Hayter, 2016b), complementary skill profiles (Müller, 2010), and mobility of academic leaders (Civera et al., 2019). In this vein, Landry et al. (2006) drew on the resource-based theory to assume that researchers are like other entrepreneurs who use a number of idiosyncratic resources and capabilities for the creation of spinoffs. In comparison, Villani et al. (2018) adopted the effectuation and causation perspective to identify and understand the individual factors that lead to spinoff creation. The dynamics and heterogeneity of the founding team at the spinoff creation stage positively affect the performance of the spinoff (Vanaelst et al., 2006). The ability of the founding team to exploit capabilities such as organizational viability, commercial resources, and technology also affects the performance at the early stage of spinoffs (Huynh et al., 2017). Also, a higher proportion of inventors in the founding team positively impacts the speed of spinoff formation (Knockaert et al., 2011). The founding team size and diversity (Ben-Hafaïedh et al., 2022) also has a positive impact on spinoff creation (Visintin and Pittino, 2014). Di Paola (2021) identifies that entrepreneurial education, entrepreneurial role models, and academic support can consolidate self-efficacy in female academic researchers.

At the individual level, inhibiting factors at the early creation stage include a lack of commitment to commercializing the technology, lack of incentives and rewards, and lack of networking between science and industry (Knockaert et al., 2010). The presence of serial entrepreneurs in the team inhibits the early phase of a spinoff because they negatively affect the spinoff's survival (De Cleyn et al., 2015). When involved in their subsequent ventures, the study found that serial entrepreneurs tend to be over-confident and negatively affect entrepreneurial euphoria (De Cleyn et al., 2015) (see Table B.4).

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***Factors impacting the growth stage:*** 29 USO variance studies investigate the growth stage. Notably, five studies have dedicated their focus to examining the *institutional determinants* that influence the growth trajectory of spinoffs. Research by Degroof and Roberts (2004), and subsequently by Lockett et al. (2005), have underscored the pivotal role of spinoff policies in shaping the growth orientation of ventures. According to their findings, spinoff policies characterized by enhanced selectivity and support mechanisms engender substantial growth in spinoffs and facilitate the pursuit of high-potential opportunities. Degroof and Roberts (2004) proposed a two-dimensional categorization of spinoff policies – selectivity and support. They contended that policies that foster improved identification and selection of high-potential spinoffs can catalyze their growth trajectories.

Conversely, the study by Galati et al. (2017) highlighted the negative implications of excessive government bureaucracy and stringent regulations concerning university and governmental access to investment and human capital on the performance of burgeoning spinoffs. Hence, a conducive regulatory environment characterized by relaxed government rules and the presence of supportive institutional mechanisms that encourage research commercialization can be instrumental in facilitating spin-off growth (Kroll and Liefner, 2008). Further, the beneficial influence of venture capital partners on the growth of USOs has been investigated in the literature. These partners contribute not merely through the provision of seed funding but also by imparting critical business acumen and competencies (Rodríguez-Gulías et al., 2017). This perspective is further corroborated by Rodríguez-Gulías et al. (2021), who posited a positive correlation between the presence of Venture Capital (VC) partners and enhanced sales growth.

Fourteen studies identified the effect of *organizational-level factors* on the growth stages of spinoffs as well as university networks or ties with industry. They found that their strength, size, and density were essential enablers in the growth of spinoffs (Hirai et al., 2013;

Soetanto and Jack, 2016; Walter et al., 2006). Hirai et al. (2013) adopted social network theory to analyze these network relationships, and found that regarding USO growth, a USO's performance improves with diverse external advice and close business relationships. Löfsten (2005) also finds that growing USOs benefit from university networks through science parks. Knockaert et al. (2011) used a resource-based view combined with upper echelon theory to analyze the networks. The growth of spinoffs can be harmed by a lack of organizational intellectual property (IP) protection and management (Harrison and Leitch, 2010), and poorly targeted support mechanisms (Meyer, 2003). Growing USOs benefit from receiving a wide variety of transferred technology. Contrary to university human capital, the involvement of industry human capital acts as an inhibiting factor for USO growth. This is because entrepreneurs are more likely to leave a USO for alternative occupation options with higher salaries as a result of having a higher performance threshold (Criaco et al., 2014). Human industry capital has a significant effect on the founder's performance threshold because it increases their opportunity cost (Criaco et al., 2014). Hagedoorn et al. (2018) finds that spinoff firms operating within emerging industries can significantly enhance their innovation performance through the strategic increase of alliances.

For growing spinoffs, the equity gap poses a challenge in acquiring investments. The discrepancy between the demand (TTOs seeking early VC investment) and the supply (VCs preferring to invest later) sides of the market constitutes the equity gap. This creates a barrier for early growth of the spinoffs (Wright et al., 2006). The internationalization strategies adopted by universities have a positive impact on the global expansion of growing USOs (Civera et al., 2019b). Furthermore, Rodríguez-Gulías et al. (2017) found a positive association between firm size and USO survival, suggesting that once a minimum size threshold is achieved, the risk of USO failure becomes largely independent of size.

At the growth phase, the effect of some *individual factors* has also been studied in the variance perspective research (10 studies). The growth of spinoffs is enabled by personal and other networks established by the actors (Johannisson, 1998), the dynamics and diversity of the management team (Diáñez-González and Camelo-Ordaz, 2016), founding team heterogeneity (Vanaelst et al., 2006), and diversity of founding team composition (Moog and Soost, 2022; Tagliazucchi et al., 2021). The founding team's intention to form alliances also play an important role in spinoff growth (Grandi and Grimaldi, 2003). Spinoffs with founders who have prior experience attain early growth by bridging and growing their networks (Scholten et al., 2015). According to Sciarelli et al. (2021), the phenomenon of CEO duality for growing spinoffs substantially contributes to the enhancement of economic performance, particularly in terms of sales and employment. Diversity among team members highly enables spinoff growth to affect performance goals (Ferretti, 2020). Academic individuals on the board and their engagement positively affect spinoff growth (Ferretti, 2020). Hayter (2016a) finds that first-order or boundary-spanning individuals play a crucial role in helping growing spinoffs develop their social networks, by instilling market-oriented values and practices in academic entrepreneurs. These key individuals also introduce other contacts who provide further resources and connections that enable the spinoff's growth.

***Factors affecting the success stage:*** Research on the effects of specific factors on mature spinoffs has been marginally investigated (7 studies). Only two studies have focused on *institutional factors*. Niosi (2006) found that support programs from industry and government, and not the university, act as enablers of success as the spinoff matures. It was also identified that the availability of VC firms (Niosi, 2006) acts as a significant enabler of mature USOs. Sternberg (2014) found that the regional context considerably enables the success of spinoffs. Three studies investigated organizational factors that impact the success stage. Research finds that continuous research and development of mature spinoffs provide pathways to new

research outcomes and IP (Leitch and Harrison, 2005). The study found that second-order spinoffs are generated by mature spinoffs from their continuous research and development (Leitch and Harrison, 2005). It was found that the universities' approach on internationalization has a positive impact on the USOs' internationalization (Civera et al., 2019b). The findings of Prokop et al. (2019) reveal that the survival of growing spinoff companies hinges on three primary actors within the university network: investors, external entrepreneurs, and TTOs. Three studies have investigated the impact of individual factors on the success stage of spinoffs. It is found that academic networks will have a continued positive influence on the financial performance of commercialized spinoffs (Dai and Xu, 2021). An increased proportion of non-academics in the team positively influenced the performance goals and innovativeness of successful spinoffs (Franco-Leal et al., 2016), and they are crucial for the internationalization of the spinoff.

#### **4. USO Research implications and future research directions**

##### *4.1 Implications*

The USO process literature suggests that (1) USOs evolve through stages in their development, and that (2) each stage involves distinct factors for USOs to attain legitimacy, pass critical junctures, and thus succeed. However, it is less clear which factors matter most during each stage of the USO development. The integrative framework delineates the USO process, outlines the factors impacting the distinct stages of USO development, and incorporates the findings of the process and variance research on USOs. In particular, while previous studies on USO development have focused on either process or variance aspects (Castrillón Muñoz et al., 2019; Hossinger et al., 2019; Mathisen and Rasmussen, 2019; Miranda et al., 2018; Teixeira and Mota, 2012), our framework helps to consolidate and integrate these two elements as important streams of the USO literature, while moving existing research toward a dynamic understanding of USO development and success. As such, this



study can assist governments in understanding which resources and capabilities are required for spinoff creation and development at each of the distinct stages of development, thereby resulting in greater growth of spinoffs.

In analyzing our integrative framework and factors that impact distinct stages, several key findings have arisen. At the early stage of USO development, supportive national policies, government commercialization policies, and university schemes foster an entrepreneurial ecosystem (Colombo & Piva, 2012). Efficient and supportive TTOs facilitate spinoff establishment (Fini et al., 2011; Huyghe et al., 2014; Lee and Jung, 2021), whereas hostile departments within universities can hinder spinoff development (Rasmussen et al., 2014). Lack of commitment to commercializing technology and lack of incentives and rewards impede spinoff growth (Knockaert et al., 2010).

At the growth stage, selectively supportive institutional policies foster growth-oriented ventures (Degroof and Roberts, 2004). Strong university networks and ties with industry, along with supportive external conditions, contribute to USO growth (Hirai et al., 2013; Algieri et al., 2013). Team dynamics, prior experience, and diverse networks positively influence spinoff growth (Diáñez-González and Camelo-Ordaz, 2016; Vanaelst et al., 2006). Lack of IP protection and poor support mechanisms can hinder spinoff growth (Harrison and Leitch, 2010; Meyer, 2003). The presence of serial entrepreneurs can negatively affect spinoff survival (De Cleyn et al., 2015).

Finally at the growth stage, support programs from industry, government, and availability of venture capital positively influence mature spinoffs (Niosi, 2006). Continuous research and development, internationalization strategies, and key actors within the university network contribute to spinoff success (Leitch and Harrison, 2005; Civera et al., 2019b). Academic networks and the involvement of non-academics in the team positively impact spinoff success (Dai and Xu, 2021; Franco-Leal et al., 2016).

Thus, our integrative use of process and variance perspectives in USO studies yields the following key four insights. First, our framework shows that vast majority of the studies focus on initial stages of USO creation. While this is important, we are lacking important insights of what happens in later stages; these are critical to explain and address USO growth and success.

Second, our framework shows that there is a key factor that remains important throughout the entire USO development – i.e., the supportive policies and programs in the institutional environment such as government programs. This is an important insight as it highlights the embeddedness of the USO in its environment and its dependence on support networks. Important implications can be derived, for instance in relation to the entrepreneurial ecosystems – systems of interdependent actors and relations directly or indirectly supporting the creation and growth of a new venture (Spigel, 2017).

Third, we detail how distinct factors matter at distinct stages of the USO development. In particular, initially, the organizational environment of the university including TTOs and the host department were found to be most critical for USO development. This stands in stark contrast to the broader entrepreneurship literature, which tends to focus on the importance of the individual entrepreneur in the venture (see e.g., Bau et al., 2017). From the growth stage onward, the USO benefits from an increasingly strong and diverse university network and team that includes non-academic actors. In the success stage, factors established from the broader entrepreneurship literature such as the availability of venture capital and implementation of successful strategies (C et al., 2012) also contribute to the development of the USO. Overall, while founding teams are important to USO development, the individual founder(s) seem much less central to the success of USOs, and the literature highlights the importance of institutional-level policies and programs.

Fourth, our framework depicts the USO development process as beginning with the interplay between various actors such as the government and the university and is then

characterized by a constant broadening of actors such as industry actors into founding teams and/or as university partners. This poses interesting theoretical and empirical questions about how to navigate potential dynamics, frictions and conflicts along the way.

#### *4.2 Future Research Directions*

The key insights detailed above lead to key areas that future studies can focus upon as highlighted below:

*Long-Term Success Factors:* There is a need for in-depth research on the long-term success factors of USOs beyond the initial stages. This includes understanding the factors that contribute to sustained growth, profitability, and competitive advantage of USOs over an extended period. Longitudinal studies and comparative analyses across different periods can shed light on the evolution of USOs over time (Clarysse et al., 2011) and provide valuable insights into the dynamics of success/failure and the factors that potentially contribute to long-term viability (Carayannis et al., 1998; Doutriaux, 1987). Our integrative framework provides a comprehensive list of factors impacting the USO development. Future studies should focus on the evolving effects of these factors on the progression of the USO process at the distinct stages, leading to either failure or success, thereby contributing to a more nuanced understanding of the USO phenomenon. Given that USO research tends to suffer from methodological limitations (Wright et al., 2006), such studies should adopt rely more on methodologies, such as longitudinal mixed methods approaches and experimental designs.

*Entrepreneurial Ecosystem Dynamics:* Given the key roles of government programs for the development of USOs, comprehensive studies on the dynamics of entrepreneurial ecosystems and their influence on USOs are warranted. Research should examine the interactions and interdependencies among various stakeholders, such as universities, government agencies, industry partners, investors, and support organizations within the ecosystem. Understanding how these ecosystem factors influence USO creation, growth, and

success can inform the development of supportive policies and ecosystem interventions (François and Philippart, 2019a; Hesse and Sternberg, 2017). Contextual studies on the diverse needs of USOs in regional and urban areas have been identified in our study as lacking.

*Market Factors, Policy and Institutional Support:* The impact of market dynamics, competitive landscapes, customer needs, and demand conditions on the establishment, growth, and success of USOs requires further investigation. Research should explore how USOs navigate market challenges, adapt to changing market conditions, and create competitive advantages in different industry contexts. Additionally, the role of marketing strategies, market positioning, and customer acquisition in USO success merits further exploration (Rasmussen and Borch, 2010; Wright et al., 2012a). In particular, research should also focus on evaluating the effectiveness of policy interventions and institutional support mechanisms and programs for USOs. This includes assessing the impact of government policies, university initiatives, funding programs, and support services on USO creation, growth, and success. It is also worth underlining that existing literature on USOs is often limited in its levels of analysis (Vohora et al., 2004). Future studies should consider the interdependencies between distinct levels of analysis (Wright et al., 2007), including individual, organizational, market and institutional factors, and explore how these various levels interact to influence USO outcomes. Importantly, research should aim to provide a more balanced view of the USO phenomenon, examining not only the predominantly studied enabling factors (Siegel et al., 2003) but also the potential pitfalls and obstacles that may hinder USO development (Mustar et al., 2008).

*Internationalization Strategies:* The internationalization of USOs and its impact on their growth and success is also an area that requires further investigation. Research should explore the strategies, challenges, and outcomes of USOs expanding into global markets. Understanding how USOs navigate internationalization processes, establish international

networks, and adapt to foreign market conditions can offer valuable insights for supporting their international growth ambitions (Rasmussen and Borch, 2010; Rasmussen et al., 2011).

*Comparative Analysis:* Conducting comparative studies across different geographical locations, cultural contexts, and institutional environments can also enhance our understanding of how the antecedents, enabling and inhibiting factors interact in different settings. Comparative analysis can uncover contextual factors that influence USO outcomes, allowing for more nuanced and tailored support mechanisms (Boh et al., 2016; Clarysse and Moray, 2004; Vohora et al., 2004).

*Intellectual Property Management:* More research is also needed to understand the challenges and strategies related to IP management in USOs. This includes investigating the impact of IP protection, commercialization strategies, licensing approaches, and the role of technology transfer offices in managing and leveraging IP assets. Understanding how USOs effectively protect and exploit their IP can enhance their competitive advantage and facilitate successful commercialization (Messina et al., 2022a; Prokop, 2021).

*Other Future Research Directions:* First, USOs are companies originating from academic institutions, utilizing the knowledge and technology developed within these institutions for commercial purposes (Pirnay, Surlemont, & Nlemvo, 2003). While there is consensus on this general concept, the specific definitions of USOs often vary, leading to inconsistencies in the literature and a potential lack of comparability between studies (Mustar, Wright, & Clarysse, 2008). This ambiguity is likely to impede the accumulation of knowledge and limit the generalizability of findings. Future studies should strive for a clearer, more standardized conceptualization of USOs.

Second, USO studies have been mainly informed by the resource-based view and the institutional theory (Rasmussen, Mosey, & Wright, 2011). While these perspectives have provided valuable insights, they do not fully capture the complexity of USO development

(Vohora, Wright, & Lockett, 2004). Future studies may benefit from incorporating multiple theoretical perspectives, such as social network theory and actor-network theory, to account for the interplay between individuals, institutions, and resources in USO evolution (Etzkowitz, 2003). Third, most of the current literature on USOs focuses on the antecedents of spinoff creation, such as university policies, availability of resources, and characteristics of the founding team (Rasmussen & Borch, 2010). However, less attention has been paid to the outcomes of USOs, such as their growth, profitability, and societal impact (Fini, Fu, Mathisen, Rasmussen, & Wright, 2017). Given that the ultimate goal of USOs is not merely to exist but to create value, future research should focus more on understanding the factors that contribute to successful outcomes. For example, future studies could examine the role of strategic decision-making, organizational learning, and the adaptation of business models in USO performance (Vohora, Wright, & Lockett, 2004).

## **5. Conclusion**

The field of USOs is evolving, and there are many aspects of the USO that have not been explored in-depth. This paper has highlighted some important aspects of USOs while presenting a number of opportunities for future research. The literature review focuses on the process of how USOs develop and what factors explain the variance of USO development. By examining 120 peer-reviewed journal articles published between 1987 and 2022 and integrating both the process and variance perspectives, we develop a comprehensive model of USO development. The paper contributes to the extant literature on academic entrepreneurship by contending that while the “how” and “what” questions pose unique challenges for USO scholars, they cannot be separated because the process and variance models are complementary and important in advancing research on USOs. As such, we explore and identify specific factors that affect each of the distinct phases of USO development at the institutional, organizational, and individual levels of analysis, forming the

basis for a rich future research agenda. In doing so, we have set the stage for an important yet neglected area of research that will continue to inform academia and practice alike. Given the intricacy of the attributes of USOs, there is still a great deal of more academic research needed on USOs. We hope this study encourages future researchers to continue evaluating the varied facets of USOs.

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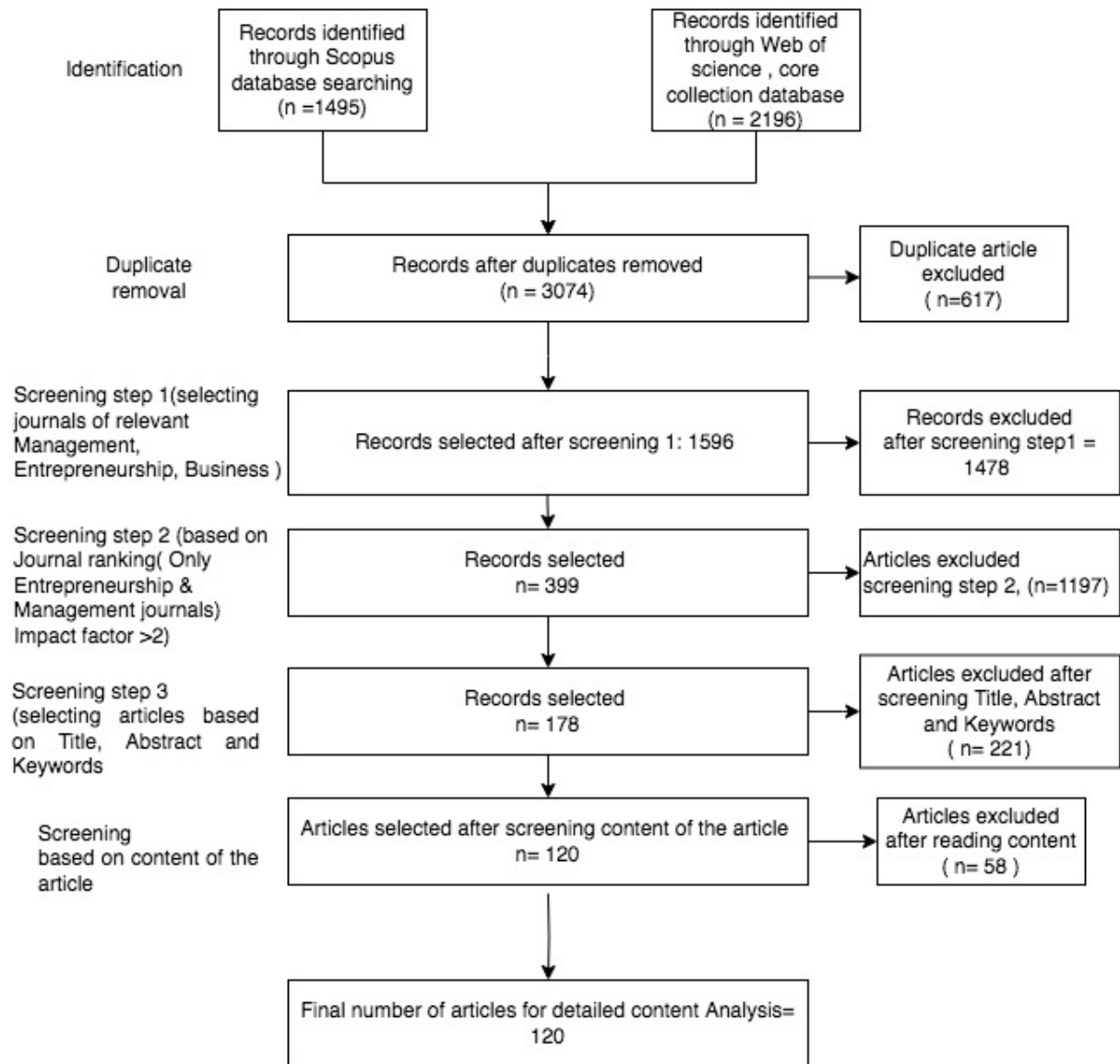
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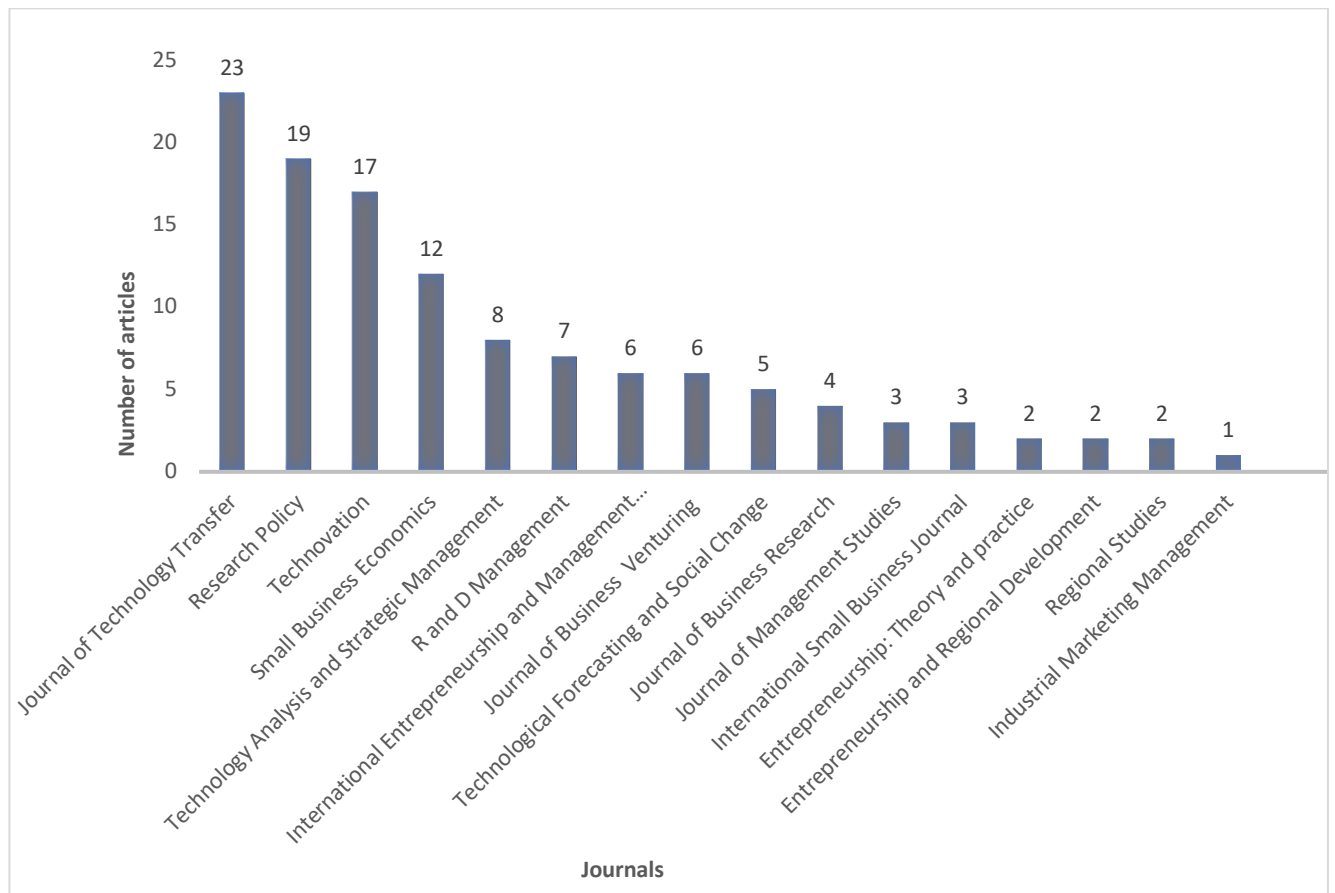


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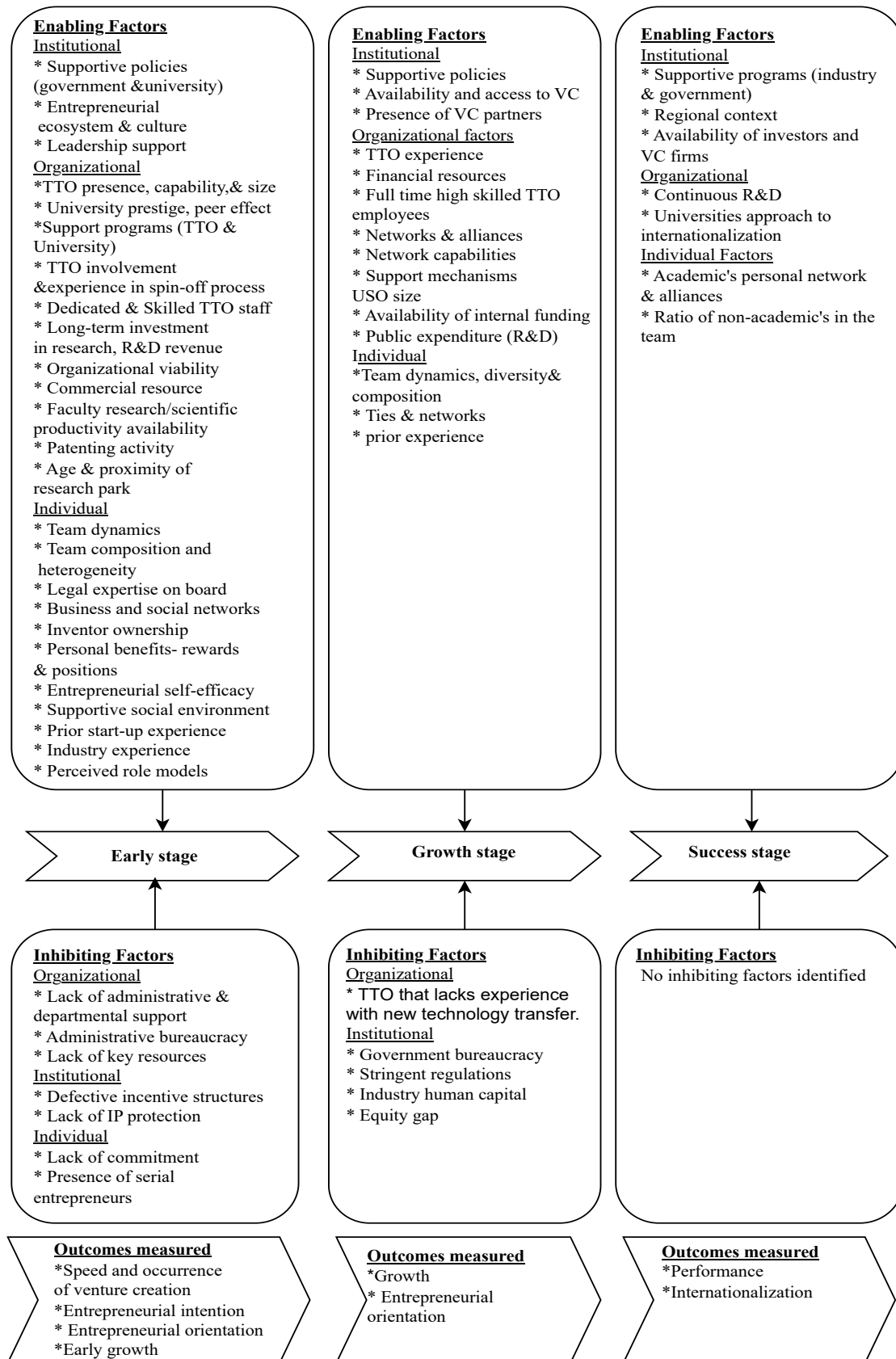
**Figure A.1: Flowchart of Systematic Literature Review**



**Figure A.2: Number of USO Research Articles Per Journal**



**Figure A.3: Integrative framework of USO development**



**Table B.1: USO Process Studies Used for Content Analyses (N=18)**

Studies using stage models (n=5)	Studies not using stage models (n=13)
<p><b>Boh et al. (2016); Clarysse and Moray (2004);</b>  <b>Ndonzuau et al. (2002); Vohora et al. (2004);</b>  <b>Messina et al. (2022)</b></p>	<p>Carayannis et al. (1998); Doutriaux (1987); François and Philippart (2019); Rasmussen (2011); Rasmussen and Borch (2010); Rasmussen et al. (2011); Van Geenhuizen and Soetanto (2009); Wright et al. (2012); Hesse and Sternberg (2017); Neves and Franco (2018); Corner and Wu, (2012); Thomas et al. (2020); Prokop, (2021)</p>

**Table B.2: Institutional Level USO Variance Studies Used for Content Analyses (N=26)**

Early stage (n=19)	Growth stage (n=5)	Success stage (n=2)
<p><b>Åstebro et al. (2012); Fini et al. (2017);</b>  <b>Gilsing et al. (2010); Goldfarb and Henrekson (2003); Guerrero and Urbano (2014); Lawton Smith (2006); Mustar and Wright (2010); O'Shea et al. (2007)*; Rasmussen and Sørheim (2012); Shane (2004); Swamidass (2013); Baldini (2010); Ayoub et al. (2017); Son et al. (2019); Lockett et al. (2005); Jung and Kim (2018); Powers (2005)*; Kroll and Liefner (2008)**; Fini et al. (2020).</b></p>	<p>Rodríguez-Gulías et al., (2017)*;            Degroof and Roberts, (2004); Galati et al., (2017); Rodríguez-Gulías et al., (2018); Kroll and Liefner, (2008)**</p>	<p>Niosi (2006); Sternberg (2014)</p>

**Table B.3: Organizational Level USO Variance Studies Used for Content Analyses (N=53)**

Early stage (n=36)	Growth stage (n=15)	Success stage (n=3)
<p><b>Iacobucci et al. (2021)</b>; Algieri et al. (2013)**; Houweling and Wolff (2020); Ferretti et al., (2019)*; Berbegal-Mirabent et al. (2015); Lee and Jung, (2021); Diáñez-González and Camelo-Ordaz (2019); Epure et al. (2016); Fernández-Alles et al. (2015); Fini et al. (2011); Gómez Gras et al. (2008)*; Hayter (2016a); Hayter et al (2017); Hebllich and Slavtchev (2014); Horta et al. (2016); Huyghe et al. (2014); Huynh et al. (2017)*; Karnani (2013); Link and Scott (2005); Markman et al. (2005); Meoli et al. (2019); Meoli and Vismara (2016); Muscio et al. (2016); Nosella and Grimaldi (2009); O’Gorman et al. (2008); O’Shea et al. (2005)*; O’Shea et al. (2007)*; Pérez Pérez and Sánchez (2003); Powers and McDougall (2005)*; Ramaciotti and Rizzo (2015); Rasmussen and Wright (2015); Rasmussen et al. (2014);</p>	<p>Clarysse et al., (2011); Criaco et al., (2014); Walter et al., (2006), Löfsten, (2005); Wright et al., (2006); Hagedoorn et al., (2018); Harrison and Leitch, (2010); Meyer, (2003); Civera et al., (2019)**; Taheri and van Geenhuizen, (2019); Soetanto and Jack, (2016); Hirai et al., (2013); Rodríguez-Gulías et al., (2017)*; Algieri et al., (2013)**; Rodeiro-Pazos et al., (2021)</p>	<p>Leitch and Harrison (2005); Civera et al., (2019)**; Prokop et al., (2019)*</p>

Rasmussen et al. (2015); Rizzo (2015); Steffensen et al. (2000); Soetanto and Van Geenhuizen (2015)		
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**Table B.4: Individual Level USO Variance Studies Used for Content Analyses (N=34)**

Early stage (n=21)	Growth stage (n=10)	Success stage (n=3)
<b>Civera et al. (2019); De Cleyn et al. (2015); Fini et al. (2009); Huynh et al. (2017)**; Kenney and Patton (2011); Krael and Mueller (2009); Knockaert et al. (2010); Landry et al. (2006); Müller (2010); O’Shea et al. (2005)*; Prodan and Drnovsek (2010); Powers and McDougall (2005)*; Vanaelst et al. (2006); Villani et al. (2018); Gómez Gras et al. (2008); Hayter (2016b)*; Knockaert et al. (2011); Visintin and Pittino (2014); Di Paola (2021); Ben-Hafaïedh et al. (2022); Hayter (2016a)**</b>	Scholten et al., (2015); Johannissson (1998); Tagliazucchi et al., (2021); Sciarelli et al., (2021); Grandi and Grimaldi (2003); Moog and Soost, (2022); Vanaelst et al., (2006)**; Diáñez-González and Camelo-Ordaz, (2016)**; Hayter, (2016a)**; Ferretti, (2020)	Prokop et al., (2019)*; Dai and Xu, (2021), Franco-Leal et al., (2016)