



## Article

# A System Dynamics Framework for Academic Entrepreneurship

Jing Xia <sup>1</sup>, Wei Liu <sup>1,\*</sup>, Sang-Bing Tsai <sup>2,3,\*</sup> , Guodong Li <sup>4,\*</sup>, Chien-Chi Chu <sup>5</sup>  and Kai Wang <sup>3</sup><sup>1</sup> School of Economics and Business Administration, Chongqing University, Chongqing 400044, China; snowxj916@sina.com<sup>2</sup> Zhongshan Institute, University of Electronic Science and Technology of China, Guangdong 528400, China<sup>3</sup> College of Business Administration, Capital University of Economics and Business, Beijing 100070, China; wangkai@cueb.edu.cn<sup>4</sup> Economics and Management College, Civil Aviation University of China, Tianjin 300300, China<sup>5</sup> Business and Law School, Foshan University, Guangdong 528000, China; jqzhu@stu.edu.cn

\* Correspondence: liuweili@cqu.edu.cn (W.L.); sangbing@hotmail.com (S.-B.T.); gdli@cauc.edu.cn (G.L.)

Received: 29 May 2018; Accepted: 7 July 2018; Published: 12 July 2018



**Abstract:** Academic entrepreneurship (AE) models have enhanced the ability of scholars to delineate elements and relationships that are consistent with entrepreneurial activities. However, previous research has not focused on the dynamic feedback loops within AE. Prior models have seldom included feedback obtained from interrupted or implemented activities integrated with individual, organizational, and strategic variables. This paper proposes a model of AE from the perspective of system dynamics that seeks to explore key features of this complex process within the boundaries of a spinoff company. To achieve this goal, we developed a framework that includes four main phases: recognition, commitment, credibility, and sustainability. The model examines and analyzes the key role of innovative academic entrepreneurship during each stage. Feedback loops provide the link between strategic assessment and entrepreneurial renewal according to which AE integrates entrepreneurial and strategic efforts. Combining various perspectives from the previous literature, the proposed model can be activated from any point during the process. By introducing a system dynamics context for the model, this research expands upon the thinking of prior AE research. In practical application, our proposed framework provides insights into the feedback loops and other complexities of the AE process that academic entrepreneurs can apply to support the transfer of innovations in science and technology from academia to commercial settings.

**Keywords:** academic entrepreneurship; system dynamics; opportunity; entrepreneurship

## 1. Introduction

Since the 1980s, the combination of emerging scientific fields and changes to funding policies has expanded the traditional relationship between academia and industry to include the transfer of technology from universities to commercial settings [1–3]. Through their research, Jain et al. (2009) [4] found that organized entrepreneurial activities have become an important catalyst for the transfer of university technology from laboratories to commercial markets, giving rise to the emergence of academic entrepreneurship. According to Jain et al., academic entrepreneurship has caused academic institutions to become increasingly important in the transfer of academic research results from the laboratory to the marketplace. As an umbrella term, academic entrepreneurship (AE) refers to the efforts of universities and their industry partners to commercialize the results of faculty research [5]. In the academic entrepreneurship process, universities play the role of catalyst, with entrepreneurial activity or profit-making agents at the heart [3,6,7]. The TTO office of universities guides and monitors the necessary steps of the AE process [8,9]. Academic entrepreneurship is not a single

event, but rather a dynamic process consisting of a series of events [10]. The success of academic entrepreneurship is related significantly to the completion of milestone events [11]. At each stage of the process, academic entrepreneurs have the ability to obtain and reorganize resources, network, and complete tasks to ensure the sustainable development of their companies, thereby achieving successful commercialization. However, the current process models of AE (e.g., Feldman 2002; Wai Fong Boh 2015) [12,13] are unable to explain completely the critical dynamic complexity within AE because they lack a comprehensive theoretical framework.

Dynamic complexity arises “from interaction amid the agents for a long time” [14]. The features of systems are dynamic, tightly coupled, feedback-oriented, nonlinear, self-organizing, adaptive, history-dependent, policy resistant, counterintuitive, and characterized by trade-offs. Given that AE exhibits a large number of the abovementioned characteristics, this study aimed to provide a system dynamics perspective of AE that can be used to capture the essence of this dynamic complexity, especially within university and new enterprise boundaries. We constructed a system dynamics framework that offers a theoretical explanation of the inherent critical dynamic complexities of AE. Our proposed framework provides insights that can be applied by academic entrepreneurs to improve the effective transfer of technological innovations from academic research to the commercial market.

According to Vohora et al. (2004) [11], AE is successful because it is iterative and nonlinear. During the AE process, spinoffs obtain and reconfigure requisite resources, capabilities, and network ties essential for passing a series of milestones that are regarded as critical junctures. Spinoff development requires forward progress through each critical juncture, and the ultimate goal of the spinoff is to achieve enterprise sustainability. In this paper, we considered that the AE process involves four phases: recognition, commitment, credibility, and sustainability. Advancement from the recognition of an opportunity to the commitment phase is marked by the establishment of a spinoff. The primary criteria for advancement from the commitment phase to credibility are the presence of professional management and early stage capital, while advancement from the credibility phase to sustainability depends on profitability [15]. Scholars have argued that interactions among these four activities are nonlinear and include recurring simultaneous cycles. This dynamic complexity constitutes the backbone of the AE process. Considering that the theory of AE keeps evolving and maturing, we suggest that the establishment of a comprehensive framework is not the end solution. Instead, in this research, we developed a dynamic framework, based on the integration of prior theoretical arguments and knowledge, aimed at offering improved understanding of the AE commercialization process.

Our research offers the following contributions to the AE literature. First, we propose a comprehensive framework that integrates the four main phases of the AE process. Second, in addition to the basic factors included in prior models, our framework considers other factors involved in AE that add to its dynamics and complexity. Our proposed model enhances the understanding of the occurrence of AE and the dynamic complexity of relationships that are an inherent part of its activities, with the purpose of obtaining a way to strengthen academic entrepreneurship. Third, the proposed system dynamics perspective makes the dynamic complexity in the system more appreciable. Finally, this paper provides a basis for conducting future research into the interactions among the four key variables.

The remainder of the paper is divided into the following parts. Section 2 includes an overview of the existing AE literature. Section 3 provides a discussion of system dynamics, and Section 4 gives an analysis of how system dynamics is integrated with AE. The four phases of AE and the related feedback mechanisms that inform and reinitiate these activities are discussed as well. Section 5 offers a description of the role of entrepreneurial renewal and strategic assessment as critical components of the AE process. Section 6 provides a discussion and conclusion, including a summary of the contributions of this work and suggestions for future research.

## 2. Literature Review

Academic entrepreneurs play multiple roles as academic researchers, company founders, and managers. Their decisions must be based on the interaction between the academic environment

and commercial or industrial environments, which makes academic entrepreneurship more complicated than other forms of entrepreneurship. Until recently, there has been little research regarding academic entrepreneurship concentrated on the interactions at each milestone of the AE process. Prior literature has been focused on academic entrepreneurship concepts, process models, and influencing factors. Louis (1989), Shane (2004), and other scholars each define academic entrepreneurship differently [16]. O'Shea (2004) believes that academic entrepreneurship is a broad concept, referring to a series of entrepreneurial activities undertaken by universities and industry partners to achieve technology commercialization [5].

Considering the ever-increasing growth and significance of academic entrepreneurship, many entrepreneurship scholars, such as Agrawal (2006) [17], Shane (2004) [3], and Wood (2009) [18], have examined the importance of developing success-oriented commercialization models using university technology. Shane (2004) [3] assumes that academic entrepreneurship refers to new spinoff companies founded by university faculty. Following the idea that AE is not an individual event, but a continuous process covering a series of events [10], it is necessary to develop a multi-stage process model to identify key actors, activities, and success drivers at every stage of the innovative commercialization process. Factors driving academic entrepreneurial activity include resource support for innovative ideas, and high-level academic entrepreneur discretion regarding task performance [19]. Both factors are likely to lead to superior innovative performance without the academic entrepreneur understanding the critical junctures needed for driving the recognition process to achieve sustainability [20,21] or the learning results [22,23].

The existing literature includes a substantial number of studies of the factors influencing academic entrepreneurship that are beneficial for commercialization. These investigations have provided in-depth interviews [24–26], analyses of metrics available for the public [27–30], and statistical analyses based on survey data [31–35]. However, this prior work covers only a small portion of the entrepreneurial activities involved in establishing a new firm [36–40], such as disclosing a new invention to the technical transfer office (TTO) [30,41], patenting research outputs [27,35,42,43], and licensing research outputs [44,45].

As described above, Vohora et al. (2004) believe that academic entrepreneurship is a nonlinear iterative process that passes through several key nodes, including the identification of an opportunity, establishing entrepreneurship, acquiring resources, and sustaining development [11]. Wai Fong Boh (2015) established a process model for the early stages of academic entrepreneurship that included the following steps: generating the idea, making the decision to commercialize, generating and establishing a prototype, forming a team, determining the commercialization strategy, and executing fundraising activities [13]. He also examined early stage academic research led by academic entrepreneurs, along with the concrete behaviors involved in early stage entrepreneurial activities. Friedman (2002) proposes that the later stages of academic technology transfer include making the decision to commercialize, participating in commercialization, and making a profit [12].

In general, the literature regarding academic entrepreneurship tends to be scattered, and much of the research studies only certain parts of the commercialization process (e.g., Owen-Smith and Powell, 2001; Markman et al., 2005; Bercovitz and Feldman, 2008) [41,45,46]. Since few studies have investigated academic entrepreneurship holistically, it is difficult for potential participants in AE to gain a deep understanding of the domain and its operations. Insufficient integration of potential stakeholders, key activities, and key success factors make the process of academic entrepreneurship rather opaque. To have a better grasp of the dynamic ongoing evolution of university spinoffs (USOs), academic entrepreneurs must understand the activities and relationships that promote these evolutionary processes [47]. Despite efforts aimed at improving the understanding of these interlinking activities, AE is never completely systematic. In many aspects, the AE model involves significant change, and, therefore, it is regarded as disruptive. To a great extent, this change is a result of the nonlinearity and complexity of the processes that lead to non-proportional outcomes in terms of inputs [48].

### 3. Theoretical Framework: The System Dynamics Perspective and Academic Entrepreneurship

As a disciplined methodology, system dynamics studies the complexity of socioeconomic systems. Put forward by Jay Forrester in the late 1950s, the methodology offered an alternative to traditional linear and static perspectives well favored by the social sciences at that time [49]. The origins of system dynamics stem from computer science, control theory, cybernetics, and management science, using modeling approaches and mathematical tools that provided researchers with a special methodology in various domains.

Because of their nature, organizational phenomena are studied readily from the system dynamics perspective. This approach considers that there is an interaction between actors within organizational boundaries that provides feedback leading to many nonlinear effects over time. These characteristics result in dynamic complexities [14] that are both counterintuitive as well as difficult to analyze using traditional methodologies common to the social sciences [50]. The system dynamics approach has been adopted by various specialties in organizational studies to examine complex problems. For example, Gary (2005) [51] used a system dynamics perspective to study the dynamism of managerial decision-making in connection with market strategies, along with the performance implications. Winch (1998) [47] applied system dynamics for modeling human resource skills and skills management dynamism. Coyle et al. (1999) [52] managed and controlled the resources and assets in defense procurement programs by applying system dynamics.

The entrepreneurial phenomena involved in AE are worth studying from the perspective of system dynamics. The AE process covers all aspects of the organization, has features that are subject to continuous change, and has long-term results that are not easily associated with a certain action set. All these attributes contribute to AE's complexity. Despite the benefits these conceptualizations bring to understanding the operation of AE in an organization, researchers have not mastered the intricacies of multiple and simultaneous engagement that reflect the realities of an organization in the pursuit of opportunities. At various phases of the AE process, various mutual influences occur between the creation and pursuit of opportunities [53]. A system dynamics perspective can be used to cover various AE variables and conditions to shed light on their inherent dynamic complexity, thereby providing a broader view of the AE process.

Researchers have examined dynamism from various organizational viewpoints. For example, Heavey et al. (2009) [54] linked decision-making at the organizational level with dynamism in an external environment. Tushman and Nadler (1978) [55] discussed the fit between an organization's need for information processing and its information processing structure. They found that the information processing ability of an organization generally will be good enough to respond to the uncertainty resulting from dynamism under both internal and external environments [56,57]. Later, Daft and Lengel (1986) [58] found that when more information is processed, uncertainty may not always be reduced because high degrees of equivocality can obstruct managerial sense-making [59]. The internal environment can be fragmented into the source of loose coupling [60] as well as added dynamic complexity.

In addition, time is also an important influencing factor, even though less attention has been paid to this topic by management researchers [61]. A system dynamics model of AE recognizes that organizations are required to develop multiple tasks at the same time during various phases of activity. The need to capture related learning comprehensively makes time a necessary dimension. From a long-term point of view, as held in this research, additional phenomena can be identified and included [62] through comparison with other AE models. Notably, after checking the dynamic complexity included by the system dynamics model, we observed that the time dimension issue, which was put forward by researchers in terms of monochronicity and polychronicity, plays a crucial role. According to these researchers, polychronicity can serve for managing dynamism to a large extent, which is definitely preferred when engaged in multiple tasks in a simultaneous or intermittent manner [63]. For example, for top management teams, polychronicity can cover both the faster speed and the weaker comprehensiveness of strategic decisions. Therefore, financial performance in

a dynamic environment can be enhanced [64]. Because the dimension of time brings about benefits for innovation and competitive advantage, it shall be included in the proposed AE model.

Generally, system dynamics refers to a method that uses the feedback relationships between different parts of a system for the purpose of learning the related dynamic and complex behaviors within the system [65]. As the center of the system dynamics approach, feedback refers to a “major organizational learning mechanism” under normal conditions [66]. By relying on feedback from past experiences, learning can occur that impacts organizational decisions and assists in building organizational rules and processes [67,68]. This process has ever-increasing importance in dynamic situations because “if the situation becomes more and more variable and unpredictable, the feedback will be more and more dependent on coordination” [68].

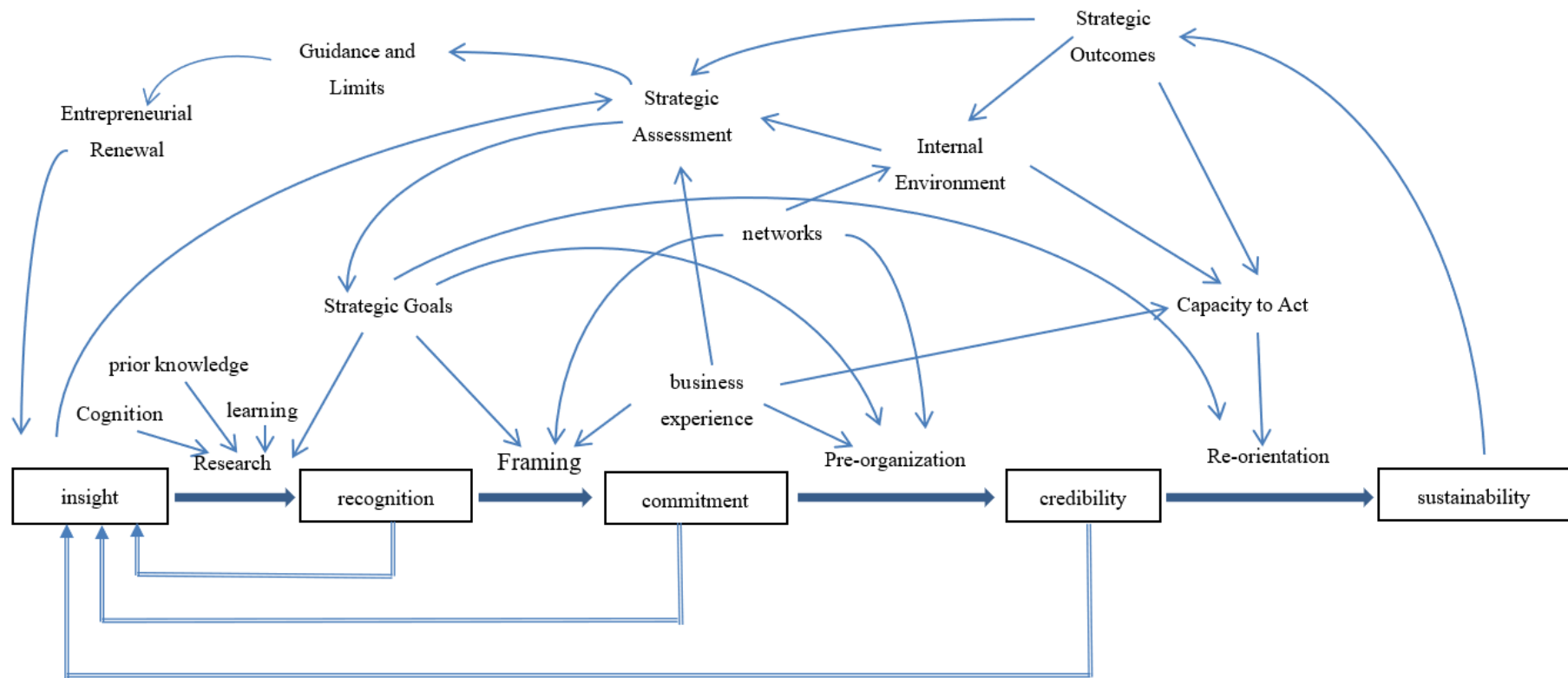
Previous research on stage-gate processes and double-loop learning sees organizational learning along related lines. As for stage-gate processes, the focus lies in the way an organization identifies opportunities and innovates by virtue of periodic progress evaluations [69,70]. Based on stage-gate models, opportunities failing to pass across a gate will be interrupted or delivered back to the previous stage [71]. Our proposed AE model learns from a large portion of the overall development stages and gates, and then supplements its knowledge with other processes related to strategic assessment and entrepreneurial renewal. In this way, the model can present modifications to the way an organization achieves future entrepreneurial endeavors. Double-loop learning is another relevant concept. This approach stresses a more active learning process that is necessary for hindering the defensive routines within an organization that may restrict learning [72]. It can strengthen organizational learning by generating helpful information and receptivity to corrective feedback. Considering the importance of feedback, the stage-gate processes and double-loop learning serve as helpful parallels to the AE model we set forth.

#### 4. Analysis of Academic Entrepreneurship from a System Dynamics Perspective

According to Vohora et al. (2004) [11], successful ventures pass through a series of milestones, also known as critical junctures, with the final goal of achieving enterprise sustainability. For AE, the establishment of a spinoff is used to measure progress from the opportunity recognition phase to the commitment phase. However, the primary criteria for measuring progress from the commitment to the credibility phase are the presence of professional management and early stage capital. Finally, advancement from the credibility to the sustainability phase is determined by profitability.

When applying our proposed model to studying AE, we paid attention to the stock and flow diagrams, considering their importance for the study of dynamic systems. A stock is an entity (broadly defined) that can be accumulated or depleted with time. A flow influences the change rate of a stock. A change in the level of a variable that is directly or indirectly caused by the previous level's change leads to the occurrence of a feedback loop. Feedback loops may have the function of enhancing or balancing [73]. With respect to the system dynamics framework for AE, the stock is composed of opportunities and the flow is made up of the four main activities: recognition, commitment, credibility, and sustainability. These stocks and flows can be observed following the major central path in the middle part of Figure 1. In the AE setting, the flow (composed of the four main activities) can exert effects on the stock (composed of opportunities). The feedback loops appear primarily on the bottom of Figure 1, but some feedback loops can be observed in the upper area as well, as a result of the strategic assessment. With the occurrence of each flow activity, some opportunities may be regarded as inadequate, illegitimate, or non-implementable, and thus will not move to the implementation phase and the actual outcomes. Yet, these feedback loops can bring valuable information, and can update the organization's entrepreneurial insight in a direct manner that informs the strategic assessment. At the top of Figure 1, organizational variables affect primary flow activities and succedent steps of AE to update the organizational strategy (i.e., strategic assessment), with entrepreneurial renewal as a final result. These stocks, flows, feedback loops, and organizational variables are discussed more specifically below.





**Figure 1.** Academic entrepreneurship from a system dynamics perspective. Boxes represent stock variables; double line arrows demonstrate flow activities. The remaining variables are auxiliary variables that inform or influence the process of academic entrepreneurship.

#### 4.1. Flow #1: Research Phase

Faculty members and their research teams engage in a wide range of investigations in the physical and social sciences that are critical to advancing our understanding of the world around us. Many of the discoveries and innovations produced by these researchers develop into the technologies that academic entrepreneurs seek to commercialize. Commercialization efforts typically take place through a university's Technology Transfer Office (TTO). The mission of the TTO is to ensure that the university's innovations realize their commercial potential properly. The TTO office guides and monitors the necessary steps of the AE process, from securing proper intellectual property protection to facilitating the transfer of the university's intellectual property to outside partners [8,9]. As such, the TTO can be thought of as the coordinating hub of commercialization activities, and it often plays one of the most central roles in the academic entrepreneurship process [45].

In this paper, the proposed AE system dynamics framework starts with an organization's entrepreneurial insight (as shown in Figure 1), converting the achievements of individuals into collective learning at an organizational level [74]. Since entrepreneurial insight is anchored at an organizational level, it promotes the transformation of ideas into innovative practices, leading to internal practices or new products [74]. Based on our proposed model, entrepreneurial insight stands for the organizational perspective that is updated continuously by the feedback loops from various aspects of research, opportunity, framing, pre-organization, and re-orientation. This updated insight gives birth to new or revised academic research. Thus, in the system dynamics framework of AE, research acts as the first flow activity.

It is worth noting that USOs that emerge from scientific research conducted over years in university academic departments are studied in the initial stage. Valuable intellectual property is created in the research phase, which accordingly leads to the potential opportunity for commercialization. Academic inventors tend to be at the top levels in their fields and are equipped with valuable technological assets and know-how. Technology-oriented USOs are usually set up by the more successful scientists and inventors who are confronted with problems about gaining strong protection for intellectual property for the spinoff [3]. The research offers the intellectual property that is the underpinning of the venture establishment.

As defined by Mitchell et al., entrepreneurial cognitions are, "the knowledge structures used by people for making judgments, evaluations, or decisions in connection with the opportunity evaluation, the venture creation, as well as the growth" [75,76]. According to this definition, the structure of prior knowledge, as well as the learning opportunities obtained from previous experience, begin at the individual level. Limited reasonable decision rules [68] as well as routines [77] that guide cognitions and behaviors, such as research, are created by previous experience. For example, past successes or failures assist in creating a dominant logic that provides guidance for entrepreneurs [78]. These experiences and structures are beneficial for guiding research activities that can lead to greater innovation by relying on their diversity and intensity [79].

Identification of opportunities for the organization depends on the degree to which the organization can attract people who are able to recognize them. In other words, opportunity identification depends on the pro-entrepreneurship cognitions of individuals [75,80,81]. Pro-entrepreneurship cognitions act as the major facilitator of entrepreneurial academic research. As Baron and Ensley (2006) [82] indicated, "it seems that people who are aware of specific opportunities will act like this due to the related cognitive frameworks that enable them to recognize the emergent patterns within a number of new business opportunities" [82]. Pattern recognition is used by these individuals to obtain the links between apparently independent events, to observe meaningful patterns, and to identify new opportunities [82]. The cognitive frameworks of experienced entrepreneurs are different from those of inexperienced entrepreneurs [82,83], which affects the recognition and implementation of opportunities in a meaningful way.

In addition to cognition, previous knowledge is an important factor in entrepreneurial research [84,85]. According to Shane (2000) [86], "the knowledge of an individual of the current market,

the way to serve that market, as well as the customers' problems will affect opportunities discovered by the individual" [87,88]. Prior knowledge affects entrepreneurial alertness and opportunity discovery [84], and opportunity identification results from the combined effect of new information and current existing knowledge [87]. As an ongoing process, research covers insight contemplation, collection and consideration of new information, and knowledge creation over time. In this way, an idea is transformed into an opportunity that will add value to the entrepreneurial enterprise [89,90].

Learning is another critical part of the research flow. Both individual and organizational learning serve as pivotal facilitators of opportunity development [83]. Previous experiences lead to trial-and-error decision-making that enables opportunity capture [91]. Lumpkin and Lichtenstein (2005) [89] demonstrated that by relying on behavioral, cognitive, and action learning, organizational learning can strengthen the research process [83]. Entrepreneurs' performance can be enhanced by transforming entrepreneurial insights into strategic advantage [89]. According to Corbett (2007) [87], there are learning asymmetries that can explain why some individuals can recognize and discover opportunities while others cannot. Likewise, Dutta and Crossan (2005) [92] found that "the organizational learning processes including intuiting, interpretation, integration, and institutionalization are essential for the discovery, development and implementation of entrepreneurial opportunities" [83].

At the research phase, the principal stakeholders are the TTO and the research faculty (if engaged). These two stakeholders often have very different goals, motivations, and reward structures. Many researchers are not strongly interested in the commercial applications of their innovations. They prefer to return to their research, and work on the next discovery and its corresponding publication. Conflicts in terms of roles and incentives can exist between the TTO and research faculty, often leaving little incentive to develop and test further the commercial viability of prior research projects. This dichotomy of purpose suggests that as the academic entrepreneurship model continues to evolve, there should be greater focus on how researchers can be incentivized and rewarded for developing their innovations beyond the requirements for journal publications. The odds of success could be increased by achieving a greater synergy between principal research faculty and the TTO. However, the academic entrepreneurship literature indicates that until more universities adjust their incentive structures and cultures to facilitate these synergies and increase the odds of a successful outcome, TTOs should determine the degree to which an innovation has been developed and reflects a pioneering technology. Based on these evaluations, continued researcher involvement would be recommended only if the disclosed innovation is not well developed or is pioneering in nature. If the researcher cannot be engaged as a key stakeholder, the TTO should be very cautious about deciding to invest in intellectual property protection, even if the technology appears to have strong commercial applications.

In light of the above, we offer the following proposition:

**Proposition 1.** *Cognition, prior knowledge, learning, and incentive structures between AEs and TTOs influence the flow of the research phase, converting entrepreneurial insight into opportunity recognition.*

In the flow of the research phase, entrepreneurial insight is converted into opportunity recognition. The next stage involves framing the opportunity. As long as actors in the organization identify ideas and recognize opportunities, they can create new USOs that pay primary attention to the academic sources.

Entrepreneurial insights that fail to lead to an opportunity can be considered insufficient in an informal or formal way. These instances may result in discontinuation of a potential opportunity and/or knowledge flow-back for other entrepreneurial insight activities. The organization may draw upon experiences associated with the failed insights, as well as the characteristics of the research process, whether the process needs revising or not. The former can be considered as involving single-loop learning, while the latter can be considered as double-loop learning.



#### 4.2. Flow #2: Opportunity Framing Phase

The second flow activity in the system dynamics framework is opportunity framing (as shown in Figure 1). This activity refers to the transition from a recognized opportunity to the formation of a new USO venture that pays primary attention to the academic researcher and the TTO. The academic researcher and the TTO check whether the recognized opportunity can provide sufficient assurance that further efforts to pursue commercialization might be successful. This “screening” process evaluates the technology, and demonstrates whether the innovation is efficient and enjoys sufficient promise for application beyond the laboratory.

Eckhardt and Shane (2003) [80] define opportunity as “the situation under which new raw materials, products, services, markets, and organizing methods will be brought in relying on forming new means, ends, or means-ends relationships” [80]. If the opportunity is used to evaluate technological validity and performance, there will be some attempt to frame it as a commercial opportunity. Considering that there are different degrees of success, the academic entrepreneur and TTO attempt to identify the alternative markets, possible applications of the technology to the alternative markets, and the best ways to access the customers who constitute the target market for the innovation.

For the initial stage, it was discussed that framing the opportunity is challenging for academic inventors, and sometimes results in opportunities regarded as imprecise, ambiguously targeted, or impracticable. The two main causes seemed to be lack of experience in framing scientific discoveries to create commercial value, and inability to understand the way to optimize returns obtained from commercial exploitation. Entrepreneurs and universities that look forward to creating a new USO venture for technology commercialization suffer insurmountable barriers if they are unable to clarify the most appropriate applications to develop from the technology, if they cannot achieve commercial performance for these applications in alternative markets, and if they cannot identify available routes for accessing these markets. The inability to access relevant experience or to frame opportunities successfully leads to lack of progress, which in turn causes failure in creating value and earning returns.

The efforts of entrepreneurs who lack experience and skills tend to result in poorly developed opportunities. Opportunities recognized in the initial stage are not necessarily the best way to exploit the maximum commercial value of the technological resource, as entrepreneurs may fail to determine precisely which complementary resources (e.g., human, physical, financial, or technological resources) would be needed further down the line. They also might not identify where and how the resources will be acquired. Some entrepreneurs do explore alternative commercial scenarios in a thorough way to seek various potential applications of their technologies. These entrepreneurs check these opportunities, carefully coupled with determination of potential customers, investors, and other needed details, for the purpose of finding the potential risks caused by any inherent weaknesses, deficiencies, and inadequacies. These entrepreneurs may take many months and even years to frame and re-frame an opportunity.

An academic researcher may find that even for a reframed opportunity, industry may not want to license or co-develop the early stage technology, preferring instead to develop later-stage technologies that are more likely to generate commercial returns. In such cases, the best route to market lies in assembling requisite resources and developing required capabilities to explore the intellectual property (IP) via a USO venture, rather than going through licensing or co-development.

Bird (1988) [93] claims that in the initial stage, the ideas and intentions of an entrepreneur constitute a new organizational strategic template, and can greatly enhance the development of a new venture. Before venture formation, intention critically affects the starting conditions [94]. In practice, intentions cannot be replaced by relying on sustained persistence and committed actions to add value to a rising business venture [95]. To transform from the opportunity phase to the pre-organization phase, it is necessary to deal with the critical juncture of entrepreneurial commitment. A potential venture should put forward the entrepreneurial commitment to transition from envisioning (mental creation) to the formation of an operating venture that is engaged in business transactions.

Entrepreneurial intention, by definition, refers to a state of consciousness. Entrepreneurial commitment refers to actions that bind the venture champion to a specific stage of events. There are three key reasons why the critical juncture of entrepreneurial commitment may result from the conflict between the demand of a committed venture champion for developing the university spinout company and the failure to attract an individual with essential entrepreneurial abilities [11].

The first reason is that academic inventors tend to be reluctant to engage in promoting their ideas or energetically exploring the potential for commercialization of their scientific discoveries. They may hold a strong feeling that this behavior would be contrary to the conventions accepted by their academic peers regarding enhanced incentives, or that such actions might go against the policies of their institutions. The primary contacts of the majority of academics are other academics involved in research, indicating that generally their social capital is limited to networks within the field of higher education. It would be a stretch for these researchers to reach out to contacts in business and finance.

Second, academic inventors tend to be negatively affected by a lack of confidence in their own abilities to deal with the unfamiliar commercial environment. Academic entrepreneurs may be unable to frame an opportunity because the decision-making process is too complex. Decision uncertainty can lead to feeling dispirited about pursuing the venture process whole heartedly, damping their progress in exploring ways to commercialize their scientific discoveries. The directors of academic departments, TTO managers, and some academics themselves have shown that academics have a common feature: they are reluctant to accept and get along with ambiguous situations. Obviously, the push of some academics to be great scientists or engineers does not provide them with the requisite entrepreneurial human capital for starting and developing a business.

Finally, the academic inventors and TTOs face a big challenge in identifying and assessing individuals suitable for their own networks, again in large part because of limited social capital. Another contributing issue is the need to provide the surrogate with adequate rewards and incentives, considering financial and resources shortages. If these issues cannot be resolved, it is difficult to find a proper venture champion who has the requisite entrepreneurial capabilities and who can commit reliably to developing the USO venture into an established business. As a result, these USOs suffer inherent deficiencies, weaknesses, and inadequacies that limit entrepreneurial activity and the amount of value to be created in the subsequent developmental phases. Failure to establish sufficient credibility is a key contributor to later-stage failure.

This phase of academic entrepreneurship requires an agreement between the stakeholders to investigate the feasibility of commercialization at a deeper level. At this point in the process, the key stakeholders would be the university, represented by the TTO, the research faculty, if engaged, and the industry partners, in the form of single or multiple entrepreneurs or business leaders from existing firms. It is important to note that the TTO may engage multiple partners or enter into exclusive agreements when commercializing, and the research shows advantages to both approaches depending on the nature of the innovation. Whether there are multiple partners or an exclusive arrangement, the collective group of key stakeholders must now decide the best way to move forward.

**Proposition 2.** *Entrepreneurial idea sufficiency, business experience, networks, and agreements between multiple partners influence the flow of opportunity framing that converts opportunity recognition into entrepreneurial commitment.*

The flow of opportunity framing converts opportunity recognition to entrepreneurial commitment. The next stage comes in the pre-organization phase. After the opportunity has been framed and committed to commercial development, the management of the USO venture carries out the strategic plans in the pre-organization phase.

#### 4.3. Flow #3: Pre-Organization Phase

In the system dynamics framework, the third set of flow activities is connected to pre-organization (see Figure 1). These actions include making decisions about existing resources, developing capabilities, acquiring resources and knowledge (currently and in the future), and determining the time and circumstances under which to obtain these resources and knowledge. Generally, decisions made at this early stage impact the entire future success of a USO in unforeseeable ways, because they direct the development path and alternatives available to the firm at future stages. A restricted resource endowment would have a negative effect on the future success of the venture.

Academic entrepreneurs face the sharpest learning curve during the pre-organization phase. Often, these entrepreneurs possess little or no commercial experience and lack knowledge of the operations of their target industries, so they have almost no existing relationships with businessmen, business capital angels, surrogate entrepreneurs, or venture capitalists. Lack of experience may lead to lost revenue and a paucity of venture capital investments. If new entrepreneurs have available expertise to draw upon, they can learn about the importance of decisions made in this early stage, and about the amount of money and time needed to bring a product to market. Working under experienced guidance is an effective way to gain entrepreneurial experience, human capital, and improved access to business networks. If the entrepreneur lacks expert support, the same lessons can be learned, but the knowledge made be gained at a premium.

Some entrepreneurs are more adept than others at handling the difficulties of securing access, acquisition, and coordination of resources. In fact, entrepreneurial teams in these USO ventures spend much time and effort developing existing resources and capabilities, and acquiring new resources and knowledge in order to assemble new capabilities. These entrepreneurs put forward their best efforts to secure the commitment of key individuals who can provide initial capital and knowledge to ensure the business operation of the ventures.

Achieving this commitment greatly depends on the level of social capital the entrepreneur can leverage to select, assess, and benchmark new management team members through their networks of contacts, investors, or professional head-hunters. Relying on the venture experience and social capital of the TTO, the entrepreneur can obtain and secure resources and expertise. In comparison, in the pre-organization phase, some entrepreneurs may try to set up their own USOs using inadequate relevant resources. Therefore, the ability of the entrepreneur to realize strategic objectives in the subsequent phases of the venture will be affected negatively by insufficient entrepreneurial experience and restricted access to advisors, mentors, and other business venture experts who can provide guidance for the embryonic USO. This is a clear mistake, so we conclude that decisions made during the pre-organization phase that follow such a path will lead to resource weaknesses, insufficient capabilities, and social liabilities in the later development phases.

At this stage in the development of a USO, the academic or surrogate entrepreneurs first observe an opportunity, and then devote themselves to making the opportunity into a USO. The critical juncture refers to an entrepreneur's ability to obtain an initial stock of resources needed to support the business. In this pre-organization phase, it is necessary to raise sufficient financial resources (seed finance) to obtain other necessary resources. Financing is the key resource. Lack of financing will prevent the entrepreneur from implementing the transformation from the venture as a "pre-organization" to a business that achieves full operation and is able to focus on productive activities. The financial problem leads to a subsequent problem, because academic and surrogate entrepreneurs observe that only by identifying the required resources, can they acquire sufficient financial resources. According to one academic entrepreneur [96], this effort was likened to making ready the building blocks of the venture, but then finding that the requisite resources could not be obtained because there was no initial financial investment or resources co-optation [96] based on current relationships and external networks [97]. This critical juncture is termed the credibility threshold. Lacking credibility restricts the ability of the entrepreneur to obtain the key resources needed to form the entrepreneurial team, such as seed financing and human capital.

In the opportunity framing and pre-organization phases, if the problems of resource weaknesses, inadequate social capital, and insufficient entrepreneurial capabilities are not resolved, they can lead to inertia at this critical juncture. The academic has failed in receiving the feedback from the investors and his TTO, and thus is unable to transform current resources, capabilities, and social capital to deal with this critical juncture. Therefore, the entrepreneur would be unable to draw a manager with good talents with whom he would like to work, or prove that any existing customers would buy the USO's technology applications.

In forming know-how and IP, there is another difficulty frequently encountered by entrepreneurs while developing fundable investment propositions: there may be very little research for the academic entrepreneur to compare with his/her own published research. In such cases, establishing credibility can be difficult. Investors will decide to invest financial resource with a team that is able to prove that it can make and deliver value, and is actively engaged in achieving what it says. The critical issue of credibility involves acquiring key customers for USOs.

If customers are familiar with a new venture and view it as established, the risks will be decreased and its legitimacy, momentum, and trust in an organizational level will be enhanced [98,99]. Without initial credibility, the new high-tech ventures cannot overcome customers' skeptical perceptions, nor can they obtain access to markets or successfully transition from being a concept to status as a legitimate business engaging in market transactions.

At this critical juncture, both the development of resource stocks and capabilities, and the level of social capital, contribute to the ability to access proper information, knowledge, and resources. In turn, these basic resources ensure other important resource endowments or profitable contracts with new clients. The abovementioned entrepreneurial capabilities either come from the entrepreneurial teams, or are accessed through their internal networks and customer contacts provided by their TTOs.

However, these entrepreneurial capabilities may not be available or developed because of timing. At the beginning, the USOs cannot access or obtain external equity financing, key customers, or achieve cooperation with existing firms because of their inherent resource weaknesses, insufficient capabilities, and inadequate social capital. These USO ventures may make many attempts to access, obtain, and assemble the necessary building blocks, aiming at achieving sufficient credibility with customers, financial agents, and other resource providers. Each attempt to make the transition is accompanied by new insights into their approach leading to changes in the current resource configuration, assembling capabilities, and understanding of which relationships are currently, or liable to be, valuable.

The path dependence of a USO born from a university environment is likely to bring about certain challenges that work against the new high-tech venture. For example, external financiers and customers are likely to be curious about the extent to which the non-commercial culture of the originating university will influence the USO. Therefore, for USOs, specific links to their universities may be regarded as liabilities. Additionally, academic entrepreneurs (and the staffs of many newly formed TTOs) may suffer from inadequate social capital outside the academic environment.

There are several informal mechanisms that can be used to facilitate commercialization. More specifically, consulting arrangements, joint publications with industry scientists, and collaborative relationships between university researchers and industry researchers have all been shown to help facilitate the formation of formal innovation transfer agreements. The general reasoning is that ongoing, informal, collaborative relationships often lead to commercialization ideas that later take the form of formal license agreements or spinoff ventures, and these entrepreneurial endeavors are less likely to develop without informal collaboration. As such, research faculty, TTOs, and potential industry partners need to heed the benefits of developing collaborative relationships that are likely to lead to formal agreements over time, and eventually to successful academic entrepreneurship.

**Proposition 3.** *Resources, social capital, entrepreneurial capabilities, and formal agreements affect the flow of the pre-organization progress that transforms entrepreneurial commitment into credibility.*

The flow of the pre-organization process converts entrepreneurial commitment to credibility. If a USO has obtained enough credibility to acquire requisite resources for starting the business, it can provide its customers with value and begin generating returns.

#### 4.4. Flow #4: Re-Orientation Phase

During the re-orientation phase, these attempts bring some challenges to the entrepreneurial teams because they must constantly identify, acquire, and integrate resources, and reconfigure them accordingly [100–102]. Reconfiguration is very common for new ventures that consist of inexperienced management teams and have poor capital endowments. Reconfiguration allows teams to identify the proper methods to develop information and knowledge, and handle newly acquired resources and assembled capabilities. Therefore, it is necessary for the USOs to bring together these capabilities and organizational routines to gain returns from productive activities.

During and after the development phase, many changes arise from knowledge and information gained by the entrepreneurial teams from interacting with customers, suppliers, competitors, and potential investors. These dramatic changes are able to alter the three key decisions made in the earlier development phases: first, the way the entrepreneurial team creates value relying on the development of current technological resources and capabilities; second, identification of the sources from whom these USOs can gain returns; and third, the way these USOs can obtain sustainable returns from the market.

It is increasingly obvious that weaknesses, inadequacies, and deficiencies that emerge during the earlier development phases for individual academic and surrogate entrepreneurs and their TTOs result in issues, and even crises, in the following development phases. If impetuous strategic decisions and commitments were made in earlier development phases, these USOs will be unable to create and exploit desirable values later. First, the entrepreneurs and TTOs may not have been proficient in applying their scientific discoveries to creating the greatest value from technological assets within the phase of framing opportunity. At that point, some may have paid too much attention to the development of the technology and too little to identifying, accessing, and targeting key customers. Second, if these entrepreneurs were not good at obtaining the proper information, knowledge, and resources in the pre-organization phase, that circumstance would suggest a need for continuous iterations of resource configuration and strategic refocusing. These firms would need to undertake key adaptations to the way technology is used to satisfy the previously unrecognized needs of customers, the methods for obtaining access to markets, and the means for securing further resources. Entrepreneurial teams would need to apply the knowledge obtained from recognized mistakes along with corrections from previously flawed decisions to reassemble and build resource stocks, internal capabilities, and technical improvements.

According to this method of continuous repackaging, USOs are regarded as experiments to measure market size and to determine whether specific competing technologies have great promise [103]. All USOs entering in this phase are confronted with some degree of turbulence during the development process, as each must learn the proper way to manage the development of various aspects of the business in parallel. Compared to USOs facing stagnant development during this phase, these USOs try to make their initial stage business plans meet the constraints from internal resources and changes in the external environmental in an easier way. For the USOs suffering difficulty or strategic uncertainty, the lack of requisite resources, capabilities, and social capital that ensure better performance is related to issues rooted in the phases of opportunity framing and pre-organization. Hence, the successful progression of USOs from this development phase into the next phase is attributed largely to preparatory work conducted by the entrepreneur and the TTO during earlier phases. The path-dependent effects on USOs that originally had insufficient resource endowments, social liabilities, and lack of entrepreneurial guidance lead to inadequate business assistance and stifled development during this phase.



Based on our study, if the venture receives seed financing and begins to exploit its technological assets commercially, it will face the final critical juncture of sustainable returns. Sources of sustainable returns include revenues from products or services provided to customers, milestone payments from cooperative agreements, and investments from current or new investors. Sustainability means that the entrepreneurial team can create value by developing the right resources, social capital, and capabilities. At the critical credibility juncture, entrepreneurs are forced to access, obtain, and assemble resources necessary for starting business activities. In comparison, at the juncture of sustainable returns, entrepreneurs can reconfigure current resources, social capital, and capabilities continuously in view of new knowledge, information, and resources. In this way, they can continue to create value based on current capabilities, technological resources, and the newly recognized opportunities.

Capabilities and social capital refer to the ability to conduct a big transformation with the purpose of gaining returns in a sustainable way. In the last development stage, certain parts of the acquired resources, developed capabilities, and formed relationships no longer help these USOs to gain sustainable returns. Some even present resource weaknesses, insufficient capabilities, and social liabilities that hinder the progress of these USOs outside this critical juncture.

At this critical juncture, it is extremely important to assist the entrepreneurial teams in obtaining the ability to reconfigure the current resource weaknesses, social liabilities, and insufficient capabilities. Reconfiguration can turn these negative features into resources strengths, social capital, and distinct capabilities that will ensure returns for the USO. It has been observed by Vohora [11] that compared with developing capabilities, USOs are more likely to acquire physical, human, and technological resources, and improve social capital. In some large organizations that rely on explicit policies, routines and procedures [77], decision-making can be simplified, and the uncertainty and complexity faced by managers can be lessened [104]. Established firms that continue developing possess the internal capability to assist managers in reconfiguring these resources into new productive combinations under changeable market conditions [100–102].

To ensure a coordinated allocation of scarce stocks and control over the consumption rate to gain proper returns, the entrepreneur (and team) must change organizational structures and design proper policies and routines. These routines and internal capabilities should also be adapted constantly. In addition, it is necessary to develop informal structures aimed at promoting communication within the organization. It is very common in individual cases that this dynamic is used to reconfigure resources of the venture constantly to move past this critical juncture. It is important to develop entrepreneurial capabilities to deal with the inadequacies, deficiencies, and weaknesses faced by the USO, and develop organizational capabilities to coordinate productive activities within the USO.

USOs will be confronted with some severe difficulties in the first stage of raising financing unless they prove that they can create value by transforming the USO into an established business able to make sustainable returns. They would be able to get first-round financing by showing their sustainable business model to investors, expending market resources and “learning by doing”, i.e., re-orienting the business model to meet recognized market demands. The USOs that have more successful experience with respect to the transition of existing resources, capabilities, and social capital clearly know how to access the market to achieve profitability. As for acquiring key customers, they can generate crucial sustainable revenues with the purpose of legitimizing their venture. Taking milestone payments from co-development deals can be a significant indicator by which existing and new investors can judge whether the USO can move forward sustainably. Therefore, ventures are likely to be enhanced by the endowments of other financial resources that are beneficial for improving the value of the venture.

As for USOs that are unable to anticipate and solve the issues of inadequate social capital, it has been proven that the sustainability juncture is extremely problematic in the face of resource weaknesses and insufficient internal capabilities [11]. The academic entrepreneur is confronted with the difficulties that arise from inadequate social capital, insufficient internal capabilities, and resource weaknesses at this critical point.

We suggest that USOs may enter stagnation if it is anticipated that the financial resources (and other resources) will be used up before the achievement of sustainable returns [105]. It is difficult to solve these problems because decisions and commitments in the early phases of development, including resource weaknesses, social liabilities, and insufficient capabilities, ultimately may dampen the entrepreneur's desire for the venture's success, leading to obstacles blocking the progress of the USO past this critical juncture.

By this juncture, there will be many ongoing activities, including acquisition of key resources, such as capital; research and development; market research and other marketing activities; and development of key networks and distribution channels. In this stage, the focus has shifted to the industry partners. Most of the activity is happening within the organization that purchased the licensing rights, or within the new venture created to commercialize the innovation. As these actions take place, the number of stakeholders begins to increase at an exponential rate. Bankers, investors, suppliers, employees, customers, and the broader local community each begin to have their own vested interests in the success of the commercialization effort. We would argue that because so many stakeholders become directly or indirectly involved in this stage of commercialization, the activities and decisions that are made in the early stages of the academic entrepreneurship process are absolutely crucial, because they provide a foundation that can have a great influence on the odds of commercialization success.

**Proposition 4.** *The capacity to reconfigure financing, entrepreneurial capabilities, and early activities and decisions affects the flow of re-orientation that transforms credibility into sustainability.*

The flow of re-orientation converts the credibility phase to the sustainability phase. On the verge of this development phase, the USO will have resolved many of the uncertainties arising from the early stages by virtue of a precise business model. The company will have achieved its goals and emerged from the re-orientation phase as an aggressive business with high focus, finally becoming a sustainable firm. However, despite the USO's separation from the research laboratory, having built its own self-sufficiency and commercial identity, the company may still have close links to the university. This status has been demonstrated by at least one academic inventor who still works on scientific research at the university while holding the post of a technical advisor to the USO [3].

The other part of the system dynamics framework involves entrepreneurial renewal and strategic assessment. Relationships among different organizational elements that affect and are affected by the development of university spinout companies will be discussed. Although these relationships are discussed separately, all are integral parts of the system dynamics perspective.

## 5. Renewal of Academic Entrepreneurship

An organization's entrepreneurial renewal and strategic assessment are the indirect products of the implementation of opportunities. In these relationships, there are several variables: the strategic outcomes, internal environment, strategic assessment, and the guidance and limits (as shown in Figure 1). By definition, the strategic assessment, also called the strategic renewal, refers to the modification and reevaluation of the strategy in an organization [106], which draws great attention from the literature on entrepreneurship and strategic planning. Entrepreneurial renewal envisions opportunities together with potential solutions [107]. Entrepreneurial renewal and strategic assessment are the crucial components of AE, for which the direct and indirect influencing factors are explained in the remainder of this section.

### 5.1. Strategic Outcomes

The outcomes from engagement or a shortage of engagement (implementation or non-implementation of opportunities) act as the major inputs that have direct effect on the strategic assessment process. Outcomes obtained from engagement can be divided into successful and unsuccessful product introduction, the manufacturing process, quality improvement, and marketing

innovation. Examination of outcomes allows organizations to determine whether the efficacy of their previous actions was positive or negative [108]. Here positive outcomes refer to certain actions that are useful and worth repeating, while negative outcomes refer to actions defined as adverse and to be prevented.

In addition, strategic outcomes affect the internal environment of an organization. Although the internal environment can be structured in a formal or deliberate manner, its features evolve over time from informal and self-acting (to a certain extent) adaptive responses to what is obtained from the activities and associated outcomes of the organization [77]. Once an organization draws experience from the effort to implement opportunities, its capabilities can be strengthened by integrating what it learns into organizational memory [109].

The direct effect of the assessment of strategic outcomes on strategic assessment comes from the potential impact of these outcomes on future strategy. During strategic assessment, organizations learn from successful or failed actions to find ways to improve their strategies [110]. In this way, progress and causality can be evaluated. For instance, if an effort has been made to introduce a new product, that effort is likely to slow down market development. Then it is necessary to examine the possible reasons for the slowed development, followed by implementation of needed modifications.

There are many reasons for changes among an organization's members with respect to the strategic evaluation of organizational outcomes. Some researchers in this field have regarded poor performance as the motivation for strategy modification [70,111,112]. According to other researchers, organizations focus on strategic changes within a period that sees rapid growth [113], or under the condition that there is no internal or external environmental change [114]. Hence, although higher current performance can enhance commitment to the status quo, strategy reevaluation can occur under any set of conditions [115].

## 5.2. Internal Environment

The internal environment is another factor that influences strategic assessment in addition to the outcomes and strategic reevaluation. In terms of strategy assessment, the internal environment can be divided into the organizational structure, continuity pressure, and distinctive competencies. Additionally, the interaction between a strategy and certain elements of structure can have a strong impact on the strategic assessment process [116]. The mutual influence between strategy and structure has been explained by Chandler (1962) [113]. For instance, the influence of the current structure on political activity within the organization leads to power arrangements. On that account, powerful individuals and alliances serve as additional factors influencing strategy [59]. The political maneuvering of members of powerful alliances can influence strategic changes toward their own interests, which makes it more difficult to achieve consensus for strategic change [117,118].

With respect to continuity pressure, easier and lower-cost changes can happen with the greatest frequency, as can the changes that maintain the most similarity to the current strategy [119]. Besides, stakeholders of an organization see huge changes from a negative perspective [120]. Organizations usually put emphasis on carrying out near-term changes and pay less attention to creating and starting on the implementation of changes of a different type [121]. Because of the nature of the pressures caused by smaller and slower changes, strategy renewal becomes less fierce than it might be for larger performance modifications.

Similarly, specific competencies can also subdue the revolutionary process of strategic change. The competencies of organizations help them to do things in a certain way. The accumulation of these competencies can help an organization be more capable of gaining and maintaining its competitive advantage [122]. Therefore, the organization will not give up these original competencies easily in favor of building untested new competencies [117]. Furthermore, given that strategic assessment features are incremental and localized, strategic changes are largely dependent on the short-term and minor outcomes that have an inhibiting effect on significant changes [77]. On that account, it is

necessary to make a clearer and cooperative organizational effort for strategic assessment, which will weaken the evolutionary features in an obviously revolutionary manner.

Entrepreneurial insight gains awareness and vision from entrepreneurial renewal and from the process of pursuing insufficient, illegitimate, or non-implementable opportunities. Therefore, insight can affect the strategy assessment. Since there are some new modifications to, and ideas about, opportunities, the strategy of an organization can be modified and informed, aiming at capturing those plans that can create the maximum benefit for the organization [123].

**Proposition 5.** *Strategic outcomes, entrepreneurial insight, and the internal environment influence the organization's strategic assessment.*

### 5.3. Entrepreneurial Renewal

Entrepreneurial renewal refers to an enhanced mechanism. Under this mechanism, the system dynamics framework is likely to be repeated for future opportunities. Entrepreneurial renewal has three principle inputs: individual knowledge, guidance and limits, and previous outcomes. Entrepreneurial renewal efforts in an organization start with the entrepreneurial cognitions of individuals. These efforts can be impacted by additional factors and the decisions of the organization. Guidance and limits are able to exert influence on the knowledge structures of individuals used for making judgments and decisions regarding specific opportunities. For example, to prevent subduing breakthrough innovations, organizations should conduct explicit experiments with respect to new technologies [124]. Despite the heavy dependence of organizations on exploring more gradual innovations [125], it is necessary for members of senior leadership to learn the full significance of determining the right direction and providing requisite guidance for larger organizations. Furthermore, because of the limitation of the extension of resources within the organization, these leadership figures are likely to have a great impact on the entrepreneurial cognitions of employees.

One main purpose of strategy is to guide organization members well [126]. By default, a strategy can also restrict members of the organization. It is necessary for strategies, even effective strategies, to be revised over time to ensure the optimal performance of the organization [108]. The guidance and limits derived from the strategic assessment are one part of this modification process. They provide organizations with strategic direction, which affects entrepreneurial renewal. Considering that an organization will blend its new entrepreneurial thinking into a particular strategy, that strategy's ability to offer guidance and direction may change at different times. To acquire needed innovative behaviors, it is necessary to balance well the guidance provided by the organization with the autonomy of the organization's members [127].

Besides guidance and limits, another influencing factor of entrepreneurial cognition derives from the previous organizational outcomes. For instance, individuals will learn how to make the organization more effective as they reflect on the organization's previous actions and outcomes [128,129]. During the entrepreneurial renewal process, knowledge is also important [130]. Individuals with rich knowledge are capable of capturing critical issues more fluidly and creating important connections, as well as imagining relevant opportunities coupled with potential solutions [107]. Last, entrepreneurial renewal will update the entrepreneurial insight of the organization, while at the same time considering the dynamic and continuing stocks and flows of opportunities.

**Proposition 6.** *Strategic assessment, strategic outcomes, the internal environment, and guidance and limits impact the organization's entrepreneurial renewal.*

## 6. Discussion and Conclusions

Academic entrepreneurship (AE) models have enriched the ability of scholars to characterize the elements and relationships that are consistent with entrepreneurial activities. However, previous research has not focused on the dynamic feedback loops within AE. Therefore, this paper proposes a model of AE from the system dynamics perspective that explores the key features of the complex AE process within the boundaries of a spinoff company. The proposed framework considers the steps taken by academic entrepreneurs to complete technology commercialization through a series of milestone events. Feedback loops provide the link between strategic assessment and entrepreneurial renewal according to which AE integrates entrepreneurial and strategic efforts. The model also examines and analyzes the key role of innovative academic entrepreneurship during each stage, and the key factors influencing the AE process.

The core of the model lies in explaining the combined effect of stocks, flows, and relationships on AE in connection with the series of milestones, termed critical junctures. This approach illustrates the effects of different organizational variables on the recognition, commitment, credibility, and sustainability phases of development. These activities can either push or hinder opportunities. The results of this research shed light on the complexity and feedback loops involved in the AE process from the system dynamics perspective, and provide direction for future strategies to promote entrepreneurial insight.

### 6.1. Theoretical and Practical Significance

This paper offers several contributions to the field. First, this dynamic model treats AE as a continuous process that feeds back directly and indirectly into future AE efforts. By emphasizing the complexity of feedback, defined as the existence of multiple feedback relationships and time delays (Diehl and Sterman 1995; Repenning 2002) [131,132], the proposed framework helps to uncover additional connections among AE elements and activities. This approach provides a more complete view of AE insofar as actions previously identified as occurring later in the AE process are recognized as influencing activities typically described as occurring earlier in the AE process. For example, an organization's sustained efforts regarding one product can influence newer innovative efforts. Although such activities and processes are often portrayed as simultaneous, they also can influence future iterations of these processes. Moreover, we have identified how disruption can potentially affect the stocks, flows, or relationships that have been identified. For instance, if the outcomes of strategic assessment are broken, the guidance and limits they provide cannot be updated, and entrepreneurial renewal can be impacted. As a result, the entrepreneur might be misinformed, and entrepreneurial insight hindered, which could result in the pursuit of some opportunities that are not desirable, or failure to pursue desirable ones.

Second, this study focuses on the progress of AE through critical junctures, and the way the process influences and is influenced by distinct organizational elements. The relationships described in this paper generate feedback routes that flow across critical junctures or other areas. We anticipate that future research will reveal more routes amid other variables. After identification and testing, these feedback routes will be added to the complex picture of AE that can be dealt with properly by a system dynamics approach. This complexity could be a result of multiple feedback paths together with time delays [131,132], which could increase the difficulty in obtaining simple, consistent feedback. In addition to the more obvious impact of the combined effects of various components, each component individually can contribute to AE. Therefore, AE is neither an absolutely separate strategy nor a strategy that stems only from the guidance and restrictions of strategy assessment.

Third, our proposed model is dependent on the established relationships, and integrates these relationships in a way that is consistent with how they are represented in the literature. Therefore, it provides an increased level of understanding of how these components are integrated, without leading to extra confusion and uncertainty. The model portrays the connectedness of these processes, which helps to confirm important indirect relationships that often are treated as distinct or as isolated.



For instance, entrepreneurial insight and strategic outcomes will be affected by the positive and negative outcomes of pursuing opportunity, which in turn will have an impact on various strategic and entrepreneurial elements. Additionally, key linchpins come into play for the cycle to continue.

Fourth, our work recognizes that in the system dynamics framework of academic entrepreneurship, academic entrepreneurs play multiple roles as academic researchers, enterprise founders, and enterprise managers. They are committed to the integration of entrepreneurial resources, technology commercialization, and enterprise value creation. In addition, they hold primary control over the development of the technology and approach to the market. Academic entrepreneurs can obtain profit from the growing returns brought by the increasing value of their enterprises. Since our proposed framework provides a description of the feedback loops and other complexities of the AE process, academic entrepreneurs can apply this knowledge to realize the commercial value of their products and to understand further their own roles and value in the process.

Last, the time-centric view explained in this paper promotes a better understanding of the simultaneous participation of exploration and exploitation, and the adaptation and alignment activities that are of great significance for organizational ambidexterity. Organizations that are ambidextrous can deal with current conditions in an effective way, and can deal well with changes in the future [133] because the changes can be met in a contextual [134,135] or structural manner (i.e., simultaneously or sequentially). For example, a behavioral context that is beneficial for improving ambidexterity can be fostered by relying on work teams that provide high performance [136]. The system dynamics model is helpful for explaining the coexistence of exploitation and exploration activities as well as for building off one another when the organization is making profits. Productive organizational learning is a strategic part of successful AE and ambidexterity [137], and the system dynamics model presented here supports the connection between the two concepts.

In summary, this paper offers a model of academic entrepreneurship that combines various perspectives from traditional research with a system dynamics approach to understand the AE process. In practical application, awareness of the feedback loops and other complexities involved in the AE process can help to identify the strategic points for supporting the commercialization of newly emerged science. In this way, our proposed framework provides insights that academic entrepreneurs can use to facilitate the AE process.

## 6.2. Considerations for Future Research

To analyze the system dynamics of academic entrepreneurship, we used root theory and literature analysis to establish the framework, and we proved a key summary proposition for each section. In the future, these propositions can be tested by empirical research using questionnaires and a Likert scale to quantify indicators. For example, we could use academic enterprises as research samples, and draw up questionnaires to investigate the degree of entrepreneurial idea sufficiency, business experience, networks, and agreements between multiple partners at the framing of the flow of opportunity. The relationships between the influencing factors can be demonstrated within the academic entrepreneurship framework, which is the key factor influencing the AE process.

Going forward, additional research can be conducted to examine the effectiveness of the proposed model. For example, we can explore the degree of impact of outflows on entrepreneurial insight, and the lessons organizations learn from failures. Some organizations may work jointly to learn from previous experiences, yet others are more likely to move on to the next challenge rather than first understanding what happened. The proposed model also involves the antecedent and outcome relationships in terms of strategic assessment. Future research will examine the degree to which an organization can learn from its successes (such as implemented opportunities), apply what it has learned to gain entrepreneurial insight, and influence the pursuit of opportunity. In the case that organizations do not use any one of these routes, we could confirm the reasons and update the model accordingly.

This paper focuses on the internal organizational activities associated with AE, but the development of AE often involves inter-organizational activities. Future studies can be performed to test the intersection between these actions with the model provided. A typical example of this intersection would be an examination of how resources can be treated as complementing each other between organizations. According to Adegbesan (2009) [138], during the organization interaction process, the appropriability of gains can be affected by resource complementarity, relative resource scarcity, and bargaining ability. Considering that organizations will make concerted efforts to develop opportunities, partner selection is likely to be affected by these factors, which will result in opportunity recognition.

In addition, the popularity of strategic alliances affects organizational capability and leads to the disruption of AE. Researchers can study whether the dependence on alliance partners to conduct entrepreneurial tasks can weaken the ability of an organization to preserve or enhance skills. Moreover, research can explore whether the omission of some steps of the AE process would have a negative effect on the ability of an organization to preserve the overall process, even though skill levels remain unchanged. For instance, if an organization carries out an opportunity with the help of its strategic alliance partners, it is likely to gain few learning experiences from this action. Without awareness about what it has not learned, the organization is likely to misjudge its ability to implement future opportunities. It is extremely difficult but very important for researchers to confirm what was not learned by an organization from an action.

**Author Contributions:** Writing: J.X., W.L.; Providing the case and idea: J.X., W.L.; Providing revision advice: S.-B.T., G.L., C.-C.C., K.W.

**Funding:** This study is sponsored by Science & Technology Foundation of Chongqing (The Academic Entrepreneurship Advocates System and Institution Innovation for High Technology).

**Conflicts of Interest:** The authors declare that there are no conflicts of interest.

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