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ASSET-LIGHT CONSTRUCTION OF TECHNOLOGY-DRIVEN STARTUPS: INSIGHTS FROM CASE STUDIES IN CHINA*

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Abstract. The resource-efficient allocation advantages of asset-light operations have garnered considerable attention from technology-driven startups in China. Clarifying the construction pathways of asset-light operations is crucial for guiding the development of such enterprises. This study examines two asset-light, technology-driven startups in China to identify key elements of the asset-light operation process and comparatively analyze their heterogeneous construction pathways using imprinting theory. The findings reveal that the alignment of open demand and connectivity conditions forms the foundation for establishing asset-light operation partnerships, while shared logic facilitates collaborations. Establishing symbiotic relationships is identified as a key factor in the sustainable development of asset-light operations. Regarding resource integration pathways, relationship-based entrepreneurial teams typically form asset-light resource networks in a $0 \rightarrow n$ diffusion pattern by engaging in acquisitive resource integration behavior, exhibiting the characteristic of expansive resource capability. Conversely, technology-based entrepreneurial teams form $0 \rightarrow 1 \rightarrow n$ bridging resource networks through accumulative resource integration, demonstrating exploratory resource capability. These findings contribute to the study of asset-light operations in independent entrepreneurship and offer differentiated asset-light construction pathway references for technology-driven startups

Keywords: asset-light operations; distinctive construction pathways; resource integration; symbiosis; technology-driven startups

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1. Introduction

China's innovation and entrepreneurship policies have driven a surge in entrepreneurial activity. Many technicians have established technology-driven startups, transforming their proprietary technologies into technological products. By the end of 2023, China had 563 000 registered technology small- and medium-sized enterprises (SMEs), marking a year-on-year increase of 25% (Data source: National Database of Science and Technology-Based SMEs). The rapid growth of these enterprises is crucial for achieving sustained technological advancement and economic development. Hui et al. (2022) highlighted that the development of technology-driven startups is often constrained by limited internal resources and difficulty in securing external resources. Business model innovation enables technology-driven enterprises to address resource constraints by expanding external resource acquisition channels, thus meeting resource demands and fostering growth (Chesbrough, 2010; Afuah, 2014; Yi et al., 2024; Lin et al., 2024; Ji et al., 2024).

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Asset-light operation models involve resource allocation (Liang et al., 2023), characterized by their ability to focus limited resources on areas closely related to company development (Wang et al., 2020). Many technology enterprises in China, such as Xiaomi, NIO, and Digital China, have adopted asset-light operation, minimizing expenditures on fixed assets and outsourcing non-core functions such as manufacturing, after-sales, and logistics. This approach allows them to allocate more resources to research and development (R&D), enhancing their core competitiveness. Further, asset-light operations enable technology-driven startups to expand their resource networks and integrate external resources through strategic collaborations (Yi et al., 2024). The model demonstrates superior resource acquisition and operational efficiency, effectively aligning with the needs of technology-driven startups. On October 11, 2024, the Shanghai Stock Exchange officially released the “Guidance on the Application of Issuance and Listing Review Rules No. 6 - Criteria for Identifying Asset-Light and High R&D Investment (Trial),” guiding technology-driven startups to prioritize R&D investment through asset-light strategies.

How do technology-driven startups establish an asset-light operational model? Research has examined the generative elements and models of asset-light operations in spin-off technology startups, revealing that their development is considerably influenced by resources from their parent companies (Li et al., 2020). However, independent technology-driven startups receive no resource support from a parent company, making their approach to asset-light operations substantially different from that of spin-off technology startups. Additionally, scholars have examined the asset-light business models of established technology enterprises, analyzing how innovation ecosystems emerge and evolve under asset-light operation (Yi et al., 2024). Nonetheless, the resource constraints and strategic motivations of established firms differ greatly from those of startups, limiting the applicability of their asset-light models as a reference. The characteristics of technology-driven startups—particularly those lacking resources from a parent company and severely resource-constrained—have not addressed asset-light operation. Therefore, this study, using the case study approach, focuses on two technology-driven startups from China to analyze the construction process of asset-light operation. Our findings fill this gap in the literature on asset-light operation regarding independent entrepreneurship while providing a reference for technology-driven startups to construct their asset-light operations.

2. Theoretical Review of Asset-light Operation in Techno-entrepreneurial Enterprises

From the perspective of value chain theory, asset-light operations benefit technology-driven startups in two primary aspects. First, asset-light operations assist enterprises in identifying key activities within their internal value chains, allowing them to allocate resources to areas closely related to the company’s value (Wang et al., 2020, Wang et al., 2024). By minimizing ownership of physical resources while maximizing the flexibility and conversion capacity of internal resources (Kang et al., 2024), asset-light operations enhance the operational efficiency of technology-driven startups (Liou, 2011). Second, asset-light operations emphasize the outsourcing of non-core business functions (Seo & Soh, 2019; Zhang & Zhang, 2024), which helps technology-driven startups gradually accumulate numerous partners, forming a vertical value chain (Yi et al., 2024). Technology-driven startups can integrate complementary resources and even create a symbiotic ecosystem from the vertical value chain (Hohberger et al., 2020; Liang et al., 2023). Despite existing research on the mechanism of asset-light operations for technology-driven startups, research is needed on “how to construct asset-light operations”, such as the criteria for technology-driven startups to identify and position key elements of asset-light operation within their internal value chains, pathways for technology-driven startups with scarce resources to establish vertical value chains through asset-light operation, and strategies for maintaining asset-light operation to obtain more resource support. Therefore, our study employs a longitudinal case study approach based on value chain theory to analyze the construction mechanism of asset-light operation in technology-driven startups.

The key to constructing asset-light operation and harnessing its effect lies in resource integration (Shou & Li, 2024). Resource dependence theory emphasizes that external resources are crucial for the development of enterprises, focusing on external resource acquisition. Some scholars argue that newly established enterprises should enhance their visibility and reputation to attract stable external resources (Li et al., 2020). However, technology-driven startups whose core competencies are not yet widely recognized face challenges in securing resource support solely based on technological potential. Generally, these startups acquire external resources

through two avenues. First, proactive external resource bricolage by the technology entrepreneurship team (Engel et al., 2017). Second, technology-driven startups rely on third-party platforms for resource acquisition, such as joining entrepreneurial platforms or business incubators (Grilli & Marzano, 2023). Research on resource integration has primarily focused on spin-off startups, with a lack of investigation into independent technology entrepreneurship. Compared with general technology entrepreneurship, spin-offs can use the resource network of the parent company, thereby effectively connecting multiple asset-light resource collaborations (Walter et al., 2014). Conversely, independent technology-driven startups lack the inherent advantages of a parent company's resources, necessitating distinct resource integration strategies for asset-light operations. Therefore, our study analyzes the resource integration pathways of asset-light operations in the context of independent entrepreneurship based on resource dependence theory.

Additionally, technology entrepreneurship heavily relies on the entrepreneurial team, with team characteristics such as entrepreneurial passion (Cardon et al., 2009; Ahsan et al., 2023), leadership abilities (Hensellek et al., 2023), influencing entrepreneurial opportunities (Li et al., 2022) and entrepreneurial performance (Wang et al., 2023). However, the application of imprinting theory in entrepreneurship primarily focuses on explaining the imprinting effects of initial conditions on newly established enterprises (Li et al., 2020), neglecting the imprinting effects of entrepreneurs' prior experiences and expertise. Consequently, there is no profound interpretation of the imprinting effects of entrepreneurial team characteristics during the asset-light operation process of technology-driven startups. Our study incorporates the prior work experience characteristics of entrepreneurial teams into the research, analyzing the differentiated paths of asset-light operation construction formed by teams with different characteristics.

3. Materials and Methods

Research has explored asset-light operation in technology entrepreneurship, but explanations of its construction mechanisms remain lacking. There is an urgent need to elucidate the research question of how independent technology-driven startups construct asset-light operations. A case study approach is well-suited for such research questions involving phenomenon explanation and theory building (Eisenhardt, 1989; Yin, 1981). Therefore, given the research context, we conduct a time-series analysis of the case data to comprehensively illustrate the asset-light operations process. Subsequently, we conduct a comparative analysis of the two cases to examine how asset-light operations emerge based on variations in entrepreneurial team characteristics.

3.1. Case Selection Based on Theoretical Sampling

Theoretical sampling is performed to identify individuals, events, locations, or entities that are likely to exhibit variations among concepts, increasing the density of conceptual attributes and dimensions. Unlike statistical sampling, which prioritizes representativeness and breadth, theoretical sampling focuses on the informativeness of the selected cases (Corbin & Strauss, 2014). Theoretical sampling emphasizes conceptual relevance and depth in the sampling process, requiring the selection of research subjects that can provide the maximum amount of information pertinent to the research question, guided by the research objective. This study analyzes the construction of asset-light operation in independent technology-driven startups. The selected cases must meet the following criteria:

1. Establishment: The selected enterprises must originate from technology transformation and be independently founded. According to Zahra's (1996) definition of young enterprises, the selected case enterprises must have been established for no more than five to eight years. Additionally, these enterprises should be founded and operated primarily by local entrepreneurs to represent the management style of traditional Asian enterprises.
2. Capital operation model: The selected cases must have undergone both the decision-making and implementation stages of asset-light operations.
3. Operation status: After establishing the asset-light operation, the enterprises must maintain operation efficiency and increase competitiveness. This can be evaluated using indicators such as R&D performance, product market share, and sales revenue.

Based on the outlined theoretical sampling criteria, this study first selects WH as a research case. The rationale for this choice is that the technology-driven startups discussed in this study are initiated by technicians who commercialize proprietary technologies. WH is a typical example of a company founded by technicians to implement technological entrepreneurship, and its entrepreneurial teams are more likely to exhibit technical characteristics. To avoid potential research bias from a focus on technology-based entrepreneurial teams, a second case, GJ, was selected. GJ was founded by technicians with diverse prior occupational backgrounds and has a relationship-based entrepreneurial team. This selection broadens the scope of asset-light research in a normal environment, enhancing theoretical validity and maximizing the saturation of theoretical sampling.

This study adheres to confidentiality agreements by using the abbreviations GJ and WH to represent the two technology-driven startups examined. GJ, established in 2018, specializes in technology products addressing sand-casting issues in glass mold cavities. GJ began planning asset-light operations in May 2018, achieving a relatively complete asset-light operation cooperation framework by the end of 2020. WH, established in 2019, focuses on addressing the high-cost problem of imported steel rings in the textile industry. It began preparing for asset-light operations in March 2019 and completed its asset-light operation transformation by the beginning of 2021. Both companies have been operating asset-light for three to four years, steadily developing their asset-light value chain. Table 1 presents key events in their asset-light operations.

Table 1. Key events for the selected cases

Firm name	Phase	Date	Event	Number of meetings the research team attended
GJ	Pre-decision stage	2018.05	Identify the resource gaps in technology entrepreneurship	2
		2018.06	Prepare for asset-light technology entrepreneurship	3
		2018.10	Initiate contact with mold manufacturers	1
		2018.12	Present the technological product's prospects to potential partners	1
	Implementation phase	2019.05	Establish material supply cooperation with upstream enterprises	2
		2019.10	Sign cooperation intentions with nearby machining enterprises	2
		2020.03	Sign a contract with the production laboratory of an upstream enterprise to set up a product performance testing base	1
		2020.05	Join the research institute	1
		2019.03	Conduct preparatory meetings for asset-light technology entrepreneurship	1
		2019.04	Perform preliminary research to determine the required resources for the product	3
WH	Pre-decision stage	2019.10	Apply for government funding support	1
	Implementation phase	2019.12	Engage with the research institute and join their facilities	1
		2020.03	Approach textile enterprises, present the product's cost advantages, and secure cooperation for pilot production lines	3

Additionally, we consider the principle of data availability when selecting cases, as timely and adequate acquisition of case data is essential for ensuring the robustness and reliability of case study conclusions. The first author of this paper is a minority shareholder in WH and a member of GJ's entrepreneurial team, primarily responsible for accounting tasks. These positions enable direct involvement in the early planning stages of asset-light technology entrepreneurship for both companies, facilitating the continuous observation of their operations.

3.2. Data Collection

To ensure research reliability and validity, triangulation verification was adopted during data collection (Yin, 2009). Secondary data, interview data, and participant observation data were combined to form multi-channel data sources. The secondary data were mainly obtained from the official websites of GJ and WH, corporate

system documents, and relevant meeting documents of asset-light operation partners. First-hand case data were collected through participatory observation, longitudinal research, and semi-structured interviews. During data collection, we fully respected the informed consent and autonomy of all participants. Prior to the commencement of data collection, we provided each potential participant with detailed research instructions, including the research objectives, methodologies, potential risks, and participant rights, ensuring their voluntary participation based on a thorough understanding of the research content. Participants were entitled to withdraw from the study at any time without any negative consequences, and written informed consent was obtained from all participants. To safeguard participants' privacy and data security, we implemented stringent confidentiality measures. All collected data were stored in an encrypted database, accessible only to authorized research team members. Our research team underwent rigorous confidentiality training to ensure their understanding and adherence to relevant confidentiality regulations. We only collected information necessary for the study and disposed of or destroyed it upon study completion. The collection of first-hand data was conducted in three stages, as illustrated in Figure 1.

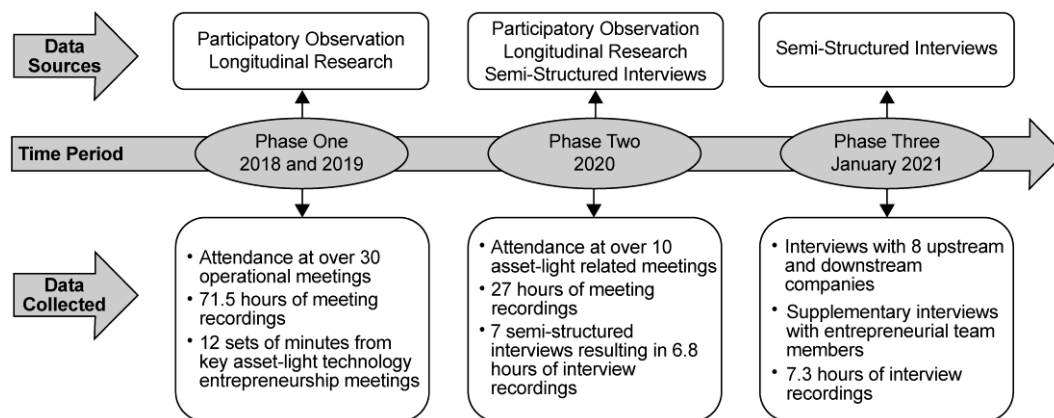


Figure 1. First-hand data collection process

3.2.1. Participatory Observation and Longitudinal Research

In the first phase of data collection, the authors conducted participatory observation and longitudinal research primarily by attending the operational meetings of the case study firms. The author team directly observed and recorded data related to the construction of asset-light operations during the meetings. The team members did not give any guidance or suggestions during discussions and decisions on asset-light operations, ensuring the authenticity and reliability of the case data. While collecting the primary data, the team attended over 40 operational meetings across two enterprises, including 22 meetings focused on asset-light operations. Table 1 summarizes the meeting schedule and relevant events of the attended meetings.

3.2.2. Semi-structured Interviews

Semi-structured interviews were conducted through face-to-face and online meetings. The interviews focused on open-ended questions related to asset-light operations. As the first author is responsible for accounting tasks and is a minority shareholder of WH, she was involved in designing the semi-structured interview guide but did not conduct interviews. The purpose of this approach is to minimize external interference and ensure the authenticity and objectivity of the case data.

The interviews were divided into two parts. The first part introduced the study, clarified the anonymity of the interviews, and gathered relevant information about the interviewees. The second part addressed questions about asset-light operations, such as the understanding of asset-light concepts, reasons for choosing this model, factors considered in constructing the operations, whether the asset-light operations achieved the expected outcomes, and how resources were pooled and integrated during the process.

During the second phase of data collection, we interviewed seven entrepreneurial team members. In the third phase, we interviewed nine upstream and downstream companies' representatives and conducted supplementary

interviews with four new entrepreneurial team members. The selected interviewees had to be deeply involved in the development of asset-light operations. This criterion enabled the provision of detailed and comprehensive data for the research. In the selection of interviewees, diversification regarding profession, position, and prior work experience was required to ensure the generality and applicability of the research results. Moreover, to enable richer and more comprehensive case data, representatives from upstream and downstream companies were included in the selection process. Additionally, we ensured that interviewees participated willingly and cooperatively, facilitating a smooth interview process. No new information or concepts emerged during the final interviews with two upstream/downstream company representatives and three entrepreneurial team members, indicating theoretical saturation (Flick, 2022). Table 2 provides detailed information about the interviewees.

Table 2. Interviewee summary

No.	Sex	Age (years)	Major	Education	Position	Previous employment experience
1	Male	34	Engineering	Master	Core entrepreneurial team member	Technical engineer assistant
2	Male	42	Management	MBA	Core entrepreneurial team member	Entrepreneurial manager
3	Male	28	Engineering	College	Entrepreneurial team member	Production supervisor
4	Female	27	Financial	Graduate	Entrepreneurial team members	Administrative
5	Male	38	Engineering	Master	Core entrepreneurial team members	Technical engineer
6	Male	40	Engineering	PhD	Core entrepreneurial team members	Technical researcher
7	Male	35	Engineering	Master	Entrepreneurial team members	Entrepreneurial manager
8	Female	45	Management	Graduate	Financial team of an upstream company	-
9	Male	49	Engineering	Graduate	Production employee in an upstream company	-
10	Male	43	Management	Graduate	Marketing executive of an upstream company	-
11	Male	39	Engineering	Master	Technical staff of an upstream company	-
12	Female	45	Management	Master	Financial employee of a downstream company	-
13	Male	37	Management	Graduate	Sales Executive of a downstream company	-
14	Male	35	Engineering	Master	Technical staff of a downstream company	-
15	Male	47	Management	Master	Operations Supervisor of a downstream company	-
16	Male	39	Engineering	Graduate	Production supervisor of an upstream company	-
17	Male	41	Engineering and Management	Master	Entrepreneurial team member	Entrepreneurial Manager
18	Female	33	Engineering	PhD	Core entrepreneurial team member	Technical Researcher
19	Male	24	Engineering	Master	Entrepreneurial team member	Technical Researcher
20	Male	34	Engineering	PhD	Entrepreneurial team member	Technical Researcher

To ensure the reliability and validity of the study, necessary measures were taken during the research process (Table 3), particularly during data collection and analysis.

Table 3. Guarantee strategies for reliability and validity

Reliability and validity indicators	Research phases	Guarantee strategies
Reliability	Research design	Theoretically guided research design. Extensive literature review to establish a reasonable theoretical framework. Develop a detailed research plan. Conduct multiple discussions and revisions until consensus is reached.
	Data collection	Establish a database and categorize the data while ensuring confidentiality.
Internal validity	Data collection	Avoidance of dual roles. The first author, who is both a researcher and a member of the entrepreneurial team, only participates in the design of the interview outline and is not involved in any data collection processes.
	Data analysis	Three groups independently conduct data coding, and expert discussions are organized to resolve disagreements until a consensus is reached.
External validity	Case selection	Case selection is based on theoretical sampling, with multiple cases chosen for comparison.
	Data collection	Multiple data collection methods based on triangulation. Validation and supplementation of primary and secondary data, using participatory observation, longitudinal research, and semi-structured interviews in the process of primary data collection.
Construct validity	Data analysis	Five experts independently review the data analysis report, and face-to-face discussions are held between the researchers and experts until consensus is reached.

3.3 Data Analysis

NVivo software (Nvivo QSR, Chadstone, Victoria, Australia) was used to analyze the case data. The case coding followed a three-stage process: open coding, axial coding, and selective coding (Glaser et al., 1968). During axial coding, the construction process of asset-light operations in technology-driven startups became evident, leading to the formation of a storyline in selective coding.

3.3.1 Open Coding

Open coding primarily identified emerging phenomena within the case data and classified them into preliminary categories. Twenty-three categories were extracted. Table 4 presents some open coding examples from our cases.

Table 4. Open coding examples

Data	Phenomenon	Category
(GJ): "...whether it's machining equipment or raw materials, substantial financial support is required. However, the funds available in the early stages of the venture are insufficient to meet these needs..." (a1) (WH): "The funds we have are really limited. We can't simultaneously cover R&D expenses and equipment costs. Solving the issue of tight funding is something we constantly face..." (a2)	a1 Initial Funding Deficiency a2 Funding Shortage	A1 Funding Gap
(GJ): "...all these require various large-scale pieces of equipment. Purchasing such large equipment would tie up valuable funds in heavy assets, which is too risky for us..." (a3) (WH): "...investing the funds in building the textile experimental workshop wouldn't be feasible. The funds are limited, and once invested, their liquidity decreases. If the product trial were to fail, we would face the risk of having no funds for improvements..." (a4)	a3 Capital Immobilization Risk in Equipment a4 Liquidity Risk	A2 Risk Avoidance
(GJ): "...there are many companies around the glass mold producers involved in glass blowing, forming an upstream and downstream industry chain from mold production to mold usage..." (a5) (WH): "...the Wuxi area has many textile companies. Through government introductions, it is relatively easy to find upstream and downstream partners..." (a6)	a5 Complete Industrial Chain a6 Upstream and Downstream Cooperation	A3 Industry Environment
(GJ): "...my technology product targets the current process updates for glass molds (a7). The current process no longer benefits from labor advantages, and the country is very strict on environmental protection..." (WH): "...imported steel collars last longer, but the individual price is too high. If we can reduce this part of the cost, the overall cost for	a7 Resolution of Process Challenges a8 Resolution of Cost Challenges	A4 Technological Interdependence

textile companies will decrease. We solve this technical problem through coating technology...” (a8)		
(GJ): “...these all require various large-scale pieces of equipment, which is almost unaffordable in the early stages of entrepreneurship. We can only collaborate with companies that have such equipment and conditions...” (a9)	a9 Insufficient Equipment a10 Limited Resources	A5 Resource Deficiency
(WH): “In the early stages of entrepreneurship, with limited funds and resources, what do we do? (a10) We have to obtain resources externally, continuously seek partners, and get the resources we need. For equipment requiring significant investment, especially general-purpose equipment, we prefer to collaborate rather than purchase, to avoid tying up our funds...” (a9)		
(GJ): “...the production process for glass mold profiles requires a profile production line to be in sync (a11). Continuous improvement of material composition is also needed. A processing center must create mold samples, which are then tested for performance on the production line (a12). All of this requires various large-scale equipment...” (WH): “...our funds are very limited, but the equipment needed for pilot testing (a11) and the production-related workshop environment (a13) require substantial investment...”	a11 Equipment Demand a12 Product Testing Requirements a13 Pilot-Testing Environment Requirements	A6 Open Demand
GJ: “The sand-casting technology we use now requires significant investment in environmental protection. Some large companies import profiles and process them into molds, but the cost is too high (a14)... “...our entrepreneurial product just happens to address the current environmental issues with sand-casting technology (a15). They are willing to give it a try, and with pilot testing in their workshops, they can directly see the real application effects of the product...” (WH): “...steel collars are consumables in the textile industry. Long-term dependence on imported materials leads to high prices, which directly impacts product costs (a14) “...”	a14 Low-Cost Demand from Downstream Enterprises a15 Environmental Demand from Downstream Enterprises	A7 Connectivity Conditions
(GJ): “...some of our technology products are still in testing, so it’s currently challenging to provide technical services to partner companies. However, we found that entrepreneurs often have some degree of willingness to contribute to economic development and industry chain upgrades (a16) ...”	a16 Entrepreneurial Contribution Willingness	A8 Shared Logic
(GJ): “During the pilot testing of our technology products, we faced two issues. One was adjusting the internal structure of iron profiles, which required finding a supplier that could meet our specifications. Our team discovered that JB Group was interested in starting an iron project and had an experimental production line that could offer us the chance to adjust the profile composition (a17) ... The other issue was that the pilot products needed to undergo several tests on the glassware production line to ensure mold quality. However, setting up such a production line was unrealistic for us. Our team’s technical leader used their academic connections to reach out to a mold manufacturer, which was also working on improving iron profile mold processes and had a suitable testing environment (a18) ...”	a17 Identification of Special Material Suppliers a18 Identification of Product Testing Manufacturers	A9 Resource Bricolage
(GJ): “Our asset-light technology venture is the result of support from many partners, including those providing raw materials (a19). The industry partnerships our team built in the early stages provided us with more options (a20) ...”	a19 Support from Multiple Partners a20 Network of Initial Collaborative Resources	A10 Diffusive Resource Network
(WH): “By applying for government funding, we gradually learned about many entrepreneurial platforms through government introductions (a21). These platforms can provide office equipment and other resources for businesses...” “...we primarily focus on technology and have some contacts with external companies. However, finding genuine partners is quite challenging. Government support helps us access other resources. For instance, we needed to test our product on textile production lines. The government assisted us in connecting with textile companies, facilitating access to pilot-testing equipment and environments (a22).”	a21 Government Bridging to Startup Platforms a22 Government Bridging to Downstream Resources	A11 Bridging Resource Network
(GJ): “During the startup phase, resources are extremely scarce. To get the necessary support—technology, funding, equipment, etc.—team members reached out to many previous partners (a23).”	a23 Acquisition of Resources from Initial Partners	A12 Acquisitive Resource Integration

(GJ): "...we continuously searched for and sought out partnerships. We didn't limit ourselves to a single resource provider, as that wouldn't be sufficient (a24). We always focused on collaborative needs, striving for mutual resource support with any partner we chose. This approach ensures long-term stability (a25)."	a24 Non-Dependence on a Single Partner a25 Exploration of New Partners Based on Existing Network a26 Team Members' Expansion of Resource Suppliers	A13 Exploratory Resource Capability
(WH): "...of course, team members also made efforts to find resources independently. For example, we frequently presented our products at various seminars hosted by research institutes, aiming to impress resource holders with our technological prospects (a26)"		
(WH): "Technology is crucial, and it's something our team has continually researched. The advanced nature and development prospects of our technology are key factors in attracting external resources (a27). We keep accumulating technological advancements and applicability to secure resource partners (a28)."	a27 Attraction of External Resources Based on Technological Advancement a28 Accumulation of Technology to Attract Resource Partners	A14 Accumulative Resource Integration
(WH): "Initially, the company's operational funds came from team members. Later, we applied for government funding and joined a research institute, laying the groundwork for acquiring additional resources. The research institute is well-acquainted with local companies and was willing to introduce us to potential upstream and downstream partners, using existing partners to connect with new ones (a29)."	a29 Government Bridging Resource Utilization Capability	A15 Expansive Resource Capability
(GJ): "To get the resources we need, we first need to understand what we can offer them. If our needs align perfectly, a stable partnership is likely (a30). Technology and talent are essential resources for tech entrepreneurship. We have two ways to acquire them (a31): First, we use technology development outsourcing, which is a common approach. Second, we offer equity to young tech professionals to join us in starting the business (a31). Outsourcing technology development meets the performance needs of R&D staff (a32). Starting a business together provides a shortcut for young people to achieve their entrepreneurial dreams..."	a30 Alignment of Mutual Resource Needs a31 Meeting Entrepreneurial Requirements a32 Meeting Performance Needs	A16 Resource Reciprocity
(WH): "...applying for government startup funds to fill our funding gap (a33) is a good option. Since our technology product is in the early stages, we can't offer much to partners in terms of benefits or resources. They have to wait, so they are unlikely to help us for free, except for the government (a34)."	a33 Obtaining Startup Fund Support a34 Government Grant	A17 Parasitism
(GJ): "...Downstream companies are willing to provide us with product testing environments and access to some equipment (a35), as our technology products could bring them tangible benefits in the future. Even though we can't offer them immediate benefits, we can provide them with technical information (a36). While this doesn't bring them direct benefits, our presence doesn't harm their interests either (a37) ..."	a35 Support for Testing Environment and Equipment a36 Provision of Technical Information a37 No Interest Harm a38 No Revenue Generation	A18 Commensalism
(WH): "...With government mediation, we established partnerships with downstream companies. Currently, we only use their equipment during their idle times (a35), which doesn't affect their production (a37), and we haven't yet been able to provide them with direct benefits (a38)."		
(WH): "...As we develop, our low-cost steel collars reduce the costs for downstream companies, and they become our market (a39)."	a39 Mutual Benefit of Low-Cost and Market Resources a40 Mutual Benefit of Market and Technical Resources	A19 Mutualism
(GJ): "...We are customers of upstream companies, which provide us with low-cost materials, reducing our costs (a39). Downstream companies are our customers. Our technology products address their long-standing issues with labor and environmental costs (a40). We've created jobs and generated tax revenue..."		
(GJ): "...During the process of refining our technology product, we encounter some challenging issues. At these times, we seek out specialized technical teams in the field to resolve them. We sign technical contracts (a41), where they help us determine technical data, and we pay them accordingly. We generally avoid deeper technical cooperation due to core technology protection (a42) ..."	a41 Technical Commissioning a42 No In-Depth Cooperation	A20 Cooperative Symbiosis
(WH): "...As our program improves, it gradually meets the needs of textile companies and significantly reduces their costs (a43). We are	a43 Cost Reduction	A21 Value Symbiosis

also beginning to see returns from the textile program's technology products (a44)."	a43 Product Revenue Generation	
(GJ): "...With the development of our technology products, we've achieved some revenue (a43). The increasing demand for raw materials provides JB with a stable market for iron sales (a45) and alleviates the environmental funding pressure on downstream companies (a44) ..."	a44 Alleviation of Environmental Funding Pressure	
	a45 Market Expansion for Upstream Enterprises	
(GJ): "...At the start, we didn't have any revenue to offer to upstream and downstream partners. However, we established communication channels to provide them with the latest technical information (a47)."	a47 Technical Information Exchange	A22 Opportunity Symbiosis
(WH): "Before collaborating with us, they didn't know that surface coating treatment could enhance the durability of the program. Our collaboration not only facilitates resource exchange but also information sharing. In the information age, our partners need to be more sensitive to information (a48)."	a48 Enhancement of Information Sensitivity	
(GJ): "JB provides us with reasonably priced raw materials, and we supply molds and mold profiles to glass mold companies. The upstream companies support us with raw material resources (a49), and we provide them with market resources (a50), as well as technical resources to the mold companies (a51), which in turn are part of our market resources..."	a49 Raw Material Resources	A23 Resource Empowerment
	a50 Market Resources	
	a51 Technical Resources	
(WH): "For downstream textile companies, we mainly provide them with technological products (a51). They are our largest market (a50) ..."		

3.3.2 Axial Coding

After identifying the categories through open coding, we employed axial coding to analyze the logical relationships between the categories. We adopted the classic analysis model of causal conditions → action strategies → outcomes (Table 5).

Table 5. Axial coding process

Main category	Causal conditions	Action strategies	Outcomes
Perceiving asset-light technology entrepreneurship	Funding resource gap and risk mitigation	Exploration of low-cost operation models based on industry chain	Opportunities for asset-light operations through heavy asset transfer
Defining asset-light operations content	Enterprise technology alignment with industry chain needs, industry chain resources meeting entrepreneurial requirements	Identifying asset-light operation partners and engaging in resource bootstrapping	Identifying feasible directions for asset-light operations
Building an asset-light technology entrepreneurship resource network	Asset-light entrepreneurship resource integration and capability	Integrative and accumulative resource integration Expansive and extended resource capability	Establishing a resource network for asset-light technology entrepreneurship
Forming integration and symbiosis in asset-light operations	Systematic operation of asset-light technology entrepreneurship resource network	Symbiosis of resources	Integration and symbiosis in asset-light operations

We identified four main categories by comparing and analyzing 23 categories: the perception of asset-light technology entrepreneurship the definition of asset-light operation content the construction of an asset-light technology entrepreneurship resource network and the formation of integrated, symbiotic asset-light operations. These categories define the key elements of asset-light operation construction for technology-driven startups. Table 6 presents the results and interpretations of the axial coding categories.

Table 6. Axial coding results and explanations

Main category	Sub-category	Definition
AA1 Perceiving Asset-Light Technology Entrepreneurship	A1 Funding Gap	Insufficient funding faced at various stages
	A2 Risk Avoidance	Liquidity risks due to the materialization of funds
	A3 Industry Environment	The industry chain of technology-driven startups, including the completeness and resource endowment of the chain
	A4 Technological interdependence	The close connection between the technology gaps of partner firms and the technology products of technology-driven startups in specific business relationships
	A5 Resource Deficiency	Various resources required by technology-driven startups besides funding
AA2 Defining Asset-Light Operations Content	A6 Open Demand	Resources that technology-driven startups find difficult to internalize and need to obtain externally
	A7 Connectivity Conditions	The need for technology products from technology-driven startups by industry chain firms, and their ability to provide specific resources to technology-driven startups
	A8 Shared Logic	The willingness of participants in asset-light technology entrepreneurship to enable technology products and upgrade industries, along with their actions in resource provision and integration
AA3 Building an Asset-Light Technology Entrepreneurship Resource Network	A9 Resource Bricolage	Actions to maximize resource exploration and acquisition channels based on open demand
	A10 Diffusive Resource Network	The formation of a diffusion characteristic resource network in asset-light technology entrepreneurship through reliance on self-networked multi-party cooperation
	A11 Bridging Resource Network	The formation of a bridging characteristic resource network in asset-light technology entrepreneurship through the reliance on early entrants' bridging capabilities
	A12 Acquisitive Resource Integration	The resource acquisition model in asset-light technology entrepreneurship involving the use of relationship resources to develop new resource providers
	A13 Exploratory Resource Capability	Integration of existing and new resources based on an acquisition model, and expansion of the asset-light technology entrepreneurship resource network through new resource channels
	A14 Accumulative Resource Integration	Attracting and cultivating resource acquisition channels based on technological advancement, characterized by technology and resource accumulation
	A15 Expansive Resource Capability	Expanding new resource acquisition channels based on existing resources, demonstrating the extension of existing resource potential
	A16 Resource Reciprocity	Technology-driven startups provide technical resources to asset-light partners, while partners provide specific startup resources
AA4 Forming Integration and Symbiosis in Asset-Light Operations	A17 Parasitism	Technology-driven startups benefit from asset-light operation partners, while partners experience some loss of benefits
	A18 Commensalism	Technology-driven startups benefit from asset-light operation partners, with no loss or minimal loss of benefits for partners
	A19 Mutualism	Mutual benefit for both technology-driven startups and partners in asset-light operations
	A20 Cooperative Symbiosis	A formal coexistence relationship emphasizing cooperation and support, without forming close resource ties
	A21 Value Symbiosis	Cost reduction for individual operational entities achieved through coordination between technology-driven startups and asset-light technology partners
	A22 Opportunity Symbiosis	Irreplaceable resource connections are built gradually between technology-driven startups and asset-light technology partners, creating joint development opportunities
	A23 Resource Empowerment	Resource support provided by the asset-light technology entrepreneurship ecosystem to all participating entities

3.3.3 Selective Coding

By analyzing the logical relationships between the four main categories, we identified that the core category “asset-light operations in technology entrepreneurship” can integrate all case data, and the following storyline emerged.

Technology-driven startups, driven by resource and capital shortages, seek operational models that facilitate resource bricolage and cost control. A complete industry chain and strong technological interdependencies trigger the awareness of asset-light operations. When open demands align with connectivity conditions, companies cultivate shared logic to identify asset-light partnerships. Technology-driven startups engage in resource integration through direct resource bricolage, expansion of new resources, or extension of existing resources. During the building of an asset-light operational resource network, technology-driven startups focus on establishing symbiotic relationships to facilitate the integration and sustainability of these operations.

4. Case Study

4.1. A Longitudinal Case Study: The Construction Process of Asset-light Operations

A longitudinal analysis of the two case enterprises is conducted to reveal the construction process of technology-driven startups’ asset-light operation (Figure 2).

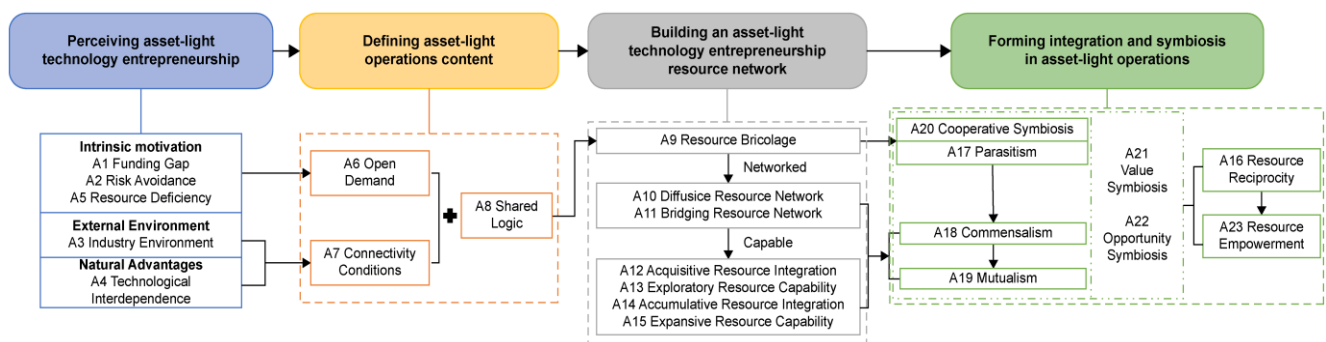


Figure 2. The construction process of technology-driven startups’ asset-light operation

4.1.1 Stage 1: Perceiving Asset-light Technology Entrepreneurship

Based on the value chain theory, a series of related activities and tasks collectively constitute the value construction process of an enterprise (Jacobides, Winter 2012). Enterprises need to identify and concentrate resources on activities with higher added value in their internal value chain to enhance the competitive advantage. Technological R&D is an internal high-value chain link, serving as the foundation of core competitiveness for technology-driven startups. However, respondents from GJ and WH indicated that the purchase of large equipment imposes enormous financial pressure, especially during the initial stage, resulting in funding constraints that hinder technological R&D. Resource dependence theory posits that maintaining organizational operations requires a variety of different resources (Pfeffer, Salancik 1978), as self-sufficiency in all resource provisions is infeasible (Ulrich, Barney 1984). Therefore, reducing heavy asset investments, seeking external resource support, and focusing limited resources on high-value-added technological R&D links within the value chain are critical strategic priorities for technology-driven startups. Asset-light operation emphasizes shifting heavy asset investments to the external environment, enhancing resource use efficiency and flexibility. This approach aligns with the needs of technology-driven startups, leading to its gradual adoption.

In addition, external environmental factors also influence technology-driven startups’ perception of asset-light operation. China boasts a relatively complete manufacturing industry chain, providing an ideal environment for technology-driven startups to develop asset-light operations based on upstream and downstream enterprises. Further, technology-driven startups are often established to incubate products with specific technical challenges in certain links of the industry chain. This characteristic directly fosters a collaborative asset-light operation

model based on technological interdependence. For example, GJ corresponds to the environmental protection mold production process, while WH corresponds to the steel guide bushing production line. Both companies exhibit strong technological interdependence with upstream or downstream enterprises, enabling the externalization of heavy asset investments related to production environments.

4.1.2. Stage 2: Defining Asset-light Operations Content

Technology-driven startups exhibit high technological interdependence within the industrial chain, guiding them to gradually define asset-light operations by using the vertical value chain to identify potential partners for collaboration. Case analysis reveals that during the transitional process of perceiving asset-light operations, technology-driven startups gradually clarify their required resources based on internal value chain analysis, a process known as open demand. Subsequently, based on technological interdependence, technology-driven startups further conduct vertical value chain analysis, focusing on excavating potential collaborators within the relevant value chain who exhibit technological dependence and resource complementarity, thereby creating connection conditions for asset-light operation cooperation. Technology-driven startups continuously match their open demand with connectivity conditions, and when both reach a state of resource complementarity and goal alignment, asset-light operation cooperation is formed, completing the definition of asset-light operation content.

However, if the potential of technological products has not yet been recognized, it is difficult for technology-driven startups to establish asset-light operation partnerships directly with upstream or downstream companies. Case analysis shows that in the absence of a technology spillover effect, technology-driven startups foster asset-light partnerships by cultivating shared logic among potential collaborators. Based on resource dependence theory, a shared logic suggests that transforming originally idle resources into valuable assets aligns with optimizing resource allocation and improving resource use efficiency (Hillman et al. 2009). For example, GJ continuously emphasizes the importance of environmental protection for industry development to stimulate resonance among target partner enterprises, and assists in asset-light operation cooperation by establishing shared logic. Through asset-light operations, GJ obtained external resource support, while partners expanded their resource boundaries, representing a valuable use of idle resources.

As shown in Figure 2, technology-driven startups conduct vertical industrial chain analysis based on their open demand, identify potential asset-light operation cooperation partners who meet the connectivity conditions, and define asset-light operations by cultivating shared logic.

4.1.3. Stage 3: Building an Asset-light Technology Entrepreneurship Resource Network

Resource dependence theory posits that no organization can independently produce or satisfy all the resources necessary for its survival, necessitating reliance on external resources from its environment (Pfeffer, Salancik 1978). Consequently, resource bricolage persists throughout the stages of entrepreneurial firm development. Whenever new open resource demand arises, resource bricolage behavior occurs. Data coding reveals that resource bricolage activities are particularly active after the identification of asset-light operation partners, especially in assembling existing resources, including general heavy assets, production environments, and social resources related to asset-light operation partners.

However, direct resource bricolage behavior cannot guarantee the stability of external resource acquisition for technology-driven startups. Resource dependence theory emphasizes that organizations need to establish interactive dependence relationships with other entities in their specific survival environments, thereby forming a resource network (Ulrich, Barney 1984), and reducing the uncertainty of external resource dependence (Drees, Heugens 2013). Technology-driven startups primarily construct an asset-light operational resource network through the following two stages:

First, by continuously expanding the asset-light resource network, technology-driven startups can alleviate their dependence on existing resource-holding entities and enhance the stability of resource acquisition.

Second, the diverse relational resources and expansion capabilities of technology-driven startups are key to this approach. By establishing new resource cooperation relationships, they can reduce dependence on existing

resource-holding entities and capitalize on resources, which is beneficial for technology-driven startups to construct a stable resource network.

Overall, aligning with the emphasis of resource dependence theory on external resource acquisition, interaction with resource-holding entities, and strategic resource behavior, the construction of an asset-light operation resource network for technology-driven startups progresses through three phases: (1) resource bricolage (external resource acquisition), (2) resource network establishment (interaction with resource-holding entities), and (3) resource capitalization (strategic behavior Figure 2). In the process of constructing an asset-light operation resource network, differentiated resource integration paths are formed due to differences in resource endowments among entrepreneurial teams. Subsequent case comparisons will further analyze these strategies in conjunction with imprinting theory.

4.1.4. Stage 4: Forming Integration and Symbiosis in Asset-light Operations

Maintaining effective asset-light operation cooperation is crucial for the stability of asset-light operations. Shared logic is insufficient to maintain long-term asset-light operation partnerships due to the lack of tangible benefits. From symbiosis theory, interdependent and interactive symbiotic relationships among organizations form the foundation for long-term cooperation, where mutual benefits determine the type of symbiotic relationship and the degree of its maintenance. Analysis of case enterprises reveals that by combining the characteristics of their technology products with the needs of their partners, startups strategically use their resource advantages at different developmental stages to establish various symbiotic relationships. For example, during the resource bricolage stage, the resource advantages of technology-driven startups are yet to be developed. However, by providing resources such as technical guidance and technical information, they maintain asset-light operation cooperation based on cooperative symbiosis or parasitism relationships. As technology products continuously evolve, partners can obtain symbiotic benefits such as small-scale process improvements and small-scale new markets through participation in asset-light operations, gradually transitioning the relationship into a commensalism symbiosis. When technology products gradually gain market recognition and the vertical value chain based on asset-light operations becomes increasingly active, both technology-driven startups and their partners can acquire necessary resources from the value chain, forming a mutualistic symbiosis. During integration and symbiosis, the symbiotic relationship exhibits an evolutionary process from cooperative/parasitic symbiosis to commensalism symbiosis, and finally to mutualistic symbiosis (Figure 2). The gradual emergence of the original advantages of technology products is a key driver in promoting the development of symbiotic relationships.

During the evolutionary process of the symbiotic relationship types, the connotation of symbiosis has also undergone changes from value symbiosis to value symbiosis coexisting with opportunity symbiosis. During the resource integration phase of asset-light operations, collaboration reduces operating costs for startups and grants them access to their partners' resources. Additionally, the innovative technical information provided by technology-driven startups lowers information acquisition costs for partners. A value symbiosis is formed that reduces costs for both parties. As technological products address specific industry chain challenges, irreplaceable resource linkages between technology-driven startups and their asset-light operational partners are established. This creates opportunities for mutual development, resulting in the coexistence of value and opportunity symbiosis.

4.2. Comparative Case Study

4.2.1. Comparison of the Asset-light Formation Paths Based on the Characteristics of Entrepreneurial Teams: From Asset-light Resource Network Construction

Axial coding analysis reveals that the two case enterprises have different characteristics of resource endowment due to the early careers of the entrepreneurial team and show different resource integration paths in the construction of a technology entrepreneurship asset-light resource network. This aligns with the imprinting theory. The GJ team accumulated extensive cooperative relationships, indicating the relationship-based characteristics of the entrepreneurial team. By contrast, the WH team, primarily composed of technical developers, had abundant technical resources, indicating a technology-based entrepreneurial team. The

differences in the characteristics of entrepreneurial teams have led to two technology-driven startups exhibiting distinct paths in constructing asset-light operation.

1. Relationship-based entrepreneurial team: diffusion-oriented asset-light operations construction path

GJ has a typical relationship-based entrepreneurial team, and social resources play a crucial role in the development of asset-light operations. Throughout this process, viable connections were explored by the GJ team's social networks to meet current resource needs and foster asset-light operational partnerships. Consequently, they continually added new, independent partners to their network, resulting in a $0 \rightarrow n$ diffusion pattern in their asset-light operation construction path (Figure 3).

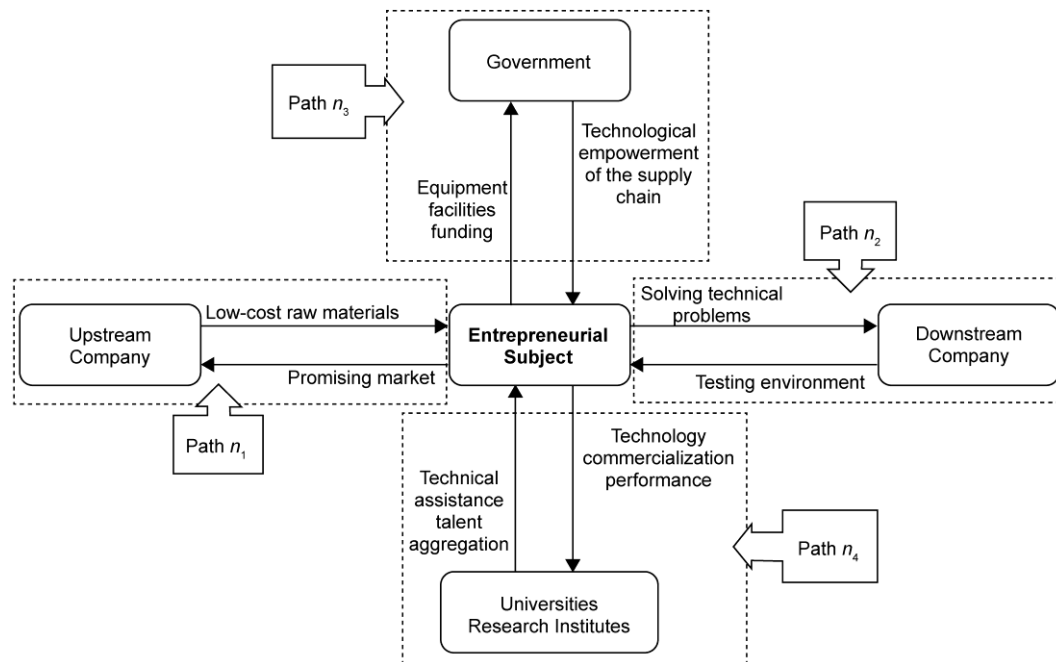


Figure 3. Diffusion-oriented asset-light operations construction path of relationship-based entrepreneurial team

Path n_1 : To reduce the capital tied up in raw materials, low-cost raw material sourcing and inventory management have become open demands for GJ. During the building of an asset-light operation, the long-standing technical consulting relationships of team members with raw material holders are used to identify low-cost and flexible suppliers. Targeted raw material suppliers that have recently initiated a molten iron casting project require extensive market outlets for iron. This created a connectivity condition between GJ and upstream suppliers and led to an asset-light operational partnership in the raw materials sector.

Path n_2 : During market research, the GJ entrepreneurial team visited multiple downstream enterprises to establish a foundation for borrowing heavy assets and testing facilities. GJ's technical products effectively address the environmental pressures caused by the current processes of downstream enterprises. Product testing by GJ did not disrupt the normal production activities of these enterprises and significantly reduced the integration costs of adopting new technologies. This arrangement led to asset-light cooperation between GJ and downstream enterprises.

Path n_3 : In the early stages, essential facilities, such as office spaces, equipment, and factory buildings, require substantial financial investment. Fortunately, government policies supporting innovation and entrepreneurship provide opportunities to meet technology-driven startups' capital shortfalls. GJ joined a government-supported startup incubator to temporarily access office spaces, equipment, and factory facilities at no cost. Additionally, the incubator facilitates access to government funding, avoiding the collateral and interest burdens associated with external financing.

Path n_4 : Solving technical problems requires significant human, financial, and time resources. Non-core technical issues can be resolved through technological outsourcing. While updating their technological products, GJ opted to outsource non-core technical problems to universities, research institutes, or other relevant technical research teams. This approach efficiently and cost-effectively resolves technical issues while contributing to the partners' technology-transfer achievements. Additionally, through this technical assistance process, GJ gained access to young and creative professionals with specialized technical knowledge, providing a channel for recruiting high-level talent.

Relationship-based entrepreneurial teams tend to use their extensive network to facilitate resource bricolage by establishing new resource partnerships. During the resource networking phase, a diffusive resource network is likely to be formed, leading to acquisitive resource integration and ultimately demonstrating expansive resource capabilities (Figure 4).

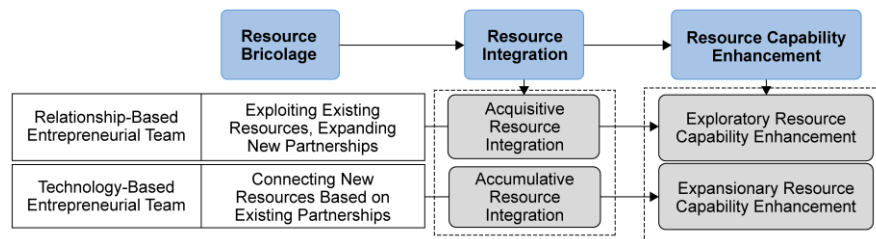


Figure 4. Contrast of resource integration evolution between relationship-based entrepreneurial teams and technology-based entrepreneurial teams

2. Technology-based entrepreneurial teams: bridging-type asset-light operation construction path

Technology-based entrepreneurial teams are often composed of specialized technical personnel who possess technical development capabilities but lack extensive relational networks. They therefore rely more on the advanced nature of their technology to attract partners and are further dependent on the bridging role of existing asset-light operation collaborators. Thus, the path for constructing asset-light operations exhibits a $0 \rightarrow 1 \rightarrow n$ bridging characteristic (Figure 5).

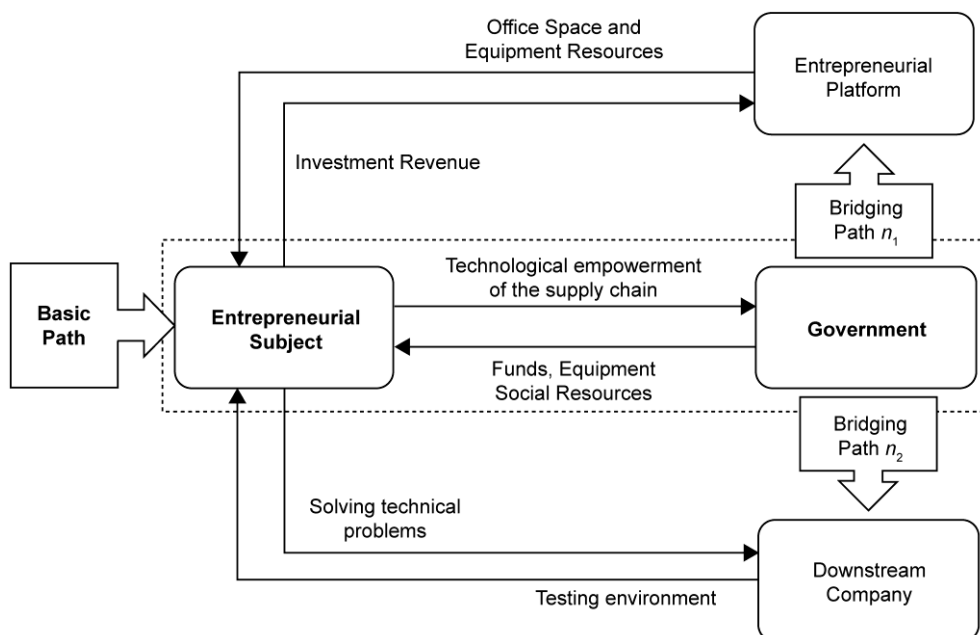


Figure 5. Bridging-type asset-light operation construction path of technology-based entrepreneurial teams

Basic Path: Owing to a lack of relational resources, technology-based entrepreneurial teams face challenges in achieving diversified asset-light operational partnerships independently. However, government policies such as startup funding and support offer opportunities for these technology-based ventures to implement asset-light operations. WH alleviated its funding gap by applying for government startup funds and constructing a bridge to engage with upstream and downstream companies.

Bridge Path n_1 : The government introduced WH to local incubation platforms specializing in metal materials. WH established asset-light operational partnerships with incubation platforms, which provided access to office spaces, equipment, and factory facilities. Owing to the advanced nature of technology products and the high potential returns from their commercialization, WH could offer future investment returns to platforms.

Bridge Path n_2 : Asset-light operation partnerships for product testing environments and equipment with downstream companies are established through government facilitation. The production costs of downstream companies can be significantly reduced using WH technology products. However, information asymmetry and a lack of trust exist between WH and downstream entities. Government intervention can facilitate information channels and enhance mutual trust. Without affecting their production capacity, downstream companies adjust their production lines to test WH technology products.

In conclusion, technology-based entrepreneurial teams depend on collaborators, such as the government—accessible due to their technological advantages—to establish connections with more resource partners and engage in resource bricolage, ultimately forming a bridging resource network. The resource integration behavior of technology-based entrepreneurial teams demonstrates the feature of accumulative resource integration and eventually leads to the formation of exploratory resource capability (Figure 4).

4.2.2. Comparison of Paths for the Maintenance of Asset-light Operations: From the evolution of Symbiotic Relationships

The formation of symbiotic relationships among resource collaborations is the core factor in maintaining and stimulating the efficacy of asset-light operation. Moreover, due to the distinct interest points of the collaborating parties, differentiated evolution paths of symbiotic relationships have emerged (Figure 6).

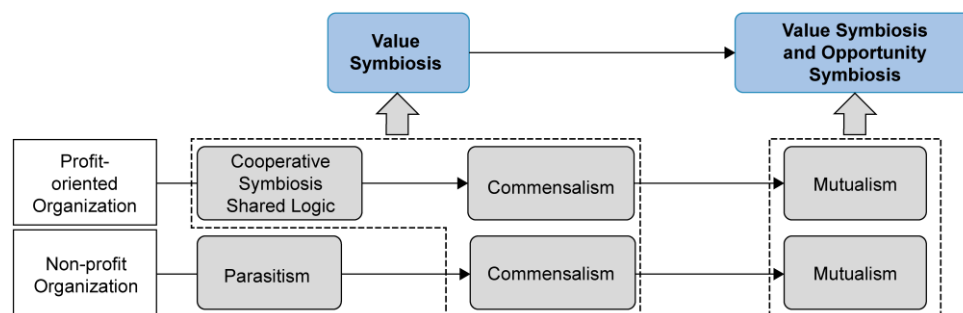


Figure 6. The evolution of symbiotic relationships

4.2.3. Evolutionary Path of Symbiosis with Non-profit Organizations

The evolution of symbiotic relationships between technology-driven startups and the government as well as incubators follows a similar pattern, transitioning from parasitism to commensalism and ultimately to mutualism. Initially, technology-driven startups derive benefits without providing immediate returns, resulting in a parasitic relationship. However, government and incubators, owing to their service-oriented and non-profit nature, accept this dynamic. With the generation of revenue from technology-driven startups, the government receives tax benefits, and incubators can secure investment returns. However, the symbiotic benefits generated in the early stages of revenue remain lower than those provided by the government and the incubators, leading to commensalism. As asset-light operations integrate and cycle, symbiotic benefits continue to grow, and the relationship gradually evolves from commensalism to mutualism.

4.2.4. The Evolutionary Path of Symbiosis with Profit-oriented Organizations

The essence of enterprises is to pursue maximum profits, making it difficult for profit-oriented enterprises to form a parasitic relationship with technology-driven startups. Thus, in technology entrepreneurship, a pattern of evolution from shared logic → strong commensalism → weak commensalism → mutualism is observed in the relationships with upstream and downstream companies. Initially, asset-light partnerships are formed through shared logic, constructing a formal symbiotic relationship with constructive collaboration but limited resource integration. Upstream and downstream companies benefit from access to the latest technical information and improve certain production processes by improving technological products. However, the benefits to technology-driven startups outweigh those to their partners, leading to strong commensalism. With further technological product development, this dynamic shifts toward weak commensalism. Once the product gains market acceptance, it provides a large market for upstream companies and reduces production costs for downstream firms. At this stage, these upstream and downstream companies become stable suppliers and market resources for technology-driven startups, establishing mutualism.

5. Discussion and Conclusion

5.1. Summary of Findings

This study employs a longitudinal case analysis and horizontal case comparison of two technology-driven startups from China to examine the construction path of asset-light operations. The main research findings are as follows:

First, the resource gap and limited funding drive technology-driven startups to adopt asset-light operation modes that use industrial chain resources. The high technological integration between technological products and industrial chains facilitates connectivity, shaping the perception and definition of asset-light operations. Through the development of an asset-light technology entrepreneurship resource network, these startups gradually achieve the integration and coexistence of asset-light operation with cooperative enterprises.

Second, based on imprinting theory, the heterogeneous asset-light resource integration path caused by the difference in entrepreneurial team resource endowment was analyzed through case comparison. Relationship-based entrepreneurial teams accumulate diverse relationship resources owing to their members' diverse prior careers. Their asset-light operation paths exhibit diffusion characteristics, focusing on expanding new resource partnerships as the main channel for resource integration, and finally demonstrate the expansive resource capability. By contrast, technology-based entrepreneurial teams are characterized by a bridging approach to constructing asset-light operations as they possess strong technical expertise but lack relationship resources. Their resource integration is based on using existing resource partnerships and forming extended channels for resource acquisition, eventually leading to the formation of exploratory resource capability.

Third, establishing symbiotic relationships is a key path to maintaining cooperation in asset-light operations. Our analysis reveals that in the initial stages of asset-light operations, technology-driven startups establish symbiotic relationships through shared logic to promote cooperation in asset-light operations. Both parties exhibit a spiraling symbiotic relationship, progressing from shared logic/parasitism to commensalism and ultimately to mutualism. However, the symbiotic relationships differ owing to the varying operational objectives of the cooperating parties. For government and non-profit incubators, the symbiotic relationship evolves from parasitism to commensalism and then to mutualism. Conversely, for upstream and downstream enterprises seeking profits or resources, the relationship evolves from shared logic to strong commensalism, weak commensalism, and ultimately mutualism. Regardless of partner type, these symbiotic relationships generally transition from single-value symbiosis to coexistence of value symbiosis and opportunity symbiosis.

5.2. Theoretical Implications

First, current research predominantly focuses on asset-light operation pathways in spin-off entrepreneurship (Li et al., 2020) or established enterprises (Yi et al., 2024). Our findings address the research gap in the mechanisms

of asset-light operations in independent entrepreneurship and complement the theory of asset-light operations in the entrepreneurship field.

Second, unlike current research on entrepreneurial resource integration, which primarily examines influencing factors (Engel et al., 2017) or acquisition channels (Grilli & Marzano, 2023), this study integrates the resource dependency theory framework of external resource acquisition → resource subject interaction → resource strategic behavior. This research contributes to a deeper understanding of the resource integration behavior and evolutionary process of technology-driven startups in asset-light operations, enhancing the theoretical diversity of research on resource integration within the independent techno-entrepreneurial sector.

Finally, this study emphasizes the maintenance process of asset-light operations in technology-driven startups, which further expands the research content on asset-light entrepreneurship. Existing research primarily focuses on the generation of asset-light operations in entrepreneurial enterprises (Yi et al., 2024) and lacks an in-depth analysis of how to maintain asset-light operation cooperation. Based on symbiosis theory, our study analyzes the role of symbiotic relationships in maintaining asset-light operations and the evolutionary process of symbiotic relationships. This represents an application and extension of symbiosis theory and provides a new perspective for research on asset-light operations.

5.3. Practical Implications

This study presents several effective approaches for establishing asset-light operations.

First, the advancement of technological products is a sufficient condition for asset-light operations, and technological adhesion of these products within the industry chain is a necessary condition. Strong technological integration facilitates initial asset-light operational partnerships during the positioning stage. Therefore, identifying key technological integration points within the industry chain is crucial during the preparation phase, as it significantly enhances the efficiency of asset-light operational partnerships.

Second, fostering a shared logic in the initial stages of asset-light operations helps these firms address the lack of technological advancement and complementary resources. This approach facilitates the formation of preliminary formal operational collaborations.

Additionally, participating in asset-light operations offers traditional manufacturing firms a pathway to enhance their technological innovation capabilities. Traditional manufacturers often struggle with inadequate R&D performance owing to a shortage of technical personnel and limited access to cutting-edge innovations. By offering equipment or specialized production environments to technology-driven startups, traditional manufacturers can acquire technological products aligned with their development, facilitating technological updates and process improvements.

5.4. Limitations and Future Research Directions

The cases selected for this study focused on the manufacturing sector; however, its applicability to sectors such as pharmaceuticals, telecommunications, tourism, and finance remains unverified. Future research could expand the selection of firms to include a broader range of industries, enhancing the generalizability of the findings.

Moreover, as asset-light operations evolve, firms' partnerships become increasingly complex. A critical future research direction involves exploring how firms can establish an ecosystem for asset-light technology entrepreneurship during resource capability development. Further investigation is needed to understand the operation, structure, functioning, and potential benefits of such an ecosystem.

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