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Providing Appropriate Technology for Emerging Markets: Case Study on China's Solar Thermal Industry

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Abstract: Building on a case study of five Chinese solar thermal companies and one association, our study aims to understand how the innovator's choices regarding the use of technology and organizational practices for new product development enable companies to design and diffuse appropriate technology in emerging markets. The study uncovers two critical factors that enhance the appropriateness of technology: redefining the identity of technology and building a local supply system. Our analysis shows that synergic innovation in both architecture and component leads to the appropriate functionalities desired by emerging markets. Moreover, modular design and the building of a local supply system enhance the process appropriateness of technology. Our study provides an empirical basis for advocating going beyond minor adaptations of existing products to creating appropriate technology for emerging markets, and extends our understandings of the upstream process of designing appropriate technology. Moreover, the emphasis on the local supply system reflects a holistic framework for shaping and delivering appropriate technology, expanding the existing research focus on the perspective of the technology itself. Our research also has managerial implications that may help firms tap into emerging markets.

Keywords: appropriate technology; technology identity; local supply system; emerging market; architectural innovation

1. Introduction

Scholars argue that emerging markets provide important growth opportunities to firms. Specifically, much research considers low-income markets in emerging economies as largely untapped opportunities for viable business ventures [1,2]. Companies that position themselves in these fast-growing markets have significant advantages, as they can capture the most attractive market segments [3]. Furthermore, emerging markets are becoming drivers of fundamental innovation in both products and the business system as a whole. A growing number of companies are initiating successful innovation and entering emerging markets [4,5]. In response to these phenomena, the extant literature has paid attention to innovation in emerging markets from different perspectives [3,6,7].

Recent literature emphasizes that emerging markets are redefining innovation trajectories [8,9]. This is leading to a broader discussion about the applicability of the findings presented by traditional innovation research in emerging market contexts [10]. Therefore, firms need to redesign their innovation strategies for entering emerging markets. Give the unique environments of emerging markets, the "appropriate technology" (AT) movement calls for a consideration of the characteristics of local environments and the appropriateness of the technology provided for local markets [11]. According to Schumacher, technologies appropriate for low-income emerging economies are small-scale, labor-intensive, easy to use and repair, and harmless to the environment [12]. As technologies from developed nations are often too complicated and expensive for customers in emerging markets [13], the AT perspective could help firms identify a new type of innovation appropriate for the specific characteristics and demand features of emerging markets. Meanwhile, as AT requires reconfiguring local manufacturing system [14], it has the potential to enhance local employment and efficient use of local resources. Therefore, AT opens up possibilities of aligning the objectives of firm innovation and sustainable socio-economic development.

This paper chooses AT as the main theme, because AT is a specific kind of innovation that can play vastly increased role in the emerging world such as China [15]. AT emphasizes the important role of demand side factor in inducing innovation. That is, AT calls for innovation based on the different local characteristics and demand features. Such local characteristics and demand features often stimulate new family of innovations which are particularly appropriate for the environment and the low-income consumers in emerging markets. More importantly, AT for emerging economies has the potential to be applied all over the world, known as reverse innovation [9,14]. Therefore, AT is a promising innovation direction that provides new business opportunities. Accordingly, it is interesting to explore how the demand of AT induces new family of innovation, and how companies organize their innovation initiatives to design and deliver AT to align business opportunity and social development.

However, the extant literature on innovation has not paid enough attention to the process of designing and providing appropriate technologies in emerging economies [16]. Some scholars argue that traditional innovation models can be easily used in emerging markets [17,18]. Although some studies discuss the potential of emerging markets as new innovation opportunities [7], the literature focuses on business model innovations for promoting the application of preexisting technologies in emerging markets. Research on the design and diffusion of appropriate technologies in emerging markets is lacking [16]. As a result, the research pays little attention to the upstream processes of innovation in appropriate technologies.

Another research gap is related to the AT concept itself. The definition of AT has been debated since Schumacher (1973) initiated the AT movement [19]. One critique of the AT movement is that, designed for poverty issues, it is not driven by a profitable and sustainable business model [12]. Therefore, the challenge is to align the concept of AT with the broader perspectives of innovation theory to create more flexible and innovative solutions. A review of the relevant literature reveals a paucity of knowledge on this topic.

In response to the arguments above, this study examines how to design and develop appropriate technologies that meet the specific requirement of emerging markets. Given the limited prior theory and empirical research, we use an inductive, multi-case method to examine five solar companies in China's solar thermal system (STS) industry. We focus on the companies' initiatives in technology selection, product design, and production organization, as well as the means by which these companies deliver AT for customers in emerging markets. We identify two primary constructs that underlie the successful design and development of appropriate technologies: redefining the identity of the technology and building a local supply system. Identifying these constructs is a major step forward in our understanding of the upstream process of AT development; thus, our research contributes to the literature on innovation in emerging markets. Our research also has important managerial implications that should help firms design an innovation strategy for tapping into emerging markets.

We focus on China because it is an enormous emerging economy with huge potential purchasing power. The low-income market in China is currently the second-largest after India [20], and it displays the unique characteristics of an emerging market environment, such as a lack of robust infrastructure and weak institutional arrangements. The low-income market in China provides both opportunities and challenges for the study of firm innovation. Furthermore, we study China's solar thermal industry because it is a successful example of designing and developing an AT targeting low-income groups in an emerging market. Solar thermal technology in many countries is not as successful as expected, but it developed very quickly in China, and via a bottom-up pattern, meaning that the technology diffused into low-income areas first and entered the high-end market afterwards. By the end of 2007, China's solar thermal system had an installed capacity of 80.8 GW, far exceeding the 15.9 GW in Europe and the 4.9 GW in Japan [21].

The rest of this paper is structured as follows. First, the paper reviews the extant research on AT and related theoretical perspectives, and presents the research design based on the literature review. Second, the paper analyzes the activities and strategies for designing and developing appropriate technologies in emerging markets based on existing research and a case study on the solar thermal industry in China. Finally, the paper closes with a discussion and concluding remarks.

2. Literature Review

2.1. Innovation for Emerging Market

The unique characteristics of emerging markets pose challenges for firms. Due to income disparities, there are large populations of low-income groups [22], known as the "people at the bottom of the pyramid" (BoP) [1]. Consumers in BoP markets are price-sensitive, with skills too low-level to use products with complicated functionalities [18,23]. Furthermore, due to infrastructure deficiencies, products for such markets need to be robust to harsh environments [24]. As service and repair are not readily available in emerging markets, products suitable for such a context need to be maintainable at the local level [3].

The constraints surrounding emerging markets also affect the kind of technology appropriate for such markets, including financial constraints, limited access to complementary infrastructure, and an insufficient knowledge, information, and skills base [2,25]. Furthermore, due to infrastructure deficiency and institutional voids in emerging economies, firms often need to build entire business ecosystems from scratch [26,27]. Accordingly, products and services need to be redesigned dramatically to meet the specific requirements of emerging markets.

Few studies focus on the upstream processes of innovation of appropriate technologies for emerging markets [28]. To address this gap, we draw on related literature to explain how firms respond to the features of emerging markets and develop products or services with functionalities different from those offered in mainstream markets. Specifically, we draw on research on appropriate technology to examine how to design products appropriate for emerging markets [11]. We also draw on the framework of disruptive innovation to explore how firms respond to demand in BoP markets [29,30].

2.2. Appropriate Technology

Realizing that technology developed in high-income countries was inappropriate for low-income countries, Schumacher (1973) advocated "appropriate technology" (AT), which would be compatible with the income levels and living conditions of low-income groups in emerging economies [11]. According to Schumacher's definition, technologies appropriate for low-income emerging economies are small-scale, labor-intensive, easy to use and repair, and harmless to the environment [12]. Unlike the traditional practice of redesigning existing technologies to lower prices, the concept of AT calls for creating breakthrough innovation. [6] Such technology could improve the economic conditions of those in emerging markets by meeting their demands and developing their capabilities using available resources. The AT view is consistent with the concept of inclusive innovation, as the latter also addresses innovations that create or enhance opportunities to improve the wellbeing of low-income groups in emerging markets [6]. The concept of AT is also unique in emphasizing the small-scale and labor-intensive features of the innovation.

However, the definition of AT has been criticized for decades. Regarding the view of AT as small-scale, labor-intensive, and operated by the local community [11,19], some scholars point out that these standard AT requirements are neither necessary nor easy to achieve [31]. According to their research, the AT movement consigns poor countries to a state of perpetual underdevelopment, whereby low-income groups become locked into the use of unproductive and inefficient technology [32]. Furthermore, the failure of initial AT projects that were not profitable caused people to reconsider the technology selection issue from the perspective of business [33].

Based on the arguments above, some research suggests extending the notion of AT, and integrating advanced Western technology with products or services designed to meet local needs and resource characteristics [34], arguing that AT can be "advanced" and based on modern technology [35]. Thus, advanced technologies should not be considered inappropriate. The recommended objective of AT is to achieve an understanding of new technology and develop innovation and technological capabilities on the basis of such modern technology. Thus, research on AT is converging with research on the technological catching-up and leapfrogging of firms in emerging economies [12]. Accordingly, AT offers an effective way to build indigenous technological capabilities for these firms.

Other scholars suggest a broadened notion of "appropriateness" whereby new technology must be compatible with not only the income level of local users but also the resource availability and existing technology and production model of the local environment [36]. An AT should also be culturally/socially appropriate and compatible with users' norms and routines [37]. Moreover, the literature on the BoP strategy calls for extending the notion of the "appropriateness" of innovations from the technology perspective to include the appropriateness of the business model. The delivery mechanisms in such business models often entail initiatives in local capability building and encouraging partnerships with local organizations [25,38].

Overall, some aspects of the AT philosophy have practical implications, such as building local capabilities related to local contexts. As AT is simple, it enables more people to use the technology and thus enhances capacity development and knowledge accumulation [39]. Thus, AT provides possibilities for positioning a new type of innovation appropriate for the emerging market context. However, critiques of AT also require an extension and further development of the term. In response to the call for an integrated approach that brings together various theories in research conducted in emerging economies [40], our research tries to integrate AT with other perspectives on innovation research. For example, the creation of new markets for BoP groups in emerging markets through the redesign of products and delivery platforms is closely aligned with the concept of "disruptive innovation" [41]. Therefore, integrating related bodies of literature could help us to better understand the mechanism for designing and diffusing AT for emerging markets.

2.3. Disruptive Innovation

Disruptive innovation is a type of innovation that provides performance packages that are not valued by mainstream customers [30]. Despite being inferior to established products in terms of the dimensions valued in mainstream markets, disruptive innovations offer other benefits; for example, they are typically cheaper, simpler, smaller, and sometimes more convenient. Their lower performance makes them unappealing to existing customers, yet they often attract new, less demanding, economy-minded customers. Disruptive innovations first benefit the poorer and less-skilled before shifting upward toward members of higher tiers. With improvements in performance, a disruptive innovation can eventually disrupt mainstream markets [42,43]. A disruptive innovation involves new designs for products, processes, or business models that challenge established value propositions and drastically change the industrial structure. Firms that take on the challenge of developing cheaper, simpler innovations with features customized for low-end markets can experience growth by initially competing against non-consumption. By using under-served markets as the testing ground for refining disruptive innovation and gradually improving their performance, such firms may eventually be able to attack mainstream markets [8].

In emerging economies, new customers with fluid needs and behaviors can be served with new technology in a flexible business context [44]. Thus, emerging economies can provide a great opportunity for disruptive innovation. Given that large populations remain underserved in emerging economies, firms are increasingly realizing growth opportunities by creating disruptive innovations for this niche [45,46]. Such innovations must be easily available, accessible, and affordable; compatible with the user's knowledge base, skills, and culture; and have a relative advantage over existing products [3,47]. The product characteristics must be compatible with their socio-economic context, robust enough for harsh environments, and require only minimum skills for easy use [10,24]. Thus, disruptive innovation provides a feasible way for firms to craft AT for emerging markets.

However, firms in emerging economies need to take the initiatives to exploit the opportunity presented by disruptive innovation [44]. Evaluating the potential of disruptive innovation is difficult [48,49]. Furthermore, serving non-customers who demand different functionalities often requires established firms to change their value and routine dramatically, and to build new processes and capability bases [50]. Such requirements impose challenges on firms attempting to initiate disruptive innovation. As a result, firms need to reengineer traditional innovation processes [29], reallocate resources [51], realign organization structures [52], and instill an organizational culture that can deliver disruptive innovations [49].

All of these findings assist firms in identifying and managing disruptive innovation. However, most of the extant literature focuses on how different types of firms should respond to pre-existing disruptive innovation, while leaving upstream processes of innovation as a black box [13]. While some research tries to explain how to identify candidates for disruptive innovation [51], in-depth studies on the innovation process itself are scarce. Using evidence from the Chinese solar thermal industry, our research tries to bridge this research gap by studying the innovation process that enables firms to develop and diffuse innovation in emerging markets.

Satisfying emerging markets does not require providing stripped-down versions of products for users there. Instead, companies need to provide value-added technologies and products compatible with local contexts [1,53]. Furthermore, companies need to consider innovations beyond the product and technology perspectives, and focus on the total value network. While some models might work well in the context of emerging markets, the unique characteristics of the new environment demand a model re-design. Therefore, we need more research on innovation processes suitable for emerging markets, including not only the design of new product properties but also the building of supply systems compatible with the socio-economic context [25].

The emphasis here is on a contextualized model, incorporating the characteristics of and conditions surrounding emerging markets. The driving of consumption by consumers in emerging markets will trigger a new family of innovations different from those in high-end markets. Moreover, the context of emerging markets is inducing technical change that affects process technologies. For example, small-scale indigenous firms might develop an architectural innovation that relies less on large-scale production. These induced technical changes in processes might also lower entry barriers and facilitate decentralized production models, thus meeting many of the criteria discussed by Schumacher (1973). Most importantly, such technical changes will allow for business-driven participation instead of philanthropy-based sponsorship.

In sum, innovation for emerging markets offers opportunities for extending existing theory on innovation. In-depth analyses of this issue could offer new variables and relationships describing how to design and diffuse innovations appropriate for the context in emerging markets.

3. Methodology

Since our topic is new and unexplored, we follow an exploratory research design [54,55]. Qualitative research, rather than traditional quantitative empirical tools, is particularly useful for exploring implicit assumptions and examining new relationships, abstract concepts, and operational definitions [56,57]. We adopt a multi-case, inductive study to analyze the strategies firms use to develop appropriate technology for emerging markets. An exploratory methodology such as this has been recognized as being particularly useful for researchers interested in examining strategies in emerging economies [58]. In doing so, we hope to facilitate theory-building in this area and the development of constructs for further empirical research.

3.1. Case Selection

The initial research questions provided guidance for this study and helped us to identify meaningful and relevant activities [55]. This study applied the following criteria in selecting the cases. First, the selected cases required innovation activities specific to an emerging market environment and had to provide appropriate products or services specific to emerging market contexts. Second, local firms had to play a dominant role in the industry. Third, the selected cases had to be financially sustainable and scalable (i.e., the business in the case required the potential for large-scale commercialization).

Given the above criteria, the solar thermal industry was selected. To promote the application of solar thermal systems in rural China, a large number of companies in the industry initiate innovation in product design and business models. The solar thermal industry therefore provides a valuable analytic setting for this study.

The case selection processes were carried out iteratively using theoretical sampling for the research participants [54]. The information obtained from the initial data analysis guided decisions on what data to be collected next and where to find them, leading to modifications of interview questions and the selection of the next research participants as we progressed. During this process, the researcher examined the data, looking for new avenues of exploration, unexpected outcomes, and emerging topics. The analysis of the data involved the ongoing iterative processing of transcripts in order to establish patterns in the data. These patterns served as input for the critical analysis, which included reviewing the whole process and structures, evaluating the outcomes, and identifying opportunities to build new constructs. Thus, new construct development emerged from the continuous interplay between the research cycle and the conceptual framework.

The addition of new cases ceases when the researcher reaches theoretical saturation [59]—when many observations have already been considered and consequently the incremental additions of new case to understanding are slight. The developed core concepts saturated after 20 research participants from five solar companies had participated in the study. The five companies are similar in terms of products, so we can explore similar technology development patterns. The cases vary in terms of organization structure and positioning in the industrial chain, so we can compare the effect of different production and innovation diffusion patterns adopted by different companies. We also interviewed the Association for the Application of Solar Thermal Technology (AASTT) to learn more about the background of the industry (see Table 1).

Table 1. Details of the Cases [a].

Company/Organization	Business	Location
HM	Produce solar thermal system	Shandong
LN	Produce solar thermal system and the vacuum tube	Shandong
SL	Produce solar thermal system	Shandong
TH	Produce solar thermal system and the vacuum tube	Beijing
TY	Produce solar thermal system	Jiangsu
AASTT	Coordinate and guide the development of the industry	Beijing

Note: [a] The company names are substituted with codes for consideration of secrecy.

3.2. Introduction of the Solar Thermal Industry in China

Development of China's solar thermal system (STS) industry began in the 1980s. Solar thermal systems are used to heat water for households and other places that use hot water. Competing with electric- and gas-based water heaters, STS can meet the normal demand for hot water at low cost, with low local infrastructure requirements.

Solar thermal systems have been targeted mainly at low-income families in rural areas and small towns. Chinese solar firms have been active in technological innovation, production modes, and delivery pattern design to promote the diffusion of STS in the targeted markets. Since the 1990s, China's STS market has grown very fast. For example, annual production grew from 500 thousand m^2 in 1991 to 13 million m^2 in 2004, with an average annual growth rate of over 28% [60] (see Figure 1). By 2004, the cumulative installations of STS in China (more than 60 million m^2) accounted for over 70% of the global market. China now has the largest STS market in the world.

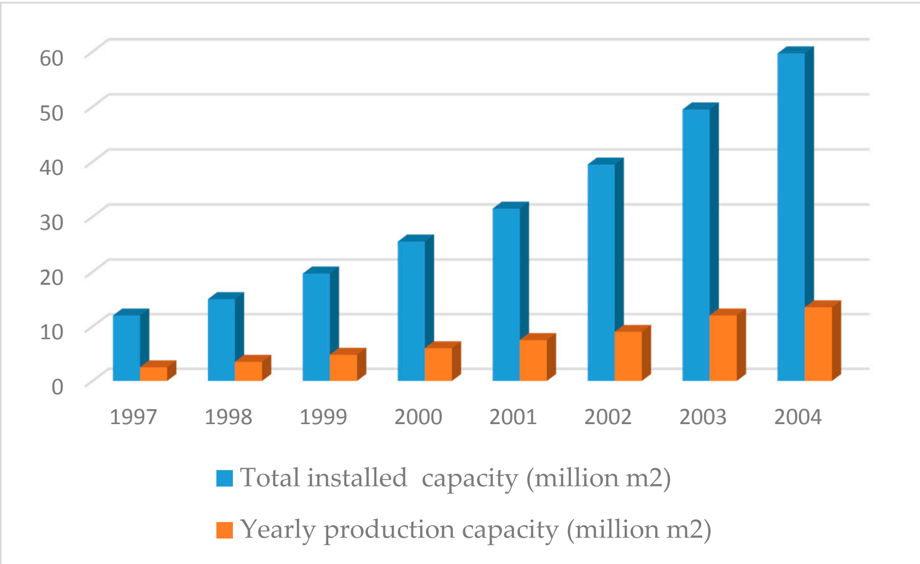

Figure 1. Total installed and yearly production capacity (million m^2) of STS in China by year. Sources: Li (2005) [22].

Three types of STS are used in China: STS with evacuated tube collectors, STS with flat plate collectors, and STS with combined storage collectors [60]. Among these, STSs with flat plate collectors are introduced from abroad, while STSs with evacuated tube collectors are developed by Chinese universities and companies. The flat plate STS dominates the market outside China, but STS with evacuated tube collectors is the leader in China. The flat plate STS cannot operate well in China's rural areas, where water pressure is unstable. Moreover, the core component of the flat plate STS, the flat plate, is made of heavy metal, which makes the product very expensive for most low-income Chinese families. In response to this problem, Chinese solar companies are working with universities to redesign the STS to make it fit local conditions.

In 1984, Tsinghua University invented the technology of "magnetron sputtering gradient aluminum-nitrogen/aluminum sun selective absorption coating", which made the production and commercialization of STS with evacuated tubes possible. Subsequently, researchers at Tsinghua University improved the quality of the evacuated tubes and started to promote the diffusion of the technology and cultivate the Chinese solar thermal industry [61].

The evacuated tube is made of glass, a locally available low-cost material. Therefore, the evacuated tube STS is much cheaper than the flat plate STS. Most importantly, TH, a leading solar company, has simplified the STS architecture. The new architecture is mainly comprised of evacuated tubes with absorption coating to assimilate heat from sun, a water tank to store water and maintain heat, water pipes to connect the evacuated tubes with the water tank, and a supporting structure for installation in a flat field or on top of a building. This simplification has lowered the price of evacuated tube STS dramatically.

The product properties of the evacuated tube STS are considered appropriate for meeting the demand of the low-income groups in rural areas. With the spread of production technology and the maturation of the industrial system, many small and medium-sized enterprises (SMEs) were set up in most provinces to provide local solutions. As a result, the market shares of the evacuated tube STS rose from 35% in 1997 to 88% in 2004. The evacuated tube STS became the dominant product in the Chinese market. China's evacuated tube STS is now benefitting the world, as Chinese solar companies are starting to export the technology and products to other countries.

The development of this evacuated tube STS industry provides a good opportunity to study how the solar companies design and diffuse AT in a complex context in which the social setting and environment differ from those in advanced economies. To simplify, we use "STS" to refer to the evacuated tube STS henceforth.

3.3. Data Collection and Data Analysis

Using data triangulation [55], we collected data from multiple sources, including interviews with solar firms, archival materials (e.g., reports of the International Energy Agency and the AASTT), and published papers on STS in China. This multiple data-source approach guarantees the validity of our findings. Following the triangulation principle, we asked multiple interviewees the same question and compared their answers. We also established a reference memo based on the archival and public materials collected during and after the field studies. We used this information to crosscheck first-hand data from the field studies in order to minimize biases caused by the interviewees' subjectivity and the retrospection bias.

Data collection involved several overlapping steps [55]. Beginning in 2012, two research assistants conducted an exhaustive search for existing cases and other archival information on the application of solar thermal technology in China's rural markets. In addition, from 2012 to 2013, companies were selected for further in-depth analysis, which included collecting archival material and, where possible, contacting key informants. Concurrent with the collection and analysis of the archival materials and case studies, interviews and discussions were held with managers of the solar companies. Extensive discussions were also held during this period with companies involved in the rural solar thermal business. Data collection occurred for years until our research reached theoretical saturation [59].

The data analysis includes onsite case analysis and synthesized cross-case analysis. The two phases are intertwined. When collecting and classifying materials from each case study, we also started to analyze, examine, compare, conceptualize, categorize, and code the qualitative data. When the field study in one case was finished, we conducted initial analyses of it. Every new field study and analysis was based on prior field studies. After having analyzed five cases, we went through all the original material again; at the same time, we compared the coding results of the cases with each other, summarized them a second time, and formulated the cross-case data coding results.

This study used grounded theory to deal with the coding process, which allowed us to go back and forth between the data and the emerging theoretical arguments [59]. First, the research group developed a narrative account of the findings by chronologically ordering the raw data, including quotations from interviews, documents, annual and committee reports, and field notes. To reinforce our understanding of the events as reflected in the emerging narrative, the research group checked the accounts with a set of informants from different companies. We used Nvivo 8.0 to accomplish this analysis. Our coding scheme built a map of the activities of different companies, paying particular attention to the variety of practices the companies engaged in to design and diffuse AT.

Second, we adopted a three-step coding procedure to analyze the narrative material [62]. The first step involved the creation of first-order codes and categories. The research group used Nvivo to keep track of the emerging categories and to view similarly coded texts simultaneously, which helped us manage the large amount of data. Following the procedures suggested by Miles and Huberman [63], the first categorical codes provided descriptive labels for the different sorts of activities that we observed. The codes were largely built upon the vocabulary of the interviewees. Once codes were named and categories developed, the research group returned to the data to check for categorical fidelity. During this process, we either corrected a category or reconceptualized it when the revisited data did not fit it well.

The second step involved axial coding [62], wherein the research group compared the first-order codes with one another to clarify themes and to create second-order constructs. This was an inductive, recursive process through which we identified a set of more abstract, theory-rich constructs. The axial coding was done by individual researchers as well as jointly by the research team. The team met numerous times to create constructs and assess the categorical fidelity of the emerging codes. These iterative discussions helped to refine the code base and to delimit the emerging theory [64,65].

Finally, in the third step, the research group identified important dimensions from the sets of second-order constructs. Next, we generated alternative theoretical frameworks to make sense of how these constructs related to one another and to the literature. Then, we worked through the relevant insights each one provided. We consolidated these available factors into two broad theoretical dimensions: "redefining technology identity" and "building local supply system". The theoretical dimensions resonated with the data and provided further analytic guidance in elaborating how to provide AT for emerging markets.

Figure 2 provides an overview of our analysis process, showing the first-order codes, second-order constructs, and the aggregate theoretical dimensions in our analysis.

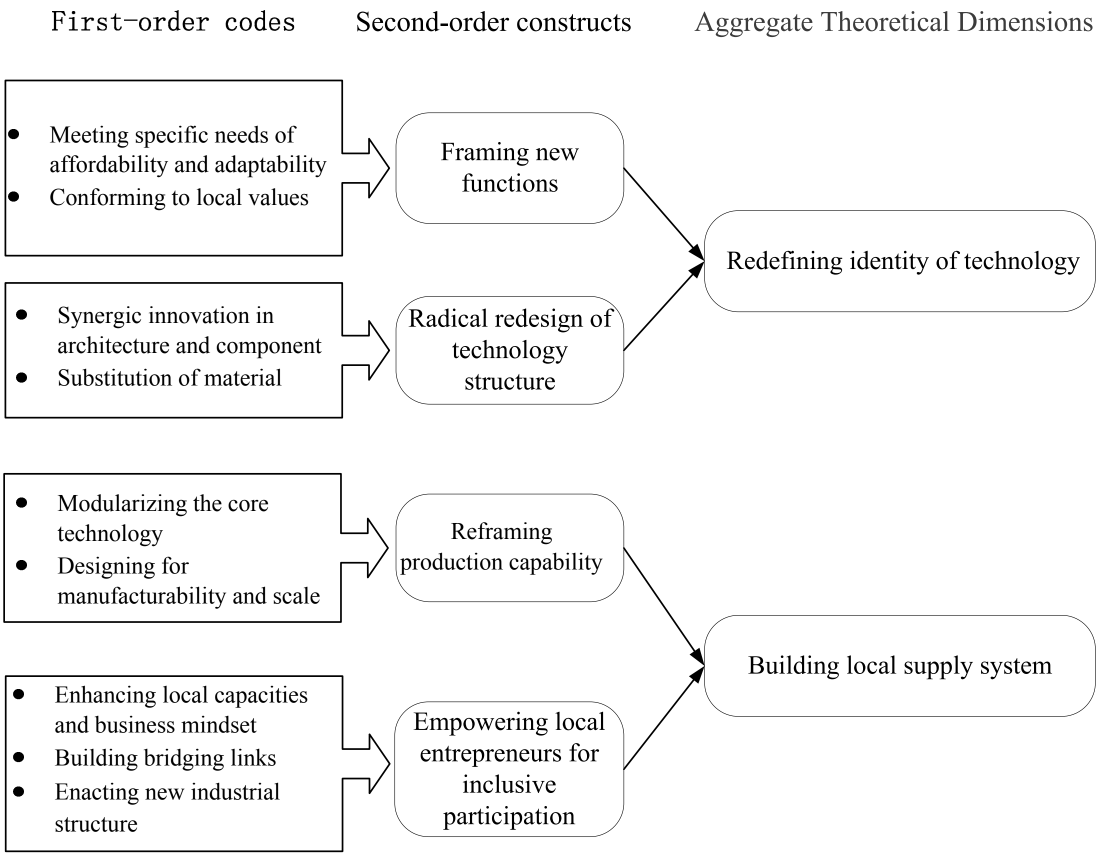

Figure 2. Coding process for obtaining the theoretical dimensions.

4. Analysis and Findings

Our analysis explores the resonance between the views and experiences of the companies and abstractions characteristic of the AT literature. Our analysis revealed two broad themes: "redefining the identity of technology", related to the property of the technology itself, and "building a local supply system", related to the process domain of the technology. These emerged from our data structures and were embedded in the case scenarios. Here, we do not discuss the data analysis process in detail but only briefly report our cross-case analyses findings. We illustrate them with typical quotations from the original interview transcripts, in the same order as the three coding steps. We present our analysis in this section to develop a provisional model of providing AT in emerging markets.

4.1. Redefining the Identity of Technology

Building on the concept of *the identity of technology* set out by Faulkner and Runde (2009), our initial findings point to the "dual" nature of technology, wherein the identity of a technology is the combination of its technical properties and its use or function [66]. Based on this argument, the appropriateness of technology is defined by two dimensions: appropriate function and appropriate technical properties. "Appropriate function" means that the usage of the technology should satisfy the specific characteristics and user requirements of emerging markets. This covers how the technology will be or may be used for the users' needs and markets. "Appropriate technical properties" refers to the built-in structure, technical performance, and the phenomenological properties that give the technology its "shape" [67]; this means that the technology should possess the physical structures, characteristics, and capabilities required to perform the functions concerned. The adequacy of the two dimensions reflects the appropriateness of a technology. Thus, we obtain two second-order constructs: "framing new functions" and the "radical redesign of technical properties".

4.1.1. Framing New Functions

The first set of activities consists of framing and providing new product functions that match the specific characteristics of emerging markets and provide perceived value for the targeted users. This second-order construct aggregates two first-order codes: "meeting specific needs of affordability and adaptability" and "conforming to local values". Our analysis highlights the latter first-order code, as functional assignments should be understood as social rules [66].

How a new product is designed in terms of new product functions is critical to its acceptance among the targeted users [24]. Consistent with the extant research, our analysis finds that the functions most valued by emerging markets are those compatible with the context and the specific demand features of the users [10,37]. From a product perspective, this translates to demand for new product functions, such as affordability and adaptability under harsh condition [3,68]. In maximizing value for customers in rural areas, the solar companies focus their innovation efforts on meeting the specific requirements there. For example, due to the deficiency of gas, electricity, and other infrastructure in rural areas, rural users in China cannot use hot water to bathe most of the year. The solar thermal system, which needs only water and sunlight, provides an alternative for them. In addition, the solar thermal products imported from Western countries would not work well due to the unstable water pressure in many rural areas. In response, the Chinese solar system replaces automated control with manual operation to enable it to work well in rural areas. One company told us the following:

> *Electricity- and gas-driven water heaters are too expensive in rural areas, and STS exported from western companies (the flat-panel-based one) cannot work well in rural areas due to water pressure problem. These products above are like expensive cars which can only run on highways, but not on village roads. Our product works well even on mountain roads. It can be used wherever there is water.*
>
> —Vice president of TH

Furthermore, in emerging markets, users' economic activities often interweave with social and emotional development [38,69]. As a result, the solar companies integrate local norms and values into their product designs to create a tight blend of emotional and economic value for users. Aligning products with local values and traditions is appropriate from a local perspective, as it enables the users to integrate new technology with their traditional values. For example, the STS incorporates simple-to-use features, and it does not require consumers to change their lifestyle. Such initiatives enhance the attractiveness of the product. Thus, a new assignment of functions spreads by being adopted by large groups of users [66], as one informant told us:

> *We tell rural users: "Without boilers and electricity, [the STS] costs you only very little money, and it can make you live a decent life like city people." They like this.*

—Market Supervisor of HM

4.1.2. Radical Redesign of Technical Structure

This set of activities emerging from our analysis suggests that changes in function are precipitated by innovation in technical structure. This second-order construct aggregates the first-order codes "synergic innovation in architecture and component" and "substitution of material".

To provide the functions mentioned above, the solar companies radically redesigned both the architecture and the components of the product simultaneously. Due to the unique context and characteristics of emerging markets, slightly modifying components in existing products is not a viable strategy [16]. Instead of making trivial adaptations to an existing product, the solar companies redesign the product dramatically through innovation in both architecture and components, including using new components and reconfiguring the architecture that integrates them [70]. TH, a leading company engaged in technological collaboration with a leading university in China, redefines the architecture of STS, making it much simpler than the architecture adopted by Western countries. The new architecture mainly comprises evacuated tubes with absorption coating to assimilate heat from the sun, a water tank to store water and maintain heat, water pipes to connect the evacuated tubes with the water tank, and a supporting structure for installation in a flat field or on top of a building. Substantial reengineering in architecture simplified the product, and provided the unique functions desired by emerging markets.

Furthermore, consistent with the call for frugal use of resources in emerging markets [7], the solar companies tried to maximize the use of abundantly available low-cost resources to provide basic functions at a low price. While evacuated tubes, the core components of STS imported from abroad, are made of heavy metal, the Chinese solar companies used glass to produce the evacuated tubes. The use of glass instead of heavy metal makes the product much cheaper than those imported from abroad. An informant illustrated this point:

> *We use glass to produce the evacuated tube, the core component of our STS, instead of the heavy metal used by Western companies. This innovation lowered the costs dramatically, thus making our product much cheaper than the flat-panel-based product provided by Western companies. However, our product has some disadvantages. For example, the product cannot endure high water pressure. But it can operate well with caution in rural areas, and it is cheap and affordable for normal rural families . . . Besides, the product uses only sunlight to heat the water, and the operation cost is very low. Therefore, it is widely used in many villages.*

—President of TH

The adoption of the principles of synergic innovation in both architecture and component provides a logical low-cost option for offering the required functions with an innovative technical structure. Moreover, the simplification of the architecture and the substitution of the materials lower the cost of manufacturing significantly, thus enabling a price dramatically lower than that of the comparable product.

Thus, we have identified two dimensions that redefine the identity of technology in ways that enhance its appropriateness. The solar companies accomplished this redefinition by radically changing both the function and the technical structure of their product. In doing so, they changed the identity of STS as appropriate technology for rural users in China.

Furthermore, scholars argue that the AT production technique is important [71], positing that the "appropriateness" of technology includes compatibility with the local resource availability and production model [36]. This broadened notion of AT points to the fixity between process and product technologies [72], whereby a given product is associated with a given process (production technique). In line with this perspective, our findings highlight a second category of activities that are related to the AT process domain.

4.2. Building a Local Supply System

This category concerns the process appropriateness of technology. We focus on two questions: (1) what kind of production technique is efficient in providing AT? (2) How do companies make it happen? Addressing the controversial arguments about the "small-scale" and "labor-intensive" characteristics of AT [12,19], our analysis reveals that the production techniques of AT are not necessarily small-scale or labor intensive. Instead, the appropriateness of a production technique is dependent on resource availability and the existing production mode. That is, AT requires a fit between production techniques and technical structure, as well as between production techniques and local resource characteristics. Based on this logic, our analysis identifies two sets of activities: "reframing production capacity" and "empowering local entrepreneurs for inclusive participation".

4.2.1. Reframing Production Capacity

This second-order construct that emerged from our analysis highlights the activities the solar companies adopted to redefine the production technique that fits both the technical structure of the technology and local resource characteristics. This construct aggregates two first-order codes: "modularizing the core technology" and "designing for manufacturability and scale".

Its strong manufacturing capacity enables China to make products with a high performance–price ratio [73]. Under conditions of resource shortage, the capability to leverage these alternative capacities and resource endowments may become critically important for building appropriate production techniques. In line with this philosophy, the solar companies incorporate modularity in the architecture of STS to simplify the production process. LN, a leading solar company, integrates the parts required for STS into a set of basic modules, and keeps the "architecture", "interfaces", and "standards" stable [74]. Thus, the technology and knowledge of the key component (e.g., the evacuated tube) are embedded into modular systems. Accordingly, the subsequent production process is characterized by standardized assembly and installation, requiring only low technological capabilities. Producing STSs requires only some related structural knowledge and the purchase of modularized components. Thus, the leading solar companies have lowered entry barriers, helping local manufacturing capacity participate in the value chain.

The reframing of production techniques also involves the simultaneous consideration of cost, speed, and scale. By reconfiguring the architecture and using alternative materials and modular designs, the solar companies aim to make manufacturing as simple as possible and to achieve low product prices. Moreover, the modularity of core components enables a separation between capital- and labor-intensive processes. The leading companies provide modularized components with capital-intensive manufacturing and R&D investment to update technologies in the component. Meanwhile, for the downstream activities, the leading companies can initiate collaborative partnerships with local entrepreneurs or small- and medium-sized enterprises (SMEs) to empower a low-cost production model. Many local entrepreneurs and SMEs, acting as satellite units of the leading solar companies, purchase modularized components from the leading companies and assemble and distribute the final product to meet local needs. An informant from the solar association told us the following:

> *LN* [a leading solar firm] *just produces and sells the evacuated tube, and let hundreds and thousands of SMEs produce the final product for local needs. They* [the SMEs] *know the local context well and know what functionalities are needed. Therefore, they can assemble different components to match local demands. Besides, they know how to sell the product.*

The new low-cost assembly model is labor-intensive, with very low break-even points. Therefore, local entrepreneurs or SMEs need to operate in local areas to provide local solutions, with no need for a scale economy. The labor-intensive model, which is popular in emerging market environments [13,39], has become part of the solar industry. Meanwhile, modularity allows leading companies to provide standard modules with common features, thereby enhancing the scale economy for their capital-intensive business. Thus, the leading solar companies integrate large-scale manufacturing and labor-intensive processes into their value chain to balance low cost, speed, and scale.

4.2.2. Empowering Local Entrepreneurs for Inclusive Participation

Our analysis reinforces the argument that the diffusion of AT is interwoven with local entrepreneurship [75,76]. The technology improvement discussed above lowers the skill requirements in the production process and lowers entry barriers for local entrepreneurs. However, in an emerging economy with limited resources, entrepreneurial activities are often hindered by resource constraints and shortages of entrepreneurship [11]. In response to this problem, the solar companies initiate various activities to empower local entrepreneurs to participate in the industrial chain. Our analysis generated the construct of "empowering local entrepreneurs for inclusive participation", highlighting the activities the solar thermal companies adopted to expand the local productive opportunity space through which local entrepreneurs can participate in the solar thermal industrial chain [77,78]. This second-order construct aggregates three first-order codes: "enhancing local capacity and business mindsets", "building bridging links", and "enacting a new industrial structure".

In the early stages of the solar thermal industry, the leading companies initiated various activities to promote the diffusion of product knowledge and manufacturing technology within the industry, including training, technology transfer, and local development programs. The knowledge sharing and the abovementioned activities set up the knowledge and technology foundation for the explosive growth of the industry. For example, TH told us the following:

> *We realized that one company could not promote the industry to grow quickly enough. Therefore, we* [the company] *started to train others to join the industry since 1980s. We initiated lots of training programs for those interested in the solar thermal industry, and taught them the principles of our technology and taught them how to produce STS. We even helped some of the trainees set up their factories. Many CEOs in the solar industry had once been trainees of our programs.*

"Enhancing the business mindset" is related to the cognitive process of empowerment. Cognitive structures often shape and articulate conceptions of value and constitute shared templates that facilitate the adoption of similar patterns [77]. Isolated from sources of knowledge from the outside world, people in an emerging economy often cannot cognitively perceive opportunities to develop their own business. In response, the leading solar companies start by providing training and demonstrating the economic potential of the STS. They also urge potential entrepreneurs to think beyond existing cognitive patterns and visualize possibilities to create value from existing productive opportunities or expand spaces for entrepreneurial opportunity. These activities enhance the sense-making capability of local entrepreneurs and motivate them to seize the productive opportunities within the solar thermal industry and build up local capacity. At the same time, solar companies also provide value-added advisory services and training programs to help local entrepreneurs build their business. For example, training programs for local entrepreneurs and factory building assistance help some regions to build up local manufacturing infrastructure and institutions critical for local business.

The second first-order code explains the social dimension of empowerment. This code points out that empowerment comes from building bridging links among local entrepreneurs, solar businesses, and other external parties. The use of "bridging links" stems from "bridging social capital" in the research on social capital [79], which refers to peripheral ties that tend to be high in unique resources and low in closure [80]. The solar companies set up "working stations" within rural areas to increase the structural diversity of local networks. These working stations act as ties that bridge the community to both the solar companies and other resources needed to create local businesses. Such links help to connect entrepreneurs with fragmented local resources, thus changing the local entrepreneurs' cognition and attitudes to the entrepreneurial opportunities within the solar thermal industry. The bridging links enhance the flow of information and other resources, increase the productive opportunity space, and provide channels of access to business capabilities.

The empowerment activities of solar thermal companies enable a growing number of local entrepreneurs to set up SMEs and integrate the existing manufacturing capacity into the solar thermal industrial chain. Thus, the leading solar companies enable a new industrial structure: they provide a modularized component with capital-intensive manufacturing, whereas local SMEs act as satellite units of the leading companies, assembling and distributing the final product to meet local needs. The industrial chain and the relationship among companies in the industry are reconceptualized by reconciling constraints and resource endowments in a local context. The collaborative partnership between leading solar companies and local SMEs creates locally sustainable innovation ecosystems, allowing better solutions for different market tiers.

We have identified a set of initiatives that the solar companies undertook to build up local supply systems for STS. Our analysis highlights the importance of appropriate production techniques and production modes in providing AT. The redesign of the technology breaks from the mass production process and radically recombines it to match the characteristics of local resources. Meanwhile, the leading solar companies empower local entrepreneurs and other resources to join the value chain, thus leveraging the available local resources. The participation of local entrepreneurs and low-cost manufacturing capacity actively contributed to the attractiveness of STS by lowering costs and adding local content to the product. The SMEs are embedded in the local community and have a better understanding of local contexts than large companies have. Therefore, they could provide tailored products to meet local demand quickly and flexibly. Furthermore, the leading companies could co-design products with local SMEs, who understand local needs, and provide the required functionality. For example, the simple-version STS with only the basic functions of hot water heating and bathing could meet the basic needs of low-income families that require cheap and easy-to-use products.

In fact, before the emergence of a large population of SMEs, TH and HM used another vertically integrated production model: the companies covered the whole value chain. Neither of them could provide the functionalities required by rural users at affordable prices. Although HM attempted to cultivate the market, the product was not adopted as quickly as expected. After LN initiated the modularization of core components, local SMEs started to enter the solar industrial chain and provide low-price products with different functionalities to meet different market tiers. Thereafter, the STS was considered appropriate technology for rural areas and was adopted quickly by rural users. The following illustrates the importance of the innovation mentioned above:

> *With the leading companies producing and selling the core components of the product, there emerged thousands of SMEs entering the solar thermal industry. Afterwards, solar thermal companies are founded by local entrepreneurs in almost every province, providing local solutions for the rural areas. The emergence of these SMEs has greatly accelerated the diffusion of STS in the rural market.*

—An analyst in AASTT

5. Discussion

This study explores how companies can provide AT in emerging markets. By investigating how Chinese solar companies make their product fit the specific features and conditions of Chinese rural consumers, our case study enables a move away from abstraction toward a grounded knowledge of the factors that enhance the appropriateness of technology. These factors are uniquely important in the context of emerging markets due to their unique demand characteristics and resource conditions.

Two broad themes characterized the efforts to design and diffuse AT in emerging markets. First, redefining the identity of technology in both functions and technical structures might be necessary to ensuring a good fit between supply and demand. The technology needs to be radically redesigned to fit the demand features of emerging markets. Second, the building of local supply systems is critical to enhancing the process appropriateness of technology. Companies need to reconfigure their production techniques to fit the emerging market-specific characteristics of available resources, as well as identify, build on, and leverage local capacity to develop and diffuse AT. We elaborate on the contributions of our research below.

First, our findings reinforce the argument that calls for a radical redesign of technology to fit emerging markets [16,38]. Minor adaptations of existing products represent a change in the function of a technology within a preexisting technical structure. Our analysis suggests that this "same-technical structure–different function" form of technological change cannot fit the context of emerging markets. Specific demand contexts in emerging markets decide the features of technology that are considered appropriate. The technology must meet certain technical requirements and local users' needs, and closely match local conditions. As shown in our case study, the flat plate STS, which is introduced from abroad, cannot meet the specific needs for affordability and adaptability in China's rural areas. In response, the solar companies radically redesign both the core components and the architecture of STS, and develops the evacuated tube STS to provide the functionalities required by rural consumers. Our analysis highlights the importance of a radical redesign of the "adequate pair" of the identity of technology—the functions and the technical structure—for emerging markets [67]. When existing technology cannot adequately meet local demands such as affordability criteria, or when poor infrastructure renders the existing technology less effective, radically reframing the functions of the technology becomes necessary. As the new functions required by emerging markets are radically different from those in developed markets, radical change in technical structure is needed. Thus, our analysis illustrates that exploring AT in emerging markets consists of knowing what kind of technical structure is needed and what it can do (i.e., its functions). This finding extends the research by providing more in-depth insights into the upstream process of designing AT.

Second, in terms of technical structure, our findings illustrate that the principle of synergic innovation in architecture and components provides a logical low cost option to create AT. Redesigning core components with the use of abundant local material enables frugal use of local resources. Meanwhile, architectural innovation—new combinations of component technologies—achieves the price-performance package required by local consumers. Thus, a substantial redesign of both core components and the architecture, as well as frugal use of local resources, provides the performance packages demanded by users in emerging markets. As architectural innovation is difficult to discern, such innovation suggest a more disruptive market environment [48,81]. Our research speaks to and provides an empirical path to continue the conversations about going beyond minor adaptations of existing products to creating AT for emerging markets.

Third, our analysis reveals that a modular design yields not only cost savings but also the flexibility to customize products that meet the requirements of users in emerging markets. A modular design treats a product as a set of separable modules with "architecture", "interfaces", and "standards" unchanged [74]. Such architecture enables production techniques that combine capital-intensive manufacturing and labor-intensive assembly. As a result, local SMEs can initiate labor-intensive and low-technique assembly of subsystems, resulting in a low-cost model. This decomposition of production enables large companies to leverage the low-cost labor-intensive assembly process to provide the required price performance. Furthermore, modularity provides a platform on which a wide range of alternative functions could be added to serve multiple needs and income segments [16]. Thus, in emerging economies with resource constraints, modularity allows for scalability and flexibility, and enables the coevolution of the product, local resources, and markets.

As illustrated by our case study, critical redesign of the technology (i.e., modularization of the core components, standardization of the production process and deskilling of the production process) makes it possible to manufacture STS locally and scale up quickly in a short timeframe. Therefore, in places with local manufacturing capacities, innovations in product architecture that enable the participation of local manufacturing capacity can create a new production mode. This new mode not only creates a low-cost and flexible technological supply system but also enables the addition of local content to local solutions, thus contributing to affordability and other functionalities valued by consumers in emerging markets [10].

Fourth, our findings illustrate the importance of empowering local entrepreneurs to participate in local supply systems. The exploitation of local entrepreneurs and existing manufacturing capacities to provide AT reduces costs. However, the context in which many entrepreneurs in emerging markets operate often features resource constraints such as poor access to education and other knowledge sources. Isolated from the resources required to realize entrepreneurial opportunities, entrepreneurs in such contexts need to be empowered in order to identify and exploit productive opportunities [77]. Our analysis shows that leading companies empower local entrepreneurs in terms of two dimensions: cognitive empowerment and relational empowerment. While the redesign of technology expands the productive opportunities within the solar thermal industry, cognitive empowerment and relational empowerment improve entrepreneurs' alertness, awareness, and mindfulness for entrepreneurial activities [82]. For example, the leading solar companies initiate various bridging links with both local entrepreneurs and other partners and enhance knowledge sharing among the partners, thus connecting fragmented resources and entrepreneurs and enabling local entrepreneurs to build up SMEs to pursue low-cost innovations for local users. These empowering activities maximize the leverage of available resources such as local entrepreneurs and existing manufacturing capacities. Our findings reinforce ongoing arguments on the frugal use of local resources in crafting AT [83].

Our fifth finding relates to the new industrial structure that provides local solutions. Due to the heterogeneity of culture, traditions, and economic behavior among people in different regions, markets in emerging economies are fragmented and diverse [84]. It is difficult and economically inefficient for large companies to serve all these heterogeneous markets by themselves. On the other hand, local entrepreneurs, empowered by the leading companies, are better suited to provide localized solutions to fit local conditions and needs. Considering the comparative advantages of the two sides, the partnership among the leading companies and the local entrepreneurs is an effective strategy for balancing the serving of local needs and operational scale [27,85]. This study reinforces this argument and shows that the leading companies can build on and leverage existing entrepreneurs and labor-intensive manufacturing capacities to create more appropriate products for local users. This new industrial structure lowers costs throughout the whole industrial chain. For example, shipping semi-assembled modules to satellite factories saves transportation costs. Moreover, the participation of local entrepreneurs and related low-cost manufacturing capacity actively contribute to the attractiveness of STS by lowering costs and adding local content to the product.

The partnership mentioned above creates a new industrial structure with distributed systems that maintain both the scale capability of the large companies and the flexibility of the local entrepreneurs [8,27]. This finding supports the view that AT may not necessarily be only small-scale and labor-intensive [39]. The requirement for small-scale and labor-intensive techniques set out by traditional AT research [11,12] does not fit the recent progress in production techniques seen in many emerging markets. Rather, our analysis reveals that companies can radically redesign their technology with modern knowhow to enable new production techniques that can combine capital-intensive techniques with labor-intensive processes. This finding extends the notion of AT in the dimension of "process appropriateness": AT requires production techniques that fit the characteristics of local resources and the existing modes of local production, and it can integrate modern capital-intensive technology and labor-intensive processes.

6. Conclusions and Managerial Implications

Our study represents an attempt to explore how companies develop and diffuse AT in emerging markets. Overall, the results are in line with the extant literature on AT and the research on innovation in emerging markets [12,86]. Building on existing research, our study provides an in-depth look at the upstream process of developing AT with a more diverse repertoire of methods. Our analysis suggests that developing and diffusing AT in emerging markets will require the following initiatives: (1) radically redefining the identity of technology in terms of both functions and technical structure to meet local needs; (2) synergic innovation in architecture and components to improve the price-performance ratio; (3) simplifying the product technology through modularized design to enable a low-cost production mode; and (4) empowering local entrepreneurs to enable the frugal use of resources and enacting a new industrial structure to balance scale and local requirements.

Our findings have managerial and policy implications for companies and governments in emerging markets. First, AT requires that companies integrate demand perspective into their innovation process. Companies need to understand the unique context and characteristics of the environment in emerging markets in order to understand and explore the basic functionalities of AT. For example, the unique affordability, acceptability, and availability criteria of emerging market customers can be a starting point for designing AT. Another example is the infrastructure deficiencies and the constraints surrounding emerging markets, which might help determine the kind of technology that is appropriate for them. Companies need to maintain an open learning orientation that enables learning from unfamiliar settings and spotting transformational consumer needs; and cultural sensitivity that enables deep examination of different contexts.

Second, companies that can produce techniques appropriate for low income users can dominate these markets. Companies should identify a distinct new family of innovations, which are particularly appropriate for low-income operating environments and low-income consumers. It is essential to redesign the overall concept of the products, with respect to components, structure and efficient use of local resources. Companies need to reconfigure the innovation process to combine the deeper understanding of unpredictable product usage scenarios, the focus on local sustainability (local materials, local skills, local culture), and the leveraging of any available resources. A radical redesign of technology in both architecture and components—with the simultaneous considerations of cost reduction, local adaptation, speed, and scale—is needed to meet the elevated requirements for appropriate technology. This will probably require that companies in emerging markets be tasked with seeking opportunities to realize the redesign locally, rather than focusing on limited adaptations of imported product designs.

Third, rather than the technology becoming an end in itself, creating markets and encouraging economic activities are ways to enhance the effectiveness of appropriate technology. Therefore, companies need to pay attention to the building of local manufacturing and supply system necessary for the sustainable growth of appropriate technology and foresight about the future directions of this technology. As illustrated in our research, collaborating with local partners is an effective path to build the ecosystem for appropriate technology. China possesses outstanding capacity for producing low-cost and high-performance physical products, led by its strong manufacturing capacity and the availability of a low-cost and high-quality labor force. Leveraging and integrating existing capabilities and resources such as low-cost assembly capacities is an effective way to enter emerging markets such as China. Therefore, large companies need to develop alliances with local players in order to tap into local knowhow and the environment to develop and diffuse AT. Moreover, tapping into local partners' low-cost processes and learning routines may enable large companies to integrate a low-cost, labor-intensive model in their value chain. Networks of local entrepreneurs could also assist large companies in building or tapping into local supply chains for procuring local inputs and raw materials at low costs.

Fourth, the energy industry is considered one of the most active fields for appropriate technology. As AT requires the use of technology and materials that are environmentally, economically, culturally and socially suitable to the location in which they are implemented, it provides a feasible solution of aligning the objectives of firm innovation, social development and sustainability. Policy makers should take actions to maximize the rate at which these new vintages of innovation take place in many emerging countries. A sound public policy can create a well-functioning innovation infrastructure that raises AT output on a sustainable basis. Policies that harmonize efforts, facilitate partnerships across sectors, can result in a superior generation, exchange and transfer of related knowledge, and take AT from conception to deployment and widespread adoption. The policy instruments should be based on the principles of achieving wider impact, greater outreach, and deeper involvement of all stakeholders. To leverage the managerial and organizational efficiency, manufacturing capabilities, market knowledge, technical and industrial expertise and risk taking capability of the companies, public policy should have provisions to encourage businesses to adopt commercially sustainable business models involving AT.

7. Limitations

Although this study uses case studies and a theoretical sampling approach consistent with grounded theory, the sample's composition from a single industry limits the generalizability of the conclusions. Future studies using cases from more industries, as well as empirical studies with large samples, are necessary to extend our findings.

Another limitation arises from the main context, China. The second-order constructs in Sections 4.1.1 and 4.1.2 are related to the availability of existing industrial skills, manufacturing capacity, and entrepreneurs in China. It remains unclear whether similar patterns can be discovered in other BoP regions with significantly different contexts. Studies comparing among different regions would be worth conducting to verify the validity of the findings in different contexts.

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