RESEARCH PAPER

Frugal innovation capabilities: conceptualization and measurement

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ABSTRACT

Firms in emerging markets are rapidly developing frugal innovation capabilities (FICs) in order to harness the growth potential of these markets. Researchers have explored this frugal innovation phenomenon through case studies of such firms. This nascent domain of study has been growing, and the demand for a specialized focus on FICs and their measurement is strong. This paper aims to satisfy the demand by conceptualizing FICs using the theoretical framework of dynamic capability, developing a measurement scale, and empirically validating the scale to measure FICs. Data from the medical device and automobile sectors in India were applied for this purpose. It is proposed that FICs are a composite variable with four dimensions: value for money, acceptable quality, scalability and marketability. The confirmatory factor analysis results validate these dimensions, presenting a gateway to explore FICs and their applications.

Introduction

Emerging markets (EMs) hold within them a plethora of opportunities veiled by a highly turbulent environment (Peng *et al.*, 1999), underdeveloped institutions (Peng and Khoury, 2008), bureaucratic structures, weak intellectual property rights, unclear customer credit assessment and infrastructural bottlenecks (Khanna and Palepu, 2010). The set of opportunities evoked is driven by the rapid growth rates of EMs, resulting in the emergence of a large segment of upwardly mobile consumers at the middle and bottom of the income pyramid (Prahalad and Lieberthal, 1998). The consumer market in EMs in India is expected to reach $US 6 trillion by 2030 (*Economic Times*, 2019). These consumers demand affordable products with a quality that is comparable with that of market leaders (Zeschky *et al.*, 2011; Bound and Thornton, 2012). De-frilled/de-featured products from developed markets would fail to attract this unique consumer base (Govindarajan and Trimble, 2012). Thus, to capture this trillion dollar market, firms must rethink their innovation agendas.

Firms in EMs are revisiting the drawing board to develop innovative products that are 'good enough', customized to suit local consumer needs in terms of lower costs, portability, fewer/different features, and ease of usage/maintenance/delivery across geographically fragmented markets. The innovative products in this distinctive class are termed 'frugal innovations' (Wooldridge, 2010; Ronald Berger Consultants, 2014), and a firm's capability to deliver such innovations successfully is its frugal innovation capability (FICs).

In addition to 'frugal innovation', related terms are applied to innovation in EMs – 'Jugaad innovation' (Radjou *et al.*, 2012a), 'inclusive innovation' (George *et al.*, 2012), 'low-end disruptive innovation' (Christensen, 1997), 'resource-constrained innovation' (Ray and Ray, 2010) and 'cost

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innovation' (Williams and van Triest, 2009; Williamson 2010). Though there is a tendency to consider frugal as equivalent to cheap, researchers have shown this to be otherwise. According to Harris *et al.* (2020), frugal innovation does not indicate low quality; rather, it means providing the best possible solution within given circumstances and constraints. Further, multinational firms entering EMs are not able to offer products that are already being sold in mature markets and are instead required to redesign their products and create frugal innovations in order to respond adequately to the needs of EMs (Williamson, 2010; Zeschky *et al.*, 2011). For instance, GE had to develop a portable ultrasound machine and a handheld electrocardiogram machine for India and China as their existing American products, even if de-featured, could not be successfully offered in EMs (Zeschky *et al.*, 2011). The COVID-19 pandemic has catalysed the need for frugal innovations, especially in the field of medical devices. Makers Asylum, a makerspace in India, has developed an inexpensive face shield kit priced at INR 55 ($US 0.73), one-third of the average market price (Radjou, 2020). In fact, to combat the pandemic, EM governments are urging both small entrepreneurs and large companies to develop low-cost ventilators, personal protective equipment, and vaccines that can benefit society at large (Harris *et al.*, 2020).

It is also observed that in order to survive in high velocity and uncertain EMs, such as India (Pandit *et al.*, 2018), firms have continuously to change/rejuvenate themselves, a core tenet of dynamic capabilities theory (O'Connor, 2008). In uncertain environments, building dynamic capabilities requires new situation-specific knowledge, risk taking by company leadership (O'Connor and McDermott, 2004), rapid learning, rough prototyping (Veryzer, 1998) and exploring co-development opportunities (Thongpapanl, 2005). Firms that want to exploit opportunities in EMs recognize that the dynamic capabilities required in the current environment are different from those developed in the past (Eisenhardt and Martin, 2000). Thus, this paper leverages the advances in dynamic capability theory (DCT) to increase our understanding of firms' capabilities to develop frugal innovations. This paper not only uses the DCT framework to explore FICs, but also offers a scale to measure FICs (see Slavec and Drnovsek, 2014).

Literature review

Frugal innovation

Frugal innovation is a resource-scarce solution that is designed and implemented in a resource-constrained environment where the final solution, though significantly less expensive, is still good enough to meet consumer needs (Hossain *et al.*, 2016). Along the same lines, Agarwal *et al.* (2017) define frugal innovation as a good enough quality product for resource-constrained customers. Zechsky *et al.* (2014) state that frugal innovation involves higher technical novelty and market novelty than good enough innovations. Tiwari and Herstatt (-2012) posit that frugal innovations seek to create valuable offerings for their targeted customer by focusing on core functionalities, thus minimizing the use of material and financial resources while fulfilling or even exceeding prescribed quality standards. Bhatti and Ventresca (2013) adopt an input–output view and define frugal innovation as 'a means and ends to do more with less for more people'. Emphasizing the nature of frugal innovation, Krishnan and Jha (2011) advocate that such innovation responds to limitations in resources, whether financial, material, or institutional, and turns these constraints into advantages. Furthermore, the authors propose that frugal innovations can lower costs by minimizing the use of resources in development, production and delivery, or by leveraging them in new ways. Frugal innovations that have been successful are not only lower in cost, but also outperform the alternative and are largely scalable (Krishnan and Jha, 2011). The economic use of raw materials, reuse of components and simpler designs in frugal products, compared with their ordinary counterparts, ultimately have a positive impact on sustainability as well (Rao, 2013). Other researchers look at the export capabilities of frugal innovations and define frugal innovation as an 'innovative, low-cost, and high-quality product originating in developing countries and exportable to the developed

world' (George *et al.*, 2012). Bringing together these disparate pieces of definition for the purpose of this study and data collection, we characterize frugal innovators as those who seek to create attractive value propositions for targeted customer groups by focusing on core functionalities and thus minimizing the use of material and financial resources in the complete value chain. They substantially reduce the cost of usage and/or ownership while fulfilling or even exceeding prescribed quality standards.

Both industry examples and past research have shown that frugal innovations are better suited for rugged environments with resource constraints. Further, it is observed that EMs with large rural communities demand frugal innovations (Pisoni *et al.*, 2018). For example, to serve rural consumers, Godrej & Boyce, an Indian firm, developed an affordable refrigerator – ChotuKool – that performed under conditions of intermittent power supply (Kuo, 2017). A few studies that have examined such frugal innovations in EMs have done so through the lens of the theory of lead markets. A lead market has been defined as a country/market where the innovation is first successfully accepted, adopted and later diffused to other nations (Beise and Gemünden, 2004). Hossain *et al.* (2016) propose four patterns of diffusion for frugal innovations – local, proximal, distance and global. Local diffusion indicates that the diffusion is contained within a limited geographic region. For example, Mitticool, a clay-based refrigerator, has not diffused beyond Gujarat, a state in India. Proximity diffusion occurs when a frugal innovation diffuses to neighbouring nations with similar socio-economic conditions. For example, the Tata Ace, a sub-one-ton mini truck manufactured by an Indian company (Tata Motors Limited) was designed to navigate through the narrow and crowded Indian roads, provide better safety and comfort than the existing three-wheeled vehicles and be available at an affordable cost. This was exported to the neighbouring country of Sri Lanka, which shares similar physical/economic conditions (Tiwari and Herstatt, 2012). Distance diffusion is when a frugal innovation spreads to neighbouring as well as to distant nations. Vortex Gramteller, an automatic teller machine (ATM) that runs on solar energy, was developed in India to address the paucity of ATMs in rural regions, typically plagued by unstable power supply and non-existent climate-controlled locations. This low-cost frugal innovation ($US2,400 *vs.* $US14,000 for a conventional powered ATM) has spread to such neighbouring nations as Bangladesh, Bhutan and Nepal as well as parts of Africa with similar socio-economic and climatic conditions, but not to developed nations.

Lastly, global diffusion is when frugal innovation diffuses in all of the above three ways and also spreads to developed nations with different socio-economic conditions. Mahindra & Mahindra, an Indian firm, invented the low-cost mini tractor, Yuvraj, to meet the requirements of small and marginal farmers owning less than five acres of farmland (Bera, 2018). The motivation to create this frugal innovation lay in the fact that only 1% of small and marginal farmers in India had access to a tractor because of the small size of their farm holdings. And no existing mechanized farming solutions met their needs. This frugal innovation is currently being exported to the United States to meet the needs of backyard and hobby farmers (Hossain, 2018). Based on all of the Indian examples indicated, researchers have rightly concluded that India is a hotbed of, and a lead market for, frugal innovations (Herstatt *et al.*, 2008; Govindarajan and Trimble, 2012).

Dynamic capability theory and innovation capability

Dynamic capability theory (DCT) has its roots in resource-based theory (RBT), which postulates that firms are a bundle of heterogeneous resources, capabilities and attributes (Barney, 1991). These attributes are hard to modify (Amit and Schoemaker, 1993; O'Connor, 2008), leading RBT to claim that a firm's competitive advantage comes from the exploitation of existing firm-based assets. However, further research argues that such assets may no longer be sufficient to maintain competitive advantage during rapid changes because, in dynamic markets, the strong focus on core resources may create rigidity (Leonard-Barton, 1992) and impede the firm from adapting its resources to new

competitive environments (Zhou and Li, 2010). This necessitated the extension of RBT to assess a firm's resource configuration in dynamic environments to gain sustained competitive advantage. This, in turn, led to DCT emphasizing the role of dynamic capabilities in adapting, integrating and reconfiguring firm assets to align with the requirements of the changing environment (Teece *et al.*, 1997). Dynamic capabilities have been described as a combination of the capacities to (a) sense and shape opportunities, (b) seize these opportunities and (c) maintain competitiveness through enhancing, combining, protecting and, when necessary, reconfiguring the business enterprise's intangible and tangible assets (Teece, 2007). In order to gain sustainable competitive advantage, especially in EMs which are characterized by high volatility and complexity (Khanna and Palepu, 2010), firms require dynamic capabilities to sense and seize market opportunities (Dixon *et al.*, 2010). In other words, firms have to build on the 'innovation function of dynamic capabilities', going beyond the mere utilization of existing capabilities (Dixon *et al.*, 2010) and seeking fresh ways to capitalize on the knowledge gained in EMs (Kogut and Zander, 1996).

Akman and Yilmaz (2008) define the aforementioned innovation function of dynamic capabilities as one that facilitates an innovative organizational culture and promotes internal activities and capabilities to understand and respond appropriately to the external environment. Adler and Shenbar (1990) define innovative capability as the capacity to respond to unexpected opportunities created by a dynamic competitive environment. Sher and Yang (2005) emphasize the importance of dynamic environments in highlighting how innovation capability works, stating that firms possessing such capability successfully integrated strategically relevant resources to drive innovation and maintain competitiveness (Lawson and Samson, 2001). Greeven (2009) incorporates all of the above and defines innovation capability comprehensively as the 'ability of a firm to integrate, build, and reconfigure internal and external critical resources to develop and successfully commercialize new products and services', thereby firmly rooting the definition in DCT. In line with such thinking, evidence from businesses operating in EMs shows that firms actually embrace frugal innovation in order to tap into a growing and aspiring middle class while simultaneously addressing the challenges of a volatile environment (Tiwari and Herstatt, 2012; Hossain, 2018). Such companies as Godrej-Boyce with its ChotuKool portable refrigerator, Mahindra & Mahindra with the Yuvraj mini tractor, Vortex Engineering with Vortex Gramteller ATM, and GE with its Lullaby baby warmer are just a few examples of successfully adopted frugal innovations addressing the needs of the emerging Indian market.

Frugal innovations in India – the critical context

India is a source of several frugal innovations (Prahalad and Mashelkar, 2010). Indian markets, characterized by large, young populations with lofty aspirations and limited budgets, have several industrial sectors providing frugal products that are versatile, affordable, robust and good enough in terms of quality (Chakravarti, 2006; Tiwari and Herstatt, 2012). Firms in the medical devices and the automobile sectors have produced several commercially successful frugal innovations (Deloitte, 2016; Tiwari and Phadnis, 2017).

The Indian medical devices sector ranks fourth in Asia with respect to market size and is expected to reach $US25–30 billion by 2025 (Deloitte, 2016). This growth will be propelled by a heightened demand for healthcare, especially in the areas of endocrinology and cardiac health. India has the highest incidence in the world of diabetes, coronary heart disease and obstructive pulmonary disease, which are currently leading causes of mortality. Additionally, rising disposable incomes and wider medical insurance coverage are driving up the demand for, and utilization of, healthcare services (Deloitte, 2016), indicating a substantial hitherto untapped market that could be well served by developing frugal and robust medical devices. India has emerged as a hub for some of the most innovative and entrepreneurial healthcare solutions in the last decade, such as GE's portable handheld ECG machine (Rosenfled, 2014). Some of these frugal products have developed niche markets

in many regions globally (Deloitte, 2016). For instance, 3nethra's digital non-mydriatic fundus camera, which eliminates waiting time for pupil dilation, has been approved by the food and drug administration in the United States and is Health Canada registered. Hailed as an innovation capable of eradicating preventable blindness, it is being used in glaucoma testing in both countries, proving that India-originated frugal technology solutions can be of high quality and built for affordability/accessibility (IAPB, 2020).

India's automobile sector has also seen an exponential growth in frugal innovations. This sector is expected to grow to $US300 billion by 2026 (Gupta *et al.*, 2018) fuelled by increasing domestic demand for low cost automobiles, a competitive value chain, low labour costs and a strategic geographic location (Ernst & Young, 2016). There is an enhanced focus on low-cost manufacturing capabilities while simultaneously meeting customer expectations for price and performance (Prabhu *et al.*, 2012).

Even though the Tata Nano car was a commercial failure, it was a pioneer frugal innovation which retailed at $US1,500. Designed not to attract a car buyer, but to replace a two-wheeler, it was intended to provide an affordable and safe alternative for the Indian family that typically travelled unsafely on a motorbike (Sharma, 2017). Since then, the automobile sector has seen several frugal innovations in many vehicle categories (e.g., pick-up trucks such as Tata Ace at $US5,000; Ashok Leyland-Nissan's Dost at $US6,600; cars such as Renault-Nissan's Logan at $US10,000; tractors such as Mahindra's Yuvraj at $US3,500) (Radjou *et al.*, 2012b). Several of these frugal innovations are also set to be sold globally. For instance, Renault-Nissan's global small car, priced at $US5,200 is to be commercialized in India and then introduced in other emerging markets such as Brazil, Indonesia and South Africa (Radjou *et al.*, 2012b). Automobile industry experts describe frugal innovation in terms of not just the mindset, but also the process capabilities that allow them to innovate under constraints and turn adversity into growth opportunities (Radjou *et al.*, 2012b).

Methodology

When new constructs are developed based on separate domains of literature, and the outcome leads to new measures, a mixed methods methodology combining both qualitative and quantitative research efforts is recommended (Edmondson and McManus, 2007; Ang, 2014). Since our study aims to develop a new measure for FICs by bringing together existing and disparate areas of literature from distinct areas, we also adopted a combination of qualitative and quantitative research methods (Johnson *et al.*, 2007). The qualitative phase is followed by the quantitative phase.

Conceptualizing and defining FICs

To conceptualize and define frugal innovation capability, we adopt a sequential methodology similar to that used by Bhatti and Ventresca (2013). The steps include (1) collating multiple definitions available in the literature for the two components of FICs (i.e., frugal innovation and innovation capability); (2) deriving core themes from the existing definitions through content analysis; (3a) creating two working definitions of FICs by combining the relevant themes extracted from step 2; (3b) then presenting core themes to academics to create two more working definitions; (4) arranging for a different set of experts and academics in the field to combine the four definitions generated in step 3 to create a single working definition for FICs; (5) obtaining validation of this definition from both medical devices experts and automobile industry experts; and (6) lastly, modifying our working definition with experts' inputs to create the final definition for FICs that guided the rest of our research. These steps are documented in Figure 1.

Definitions of frugal innovation (Wooldridge, 2010; Bhatti and Ventresca, 2013; Tiwari *et al,* 2016) and innovation capability (Martinez-Román *et al.*, 2011) from past research were subjected to content analysis. Six relevant themes (e.g., resource constraints) for frugal innovation and

seven core themes (e.g., capability to respond to the dynamic environment) were extracted. These themes were used by the researchers to develop two working definitions while the themes were simultaneously presented to fellow academics to create two additional working definitions of FICs. Next, these four working definitions were presented to six academics in the field from accredited business schools in India and the United States. From the input received, a single synthesized definition for FICs was developed as:

> *The capability of an organization to explore new concepts and generate marketable and scalable low-cost acceptable quality product/service solutions in a resource-constrained environment by applying combinations of available resources to respond to market opportunities.*

Next, the definition was subjected to face validity testing through semi-structured interviews of industry experts from the medical devices and automobile sectors in India. Experts chosen through referrals were busy top management executives who preferred shorter interviews with pointed questions and high clarity. These executives from medical devices and automobile firms were located primarily in the cities of Bengaluru and Chennai. Bengaluru is a leading hub in India for technology-based medical devices (SKP Business Consulting, 2016), while Chennai leads in the automobile sector and is often referred to as the Detroit of South Asia (Ramanathan, 2008). As there were no publicly available databases with executive names/contact information, we used the professional platform LinkedIn to connect with a network of senior executives. LinkedIn profiles helped identify the right executives for the interviews where the respondents had a minimum of five years of experience in a C-level/product development/product management/leadership role. Once an executive respondent was identified, an introductory message with the purpose of the study, the broad area of research and a request for an interview was sent. Executives typically replied within 72 hours, and the positive response rate was 64%. A total of 16 interviews (nine from the medical devices sector and seven from the automobile sector) were conducted. Selected excerpts from the interviewer's opinions of our definition are presented next (editorialized for clarity):

> It is a great (definition) and encompasses all the things (aspects). It talks about resource constraints, scalability, quality, affordability, putting together resources in a meaningful way and see to how this can work in a robust user-friendly way in the market. That is exactly what your definition addresses. I think it (the definition) really addresses all these (aspects). (Expert 2, medical devices sector)
>
> Cost effective is fine, but using 'low cost' seems inappropriate. So, exclude (or replace) low cost from (in) the definition. (Expert 4, automobile sector)
>
> Instead of low cost, value-added products (value for money), or cost effective would be a better way of saying this. (Expert 10, medical devices sector)
>
> Generally we look at what others are doing (producing), and we repeat the same (but) it is not a good thing for us to do. Your definition is very appropriate. (Expert 6, medical devices sector)

Most of the experts opined that the term 'low cost' in our working definition wrongly portrayed frugal innovations as make-do products with cheap quality, sub-par functionality and minimal effort spent in designing them. In contrast, frugal innovations demand that the innovating team of engineers, designers, scientists, market experts and other firm leaders design the product from scratch in conjunction with a thorough understanding of customer needs and product functions. The experts suggested using the terms 'cost effective' or 'value for money' instead of 'low cost'. We therefore replaced 'low cost' with 'cost effective' in our final definition of FICs. Our modified definition of FICs henceforth reads:

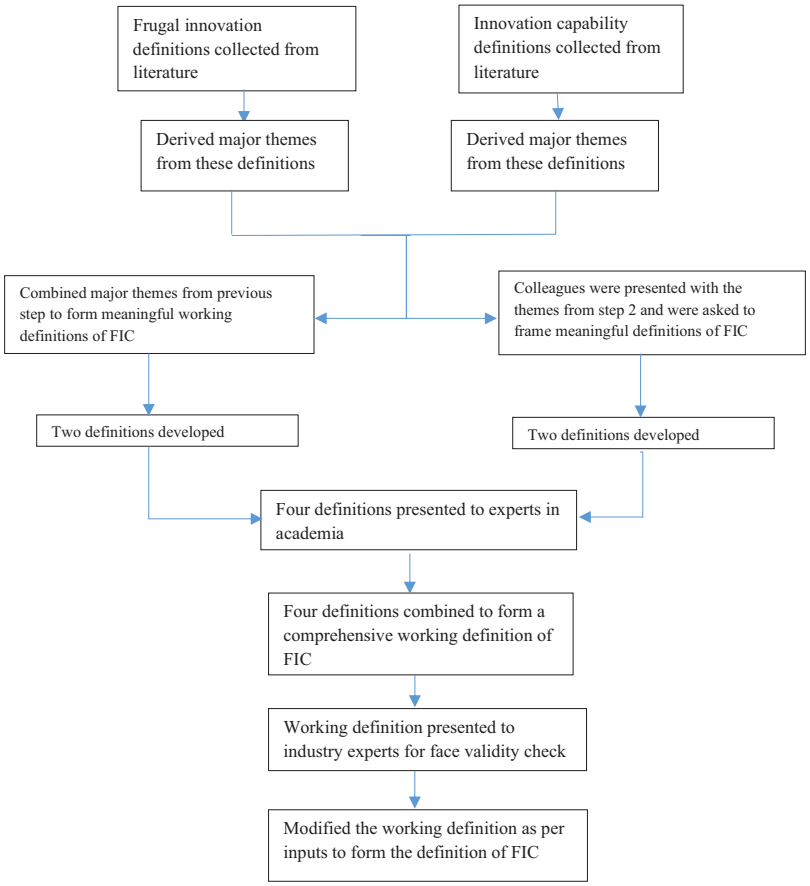

Figure 1. Conceptualization process of FIC

> *The capabilities of an organization to explore new concepts and generate marketable and scalable cost effective, acceptable quality product/service solutions in a resource-constrained environment by applying combinations of available resources to respond to market opportunities.*

Measuring FICs

To develop the measure of frugal innovation capabilities, a scale-development process suggested by Slavec and Drnovsek (2014) was adopted. The first step of construct conceptualization is addressed in the previous section. The next step was to operationalize the indicators or items to measure the different dimensions of our FIC construct (DeVellis, 2016). Several reflective indicators (derived from our definition) contribute to the underlying construct and represent the different dimensions of FICs. To measure FIC, a uniform five-point Likert scale (1=strongly disagree to 5=strongly agree) was used (Li, 2013). Based on our definition, we propose that the FIC is a second-order firm-level construct comprising four first order dimensions: value for money, acceptable quality, scalability and marketability.

- *Value for money (vm) (cost effective)*: defined in the *Cambridge Dictionary* as 'cost effective' as 'good value for the amount of money paid' or value for money. Industry experts suggested the term 'low-cost' be replaced with 'cost-effective' or 'value for

money'. To avoid any negative connotations of low quality/functionality, the term 'value for money' will be used in this paper. A literature-based definition of value for money might be the most favourable combination of lifecycle costs, quality of goods/services to satisfy consumer requirements (Morallos and Amekudzi, 2008). Lifecycle costs to the consumer include monetary, temporal, energy and psychological outlays in addition to the expenses incurred in evaluating, obtaining, using and disposing of an offering (Kotler *et al.*, 2013). When evaluating the value for money of frugal innovation, consumers compare lifecycle costs with non-frugal alternatives on the market, provided the frugal product also exhibits an acceptable level of quality (Hossain, 2018). Three items (see Appendix 1) were developed to measure the dimension of value for money.

- *Acceptable quality (aq*): defined in the literature as something like the minimum level of user requirements that fulfils user expectations and needs as part of user experience (Jumisko-Pyykko *et al.*, 2008). It is the threshold level of quality below which the consumer would not accept the offering (Dumicic *et al.*, 2006). To measure acceptable quality, four items were created, based on the dimensions of quality proposed by Garvin (1987).
- *Scalability (sc)*: referring to the ability of an organization to maintain or even increase production, sales, revenues, operational and human efficiencies when tested by larger market demands in a short period of time, while simultaneously lowering marginal costs of each additional unit produced (Dudnik, 2010; Angel Investor Report, 2021). When a firm evidences the ability to scale up successfully, the firm is capable of increasing several firm metrics without requiring additional investments in human resources (Angel Investor Report, 2021), capital (Vyge, 2013) or operational expenditure (LeBlanc, 2019). Based on this discussion, five items were developed to measure scalability.
- *Marketability (mkt)*: indicating whether a frugal product will appeal to buyers at a certain (affordable) price point generating a profit for the firm (*Chron*, 2020). Even if the frugal product is more affordable at a lower price compared with prevailing mature-market offerings, this affordability factor would still sustain consumer trust in the quality of the product (Radjou, 2020). Further, the frugal product will be perceived by the market to be desirable/appealing and 'capable of fulfilling or even exceeding acceptable quality standards' (Weyrauch and Herstatt, 2016). Based on this discussion of market appeal, comparable quality, and consumer trust in quality, three items were developed to measure marketability.

An initial item pool of 15 items (Appendix 1) was created to measure FICs and tested for content validity, which is the next step of scale development. Content validity, defined as 'the extent to which measurement items represent a proper sample of the theoretical content domain of a construct' (Nunnally and Bernstein, 1994), is typically ascertained by experts/judges (Hardesty and Bearden, 2004). The 15 items were presented for review to six experts/judges who either had high familiarity with the term 'frugal innovation' or were involved in the research/sales of frugal innovations in the two industries in our study (Hardesty and Bearden, 2004). Judges comprised faculty from business schools, consultants and practitioners from the medical equipment and automobile sectors, and physicians. Feedback from the judges was examined, and the inter-judge content validity ratio (CVR) (Lawshe, 1975) was calculated to quantify consensus (see Appendix 3). The average CVR achieved was 0.932, above the 0.80 cutoff for content validity. In the validity literature, achieving 0.80 agreement is the threshold for having confidence in the instrument items when ascertaining content

Table 1. Descriptive statistics of the sample

Descriptive	Frequency (n=121)	%
Sector		
Medical devices	93	76.9
Automobiles	28	23.1
Major locations		
Bengaluru	51	42.1
Chennai	18	14.9
Mumbai	10	8.3
Delhi	7	5.8
Gurgaon	7	5.8
Legal entity		
Sole proprietorship	4	3.3
Private limited company	103	85.1
Public limited company	14	11.6

validity through expert judges (Newman *et al.*, 2013). The final measurement instrument, including the above-mentioned validated items and additional demographic questions, is provided in Appendix 2.

Sampling and data collection

For this research, we adopted purposive sampling, where the respondents are chosen because of a desired set of characteristics they possessed, which best enabled them to answer the research questions we posed (Etikan *et al.*, 2016). A purposive expert sample is a type of non-probability sample assumed to be representative of the population because researchers apply their expert knowledge of the population to select in a nonrandom manner a sample of respondents that best represents a cross-section of the population (Lund Research, 2012). Further, purposive expert sampling is recommended when researchers are pursuing a mixed methods research design and need to gain knowledge from individuals who have particular expertise. Application of the technique 'is not considered to be a weakness' (Etikan *et al.*, 2016). The population of interest included experts from the medical devices companies listed in the database maintained by the central drug standard control organization and ten large companies in the automobile (passenger vehicles only) sector in India (Shah, 2017). The 412 experts approached typically occupied executive level positions including MD, CEO, SVP/EVP/VP, founder, president and chairman. Positive contact via LinkedIn was made with 174 senior executives, and 121 respondents completed the questionnaire with a response rate of 69.14%. In purposive expert sampling, a response rate of 60% or greater is considered to be optimal because nonresponse bias is thought to be minimal with higher response rates (Fincham, 2008). Descriptive statistics of the respondents are presented in Table 1.

DATA ANALYSIS AND RESULTS

Factor analysis

Factor analysis is the primary statistical technique used (1) in psychometric evaluations of multi-item measurement instruments, such as surveys (Nunnally, 1978), and (2) in validation of new constructs by demonstrating that measurement items load on to underlying factors in anticipated ways (Gorsuch, 1983) and (3) in reducing data by compressing intercorrelated items into factor scores for use in further analysis (Thompson, 2004). Factor analysis is based on the seminal work of Thurstone's (1947) common factor model, which suggests that each item in a measurement instrument is a linear function of one or more common factors and one unique factor. Factor analysis thus separates the common variance, the unique variance and the random error variance in order to extract the unique latent factors underlying the observed indicators. According to Kim and Müller (1978), there are two main types of analyses: exploratory factor analysis (EFA) (Spearman, 1904) and confirmatory factor analysis (CFA) (Jöreskog, 1969). EFA is the first step in dimension-reduction and is used during scale development to identify the latent factors (Slavec and Drnovsek, 2014). EFA is data-driven and no *a priori* specifications are made in regard to the number of latent factors or to the nature/magnitude of the item factor loadings. On the other hand, CFA (which follows EFA) requires prior specification of the number of factors, the factor loadings and the variances. The researcher uses metrics[1] to determine how well CFA reproduces the covariance matrix of the measured variables in order to evaluate the factor model proposed by EFA.

Exploratory factor analysis

Frugal innovation capabilities (FICs) is a new construct; hence, we used factor analysis to identify the factors/dimensions that comprise FICs. Typically, EFA requires several measured variables (items) and researchers have suggested varying numbers of individual items – ranging from two to five – that would load on to each latent factor (MacCallum *et al.*, 1999). Though there are scales in the psychology literature that contain only two items per factor, a minimum of three items loading onto each factor is usually recommended, as this number will yield convergent solutions in CFA that would typically follow EFA (Marsh *et al.*, 1998).

To check the applicability of EFA for the data, a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity was tested. The KMO measure of sampling adequacy is a statistic that indicates the proportion of variance in measurement variables which might be caused by underlying latent factors. It ranges between 0 and 1, and tests whether partial correlations between variables are sufficiently small. It has been suggested that, though a KMO measure greater than 0.5 is acceptable, a measure >0.8 is *meritorious* and will yield satisfactory factor analysis (Kaiser, 1970; Kaiser and Rice, 1974). The KMO value obtained with our data was 0.84, confirming that the proportion of common variance is low and that our data are suitable for EFA. We next conducted Bartlett's test of sphericity to ensure that the correlation matrix of our variables diverged significantly from an identity matrix. More specifically, the p-value from Bartlett's Test of Sphericity was lower than our chosen significance level ($p=0.05$), thus confirming that our data were suitable for EFA.

We applied principal component analysis (PCA) as the method of extraction for the underlying factors in EFA. PCA is a dimensionality-reduction technique that effectively reduces a large dataset of variables into a smaller one while keeping intact/preserving most of the information in the larger dataset (Jolliffe and Cadima, 2016). The new latent variables (unnamed principal components) are constructed as linear combinations of the initial variables, which are compressed into

[1]Such as GFI, NFI, TLI, RMSEA and CFI (to be discussed later).

Table 2. Rotated component matrix of FIC

	Components			
	1	**2**	**3**	**4**
vm1				0.800
vm2				0.787
vm3				0.698
aq1		0.813		
aq2		0.785		
aq3		0.834		
aq4		0.817		
sc1	0.881			
sc2	0.928			
sc3	0.896			
sc4	0.878			
sc5	0.770			
mkt1			0.848	
mkt2			0.882	
mkt3			0.795	

Notes: Extraction: PCA
Rotation: Varimax
Kaiser-Meyer-Olkin measure of sampling adequacy: 0.848
Bartlett's test of sphericity: 0.000

these new variables still preserving most of the information (Jolliffe and Cadima, 2016). Significant eigenvectors, computed from the covariance matrix, that account for most of the variance (>60%) (Hair *et al.*, 2014, p.112) and identified from corresponding higher eigenvalue s (factor loadings of at least |0.4| (Stevens, 1992)) help indicate the underlying factor structure. According to Kaiser (1960), factors with eigenvalue of greater than 1 have to be retained. We find four distinct factors with eigenvalues greater than 1 that explain more than 78% of the total variance. Table 2 lists all 15 items and summarizes the results by providing the dominant loading for each item. Upon varimax rotation, a clear factor structure was observed (see Figure 2) and all the factor loadings were greater than 0.6. The four distinct factors were labelled as 'value for money', 'acceptable quality', 'scalability' and 'marketability'.

Confirmatory factor analysis and assessing model fit

Analysis of moment structures (AMOS) was used to conduct CFA. The results of the CFA model are presented in Figure 3, depicting FICs with its four factors (value for money, acceptable quality, scalability and marketability), along with their respective observed variables (15 items). Finally, reliability, average variance extracted and discriminant validity were examined.

We hypothesized a four-factor model to be confirmed in the measurement portion of our analysis. After confirming the absence of univariate/multivariate outliers and variable normality through SPSS, we conducted CFA in order to confirm the factor structure by hypothesizing *a priori* the four factors expected separately, and by constraining each item to load on one (and only one)

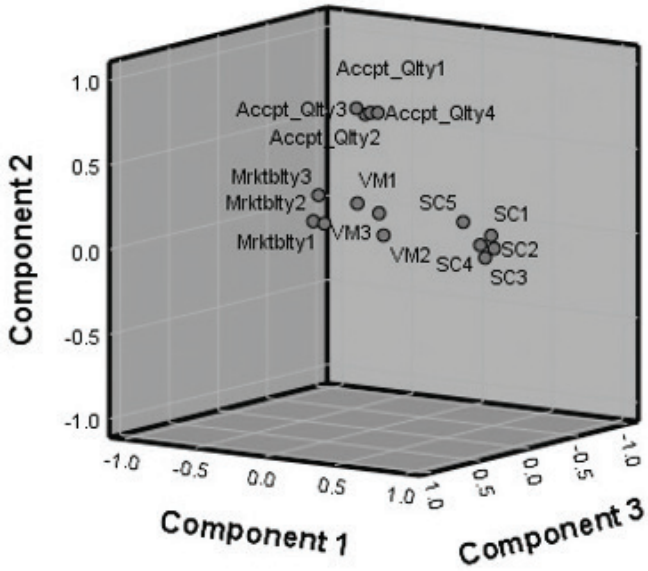

Figure 2. Component plot in rotated space

factor and setting all cross-loadings to zero. Assessment of fit indices are below; and the theoretical model is presented in Figure 3, where larger circles represent latent factors, rectangles represent measured variables/items and lines represent the connections. In CFA, it is assumed that the latent factors may not completely explain the variance, hence the error terms (e1 to e15, in smaller circles) are connected with each corresponding observed variable. Specifically, the model fit is evaluated based on certain suggested parameters. The ratio of chi-square over the degrees of freedom (CMIN/DF) is 1.77, which is lower than the threshold value of 3.0 (Hair *et al.*, 2006). The goodness-of-fit index (GFI) which indicates the proportion of variance accounted for by the estimated population covariance and analogous to R^2 is 0.86, higher than the recommended 0.8 (Forza and Filippini, 1998; Greenspoon and Saklofske, 1998). The normed fit index (NFI) is 0.9, which is in line with the recommended threshold of 0.9 (Hair *et al.*, 2010). An NFI of 0.9 indicates that our model of interest improves the fit by 90% relative to the null model. The comparative fit index (CFI), a revised form of NFI which compares the fit of our model to the fit of a null model, is 0.95, higher than the prescribed threshold of 0.9 suggested by Hair *et al.* (2010). The root mean square error of approximation (RMSEA), a parsimony-adjusted index where values closer to 0 represent a good fit, is 0.08, lower than the 0.10 suggested by Hair *et al.* (2010). NNFI, an index often reported for smaller samples and called the Tucker Lewis index (TLI), is 0.94, which is higher than the recommended value of 0.9 (Forza and Filippini, 1998; Awang, 2012). The values of model fit parameters indicate a good fit between our model and the observed data.

Assessing reliability and validity

To evaluate the psychometric properties of reliability and construct validity, we compared several metrics produced by our data analysis against suggested thresholds. The composite reliability (CR) values for each of the factors (see Table 3) are higher (range from .71 to .93) than the recommended value of 0.6 (Hair *et al.*, 2017), indicating satisfactory reliability. To establish convergent validity, the values of the average variance extracted (AVE) are considered. The AVE values, ranging from 0.46 to 0.79, are higher than the recommended value of 0.4 (Gefen *et al.*, 2000; Huang *et al.*, 2013), indicating satisfactory convergent validity. Convergent validity is also confirmed from the item loadings. The item loadings from 0.57 to 0.93 (see Table 3) are all above the recommended value of 0.5 (Hair *et al.*, 2009).

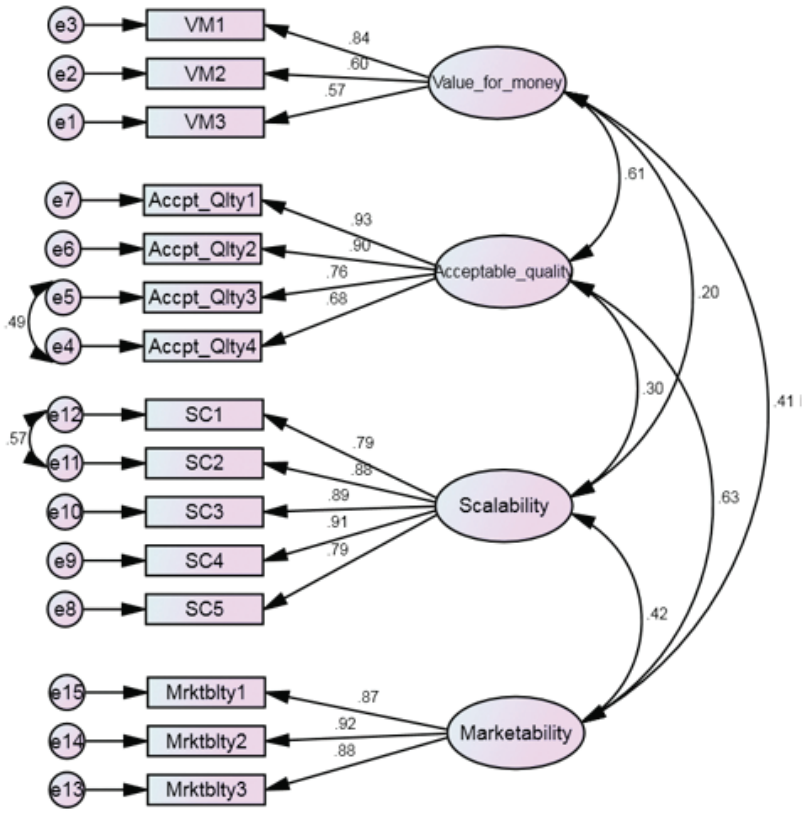

Figure 3. Model: output of CFA

Table 3. Convergent validity and reliability assessment

Dimension	Item code	Item loadings	AVE	Composite reliability
Value for money	VM1	0.84	0.46	0.71
	VM2	0.60		
	VM3	0.57		
Acceptable quality	AQ1	0.93	0.68	0.89
	AQ2	0.90		
	AQ3	0.76		
	AQ4	0.68		
Scalability	SC1	0.80	0.73	0.93
	SC2	0.88		
	SC3	0.89		
	SC4	0.91		
	SC5	0.79		
Marketability	MKT1	0.87	0.79	0.92
	MKT2	0.92		
	MKT3	0.88		

To establish discriminant validity, the diagonal in Table 4 represents the square root of the AVE of each construct, and the non-diagonal elements represent the correlation between the latent variables. The square root of the AVE for each construct, represented by the bold elements in Table 4, are higher than its correlation with other constructs (Hair *et al.*, 2006), indicating satisfactory discriminant validity. This evaluation of discriminant validity is based on the Fornell-Larcker criteria (Fornell and Larcker, 1981), where the AVE of each latent construct needs to be greater than its highest squared correlation with any other latent construct. In a second test to assess discriminant validity, the values of the AVE have to be higher than the maximum-shared variance (MSV) (Hair *et al.*, 2006; Alumran *et al.*, 2014). The results from Table 5 indicate AVE higher than MSV, displaying satisfactory discriminant validity. Finally, the difference between the factor loadings and the cross loadings of each item are greater than 2.0, showing additional evidence of discriminant validity (Bagozzi and Phillips,1982) and establishing the strength of the psychometric properties of the FICs scale.

Discussion

Looking ahead, emerging markets are expected to have a greater impact on global trade than industrialized nations (Shivdas and Sivakumar, 2013). China, labelled an emerging market two decades ago, is now the second largest economy and the largest exporter in the world (Blazyte, 2020). Emerging economies are not only impacting world trade, they are also poised to surpass developed nations. For example, India overtook the United Kingdom (after Brexit, so GDP does not include the EU market) in 2017 (Gramer, 2019) with its rapid growth in the past decade. Today, EMs account for 36% of global trade, but MNCs that operate in EMs earn only 17% of their revenue from these countries (Atsmon *et al.*, 2012). It has been suggested that the few organizations that are successful in EMs are doing well because they have adopted a frugal innovative mindset and have developed associated capabilities (Mahmood *et al.*, 2014). Economic growth in emerging markets should be spurred on by increased spending on infrastructure (Mauro, 2017), investment in R&D (Inekwe, 2014), expansion of innovation capabilities (Govindarajan and Trimble, 2012) and capital

Table 4. Discriminant validity assessment based on Fornell-Larcker criteria

	Value for money	**Acceptable quality**	**Scalability**	**Marketability**
Value for money	**0.68**			
Acceptable quality	0.61	**0.82**		
Scalability	0.20	0.30	**0.85**	
Marketability	0.41	0.63	0.42	**0.89**

Table 5. Alternate method to assess discriminant validity

Dimension	**AVE**	**MSV**	**Is AVE > MSV**
Value for money	0.46	0.37	Yes
Acceptable quality	0.68	0.39	Yes
Scalability	0.73	0.17	Yes
Marketability	0.79	0.39	Yes

(Woetzel *et al.*, 2018). To remain relevant and competitive in EMs, firms need to employ a revolutionary approach to innovation at the local level, taking a fresh look at developing the right capabilities across their value chains, including sustainable and scalable product innovation (Mahmood *et al.*, 2014; Shivdas and Chandrasekhar, 2016).

While research has explored the nature of frugal innovation (Tiwari and Herstatt, 2012; Bhatti and Ventresca, 2013; Radjou and Prabhu, 2015), there is less understanding of the innovation capabilities required to tap into these emerging markets (Sharmelly and Ray, 2018). We seek to remedy this by developing and validating a FIC scale. Even recent papers on measuring innovation capabilities focus on the service industry (Hogan *et al.*, 2011), exporting firms (Vicente, Abrantes and Teixeira, 2015) and on innovation in general (Calik *et al.*, 2017), but not on FICs. This paper not only conceptualizes FICs and examines their constituent dimensions, it also specifically addresses this gap by providing a validated measurement scale for FICs.

There is appreciation of the need for new measurement and calibration of innovation at the industry level (Gann and Dodgson, 2019), but not at the firm level. Any measurement of a firm's innovation capability should be able to 'assist management in assessing priority innovation areas that need to be addressed, and allow them to respond to challenges posed by the types of innovation capability that need to be improved' (Hogan *et al.*, 2011). This paper provides exactly this by developing a measure of FICs and its dimensions to be used at the firm level. The wide applicability of this particular measure is enhanced at this scale by pooling concepts from multiple domains evident in the four FIC dimensions: marketing (marketability and value for money), operations management (acceptable quality) and business strategy (scalability). Clean factors generated from EFA and satisfactory CFA results, accompanied by successful reliability and validity outcomes, provide an opportunity for the widespread adoption of this FIC scale across various domains. Further, these dimensions find support in several studies on frugal innovation; for example, affordability (Prahalad, 2010; Nakata and Weidner, 2012), value for money and quality (Gadiesh *et al.*, 2007; Radjou and Prabhu, 2015; Sharmelly and Ray, 2018) and acceptable quality (Brem and Wolfram, 2014). Our measure of FICs is thus a holistic composite based on theory but with broad practical relevance.

FICs, rooted in dynamic capability theory, seek to integrate, build and reconfigure internal resources and capabilities. As a part of developing FICs, firms are involved in the forming the multidisciplinary teams required for the development of a frugal product, developing external competencies by collaborating with experts, universities, research centers, venture capitalists and government agencies to develop specialized capabilities. At the institutional policy level, in several EMs that desire freedom from dependency on global supply chains, there is a concerted push for self-sufficiency. For example, the government of India is encouraging innovation by funding collaboration among government, for-profit corporations and academic/research institutions. Labelled *atmanirbhar*, the initiative is expected to see investments of $US500 billion in selected industrial sectors (e.g., medical services) (*The Hindu*, 2020) with a focus on promoting frugal innovation and developing entrepreneurial ecosystems.

At the firm level, the FIC measure can provide managers with better understanding of how to build innovation capability. Any measure of a firm's innovation capability should be able to guide management in assessing priority innovation areas, revealing deficiencies and assisting them in responding to challenges. Our measure, which neatly partitions FICs into various factors, provides the opportunity to develop industry-specific benchmarks for each of the dimensions, evaluating firm performance against the benchmarks. Such quantification can help companies to assess their strengths and weaknesses *vis-à-vis* competition and to develop corrective strategy, such as training programmes for employees (Kaplan, 2018).

Increasing disposable incomes is driving consumer aspirations in EMs. Firms able to take advantage of frugal innovative capabilities are better able to serve a demanding population and harness the demographic dividend. Satisfying a younger population (over 500 million middle class

consumers in India with an average age of 28) (*Consultancy Asia*, 2019) that wants to ape Western lifestyles but with limited budgets, requires companies that will innovate and offer affordable, high-status products. Firms such as Hyundai India with the Hyundai Eon (Sharmelly and Ray, 2018), and Mahindra & Mahindra with its Kwid automobile (Crabtree, 2015) have successfully ingrained frugal innovation practices into product design and development.

This paper offers a framework for future quantitative studies of frugal innovation. Our FIC scale is currently limited by being tested in only two industrial sectors and in only one emerging market. Future research might extend this to other sub-sectors of healthcare, such as screening, diagnosis, treatment, reparation, patient monitoring and healthcare delivery/access (Swissnex, 2016). It might also test applicability in industries paying increasing attention to frugal innovation; for instance, the advanced electronics sector (especially firms in the defense and space exploration industries), and where firms are beginning to practise stringent cost-effective regimes, which imply a stronger involvement in frugal innovation (Sahay, 2014; *Economic Times*, 2020). An extension of this research to other EMs could reveal potential insights that can be harnessed by firms for competitive effectiveness and market relevance. Additionally, comparisons between MNCs serving a global population versus localized firms catering to a single demographic could lead to interesting results with policy/strategy implications. The application of the FIC scale requires further investigation in other countries/contexts/industries. Since recent frugal innovation examples come from defence (IDEX4Fauji) (*Economic Times*, 2020) and space research (India's ISRO Mars orbiter mission, Mangalyaan) (Sahay, 2014), assessing the applicability of the FIC scale in these sectors would seem to offer promising returns.

APPENDICES

Appendix 1. Item pool of FIC

Dimension	Label	Item description
Value for money	VM1	The price and the acquisition cost (other than price – e.g., delivery charges, service charges, search time, installation costs) of our product are less than prevailing market offerings
	VM2	The maintenance cost of our product is less than prevailing market offerings
	VM3	The production cost is less than prevailing market offerings
Acceptable quality	AQ1	Performance of our product is comparable with prevailing market offerings
	AQ2	Features of our product are comparable with prevailing market offerings
	AQ3	Durability of our product is comparable with prevailing market offerings
	AQ4	Conformance to specifications and industry standards of our product is comparable with prevailing market offerings
Scalability	SC1	We have the ability to increase production volume without incurring significant fixed costs
	SC2	We have the ability to increase sales volume without incurring significant variable costs
	SC3	We have the ability to expand our operations without incurring significant marginal costs
	SC4	We have the ability to increase our revenues without incurring substantial marginal costs
	SC5	We have the ability to grow without incurring significant human resource costs
Marketability	MKT1	Our customers perceive our product to be as appealing as prevailing market offerings
	MKT2	Our customers perceive our product to have quality comparable with that of prevailing market offerings
	MKT3	Our customers perceive our product to be as trustworthy as prevailing market offerings

Appendix 2. QuestionnaireFor each statement, please select the option that best suits your organization.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The price and the acquisition cost (other than price – e.g., delivery charges, service charges, search time, installation costs) of our product are lower than prevailing market offerings	1	2	3	4	5
The maintenance cost of our product is less than that of prevailing market offerings	1	2	3	4	5
The production cost is less than that of prevailing market offerings.	1	2	3	4	5
Performance of our product is comparable with that of prevailing market offerings	1	2	3	4	5
Features of our product are comparable with those of prevailing market offerings	1	2	3	4	5
Durability of our product is comparable with that of prevailing market offerings	1	2	3	4	5
Conformance to specifications and industry standards of our product is comparable with that of prevailing market offerings	1	2	3	4	5
We have the ability to increase production volume without incurring significant fixed costs	1	2	3	4	5
We have the ability to increase sales volume without incurring significant variable costs	1	2	3	4	5
We have the ability to expand our operations without incurring significant marginal costs	1	2	3	4	5
We have the ability to increase our revenues without incurring substantial marginal costs	1	2	3	4	5
We have the ability to grow without incurring significant human resource costs	1	2	3	4	5
Our customers perceive our product to be equally as appealing as prevailing market offerings	1	2	3	4	5
Our customers perceive our product to have quality comparable to that of prevailing market offerings	1	2	3	4	5
Our customers perceive our product to be as trustworthy as prevailing market offerings	1	2	3	4	5
Our organization is constrained by lack of: (a) Government supplied infrastructure (e.g., special economic zones, roads) (b) Government support in the regulatory environment (c) Clarity in rules in the regulatory environment	1	2	3	4	5
Our organization is constrained by lack of government R&D investments (e.g., grants, funds for research)	1	2	3	4	5
Our organization is constrained by the difficulty of raising funds from banks	1	2	3	4	5
Our organization is constrained by the difficulty of receiving timely funds from government sanctioned loans	1	2	3	4	5
Our organization is constrained by the difficulty of raising funds from venture capitalists who are risk averse	1	2	3	4	5
Our organization is constrained by the high cost of borrowing capital	1	2	3	4	5
Our organization is constrained by the lack of skilled labour force.	1	2	3	4	5
Our organization is constrained by the lack of opportunities to collaborate with academic partners such as universities	1	2	3	4	5
Our organization is constrained by the lack of follow through by the government in implementing industry incentives	1	2	3	4	5

(Continued)

Appendix 2. (Continued)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Our organization is constrained by the lack of access to experts (e.g., industry experts, medical doctors, academicians)	1	2	3	4	5
Our organization is constrained by the hesitation of our innovators to work with busy customers (e.g., doctors, industry experts)	1	2	3	4	5
Our organization is constrained by less ability to practice expert marketing than prevailing competitors (e.g., MNCs)	1	2	3	4	5
Our organization is constrained by less ability to attract technical know-how and innovative brainpower than prevailing competitors (e.g., MNCs)	1	2	3	4	5
Our organization is constrained by the inability to detect quickly changes in our customers' product preferences	1	2	3	4	5
Our organization is constrained by the inability to detect quickly fundamental shifts and trends in our industry such as competition, technology, and regulation	1	2	3	4	5
Our organization is constrained by the inability to resolve customer complaints quickly	1	2	3	4	5
Our organization is constrained by the inability to disseminate quickly competitor intelligence throughout the organization	1	2	3	4	5
Our business objectives are driven primarily by customer satisfaction	1	2	3	4	5
Expert understanding of customer needs is the most important source of our competitive advantage	1	2	3	4	5
Our organization takes product-related decisions only after conducting thorough market research	1	2	3	4	5
Our organization takes product-related decisions only after consulting key opinion leaders in the industry	1	2	3	4	5
Our organization systematically measures customer feedback and customer satisfaction	1	2	3	4	5
Our organization has the ability to respond rapidly to competitor actions	1	2	3	4	5
Our organization has the ability to monitor competitors' strengths and weaknesses	1	2	3	4	5
Our organization has the ability for salespeople to share competitor information with top management	1	2	3	4	5
Our organization has the ability to identify and tap opportunities for competitive advantage	1	2	3	4	5
Our organization emphasizes R&D and technological innovations	1	2	3	4	5
Our organization has introduced at least one new product in the past 3 years	1	2	3	4	5
Very often our organization is the first in the industry to launch a new product	1	2	3	4	5
Our organization is typically the first to initiate actions to which competitors then respond	1	2	3	4	5
When faced with a risky economic environment, our organization typically explores it gradually via cautious, slowly increasing behavior	1	2	3	4	5
In general, our organization has a strong preference for low-risk projects	1	2	3	4	5
When faced with uncertainty, our organization typically adopts a wait and see approach in order to reduce risks.	1	2	3	4	5

Appendix 3. Content validity ratio

Formula to calculate content validity ratio (CVR) according to Lawsche (1975):

$$CVR = (n_e - N/2) / (N/2)$$

Where n_e is the number of experts who agree on the relevance of the item
N = total members of the panel of expert judges
CVR equals 1 when there is a total agreement among all judges.

In this research, all six judges agreed on the relevance of twelve items. For the remaining three items, five judges agreed while one judge felt slight modification was needed. Hence, the CVR for twelve items is:

CVR for an item where all judges agreed = (6 – 6/2) / (6/2) =1
Thus, CVR for 12 items = 12 × 1 = 12
CVR for an item where one judge did not agree = (5 – 6/2) / (6/2) = 0.66
Thus, CVR for 3 items = 3 × 0.66 = 1.98
Therefore, the average CVR for the scale will be (12+1.98)/15 = 0.932

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