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**DOI**

[10.1080/14479338.2020.1825089](https://doi.org/10.1080/14479338.2020.1825089)

**Publication date**

2020

**Document Version**

Final published version

**Published in**

Innovation: Organization and Management

**Citation (APA)**

Ploeg, M., Knobens, J., Vermeulen, P., & van Beers, C. (2020). Rare gems or mundane practice? Resource constraints as drivers of frugal innovation. *Innovation: Organization and Management*, 23(1), 93-126.  
<https://doi.org/10.1080/14479338.2020.1825089>

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To cite this article: Matthias Ploeg , Joris Knob , Patrick Vermeulen & Cees van Beers (2020): Rare gems or mundane practice? Resource constraints as drivers of frugal innovation, Innovation, DOI: [10.1080/14479338.2020.1825089](https://doi.org/10.1080/14479338.2020.1825089)

To link to this article: <https://doi.org/10.1080/14479338.2020.1825089>



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# Rare gems or mundane practice? Resource constraints as drivers of frugal innovation

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## ABSTRACT

Frugal innovation and related concepts are receiving increasing scholarly attention. While recent progress in the conceptualisation of frugal innovation as a phenomenon has been considerable, insights into the antecedents of frugal innovation remain relatively poor. We add to this literature by systematically conceptualising, theorising and empirically testing the relationship between resource constraints and the propensity of firms to produce frugal innovations, drawing on concepts of problemistic search and opportunity recognition. We distinguish two levels of resource constraints (firm-level and firm environment-level), and two types of frugal innovation (internally oriented and customer-oriented), while using managerial experience as a moderating internal factor. We find that firm-level resource constraints have a strong effect on the propensity of firms to engage in internally oriented frugal innovation, although only so for firms with experienced managers. This effect is lower when these firms operate in an environment that also faces high constraints. We find no effect of resource constraints on customer-oriented frugal innovations, but find a surprising negative moderating effect of managerial experience. We discuss the theoretical and policy implications of these findings for the frugal and wider innovation literature. This study is the first large-scale empirical investigation of frugal innovation that estimates its prevalence. We find that frugal innovation is quite common when using the widest definition of frugal innovation. The majority of frugal innovations are mundane internal efficiency upgrades through capital investment.

## ARTICLE HISTORY

Received 18 April 2020

Accepted 13 September 2020

## KEYWORDS

Frugal innovation; resource constraints; resource efficiency; emerging and developing countries; problemistic search

## Introduction

The concept of *frugal innovation*, often described as new, low-cost, and resource-efficient products and services aimed at providing low-income groups with affordable products and services has received substantial academic attention in the last decade (Bhatti & Ventresca, 2013; Navi et al., 2012; Stott & Tracey, 2018; Von Janda et al., 2020; Zeschky et al., 2011).<sup>1</sup> The literature shows many insightful case studies of how firm managers introduce new products, services or improved business processes that are fit for resource-constrained situations. Well-known examples range from the Tata Nano car (Roiland,

2016) to the 150-dollar prosthetic ‘Jaipur foot’ (Bound & Thornton, 2012), the GE Logiq Book and the Grameen Bank Microfinance. However, in the last years it has become clear that frugal innovation is not only the purview of large multinational corporations (MNCs), but in fact predominantly the domain of small and medium-sized domestic firms that introduce often more modest process and product innovations such as sewing machines that work well without electricity, passive coolers, low-cost urban transport services (Navi et al., 2012), or new types of bamboo shoot processing using traditional techniques (Devi & Kumar, 2018; Singh et al., 2019).

The frugal innovation literature has investigated the concept from a perspective of individual products or services and their respective research & development process (Annala et al., 2018), market entry strategy and business models (Rosca et al., 2017) or product characteristics (Von Janda et al., 2020). However, the literature so far integrated the perspective of *firm-level* decision-making around pursuing frugal innovation only to a limited extent. Specifically, the precise role of resource constraints as antecedents of frugal innovation remains ambiguous. Some research posits resource constraints as a driver of frugal innovation (Navi et al., 2012; Zeschky et al., 2014), whereas others call this possibly a ‘fable’ (Rosenzweig & Grinstein, 2016), others confirming high divergence (Keupp & Gassmann, 2013). Moreover, different streams of literature present different explanatory mechanisms for the expected positive effect of resource constraints on frugal innovations. For instance, parts of the literature focuses on the role of firm-level resource constraints, and how firm managers are triggered to engage in innovation activities to address a particular resource constraint (Navi et al., 2012; Prabhu & Jain, 2015). Other research streams build on the opportunities in resource-constrained environments for firms that are able to introduce a frugal innovation tailored to the challenges of that particular environment (Kolk et al., 2013). These different findings show the need for a more robust conceptualisation of the type and locus of the resource constraints (firm-level or firm environment-level), the type of frugal innovations and the mechanisms that connect them.

Furthermore, the current understanding of the frugal innovation phenomenon is severely limited by the lack of large-scale, systematic studies of the prevalence and drivers of frugal innovation. A recent literature review showed that 94% of the current literature consists of purely qualitative, mostly case-study-based studies, with only three papers using quantitative methods featuring surveys with up to 200 respondents (Agarwal et al., 2017). As such, it is unclear yet to what extent frugal innovation is a systematically present phenomenon. Are successful frugal innovations ubiquitously present in developing and emerging countries, or are they in fact rare, but possibly inspiring gems?

This paper aims to fill these gaps by providing a large-scale quantitative study that conceptually builds on the concepts of *problemistic search and performance feedback* (Cyert & March, 1963; Greve, 2003; Posen et al., 2018), *opportunity recognition* (Ardichvili et al., 2003; York & Venkataraman, 2010), as well as the moderating role of *managerial experience* (Cohen & Levinthal, 1990; Manral, 2011; Menon, 2018; Walsh, 1995). In doing so we make two contributions to the literature. First, we fill an important gap in the frugal innovation literature by conceptually and empirically investigating whether and how resource constraints induce frugal innovation, building on existing entrepreneurship and innovation literature. This relationship is often only implied, assumed, or shown through individual cases up until now. We do so by distinguishing

between different levels of constraints (firm-level and firm-environment) and a clear typology of frugal innovation types. Here, we also contribute by including ‘internal’ frugal innovation, typically frugal process innovation, in our typology, an often overlooked category of frugal innovation.

Second, we contribute to the wider innovation & entrepreneurship research fields. By jointly investigating the roles of firm-level and firm-environment level constraints in inducing innovation, we extend the framework of innovation induced by resource constraints, in line with recent calls to pay more attention to the firm environment (Gavetti et al., 2012; Su et al., 2019). We also extend the existing frameworks by going beyond the typical focus on profit as a performance measure, but investigate whether a broader range of problems can also induce search, in line with original interpretations of problemistic search (Cyert & March, 1963). Thereby we develop a richer view of the boundary conditions to one of the central questions of the innovation literature, the link between negative feedback and innovation behaviour.

## Theory

### Defining frugal innovation

Like other new innovation concepts, such as social innovation (Cuntz et al., 2020), and eco-innovation (Díaz-García et al., 2015), frugal innovation suffers from a lack of tight definitions and broad divergence of understanding due to their trans-disciplinary character, covering economic, management, development, and engineering disciplines. Recent systematic literature reviews (Agarwal et al., 2017; Brem & Wolfram, 2014), as well as a policy review (Kroll & Gabriel, 2017) show that frugal innovation is a difficult concept since it is interchangeably used to describe different *dimensions* of innovation:

- **Drivers/antecedents:** the reason for innovation (e.g., problem-induced, a certain demand from Bottom of the Pyramid consumers);
- **Characteristics of the innovation output:** a new product, service, or business process that is frugal, affordable, resource-efficient, adaptable (various similar attributes are used)
- **The innovation method:** an inclusive, bottom-up, grass-roots R&D process

The simultaneous use of multiple dimensions in many definitions, and the use of multiple attributes within each dimension, make frugal innovation a difficult concept to coherently discuss as well as tangibly measure (Kroll & Gabriel, 2017). To achieve the present paper’s research goal of analysing the relationship between resource constraints as a driver of frugal innovations on the one hand and the frugality of innovations that firms generate on the other hand, it is necessary to separate these dimensions in our definitions and focus only on essential characteristics. Given our research focus, frugal innovation is considered to be exclusively the innovation output dimension, whereas we conceptually treat resource constraints as a specific *driver/antecedent* that is associated with the likelihood of generating a frugal innovation. We make no suppositions or assumptions regarding the innovation method as it is not directly linked to the research problem at hand.

We, therefore, define frugal innovation succinctly as ‘*a resource-efficient innovation*’, i.e., a product, process, or marketing method or organisational approach (OECD & Eurostat, 2005) that is resource-efficient. Its only attribute ‘resource-efficient’ is consistent with the most typical output attribute of frugal innovation (Agarwal et al., 2017), and also fits well with the most common understanding of the word ‘frugal’. In contrast with some of the literature (Agarwal et al., 2017), we see no *prima facie* reason to exclude non-product innovation such in internal firm process innovations. In fact, process innovations, in particular achieving scale and throughput efficiency, are seen as key routes to frugal innovation (Kroll & Gabriel, 2017). A classic example is the case of the Narayana Hrudayalaya hospital in India that specialises in heart surgery, greatly reducing costs per operation through process and/or organisational innovations (Bound & Thornton, 2012).

Resource efficiency creates value by delivering ‘more for less’ (Delmas & Pekovic, 2015; UNIDO, 2016). The value created through resource-efficient innovations, if successfully implemented in the firm and/or launched on the market, will result eventually in economy-wide benefits through higher productivity and/or lower prices. However, we can distinguish between two main pathways of value creation, characterised by the initial locus of the value creation. For a first type of innovations, value creation through resource efficiency happens mainly at the firm-level itself. Higher output efficiency generally see the resource-efficiency gains happening *first* internally to the firm. Most process innovations fall in this category, a well-known example being the way Chinese car manufacturer BYD reduced lithium battery production by 80% through the development of a method that allows for manufacturing at room temperatures (Williamson, 2010). The second type of frugal innovations mainly create value through resource efficiency at the level of the *customer* (either households or businesses). Examples include cheap portable coolers that do not require electricity like the ‘Mitti cooler’ (Tiwari et al., 2014), or cheap LED-based solar-powered lights.

Of course, value may subsequently be distributed from firms to customers (through lower prices), or from customers to firms (profit from sales from new or improved products), the extent of this transfer being determined by competition conditions in output markets. However, this distinction between the location of first-order value creation is highly relevant, as these are likely to be associated with different innovation mechanisms, in particular their relationship with resource constraints as a potential antecedent. Innovations that generate value through resource efficiency inside the firm are likely to be the result of problem-induced search that pertain to resource constraints affecting the firm itself. Innovations that generate value for customers through resource efficiency are more likely to be associated with resource constraints at the level of customers. These mechanisms will be further elaborated in sections.

We, therefore, define the following two types of frugal innovation:

- **Type 1:** Frugal innovations where value creation through resource efficiency happens *in the firm*.<sup>2</sup>

- **Type 2:** Frugal innovation where value creation through resource efficiency happens *in the external environment* of the firm at the level of the customer (business or consumer).

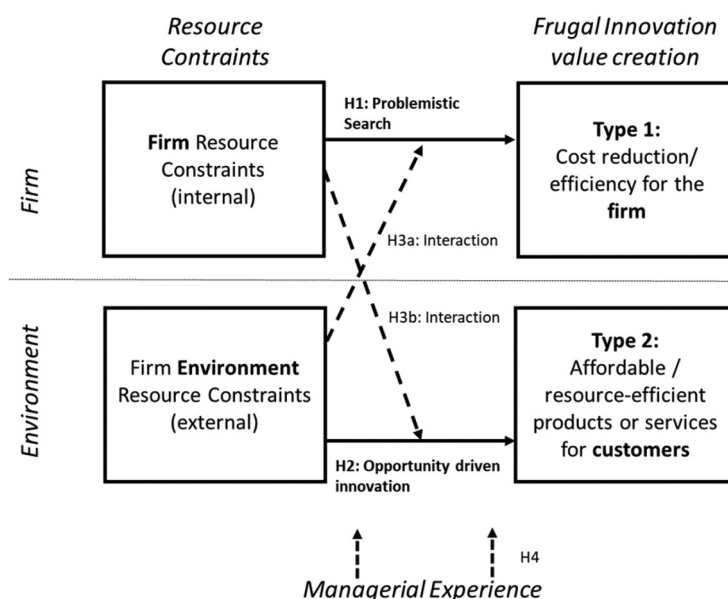
### *Resource constraints as drivers of frugal innovation*

Many firms and households in developing and emerging countries are confronted with severe resource constraints. Access to finance is a pressing constraint for many firms (World Bank Group, 2014), as well as access to reliable electricity (Clark, 2011). A lack of access to adequate transport infrastructure is often cited as another main challenge for many firms and households alike (Hope, 2010). As a result of all these constraints, firms in these environments often lag in productivity, profit and growth rates (Goedhuys & Sleuwaegen, 2009).

Beyond just barriers, resource constraints have also been identified as *drivers* for innovation behaviour. In a first body of literature, emanating from the behavioural theory of the firm, resource constraints experienced within firms and the associated negative performance feedback are known to induce problemistic search (Cyert & March, 1963; Greve, 2003). This effect was investigated for the case of resource constraints in general, where research showed that resource constraints can indeed induce innovations, in particular so in small, competitive markets and product domains where no major capital investments are required (Katila & Shane, 2005). A second body of literature focuses on the role of resource constraints as opportunities for entrepreneurs, creating efficient and affordable products and services that help their customers deal with these resource constraints (Navi et al., 2012; Rosenzweig & Grinstein, 2016). While both bodies of literatures use the concept of resource constraint, they are conceptually not the same. The first relates to resource constraints directly experienced as a barrier *inside the firm*, for instance, when high electricity costs threaten to make production unprofitable. The second relates to a resource-constrained *environment*, in which firms operate, regardless of the exposure of individual firms to these specific resource constraints. An example here would be firms, perhaps well provisioned on dedicated industrial sites, that have a customer base that regularly suffers from power outages. As such, we distinguish between two types of resource constraints:

- Firms experiencing resource constraints directly (*firm* resource constraints),
- Firms operating in an environment where customers face resource constraints (*firm environment* resource constraints).

As a result, we arrive at the first contours of the model where we distinguish between two levels of resource constraints (firm and firm environment) as potential drivers on the one hand and two types of frugal innovations (Type 1 and Type 2) as expected innovation outputs on the other hand. The resulting matrix is presented in [Figure 1](#) below, which will be discussed in more detail in the next sections.



**Figure 1.** Conceptual model.

### *Firm resource constraints as a driver of frugal innovation (problemistic search)*

Internal, firm-level resource constraints generate operational barriers and are likely to reduce current or expected firm performance. For instance, an irregular and/or intermittent access to power reduces firm-level throughputs, can damage electric equipment and complicate production and delivery schedules. Another example are firms faced with high transport constraints, such as high costs for distribution or a high degree of a products lost in transit, raising operational costs.

Such (expected) performance shortfalls can trigger problemistic search (Cyert & March, 1963). The problemistic search mechanism, developed within the context of the behavioural theory of the firm, is based on the behavioural insight that managers are not rational strategic optimisers but rather myopic satisficers, and as such are typically only inclined to take initiative if there is a real problem. This mechanism was further developed in due to negative performance feedback theory (Greve, 2003), which links the insights from the behavioural theory with the concepts of aspirations and risk. Negative performance feedback is the signal when a firm's performance falls below its aspirations. These aspirations can be either an absolute performance level or a relative performance vis-à-vis peers, and present the 'benchmark' against which managers evaluate their performance. In this context, aspirations are not 'future ideal goals', but rather a 'good enough' standard of performance that is acceptable to key stakeholders such as peer colleagues (Baumann et al., 2019) or shareholders (Baum et al., 2005; Kahneman, 1992). This mechanism is further evidenced by insights from the risk literature. Investments in innovation are inherently risky, and managers are typically risk-averse. However, when performance is actually entering the negative domain, prospect theory learns us that loss aversion can overpower the inherent risk-



avoidance as the trade-offs change (Kahneman & Tversky, 1979). The performance feedback mechanism has been empirically validated in various settings (Chen, 2008; Lucas et al., 2018; Vissa et al., 2010), and also for the direct relationship between resource constraints and research and development efforts of firms (Keupp & Gassmann, 2013). As such, firm-level resource constraints are likely to induce firm-level innovation activities.

It is important to note that this innovation inducement effect of resource constraints is not a sufficient condition for the emergence of innovations of a specific frugal, resource-efficient character. The frugality of the innovation output depends on the direction of the search. However, it is expected that resource constraints result typically in search that is guided towards frugal solutions. It is an essential characteristic of problemistic search that it is triggered by a *specific* problem, and that potential solutions generated through search are evaluated largely with respect to the degree that they solve or mitigate that problem, in this case the internal resource constraints. As such, there is an inherent 'relatedness' between the problems and solutions generated by problemistic search (Van Burg et al., 2012). In the case of resource constraints, firms often look for solutions that cut cost, through strategies including substitution of input materials for cheaper alternatives, energy efficiency measures and further vertical integration to reduce expenses (Brem & Wolfram, 2014; Chen, 2008). Such solutions are often, though not always, of an innovative character, as the constraints cannot always be resolved or mitigated with existing methods. There is a dual mechanism of the inducement and guidance effects of resource constraints in developing and emerging country settings (Brem & Wolfram, 2014). There are various examples of firm resource constraints, such as lack of access to water or energy, inducing firms to introduce frugal innovations. (Navi et al., 2012; Prabhu & Jain, 2015).

Given the innovation inducement and guidance effects of the problemistic search triggered by resource constraints, it is expected that firms experiencing a high level of firm-level resource constraints are more likely to produce innovations with of a frugal character of Type 1, addressing internal resource constraints through innovation.

*Hypothesis 1: Firms experiencing a high level of internal resource constraints are more likely to produce Type 1 (firm-level value) frugal innovations.*

### ***Firm-environment resource constraints as drivers of frugal innovation value creation***

Insights from entrepreneurship research, in particular the concept of opportunity recognition, can help us to further theorise these mechanisms. In their efforts to generate profits, firms look for market opportunities within their firm environment. Opportunity discovery and recognition are therefore among the key factors of entrepreneurial success. Entrepreneurship research has shown that successful opportunity recognition greatly depends on knowledge of markets, of ways to serve markets, and of customer problems (Shane, 2000; Su et al., 2019; York & Venkataraman, 2010). Navi et al. (2012), for example, present various case studies in India where external resource constraints were indeed a key source of innovation through a mechanism of opportunity-identification.

Optima Energia in Mexico, a vendor of thermosolar panels for hotels, found it difficult to sell its products as clients have a lack of access to finance for up-front investments. Noticing this barrier, Optima innovated to provide integrated energy performance contracts that required no upfront investment for their clients by partnering with financial institutions. Another example is the 'pay-as-you-go' solar-as-a-service product *M-Kopa*, where customers pay off a solar unit over time by micropayments, reduces the upfront capital investments costs which are impossible to bear for low-liquidity customers (Faris, 2015). These examples show that firms can be opportunity-driven when searching for products or service innovations that aim to resolve a need directly linked to the resource constraints present in the environment.

Due to the general insights that firm managers are myopic (Levinthal, 1993) we know that firm managers gain information on opportunities mostly from their *immediate* environment, often their existing clients, distributors, suppliers, and local authorities (Wang et al., 2013). As such, the local firm environment directly determines the access to information on opportunities. Therefore, resource constraints affecting the firm environment as a whole directly shape the problems of customers and business partners, and thereby also the opportunity space for firms that are aware of these problems and have a potential solution, often an innovation. The higher the resource constraint in the firm-environment, the more likely this 'opportunity signal' will be picked up by the firm manager and translated into innovation activities. This expected pathway is strengthened by recent evidence that 'embeddedness' in local environments is a critical success factor for companies wanting to introduce a successful frugal innovation attuned to the needs of its customers (Ernst et al., 2015).

*Hypothesis 2: (Opportunity-driven Innovation): Firms operating in a high-resource constrained external environment are more likely to produce Type 2 frugal innovations*

### **Interaction effects between firm-level resource constraints and firm-environment resource constraints**

It is likely that firm-environment and firm-level resource constraints do not just have direct effects on the likelihood of firms engaging in frugal innovation, but that they also interact. Firm managers use both signals when deciding to pursue search, and ultimately innovation, concurrently. We know from the behavioural theory of the firm that firm managers tend to show satisficing behaviour, having specific aspiration levels that are tied to past but also *peer* performance (Greve, 2003). This effectively means that problemistic search occurs when firms perform (much) worse than their peers or their own past track record. Recent research in the field of problemistic search has shown that firms take both past and peer feedback into account in conjunction (Lucas et al., 2018), meaning they are both relevant for investigating the relationship between constraints and innovation behaviour.

When all firms in the firm's environment are suffering from high-resource constraints, it becomes a norm instead of a problem requiring a solution. These arguments are founded on the behavioural insights embedded in the behavioural theory of the firm, focusing on the satisficing nature of managers, meaning they have no absolute profit-

maximising motive but desire to perform ‘good enough’ by the standards of themselves and their environment (Cyert & March, 1963). If all firms are struggling, ‘good enough’, may equate to struggling with resource constraints like everybody else, without a clear signal that change is needed.

These findings from the behavioural theory of the firm resonate with similar insights from entrepreneurship studies, particularly around entrepreneurial motivations and ambition, such as the study by Lant et al. (1992) that showed how entrepreneurs in a turbulent environment are more likely to attribute their poor performance externally. A recent study showed how shared negative experiences in an entrepreneur’s direct social context result in discouragement (Neville et al., 2018). Entrepreneurial action such as innovation depends on a manager’s sense of *agency*, which in turn is based on their beliefs regarding their own competence and locus of control (contingency) (Harper, 2003). When similar firms are affected by the same resource constraints as their own firm, managers will tend to infer that their locus of control is limited, as the problem appear to not be contingent on their own actions. While this may be true for some problems, it may also be a sign of collective paralysis. Regardless of whether the actual locus of control is indeed limited in the case of collective problems, what matters for managerial decision-making is the *perceived* reduced locus of control and as such reduced agency. As such, we expect that firms operating in high resource-constrained environments are less likely to develop Type 1 frugal innovations even when firm-level constraints are high, indicating a negative interaction effect.

Similarly, for Type 2, customer-oriented frugal innovations we can expect that the firm-level resource constraints may affect the firm’s innovation behaviour. Due to the limited attention of firm managers and therefore sequential focus on firm goals (Kotlar et al., 2014; Ocasio, 1997), it is likely that firms confronted with their own resource constraints focus on solving those internal problems first, before pursuing more opportunity-driven innovation behaviour (Van Burg et al., 2012). This expectation is also underpinned by the underlying agency theories described above. Whereas we theorised a reduced sense of agency due to a lower perceived locus of control for the interaction effect of environmental constraints on Type 1 frugal innovations, here we see an impact on the other pillar of agency, perceived competence. Entrepreneurs that want to engage with opportunities do so within the frame of the individual-opportunity nexus (Shane & Eckhardt, 2003), where perceived individual ability to overcome the hurdles towards the opportunities is what drives entrepreneurial action (Chell, 2000). When manager are bogged down in internal firm problems, their sense of competence will be lowered until the problem is resolved, thereby reducing their perceived sense of agency in engaging with external opportunities. This effect was also empirically confirmed by a recent entrepreneurship study that showed that firm-level resource constraints induces people to engage in ‘inside the box’-thinking instead of ‘outside the box’ (Dahl & Moreau, 2007). Although it is possible that the internal solutions (Type 1) emanating from problemistic search may also result in products or services for customers (Type 2), we expect that such spillovers are relatively rare and take time to materialise. Overall, we, therefore, expect a negative interaction effect between firm-level constraints and firm-environment constraints for Type 2 frugal innovations as well.

*Hypothesis 3a: (Interaction effect): High firm environment constraints have a negative interaction effect with firm-level environment constraints on the likelihood of firms engaging in Type 1 frugal innovations*

*Hypothesis 3b: (Interaction effect): High firm-level resource constraints have a negative interaction effect with firm environment constraints on the likelihood of firms engaging in Type 2 frugal innovations*

### **Managerial experience**

The mechanisms described above ultimately hinge on managerial decision-making. Having extensively reviewed the role of external and internal resource constraints as drivers of frugal innovation decision-making, it is relevant to acknowledge that managers do not have equal aptitude in translating external and internal drivers or signals into decisions. We know that managers learn by doing (Levitt & March, 1988), or in other words, gain experience. Research building in the capability literature (Teece et al., 1997) has shown that a firm's management capabilities are based on current and acquired knowledge of its managers, although limited by their cognitions and dominant logics (Augier & Teece, 2009). Through such accumulation, managers increase their cognitive complexity of the causal links within their organisation and between their organisation and the firm environment, resulting in more accurate predictive capabilities based on understanding through learning by doing, i.e., experience. Such experience is not just a general modifier for a person's managerial capability, but is particularly important for dealing with new challenges and opportunities that arise inside and outside the organisation. It is, therefore, no surprise that experience has been identified as one of the drivers of potential absorptive capacity for innovation (Cohen & Levinthal, 1990), as it by definition requires recombination of new ideas with existing structures. Given the hypothesised relationships between resource constraints and frugal innovation described above, it, therefore, can be expected that managerial experience is a positive moderator of the inducement effect of resource constraints on innovation behaviour. However, we deduce that this general effect is likely to have different implications for Type 1 and Type 2 frugal innovation in particular. For three main reasons, we expect managerial experience to be more relevant for Type 1 frugal innovation, where firm-level constraints induce firm-level innovations, compared to Type 2 frugal innovation, where firm-environment constraints induce innovations that benefit customers. First, managerial experience is likelier to be more systematically associated with more accurate mental models of internal causalities than those of the external environment, because the external environment has a less well-defined structural space, especially in developing & emerging countries, and managers tend to by nature of the fundamental myopic character of people have more 'practice' with and hence knowledge accumulation of internal matters than external (Vermeulen & Curşeu, 2008). Second, managerial experience is likely to be an even more *relatively* important factor among other drivers in times of internal constraints, because those constraints are known to reduce internal communication and will centralise control (Staw et al., 1981). Third, Type 2 innovation is more opportunity-driven, and as such

dependent on an entrepreneurial orientation. However, here recent work on entrepreneurial orientation has shown that managerial experience has an inverse U-shaped relationship with entrepreneurial attitudes, as older managers' routines may become so ingrained that it outweighs the benefit of better mental models (Bolin et al., 2015). As such, we expect a positively moderating effect of managerial experience for Type 1 frugal innovation, but for Type 2 the mixture of positive and negative expected effects makes it a priori unclear what the net direction of effect would be. We, therefore, do not hypothesise a moderating relationship of managerial experience of firm-environment constraints and Type 2 frugal innovation.

*Hypothesis 4: (Interaction effect): Managerial experience has a positive interaction effect with firm-level constraints for Type 1 frugal innovations*

## Materials and methods

### Data

The World Bank Group Enterprise Survey has included innovation variables in its enterprise surveys and innovation follow-up modules since 2010. As such, the data provides a unique firm-level perspective on innovation behaviour, including descriptions of recent innovations (product, service, or process), as well as characteristics of these innovations. An additional advantage is that these surveys are designed to be statistically representative of the entire formal non-agricultural economy, being selected using stratified random stratified sampling for sector, firm size, and region based on the distribution of formal sector firms (see also Birhanu et al., 2016).

We use the surveys in the period 2010–2016, providing firm-level data sample for 32,897 firms, representing a total population of 1.14 million firms in 168 regions, in 36 countries across Africa, Latin America, and Asia. Of the firms in the sample, 10,273 firms (30.8%) also provided descriptions of the innovation and a description of the change from the old situation, which can be used to characterise the innovation in terms of resource-efficiency. Note that these innovations are *new to the firm*, a relatively broad but valid conceptualisation of innovation and typical for measuring innovation via firm-level surveys, especially in emerging countries (OECD, 2012). In order to validate whether the availability of innovation descriptions could introduce a selection bias, we ran a probit regression on key background variables, in order to determine whether there was a skewed subsample. When controlling for introducing an innovation, only the binary indicator whether the firm is part of a larger firm has a significant, positive effect on the likelihood of being included in the sample. Marginal effects analysis shows that firms not part of a firm group have a likelihood of 30.2% to be included in the sample, while firms that are part of a firm group have a likelihood of 33.8% to be included in the sample. Since none of the other background variables have any predictive effect, and the marginal effect of firm ownerships (i.e., 3.6% point) is relatively modest we proceed with the assumption that our firm sample is representative of these economies, taking into account that we will control for firm ownership in the descriptive and inferential models.

In terms of the (external) firm environment, the data have been organised at the regional (sub-national) level where possible, as large countries such as India have substantial heterogeneity in institutional profiles and the degree of resource constraints. From behavioural economics it is known that managers are myopic, meaning they have limited information and generally only in their specific locale (see for instance, Gavetti et al., 2015). They are therefore likely to focus opportunity-driven innovation activities mostly on local challenges rather than those across the country or abroad.

Note that the available data excludes the agriculture sector and does not include the informal sector, which account for significant parts of developing and emerging country economies. However, a large part of the informal sector in developing and emerging countries exists of one-person ventures (e.g., small-scale retail, transport, small restaurants, domestic services) who are more self-employed rather than being a ‘firm’. These firms typically focus on subsistence entrepreneurship rather than transformative entrepreneurship geared towards growth and job creation for others, and are thereby less likely to engage in innovation activities (Schoar, 2010). If they are engaging in frugal innovation, it is likely to be Type 1 (internal) frugal innovation, focusing on relatively simple efficiency upgrades. It is unlikely that Type 2 frugal innovation, which focuses on resource efficiency value creation at the level of the customer, will systematically take place in the informal sector, as successful product-focused innovation is more likely to happen in a formal firm. Overall, we expect that this possible bias is relatively limited in terms of frugal innovation prevalence rates for both types of frugal innovation.

**Table 1.** Keyword selection and presence.

Keyword	# Innovation Descriptions with keyword	# Innovation descriptions frugal
<b>Affordable</b>		
Cheap	28	10
Saving	159	23
Efficiency	275	120
Affordable	2	0
Low	313	47
Cost	307	108
Budget	4	1
Frugal	0	0
Economy	3	1
Bargain	1	0
Reduce	146	53
Lean	64	9
Sufficient	5	0
Economical	7	5
Inexpensive	1	0
<b>Adaptable</b>		
Flexible	12	0
Portable	12	5
Adaptable	0	0
<b>Accessible</b>		
Convenient	13	3
Accessible	1	0
Easy	81	37
Light	122	33
Simple	45	11

N = 32,897 firms, of which 10,237 innovating firms.

## Measures

The dependent variable, *innovation frugality*, indicating whether a given innovation is frugal or not, is developed by making use of the actual descriptions of innovations in the Innovation module of the Enterprise Survey. In the first stage, all descriptions were screened on the presence of selected keywords that could signify a frugal, resource-efficient innovation. The selection of keywords is a subset of those attributes as identified in a systematic literature review by Agarwal et al. (2017), focusing on the resource-efficiency element and any comparable keywords and organised by Bhatti et al.'s (2018) frugality aspects of affordability, accessibility, and adaptability (see Table 1). The result is a binary measure that indicates whether the innovation is framed as being of a resource-efficient character or not. We relax the requirement of the Bhatti et al. (2018) frugal innovation identification tool for a frugal innovation to have at least some component of affordability, accessibility, and adaptability, with the simple requirement of one aspect match being enough to qualify. We choose this operationalisation because our guiding property for frugal innovation is resource-efficiency, which may be present in any of the affordability, accessibility, or adaptability aspects. One limitation of our operationalisation is its binary character. Resource efficiency is arguably inherently continuous, but a reliable and empirically feasible method of measuring these aspects on a scale is simply not readily available.

All matching records were manually verified for false positives, and subsequently assigned to the Type 1 (firm-focused) or Type 2 (customer-focused) frugal innovation types. A random sample was verified by an independent researcher, leading to an inter-coder reliability (kappa) statistic of .77, indicating a good reliability. The results are shown in Table 1 below.

Note that nine firms simultaneously introduced both a Type 1 and Type 2 innovation. Table 2 presents some typical examples of both types of frugal innovation present in the dataset. The variation is quite large between and within sectors, ranging from very low-tech (using cassava flower as plaster) to high-tech (e.g., new energy-efficient electrical transformers).

For the firm-level and firm-environment resource constraint measures, we use a factor variable of six different specific resource constraints measured in the questionnaire at the firm-level, each ranging from a scale of 0 (no barrier) to 4 (high barrier), including electricity, telecommunications, transport, land, finance, and capable staff. The six variables clearly resolve into a single main resource constraint factor variable, with relatively

**Table 2.** Typical generalised examples of frugal innovations.

Typical Examples Frugal Innovation Type 1	Typical Examples Frugal Innovation Type 2
<ul style="list-style-type: none"> <li>● Installation of a sewing machine that also works without electricity</li> <li>● Installation of an iron wall to reduce cooling needs in the storage room</li> <li>● Installation of a more energy efficient machine</li> <li>● Introduced online booking services</li> <li>● In-house delivery of products instead of outsourcing</li> <li>● Use of cassava flour instead of plaster for construction services</li> </ul>	<ul style="list-style-type: none"> <li>● Provision of follow-up repair services</li> <li>● Energy efficient lighting productions (LED)</li> <li>● Hand-pump that does not require electricity</li> <li>● Energy efficient ventilators</li> <li>● Cheaper package deals for families in hotels/travel</li> <li>● Price reductions for value-conscious consumers</li> <li>● Energy-efficient electrical transformers</li> </ul>



similar factor loadings in terms of size and orientation (all between 0.48 and 0.63). The recommended Kaiser-Mayer-Olkin test gave a 0.8 measure of sampling adequacy, which is considered as ‘meritorious’ (Kaiser, 1974), allowing to continue with this factor variable.

For firm-environment resource constraints, we focus on individual regions as definition for the firm environment. The regional and national means were computed for each of the 36 countries and 187 regions. For regions with less than 50 observations, the mean value was constructed using the national mean. The final data set shows a broad range of firm-environment constraints values, with the top three most resource constraints regions being Ibb (Yemen), Abidjan (Cote d’Ivoire) and Mwanza (Tanzania), and the least constrained regions being Java (Indonesia), Bali (Indonesia) and Bangkok (Thailand). These resource constraints are measured from the perspective of all surveyed firms (including non-innovators), but do not include a household perspective. However, given the substantial samples involved and the broad spectrum of firms surveyed, the regional mean of perceived constraints among all firms should be a good proxy for overall regional resource constraints.

For control variables, we control for whether firms engage in R&D or not, which is obviously a major predictor of innovation outcomes. Furthermore, we use company size (in FTE) and age (in years) in log-linearised forms. As the surveys are designed to be able to represent a representative firm population after using sample weights, we indeed find that our sample includes a wide range of company sizes (ranging from 1 to 29,737 employees) and ages (from 1 to 167 years). We also include information on ownership structure, specifically whether a firm is part of a wider group (20%), and a dummy whether the firm is directly engaged in exports (17%). These characteristics represent the overall capacity of these firms, strategic freedom, and linkages with foreign partners, which all are known factors to influence a firms innovation capacity and strategy (Camisón-Zornoza et al., 2004; Castellacci, 2015; Kim et al., 2008; Vissa et al., 2010). We also included a manufacturing dummy to control for whether the firm is part of the economy’s secondary or tertiary sector, respectively, with 68% of the firms in our sample part of the manufacturing sector. Finally, we control for managerial experience. Managerial experience has been identified as one of the drivers of potential absorptive capacity for innovation (Cohen & Levinthal, 1990), as it by definition requires recombination of new ideas with existing structures. As such, it is defined in interaction with the external and internal resource constraints. For managerial experience, we use the number of years of experience of the firm’s manager within the sector (not necessarily the company). Given the already complex model in a relatively small sample with multiple interaction effects, we have translated this variable to a binary indicator of managerial experience of those having experience above the mean (16 years).

At the firm environment level, we control for various general country characteristics, as well as economic development and formal institutions, in order to avoid the common pitfall of region-level scores for independent variables capturing various other country-level characteristics (Kirkman et al., 2006). Using World Bank data, we include a measure of log-transformed GDP per capacity on a purchasing-power parity basis to capture the level of economic development of a country. Our data set covers a wide range from 765 USD GDP (PPP) per capita in the Democratic Republic of The Congo to 25.6 k USD per capita in Malaysia. In terms of formal institutions, we include country ratings on Rule of Law and Government Effectiveness from the World Wide Governance Indicators, based on an





**Table 3.** Descriptive statistics.

Variable	Description	Model Sample Mean	Standard Error	Min	Max
Firm Resource Constraints	Predicted Factor Score from Factor Analysis	−0.03	.82	−1.30	2.76
Firm-environment Resource Constraints (regional)	Regional mean of Firm-level Constraints	−0.03	.46	−1.23	1.15
R&D-status	Binary indicator whether firm engaged in any R&D activity in the last 3 years	.39	0.48	0	1
Firm size	Log of Total number of firms FTE (non-log value in brackets)	3.40 (29.96)	1.34	0	10.31
Firm age	Log of firm age (non-log value in brackets)	2.73 (15.33)	.72	0	5.12
Firm Group Ownership	Dummy variable indicating whether the firm is part of a larger group	.20	.40	0	1
Export Status	Dummy variable indicating whether firm is exporting	.17	.37	0	1
Manufacturing sector	Dummy variable whether firm is in the manufacturing sector ( <i>vis-à-vis</i> the service sector)	.68	.46	0	1
Managerial Experience	Binary indicator whether firm manager has 15 years or more of experience in the sector	0.51	.50	0	1
WB Doing Business Ranking	Country ranking for WB composite doing business indicator (lower is better)	108.74	36.82	24	187
GDP PPP	GDP Purchasing Power Parity (World Bank data 2014), log-transformed, USD	8.66 (5767)	.64	6.64 (765)	10.15
WB Government Effectiveness Score	World Bank Government Effectiveness Score, standardised	−0.41	.53	−2.1	1.12
Corruption	National mean of to what extent firms perceive corruption as a barrier for doing business (lower is better, scale 0–4)	1.89	.53	.36	2.85

N = 29,309 firms, of which 14,863 innovating firms.

aggregation of sources from a variety of surveys among citizens, firms, and experts following the methodology developed by Kaufmann et al. (1999). To represent formal institutions, include the country's score on the World Bank's Doing Business Reports as an aggregate measure to represent a country's business climate, in particular in areas of licencing, corruption, property right protection etc. These are specific formal institutions that are highly relevant for firms and their innovation behaviour (Oluwatobi et al., 2015). The average score (119.91) is relatively low and in the bottom half (there are 190 ranks), but the range is substantial with South Sudan being the worst performer (187) and Malaysia (24) the best. To represent key informal institutions that play a role in the business environment, we have included a national mean of the perceived barrier of corruption in doing business, based on the WB Enterprise survey. Here we find a range from .36 (Thailand) to 2.85 (Mali). Descriptive statistics for all measure are presented in Table 3.

### Model

For our inferential analysis, we test our hypotheses using the following two regression models, one for each type of frugal innovation:

$$\begin{aligned} \text{Frugal Innovation (Type 1/Type 2)} = & \beta_0 + \beta_1 \text{Firm level Constraints} + \beta_2 \text{Firm} \\ & \text{environment constraints} + \beta_3 \text{Firm level constraints} \times \text{Firm} \\ & \text{environment constraints} + \beta_4 \text{Managerial Experience} + \beta_5 \text{Firm level} \\ & \text{constraints} \times \text{Managerial Experience} + \beta_6 \text{Firm environment} \\ & \text{constraints} \times \text{Managerial Experience} + B \text{ Controls} + \varepsilon \end{aligned}$$

There is a risk that the prevalence of frugal innovations for both Type 1 and Type 2 in our sample is possibly relatively low, due to the exclusive narrow focus on resource efficiency as a characteristic among many other possible innovation characteristics. Should the prevalence be low, normal maximum likelihood logistic estimation is likely to result in econometric downward estimation bias as a result of monotone separation of parameter estimates. We, therefore, use the *Rare Events* penalised maximum likelihood approach (PMLE), initially proposed by Firth (1993) and later developed by Heinze and Schemper (2002). While PMLE is the preferred method above other available methods (Leitgöb, 2013), it does not allow for a correction for clustered standard errors, which is relevant given the clustered independent variable of firm-environment constraints. We, therefore, complement this analysis with the comparable bias reduction method (BRM) proposed by King and Zeng (2001) as a robustness model, which does allow for clustered standard errors. Finally, we include another robustness model for both Type 1 and Type 2 frugal innovation each that only runs the analysis on innovating companies, in order to account for the scenario where frugal innovation captures an effect on innovation in general, not just frugal innovation. Note that for all models, unlike the descriptive analysis of prevalence, no population weights were applied, in order to avoid introducing a bias given the rarity of positive events.

**Table 4.** Frugal innovation prevalence statistics.

Key descriptive statistics	Type 1 (internal)	Type 2 (external)
N in sample	384	66
N in population (est)	7,115	3,585
% in sample (innovating companies)	3.7%	0.6%
% in population (innovating companies)	3.1%	1.6%
Top 5 countries (N in sample)	India (248); Kenya (26); Bangladesh (21); Zimbabwe (13); Ghana (9)	India (31); Philippines (8), Nigeria (3), Zimbabwe (3); Uganda (3)
Top 5 countries (% in sample)	Kenya (9.1%); Benin (8.9%); India (7.6%); Zimbabwe (7.1%); Togo (6.9%)	Philippines (1.8%) Zimbabwe (1.6%); Malawi (1.6%); Cambodia (1.1%); Nepal (1.1%)
Top 5 sectors (% in sample)	Recycling (29%); Transport Machine Man. (10,8%); Petrol Refining (10,5%); Paper (8,0%); Basic Metals (7.8%)	Recycling (7.1%); Electronics (2.8%) Transport (2.2%); IT (2.4%); Machine equipment (2.3%)
Top 5 sectors (N in sample)	Food (37); Transport Machines (30); Machine Equipment (26) Electronics (25) Basic Metals (24)	Electronics (11); Retail (10) Transport (8); Machine Equipment (5); Horeca (5)

## Results and discussion

### *Prevalence of frugal innovations in emerging markets*

As presented in the description of the data set, 34% of the firms in the population introduced a new product, service, or process innovation in the last 3 years. This is quite close to a corrected mean of a recent World Bank analysis that aimed to estimate innovation rates in developing and emerging economies, which arrived at a range of 39–45% (Cirera & Muzi, 2016). These figures are high, which corresponds with the broad definition of innovation used including all new products, services, or processes that are new to the firm.

Using the keyword analysis, we identified 459 firms with frugal innovations in the sample, of which 384 of Type 1 and 66 of Type 2, and 9 cases consisted a composite innovation where both categories applied, e.g., installation of a newer efficient machine to produce a frugal product. This corresponds with 3.1% of firms that have introduced a Type 1 frugal innovation, and 1.6% a Type 2 frugal innovation (see Table 4 below). As such, 1.6% of all firms has introduced a frugal innovation in the last three years. In the total population of 1.14 million firms in 36 countries, this corresponds to an estimated mean of some 10,500 frugal innovations, of which around two-thirds are Type 1 and one-third Type 2.

Table 4 also shows the cross-country variation in the presence of frugal innovations. India has by far the highest absolute number, but this is partly due to the large size of its economy. Relatively, in addition to India, countries such as Zimbabwe, Benin, Kenya, Togo, Democratic Republic of the Congo and Cameroon have the highest shares of frugal innovations with more than 5% of innovations being frugal. It is not surprising to find countries like India and Kenya in this top five, as India is well known for being a hub for frugal innovation (Bound & Thornton, 2012), while Kenya has a very strong entrepreneurial ecosystem, known for innovations such as M-PESA (Kumar, 2014). Some

countries with small samples have zero incidence of frugal innovation in the sample, such as Djibouti, Yemen, Namibia and Guinea. However, given the small sample sizes of frugal innovation for some countries, and the fact that there is some heterogeneity in the level of detail of the descriptions between countries, these percentages should be considered as orders of magnitudes rather than precise estimations.

Further descriptive analysis of our data shows that for Type 1, the majority consists of simple technology upgrades to improve efficiency. Additional analysis shows that out of the 3.1% Type 1 frugal innovations, 2.9% point are such upgrades, with only 0.1% point of innovations based on a simplification approach. Many Type 1 innovation descriptions include of references to high electricity, labour, material/input costs, and transportation costs. Type 2 innovations are relatively sparse (66 in the sample) and are energy-efficient products, with some also oriented towards low-cost, affordable service packages. For both types, it is important to note that virtually all innovations are relatively marginal improvements or the introduction of relatively commonplace products: a new machine, a LED-lamp, software upgrade etc. Such innovations are very unlikely to be of a radical nature, but are still new to the firm and therefore count as frugal innovations.

### *Resource constraints and frugal innovation: model estimation results*

The model estimation results are presented in Table 5, showing the relationships between both firm-level constraints and firm environment resource constraints on the one hand and each of the two types of frugal innovation on the other hand. With regard to the interpretation of the model coefficients, it is important to note that both firm environment and firm-level constraints are included in the same estimation equation, which means that any effect has to be interpreted as having already taken into account the other.

Models 1 and 2 are baseline models that include controls only. They highlight that R&D Status has a high predictive effect on frugal innovation behaviour, indicating that firms that engage in informal or formal research and development activities are more likely to produce an innovation, a relatively uncontroversial finding. Secondly, firm size has a positive effect on Type 1 innovations, suggesting that larger firms are more likely to introduce a Type 1 frugal innovation. This finding is consistent with literature on general determinants of innovation behaviour of firms (Kleinknecht & Mohnen, 2002). Manufacturing companies prove to be more prone to Type 1 innovation but less prone to Type 2 innovation, likely due to being internally more resource-intensive, and as such more sensitive to internal resource constraints.

Models 3 and 4 present the baseline models, without interaction effects, for the Type 1 frugal innovations (internal) and Type 2 frugal (external) innovations, respectively. We find a significantly positive effect of firm-level resource constraints on the likelihood of firms introducing Type 1 frugal innovations. We, therefore, find support for Hypothesis 1. However, we find no significant effects for either a direct effect of firm-environment on the likelihood of firms introducing Type 2 frugal innovations. We, therefore, reject Hypothesis 2. Interestingly, we also find a significant negative effect of firm environments directly on Type 1 frugal innovation introduction, an issue which we will revisit during the marginal effects analysis.

Models 5 and 6 present the full models that also include the various interaction effects between firm-level constraints, firm-environment constraints and managerial



**Table 5.** Model estimation results.

Model	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Type 1: Control Only	Type 2: Control Only	Type 1: Baseline PMLE	Type 2: Baseline PMLE	Type 1: Full PMLE	Type 2: Full PMLE
Firm-level Constraint Factor						
Firm-environment Constraint Factor						
Firm-level Cons. # Man. Exp						
Firm env. Cons # Man. Exp						
Firm-level Cons # Firm Env. Cons.						
Manager Experience	0.043 (0.118)	-0.568* (0.302)	0.061 (0.119)	-0.557* (0.302)	0.086 (0.108)	0.122 (0.220)
R&D activity	1.093*** (0.117)	1.235*** (0.281)	1.152*** (0.120)	1.323*** (0.287)	0.086 (0.108)	-0.674 (0.429)
log FTE	0.085* (0.046)	0.079 (0.106)	0.081* (0.106)	0.057 (0.106)	-0.522*** (0.197)	-0.778* (0.457)
Part of larger firm	-0.002 (0.135)	0.579** (0.280)	0.001 (0.135)	0.579** (0.279)	0.362** (0.161)	0.645 (0.795)
log Age	0.101 (0.083)	0.056 (0.193)	0.080 (0.084)	0.032 (0.194)	-0.409 (0.299)	0.001 (0.795)
Export status	-0.026 (0.150)	0.074 (0.357)	-0.021 (0.150)	0.099 (0.356)	-0.530*** (0.165)	0.001 (0.377)
Sector: Manufacturing	0.410*** (0.141)	-1.031*** (0.273)	0.380*** (0.142)	-1.048*** (0.273)	0.022 (0.122)	-0.626* (0.324)
WB Doing Business	-0.007** (0.003)	0.003 (0.007)	-0.007* (0.003)	0.004 (0.003)	1.100*** (0.121)	1.319*** (0.288)
Government effectiveness	2.626*** (0.365)	1.317** (0.540)	2.606*** (0.369)	1.305** (0.554)	0.084* (0.046)	0.051 (0.106)
					-0.025 (0.135)	0.570** (0.281)
					0.088 (0.083)	0.029 (0.193)
					-0.032 (0.150)	0.112 (0.356)
					0.391*** (0.142)	-1.043*** (0.273)
					-0.006* (0.007)	0.004 (0.007)
					2.679*** (0.375)	1.314** (0.556)

(Continued)

Table 5. (Continued).

Model	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Type 1: Control Only	Type 2: Control Only	Type 1: Baseline PMLE	Type 2: Baseline PMLE	Type 1: Full PMLE	Type 2: Full PMLE
GDP PPP	-1.921*** (0.177)	-0.796*** (0.284)	-1.990*** (0.179)	-0.883*** (0.294)	-2.047*** (0.181)	-0.889*** (0.294)
Corruption	1.865*** (0.220)	0.294 (0.341)	1.825*** (0.216)	0.284 (0.334)	1.909*** (0.226)	0.291 (0.338)
Constant	8.964*** (1.429)	0.313 (2.610)	9.548*** (1.452)	0.968 (2.676)	9.940*** (1.441)	1.048 (2.670)
Observations	21,660	21,660	21,660	21,660	21,660	21,660
Wald Chi-2	282.5	61.07	294.9	64.49	305.8	66.07

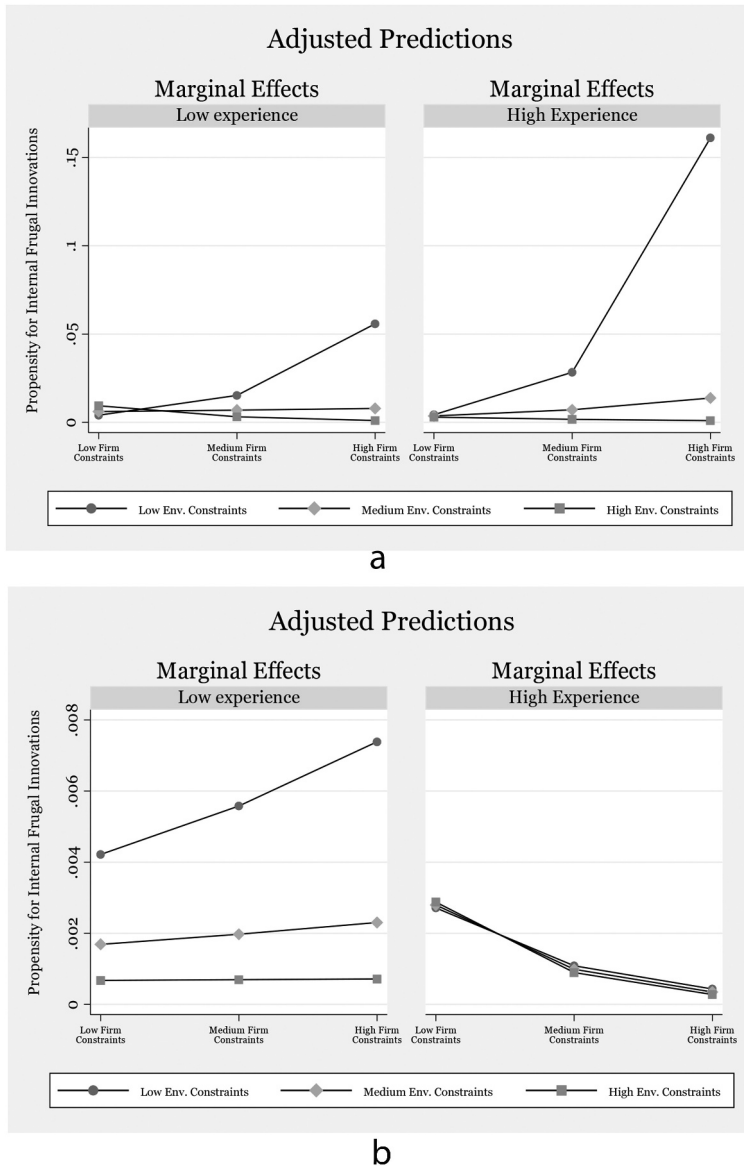
Standard errors in parentheses

\*\*\* p < 0.01, \*\* p < 0.05, \* p < 0.1

PMLE: Penalised Maximum Likelihood Estimation, Firth method (Heinze & Schemper, 2002)

BRM: Bias-reduction method (King & Zeng, 2001)

Note: a triple interaction model between firm-level constraints, firm-environment constraints and managerial experience was explored but proved to be insignificant and not contributing to the model, and was left out.



**Figure 2.** (a) Marginal Effects Analysis internal value frugal innovations (Type 1) (b) Marginal Effects Analysis external value frugal innovations (Type 2).

experience, respectively. Firstly, we find as expected, a significantly negative interaction effect between firm-level and firm-environment resource constraints for Type 1 frugal innovations, supporting Hypothesis 3a. However, we do not find the similar expected negative effect on Type 2 innovations and reject Hypothesis 3b. However, we do not find the similar expected negative effect on Type 2 innovations and reject Hypothesis 3b. For the interaction between firm-level resource constraint and managerial experience, we find support for the expected positive interaction under Hypothesis 4. In fact, while the interaction effect size is relatively high, the main effect turns insignificant in this full

model, meaning the effect of firm-level resource constraints on Type 1 frugal innovation (H1) is fully conditional on the firm's managerial experience. As expected, we do not find confirmation for a similar moderating role of managerial experience for the relationship between firm-environment constraints and Type 2 frugal innovation. In fact, we find an unexpected significant highly negative moderating effect of managerial experience on the relationship between firm-level constraints and Type 2 frugal innovation, which we will further explore in the discussion.

As an extension of the model regression analysis, we have carried out a marginal effects analysis for both Type 1 and Type 2 Frugal Innovations. By evaluating the likelihood function at several levels of firm and firm-environment resource constraints, controlling for managerial experience status, we can interpret the relative size differences for these effects as well as the interaction effects. [Figure 2\(a\)](#) shows that the differences between low and high environmental external resource constraints can be quite substantial for Type 1 between experienced and non-experienced managers, and that the interaction effect between firm-level and firm-environment is also strong. Firms with experienced managers, with high firm-level resource constraints in a low-resource constraint environment have a predicted frugal innovation propensity of 16%, while firms with less experienced managers and low firm-level resource constraints only have a propensity of 0.8% for frugal innovations. This effect size is strikingly large compared to the average incidence of 1.6% in the non-weighted sample. However, for firms operating in a medium or high-level constraints environment, there is almost no difference in terms of frugal innovation propensity for firms that are subject to medium or high-level firm-level resource constraints. This suggests that, in addition to the aforementioned strong effect of managerial experience, it is the interaction effect between firm-level and firm-environment driving these results, and that the unexpected direct negative effect of firm environment on Type 1 innovation is relatively less important. For Type 2 frugal innovation ([Figure 2\(b\)](#)), the marginal effects analysis shows that for less experienced managers the predicted incidence is 0.8% with high firm-level constraints, and less than 0.1% for more experienced managers. While relatively a large difference, it should be noted the absolute difference is small due to a generally low incidence of Type 2 Frugal innovation of only 0.2%

[Tables 5](#) and [6](#) also provide insights in terms of other variables that have an effect on the incidence of frugal innovation (both types). Firstly, we find that firms that are part of larger firms are significantly more likely to show Type 2 frugal innovations. Type 2 innovations are likely to require better-developed capabilities as well as resources to produce than Type 1 due to their external, and therefore more uncertain nature. Smaller, stand-alone firms may lack the resources and capabilities to engage in this more complex innovation strategy. Secondly, we find that manufacturing firms are less likely to produce Type 2 and more likely to produce Type 1 frugal innovations. Internal resource-saving opportunities may be more pronounced for manufacturing companies, leading to higher likelihood of these companies pursuing Type 1 frugal innovation. Service companies are more likely to have extensive direct interaction with clients, resulting in more opportunities to scout for resource-saving opportunities at the level of the customer. Thirdly, at the country level, we see that countries that have lower GDP PPP as well as higher Government Effectiveness ratings tend to show more companies with frugal innovations (both types). This is consistent with the literature on frugal innovation, where less



**Table 6.** Robustness model estimation results.

Variables	(7)	(8)	(9)	(10)
	Type 1: BRM	Type 2: BRM	Type 1: PMLE Innovator- only	Type 2: PMLE Innovator- only
Firm-level Constraint Factor	0.086 (0.096)	0.123 (0.180)	0.044 (0.110)	0.062 (0.223)
Firm-environment Constraint Factor	−0.522* (0.281)	−0.674 (0.518)	−0.515** (0.209)	−0.730 (0.451)
Firm-level Cons. # Man. Exp	0.362** (0.172)	−0.779** (0.385)	0.314* (0.166)	−0.882* (0.465)
Firm env. Cons # Man. Exp	−0.409 (0.275)	0.645 (0.503)	−0.345 (0.310)	0.804 (0.815)
Firm-level Cons # Firm Env. Cons.	−0.530** (0.208)	−0.001 (0.358)	−0.420** (0.168)	0.148 (0.378)
Manager Experience	0.022 (0.124)	−0.622* (0.322)	−0.040 (0.124)	−0.625* (0.325)
R&D activity	1.100*** (0.192)	1.319*** (0.307)	−0.076 (0.124)	0.195 (0.285)
log FTE	0.084 (0.054)	0.051 (0.087)	0.001 (0.048)	−0.046 (0.108)
Part of larger firm	−0.025 (0.132)	0.570** (0.222)	−0.067 (0.136)	0.488* (0.281)
log Age	0.088 (0.126)	0.030 (0.209)	0.068 (0.085)	0.042 (0.194)
Export status	−0.032 (0.203)	0.113 (0.329)	−0.141 (0.150)	0.036 (0.353)
Sector: Manufacturing	0.391** (0.158)	−1.044*** (0.273)	0.453*** (0.145)	−1.013*** (0.275)
WB Doing Business	−0.006 (0.005)	0.004 (0.008)	−0.010*** (0.003)	0.002 (0.007)
Government effectiveness	2.679*** (0.632)	1.313* (0.701)	2.314*** (0.382)	0.998* (0.535)
GDP PPP	−2.047*** (0.279)	−0.889** (0.391)	−1.873*** (0.192)	−0.613** (0.309)
Corruption	1.909*** (0.381)	0.289 (0.388)	1.964*** (0.228)	0.286 (0.342)
Constant	9.941*** (2.310)	1.055 (3.172)	10.621*** (1.538)	0.736 (2.791)
Observations	21,660	21,660	7,416	7,416
Wald Chi-2			150.7	34.63

Standard errors in parentheses

\*\*\* p &lt; 0.01, \*\* p &lt; 0.05, \* p &lt; 0.1

PMLE: Penalised Maximum Likelihood Estimation, Firth method (Heinze &amp; Schemper, 2002)

BRM: Bias-reduction method (King &amp; Zeng, 2001).

affluent customers in low-income countries and efficiency-seeking drive frugal innovation practices. Good formal institutions are an important factor in making formal firms invest in the future through innovation (Urbano et al., 2019). Interestingly, we also find that countries in which firms suffer more from corruption practices, firms have a higher incidence of Type 1 frugal innovation, but not the external Type 2 frugal innovation. These results are consistent with literature on the role of corruption and innovation (Anokhin & Schulze, 2009) and analogues to the earlier mentioned positive role of formal institutions, where external engagement to solve problems is less likely when trust is low. This barrier is not present for more internally oriented innovations.

### **Robustness analysis**

Our model analysis also included four robustness models (See [Table 6](#)). The first two models, Model 7 and 8 show the estimations using the bias-reduction method (BRM) as an alternative for the penalised MLE in our main models. Overall, the differences between the PMLE and BRM methods are small, and the models shows similar estimates, although the significance levels differ slightly for some estimates. Secondly, we included two models (Model 9 and 10) that run the same analysis on a subset of innovating firms only. Although estimated effect sizes slightly differ, effect directions and significance levels are highly comparable for this group. This means that our analysis does not inadvertently capture a general innovation-inducing effect of resource constraints, but is also specifically valid for the case of frugal innovations. However, the innovator-only models (7 and 8) show that this effect, albeit substantially smaller, also persists when looking exclusively at frugal vs non-frugal. This would suggest that frugal innovations are more likely to be preceded by R&D than non-frugal innovations. However, this effect is not consistent across models and falls away when focusing on innovators only, suggesting that this is only a predictor for innovation in general, not frugal innovation in particular.

### **Discussion of results**

The results merit further discussion and qualification. Firstly, we find a clear difference in prevalence between Type 1 and Type 2 frugal innovations. Type 1 frugal innovations can be considered ‘slightly common’, although certainly not mainstream, but Type 2 frugal innovations are certainly ‘rare’. Type 2 frugal innovations typically are more difficult to develop for firms in developing countries compared to Type 1, and extracting subsequent value is more uncertain. In addition, Type 2 innovations require firms to have better environmental awareness and capacity to translate unmet customer needs to a solution, beyond the standard capabilities to successfully engage in search (Danneels, 2002; Wang & Ahmed, 2007). Extracting value from these innovations is more difficult because the value created by the resource efficiency benefits the customer first, and only indirectly benefits firms through additional demand for new products. Demand is inherently uncertain to predict, and value can only be captured if market conditions, such as competitive forces, allow so. Compared to Type 1 frugal innovations, which often involve cost-cutting solutions that generate savings immediately, Type 2 frugal innovations are simply riskier investments due to this increased uncertainty, even though potential gains could be high. As such, Type 2 frugal innovations are more difficult and riskier, leading to a lower prevalence.

Secondly, a major unexpected result is that we find no evidence of a main effect of firm-environment resource constraints on Type 2 frugal innovation. This finding might be partially due to the general scarcity of such types of innovations with only 66 Type 2 innovations in the sample, making it statistically more difficult to determine effect sizes, despite having applied adjusted estimation models for rare events. However, the absence of an effect might also reflect the fact that frugal innovations that benefit customers in terms of resource efficiency are often more complex, even radical innovations (Zeschky et al., 2014), whereas internal (Type 1) innovations are often more incremental. Radical, more complex innovations are typically more idiosyncratic in their origins, and rely more

on exceptional firm-level capabilities in terms of opportunity recognition (Danneels, 2008) and entrepreneurial ambition. In addition, developing new products and services is a typical characteristic of a small number of firm managers that engage in transformational entrepreneurship, while dealing with low-level process innovation to solve immediate problems is something that the majority of subsistence entrepreneurs also engage in (Schoar, 2010). If firm-level capabilities are more important for Type 2 innovations, contextual factors such as firm-environment resource constraints could arguably be relatively less important. This finding is also consistent with earlier insights that indicate that opportunity recognition is only one amongst many factors for successful product innovation, others including creativity, networks, self-efficacy (Ardichvili et al., 2003).

Thirdly, the results on the role of managerial experience as a moderator between resource constraints and frugal innovation further highlight an important divergence between Type 1 and Type 2 frugal innovations. For Type 1, we found that sufficient managerial experience is actually a *sine qua non* for the inducement effect of firm-level resource constraints. On the other hand, we found a surprising negative interaction effect of managerial experience and firm-level resource constraints for Type 2 frugal innovation. We found no interaction effects between managerial experience and firm-environment research constraints. For Type 1, this implies that the problemistic search phenomenon is conditional on manager's capabilities to process the problem signals and translate this into effective action. An interesting question for further research would be whether this requirement of managerial experience is due to the former (engaging in search) or the latter (translating to an actual innovation). As expected, we found no role for managerial experience in the relationship between firm-environment constraints and Type 2 frugal innovation, as we expected a less close link between managerial experience and accurate mental models of external causalities, due to the relatively more important role of managers in times of internal constraint and the typically lower entrepreneurial orientation of more experienced managers. The negative effect of managerial experience in the relationship between firm-level resource constraints and Type 2 frugal innovation could potentially be explained similarly by the reduced entrepreneurial orientation of more experienced managers. Pursuing external Type 2 innovations in a time of substantial firm-level constraints would certainly require high entrepreneurial orientation, as it is arguably quite risky (Gudmundsson & Lechner, 2013).

Our study has a number of limitations that deserve attention. First, it is important to note that these findings are based on self-identified descriptions of innovations and their characteristics by firm managers. Such survey-based assessments are intrinsically subjective due to distortions such as cognitive problems and social desirability (Bertrand & Mullainathan, 2001), and these challenges have also been confirmed for the measurement of innovation using enterprise surveys (Cirera & Muzi, 2016). It is possible that this has led to underreporting of frugal innovations, for reasons of social desirability, since a focus on affordability or resource-efficiency may undermine the aspirational character of their product or service. Firm managers may want to avoid associating their product with poverty, and focus on other characteristics. Research has indeed shown that the presence of conspicuously aspirational consumption is an important characteristic of the emerging and developing countries (Gupta & Srivastav, 2015). Also, managers may unknowingly fail to articulate the aspects of frugality, as concepts of affordability, resource-efficiency

and environmental protection may not be part of their explicit discourse and cognitive understanding. As both biases point in the same direction, it is likely our approach results in some underreporting of frugal innovation, and that the potential and prevalence in reality is higher than the figures presented here. However, it is most likely to underreport on the more mundane frugal innovations, as the more radical, highly frugality-focused innovations are almost by definition produced by articulate and proud innovators, who would describe their innovation accordingly. As such, it is unlikely that this limitation materially affects our findings.

Second, using a cross-sectional data set instead of panel-based data has inherent consequences for the level of confidence in terms of assigning causality to the explored hypothesised links. While our models include appropriate controls, a single data point for each firm leaves open the risk of reverse causality (Bascle, 2008). This risk is relatively minimal for the analysed linkages between firm environment resource constraints, which are based on regional medians. There is generally not a plausible way a single firm could have already impacted the regional level of resource constraints through their frugal innovations in the timeframe of the study. Of course, there is a more substantial risk of reverse causality between firm-level constraints and frugal innovations. In that case, an alternative explanation could be that successful frugal innovations have already impacted the firm's perception of resource constraints. Such an effect could have put a downward bias on the measured estimate of the effect of firm-level resource constraints on frugal innovations. However, despite this potential bias, a significant main effect was found, so is unlikely to affect our findings.

## Conclusion

We will briefly describe the key contributions of this work to the field of frugal innovation, as well as more broadly to the wider innovation literature, concluding with avenues for further research and key lessons for policymakers and practitioners.

We identify two main contributions to the field of frugal innovation specifically. First, this paper contributes by embedding the relationship between one of the main expected drivers of frugal innovation, resource constraints, and frugal innovation incidence in established frameworks of problemistic search and opportunity recognition. Our findings suggest that the phenomenon of frugal innovation is, at least partly, a logical extension of the concept of problemistic search. As such, the study of frugal innovation can benefit from a rich literature of the interaction between constraints, performance, and innovation (Posen et al., 2018).

Second, this study deviates from existing literature on frugal innovation by moving beyond case studies and bringing first estimates of the total prevalence in developing and emerging countries. Building on recent theoretical developments (Bhatti et al., 2018) we further contribute to the development of a typology that clearly categorises frugal innovation into two fundamental types depending on the locus of the resource-efficiency value creation, and which provides a practical operationalisation that disentangles antecedents, output and method dimensions of frugal innovation. The findings highlight that this approach can be productive for theoretical and empirical investigation of the phenomenon of frugal innovation, and can be used in the future by researchers to investigate other aspects of frugal innovation.

We also identify two main contributions to the wider problemistic search and opportunity recognition fields. First, we extend beyond conventional frameworks of performance feedback or constraint-induced search by jointly investigating firm-level and firm-environment constraints, yielding rich additional perspectives. Our finding that the interaction between firm-level and firm-environment performance is a critical driver for problemistic search shows how important the firm-environment dimension is for firm-level innovation behaviour, thereby providing further credence to recent calls to better integrate this dimension into the behavioural theory of the firms (Gavetti et al., 2012).

Second, whereas most of the literature has focused relatively narrowly on profit declines being the specific problem triggering problemistic search, the initial conception of problemistic search referred more broadly to ‘a’ problem in general (Cyert & March, 1963, p. 61). Our work suggests that problemistic search may indeed also be induced by resource constraints, which only possibly result in lower profits at a later stage. It is likely that firms do not wait for the end-of-year profit balance to be known, but rather that search can already be triggered by a broad range of signals that indicate performance is at risk.

Third, our striking findings regarding managerial experience show that sufficient experience is a key boundary condition for the inducement effect of resource constraints on internal efficiency frugal innovations (Type 1), but actually has no effect for external constraints on Type 2 frugal innovation. If an effective search response induced by constraints may be conditional on the presence of enough capabilities to recognise the problem and opportune search pathways, it could explain why so far the literature of problemistic search (Posen et al., 2018) and resource constraint-induced innovation (Rosenzweig & Grinstein, 2016) has suffered from a relatively high degree of inconsistent findings. By including the managerial experience, or more broadly the capabilities and cognition fields, future work into problemistic search could potentially yield more consistent findings.

This work opens up a number of clear avenues for future research. For frugal innovation specifically, the comparatively high presence of Type 1 frugal innovations combined with a relative paucity of research focusing on this type of frugal innovation as compared to Type 2 innovations imply a strong opportunity to further investigate the former. Other opportunities include a more detailed investigation of the interaction between the type of innovation *method* (e.g., bottom-up) as a determinant for the frugality of innovation outputs (Pansera & Owen, 2018), investigating the required firm-level competences, including human capital, for generating Type 1 and Type 2 frugal innovation (Danneels, 2008; Van Uden et al., 2017), looking the effectiveness in terms of development outcomes for both types (Leliveld & Knorringa, 2018) or analysing the relationship between socio-economic causes of constraints and subsequent frugal innovation behaviour (Pansera, 2018). Within wider innovation research, this work opens up possibilities to investigate a broader set of feedback measures, going beyond the typical turnover or profit performance, to include problem signals as heuristics for upcoming performance within the framework of problemistic search and performance feedback (Posen et al., 2018). A second logical wider extension of this work would be to investigate the role of managerial experience as a moderator in case of positive feedback.

This work has also produced various relevant insights for practitioners and policy-makers in the field of innovation. The study shows that frugal innovation is used by firms as a response to resource constraints. Although we do not analyse the subsequent success of these innovations, its prevalence shows that using frugal innovation may be a useful firm strategy to cope with resource-constrained situations. The results suggest that the colourful Type 2 frugal innovations we know from the case studies are not yet mainstream practice among innovators in developing countries, and are arguably very rare among traditional firms. Of course, in the world of innovation, quantities are rarely the sole driver of impact, and one powerful radical frugal innovation may yield more aggregate effect than dozens of small-scale modest efficiency improvements. Moreover, Type 2 frugal innovations may also be particularly present among other type of economic actors, such as NGOs, semi-public sectors (e.g., health care) or even public actors. However, both from a research and a policy perspective, the large ‘bulk’ of more mundane efficiency upgrades deserve at least as much attention in the discussions on frugal innovation. A second lesson for practitioners and policymakers centres around the role of managerial experience. Upgrading managerial capabilities in firms is a staple of many national development strategies, and are shown to be indeed also very relevant for promoting frugal innovation capacity, although it may be important to not implicitly discourage entrepreneurial orientation when promoting capacity development. Of course, in actual implementation aspects such as ultimate development outcomes of frugal innovation, socio-economic inequality, and market disturbance would need to be taken into account.

## Notes

1. The same is true for closely related and partially overlapping concepts such as *jugaad* innovation, cost-innovation, and resource-constrained innovation (Brem & Wolfram, 2014; Cunha et al., 2014; Nahi, 2016; Pansera & Owen, 2018; Williamson, 2010).
2. In parts of the literature, similar types of frugal innovation are called ‘cost innovation’ (Zeschky et al., 2014), but often this type of innovation is also defined simply as frugal innovation (Devi & Kumar, 2018; Kroll & Gabriel, 2017). We keep the term ‘frugal’ here for both types of resource efficient innovations for narrative ease, but also, more importantly, because of our theoretical framework where we focus on separating the locus of the resource efficiency value creation and the locus of the driver. While cost-innovation is typically defined as ‘doing the same with less’ (Zeschky et al., 2014), our definition does not impose necessarily the condition of it being ‘the same’, as some firm-internal process or business model innovation may actually result in quite a different service/product experience for the client.

## Highlights

- A conceptual separation of frugal innovation dimensions is needed for theorizing.
- We find modest (low) prevalence of internal (external) frugal innovation.
- Firm-level resource constraints strongly induce internal frugal innovation.
- This effect is contingent on firms being more constrained than their peers.
- Managerial experience is a critical moderator in the constraint–innovation relationship.
- No effect of constraints on customer-oriented frugal innovations can be reported.



## Disclosure statement

No potential conflict of interest was reported by the author(s).

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