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FRUGAL INNOVATION AS ENVIRONMENTAL INNOVATION

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Frugal innovation as Environmental Innovation

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Abstract

In this paper we contribute to the literature on frugal innovation through two directions. First we define FI as a new technological paradigm. Secondly we consider FI as an environmental innovation by defining, considering, drawing the consequences of the economic impact of the environmental side of FI. We suggest a framework accounting for how frugal innovation contributes to sustainability. At last we set out the factors driving the implementation of FI and point barriers to their diffusion.

Key word: frugal innovation, environment, technological paradigm, sustainability

Introduction

In this paper we contribute to the literature on frugal innovation (FI thereafter) through two directions. First we define FI as a *new technological paradigm*. We outline consequences related to this proposal. Secondly we show the positive consequences for the environment of the implementation of the new paradigm. If recent contributions point the positive environmental consequences of FI, only a few analyze them in depth. We still have a weak understanding of FI as an environmental innovation. This conceptual paper wants to fill this gap by systematically defining, considering, drawing the consequences of the economic impact of the *environmental side* of FI. We develop a conceptual (analytical) framework for future research and a better understanding of management practices as far as FI is concerned (section 2). At last we set out factors driving the implementation of FI and point barriers to their diffusion (section 3).

1. FI as a new technological paradigm

1.1. How the literature define Frugal innovation

The recent literature offers several definitions for FI (for a compendium see Tiwari and Kalogerakis, 2016). For Basu et al. (2013) "Frugal Innovation is a design innovation process in which the needs and the circumstances of citizens in the developing world are put first in order to develop appropriate, adaptable, affordable, and accessible services and products for emerging markets". According to Radjou et al. (2013, p.45) FI is a type of Jugaad innovation/ It relies on six principles: "1. Find opportunities in a context of adversity and transform constraints into opportunities, 2. Do more with less, 3. Think and act with agility, 4. Aim for

simplicity, 5. Involve the marginal population, and 6. Follow your heart" [Radjou et al., (2013), p.45]. Woolridge (2010) notes FI is "not just a matter of exploiting cheap labour (although cheap labour helps), it is a matter of redesigning products and processes to cut out unnecessary costs". For Eagar et al. (2011) FI is related to new market segments linked to new needs (Tiwari et al., 2017a). Recently Weyrauch and Herstatt (2017) on a basis of the results of a literature review and managers interviews retain three criteria for frugal innovation: substantial cost reduction, concentration on core functionalities, and optimized performance level.

Many among the first definitions of FI draw on the innovation dynamics in emerging economies (India in particular). But this type of innovation has general features valid for developed economies as well. For instance Tiwari et al. (2016) have hypothesized that frugality has an important social value. In effect economic crisis in the industrialized world and the rising consumption in developing world to turn frugality into an important societal value for increasing BOP consumption (in the North and in the South). Gupta and Wang (2009) argue FI can also affect services and business models with low resources and environmental implications. In the context of emerging markets, giving non-affluent customers opportunities to consume affordable products and services suited to their needs (Tiwari et al. 2017). For summing up Frugal innovation is designed as offerings made specifically for low-income market segments (Nunes and Breene, 2011). In a nutshell frugal products are less sophisticated (Brem and Wolfram, 2014) and more inclusive because more of the poor's needs are now satisfied (Tiwari et al., 2017b)[1]. FI is considered as in line with the demand on new markets related to new needs (Eagar et al., 2011), but especially performant for the poorest consumers (Nunes and Breene, 2011). Nevertheless it could be relevant for the products dedicated to poor people from the North (Zeschky et al., 2011). Following Chataway et al. (2014) we can outline the characteristics of the dominant form of technological innovation as capital-intensive, scale intensive, dependent on high-quality networked infrastructure, relying on skilled labour. By contrast FI has none of these characteristics except may be the scale intensity. FI has important "positive" characteristics: a low technological complexity (see next development), no clear relation with any Science Push

[1] Fi is sometimes related to reverse innovation (see for instance Brems and Ivens, 2013). In our view reverse innovation is a type of innovation performed in the South that is transferred to the North after some incremental or larger changes (Immelt et al., 2009). Nunes and Breene (2011) suggest defining reverse innovation as new products developed in emerging markets which are then modified for sale in developed countries.

effect, a design based on the systematic cutting out the "luxury" and unnecessary features of products developed for developed markets.

1.2. A suggestion: FI as a new 'technological paradigm'.

As for us we draw on the foundations of the Economics of Innovation for defining rigorously FI. We consider FI as a 'technological paradigm'. According to Dosi (1982) "a 'technological paradigm' defines contextually the needs that are meant to be fulfilled, the scientific principles utilized for the task, and the material technology to be used. In other words, a technological paradigm can be defined as a 'pattern' of solutions of selected techno-economic problems based on highly selected principles derived from natural sciences... jointly with specific rules aimed to acquire new knowledge and safeguard it, whenever possible, against rapid diffusion to the competitors". Dosi (1982) uses also the term of *research program* as equivalent to technological paradigm. It is a set of positive powerful heuristics giving strong prescription on the directions of technical change to pursue and those to neglect. In this respect it offers an excellent example of exclusion (selection) effect: the efforts and the imagination of engineers are directed to precise directions of research. FI matches this concept of technological paradigm[2]. This notion helps to get a better understanding of the structure and characteristics of new technologies as shown by Coccia (2012, 2014) in the cases of converging scientific fields in drug industries and health organizations. As a research program it directs work by engineers and researchers and can be applied to a large set of technologies. It is a matrix from which new technological solutions can be designed and implemented.

According to our view: the main structural techno-economic features of FI as a new paradigm is the search of less functionality with a minimum quality matching the needs of more poor (or less rich) people[3]. As a consequence we can observe a systematic cutting out the "luxury" and unnecessary characteristics of products. The search of a less number of functionalities is the path of researching for engineers and researchers. Of course the main core functionalities of the product are conserved. A lot of definitions we found in the literature emphasize this point. It must be noted for a particular set of products it is simpler to decrease the number of

[2] See also Le Bas (2016).

[3] It is seems to us this characteristic unable us to discriminate products based on FI and those simply acknowledged as *low costs*. When there are less functionalities and technological coherence is maintained we are in the frame of frugality.

existing functionalities instead to increase them because the structure and the working of the product are less impacted. This characteristic is crucially in relation with technological complexity.

As a first approximation and following Ayres (1987) we define technological complexity as the "amount" of information processing needed for the functioning of a system (in other terms the number of different parts in system). We can infer of that FI relies on lesser technological complexity. When the number of functionalities decreases it comes that the number of elements of the product and correlatively the number distinct operations involved in the manufacturing necessarily decrease. FI is a way for solving problems by producing products with less functionalities and low price but a certain level of performance. Performance stands at the core of the notion of technological paradigm. The performance of all functionalities and engineering characteristics (speed, power, durability, and accuracy) are of course of a real importance for frugal technologies. In this context Tiwari and Herstatt (2012, p.98) note that frugal innovations are "fulfilling or even exceeding certain pre-defined criteria of acceptable quality standards". For Weyrauch and Herstatt (2016) FI tend to optimize the performance level. It simply means taking into account the fact we cut the number of functionalities the performance is good enough, in a nutshell acceptable. FI must meet the performance level that is needed for its purpose and the local conditions compared to current solutions available in the market or over-engineered (Weyrauch and Herstatt, 2016).

In order to correctly assess the radical gap made by this new paradigm it is important to study in a deeper way the relationship between complexity and performance. The dominant approach draw on the idea there is a causal correlation between performance and technological complexity. For instance Aryes (1987) argued: "high performance in a product tends to require a high degree of precision and complexity in the design and manufacturing process". One crucial consequence of our definition of FI is the links between technological complexity and technological performance does work anymore. With the paradigm built up on frugality the products we get are less technological performant. With the standard (I mean not frugal) products higher technological performance is a mean for pricing higher and finding new consumers. It does work for frugal product. Lesser technological performance with a *minimum threshold* enables to drastically decrease the average costs of production and to sell the products with lower prices for poorer consumers.

It is time to analyze the manufacturing process through the perspective of frugality. In general FI is performed in a frugal way (Brem and Wolfram, 2014; Moore, 2011). In the recent literature such a process is known as *frugal engineering* sometimes also labelled as *constraint-based innovation* (Brem and Wolfram, 2014). Moore (2011) notes that frugal innovation goes beyond R&D by increasing the efficiency of the whole supply chain: there is no use of modern technology and no capital investment but a high level of service and adaptation to circumstances in the operating environment. There is one important consequence of the diminution of product complexity on manufacturing process: the production system becomes less complex and the cost of information required for controlling the manufacturing process as a whole can be decreasing drastically. This approach aiming to adapt existing technologies to local constraints and markets in order to reduce development costs and time has numerous implications in terms of local development.
In the case of previous technological paradigms their emergence and diffusion were closely associated with the rise of interrelated and pervasive radical innovations, which had the potential to be used in many sectors of the economy and to drive their long-run performance (Castellacci, 2008). Here as in the context of frugality we do not see really radical innovations that play such a role.

Of course considering FI as a new technological paradigm is not in opposition with the numerous definitions of FI we found in the literature (see above). Using the notion of technological paradigm aims to underline the *dynamic nature* and the characteristics of this type of innovation. In particular we retrieve the three criteria put forth by Weyrauch and Herstatt (2016): substantial cost reduction, concentration on core functionalities, and optimised performance level.

If Frugality shapes a generic knowledge technology for producing technological change it can relies on diverse technics for searching new (frugal) technological options. Tran and Ravaud (2016) in the field of medicine show there are new and old intellectual tools for discovering relevant FI (of course the list is not comprehensive):

- Lean tools refer to the simplification and adaptation of existing technologies to reduce costs
- Opportunistic solutions refer to the clever use of modern for-everyone technologies to tackle “old problems”

- Contextualized adaptations refer to the diversion of existing techniques, materials or tools for completely different purposes.
- Local bottom-up innovations refer to original, simple – and even simplistic – ideas to obtain results not previously attainable

While the literature has not dealt with this point so much until now we find in many papers different categories of frugal products, for instance frugal low-end and frugal high-end. One example drawn from the car industry enables us to highlight this point. In India the Tata Nano car is sold for less than $2,500. It aimed at low income consumers wishing to move up from a two wheeled scooter. Nevertheless many experts have noted this car would not have passed the safety tests in Europe and North America. As a consequence it does satisfy the demands coming from high income consumers in developed countries. In a nutshell it would not be candidate to a reverse innovation process. By contrast the Kwid launched in 2015 3500 euros (around $4000) manufactured in India for in a first step the Indian market by Renault-Nissan enters in the category of frugal high-end product having more comfort and fulfilling the different norms (Midler et al., 2017). This car is now sold in Brazil (in 2017). In order the Kwid be homologated in Europe new equipment in terms of safety and anti-pollution are necessary. The Tata Nano might be considered as frugal low-end while Kwid would be frugal high-end product. Nevertheless it appears clearly there is no one best way for designed and performed a frugal technology and frugal types of products.

By a way of conclusion we want to draw the attention on the cognitive dimension of technological paradigm (von Tunzelmann, 1995). Heuristics is a powerful tool for producing relevant technological knowledge[4]. Said in other terms: a paradigm is economically relevant because it is a *generic knowledge technology for producing technological change.* What does the notion of paradigm bring to the analysis of frugal innovation? FI does not shape an innovation as another. It relies on an engine (paradigm) for producing new technological knowledge. We now would like to set out another characteristic of FI. As a new engine for producing frugal products it has important consequences for the environment.

2. The positive environmental implications of FI: a framework

[4] See also Micaëlli et al. (2016).

We here develop the idea FI has clearly a lower impact on the environment. Basu et al. (2013), Jänicke (2014), Sharma and Iyer (2012) and very recently Pisoni et al. (2018)[5] have pointed out this important characteristic. We here develop it in depth.

2.1. FI and environmental innovation: the issue of intentionality

Since the work by Kemp and Foxon (2007) we consider that environmental innovation (EI thereafter) matches new "technologies whose use is less environmentally harmful than relevant alternatives" (Kemp and Foxon 2007: 2). As for Rennings (2000) he defines EI with more precisions as: "…all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which: develop new ideas, behavior, products and processes, apply or introduce them; and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets"[6]. These definitions matches what the literature tells us about environmental technological change (Gilli et al., 2013; Horbach et al., 2012).

It is also important to give the definition retained by the survey launched at the European Community level (CIS 2008 survey) that addressed empirically for the first time the innovations having environmental benefits: an environmental innovation « is a new or significantly improved product (good or service), process, organizational method or marketing method that creates environmental benefits compared to alternatives. *The environmental benefits can be the primary objective of the innovation or the result of other innovation objectives.* The environmental benefits of an innovation can occur during the production of a good or service, or during the after sales use of a good or service by the end user » (underlined by us). OECD emphasizes the same spirit by noting with EI we put an "explicit emphasis on a reduction of environmental impact, *whether such an effect is intended or not*. And, it is not limited to innovation in products, processes, marketing methods and organizational methods, but also includes innovation in social and institutional structures" [OECD, (2009), p.13, we underline]. Same idea shared by Triguero et al. (2013): the

[5] For instance Pisoni et al. write "By providing a better value proposition for less affluent customers with a more efficient use of resources, a frugal approach to innovation could generate social and environmental benefits in advanced economies…." [Pisoni et al., (2018), p. 122].

[6] Because there are other terms that is used interchangeably it is useful to keep in mind what De Marchi (2012) tells us: "Green, sustainable, environmental or eco-innovation may be defined as "new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harms… this definition includes all the changes in the product portfolio or in the production processes that tackles sustainability targets, like waste management, eco-efficiency, reduction of emissions, recycling, eco-design or any other action implemented by firms to reduce their environmental footprint", (p. 615).

innovations benefits can be *intended or not*, in others words matching an environmental friendly strategy or not.

It stays true products acknowledged as frugal have no in general environmental aims. For instance the mini-truck Tata Ace for the Indian market was invented to meet local needs rather than to meet green objectives (Tiwari and Herstatt, 2014). Nevertheless we argue FI is basically a *special kind of an environmental innovation* (EI). If its first goal is not to generate positive feedback for the environment it has some properties of environmental innovation (Le Bas, 2016). In effect as a new technological paradigm FI aims to produce not expensive goods with a minimum quality using local cheap inputs. Because it saves material and energy in manufacturing *and in the use* of goods it contributes to the fair management of exhaustible resources. Moreover due to its lower technological complexity, FI exhibits three important environmental properties: the ability to repair in case of failure, the possible recovery of end of life components, and recycling. In brief FI is linked to sustainability principles and fits well the structural features of circular economy. We now will take over in depth these two ideas.

2.2. FI and Sustainability

As far as FI is concerned Weyrauch and Herstatt (2016) have noted its possible additional characteristic such as "eco-friendly", "little environmental intervention", and "meets green marketing objectives". We coded them into the attribute category "sustainable". Their interview results show that only 17 interviewees (over 34) think frugal innovation can be characterized as scalable and 11 think it can be characterized as sustainable. This indicates that frugal innovation does not necessarily involve sustainability but they show there is a link perceived by a significant proportion of economic players between frugality and sustainability.

Pieces of knowledge available in the recent literature indicate the *green roots* of FI. Frugal innovation can contribute to sustainability by minimizing resource use (Jänicke, 2014; Sharma and Iyer, 2012). Otherwise Brem and Ivens (2013) analyzing the kink between FI and sustainability point out: "*The link between frugal and reverse innovation on the one hand and sustainability performance on the other hand is established through a differentiated perspective on dimensions representing different fields of sustainability management*".

Sustainable development is acknowledged as the organizing principle for sustainability. At this point impossible to do not quote the report Brundtland (Brundtland, 1987) which provides

the well-known definition of sustainable development: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs. "The environmental protection is an essential element of sustainable development but not the only. Essential because it is a source of welfare services to people included poor classes and primarily from poor countries. Long-term ecological sustainability is the reduction of anthropogenic pressures on the environment. These pressures arise primarily from extraction and processing of natural resources and using the environment as a sink for the disposal of waste effluents (Ayres, 2008). The recent literature on sustainable development equally emphasizes the loss of bio-diversity and global warming (the dependence on fossil fuels). A lot of FI characteristics are related to sustainability: eco-friendly, ecological, no environmental damage, low carbon footprint, green marketing objectives, service ecosystem. However, we assume that being sustainable often is not the primary focus of FI.

2.3. FI and circular economy

The concept of a circular economy was first pictured by Pearce and Turner (1989) as a tendency to recycling and not considering the "environment as a waste reservoir as exemplified by traditional open-ended economy". According to Bound et Thornton (2012) « the design and manufacture of products that reduce their impact on the environment by using less resources, lasting longer, wasting less and being able to be reused can be classed as a form "frugal sustainability". A similar and well known definition has been suggested by the Ellen MacArthur Foundation, introducing the Circular Economy as an industrial economy "that is restorative or regenerative by intention and design" (2013). It describes "how natural resources influence the economy by providing inputs for production and consumption as well as serving as a sink for outputs in the form of waste, they investigate the linear and open-ended characteristics of contemporary economic systems" (Geissdoerfer et al., 2017).

Stahel (1982) puts forth the idea of circular economy as "loop economy" based on selling utilization instead of ownership of goods (economy of functionality). It shapes a relevant mean to develop sustainable business models in a loop economy. In this context industrial firm can generate profits without externalizing costs and risks of wasting[7]. It is a new mode of socio-technical organization in which the environment and the economy are rebalanced (de Jesu and Mendoça, 2018).

[7] Industrial symbiosis sets up a form of Circular Economy (Chertow, 2000) based on firms collaboration about the exchanges of wastes. Those produced by a firm are exploited as inputs by other firms. This approach enables to generate environmental benefits in general and economic benefits as well.

The concept of Circular Economy encompasses a lot of relevant topics (de Jesus and Mendoça, 2018) as life extension activities or waste management and networks of recovery. Circular Economy is aiming at a closed loop, eliminating all resource inputs and waste and emission leakages of the system (Geissdoerfer et al., 2017). On the other hand the considerable goals of sustainability aim at benefiting the environment, the economy, and society at large (Elkington, 1997). The impressive bibliometric analysis carried out by Geissdoerfer et al. (2017) does not quote Frugal Innovation as a mean allowing the building and the strengthening of a circular economy. It seems to us linking technological frugality and circularity shape a lot of opportunities for future research in the area of Organizational Innovation and Management of technologies. We believe this matching is particularly critical to the advancement of literature.

The reinforcement of a circular economy in Europe could be supported by borrowing a frugal innovation approach. Reducing the resources required to produce goods and services sets up one important characteristic of FI. In that sense it matches the main principles of a circular economy that aims to reduce the impacts on environment by using less resources, lasting longer, wasting less and being able to be reused (EU Commission, 2017)[8]. In other words "frugal sustainability" (Bound and Thornton, 2012) matters in this context.

Previous studies point out the crucial importance of design activity (eco-design) in order the products be manufactured in a way which makes them easily repairable or reusable. The challenge to save natural resources is also at the heart of frugality.

2.4. A framework

In the following we outline the diverse causal relationships between FI and sustainability in more stylized details. With respect to the clean or sustainable characteristics of FI Kuo (2017) gives many interesting industrial examples[9]. Overall we get a scheme (see Figure 1).

a. Because the (new) frugal product contains less functionality it is smaller, less voluminous, lighter. FI reduces the amount of input resources for producing offerings (Brem and Iven, 2013). FI is a type of innovation that saves in absolute terms raw materials and natural resources. In general innovation is factor-saving, it saves the factor (input) becoming relatively more expensive. Here we do not face a change

[8] The report noted: "A frugal innovation approach can help achieve resource reduction targets while not expressly aiming at this goal. Often frugal innovation reduces resource use or wastage without letting this have an adverse impact on the cost or effectiveness of a product, rather, creatively innovating around resource constraints to create products that offer greater benefits than the competition".

[9] The interesting paper by Tran and Ravaud (2016) provides several examples of FI in medicine.

along an isoquant (a technological substitution) as a response to an increasing move of a factor-price, but a systematic move from one isoquant to another.

b. As a consequence FI save absolute amount of raw materials, inputs, and others physical resources. The pressures on natural resources are weaker. Consequently it increases the sustainability of the economy.

c. The fact FI decreases the level of technological complexity has a lot of consequences. Two main are here considered. Frugal product has lesser components therefore we expect a greater ease to repair. Frugal product can be considered as very reliable and consequently has longer life duration. That is good for general sustainability because the pressure on natural resources through this mean is also decreased. Moreover it has a greater capacity to be recycled. The two effects reinforce the strength of the mechanisms of circular economy (Brem and Yvens, 2013).

d. We know there is a close relationship between frugal product and more frugal manufacturing process. It is encapsulated in the term of *frugal engineering innovation* (Brem and Wolfram, 2014). It means such a process of manufacturing is designed for saving resources and energy[10]. It has many properties pushing the industrial system towards a more thickser sustainable development.

e. Another point: the user (consumer) has a role to play in these relationships working towards a sustainable greener economy. In particular because he buys and uses the frugal product. In the very process of consuming he may be saves energy accentuating the capacity to stay on a sustainable path of development. Brem and Yvens (2013) add FI allows reducing negative external effects that occur once the consumers start to use the frugal product.

f. Lastly FI is a *time saving innovation*. We define it as follows: in the context of the *time saving innovation* worker completes a production task in shorter time with the overall same number of employees (Von Tunzelmann, 1995)[11]. It releases time for doing something else (spare-time or working on other tasks) what is in lines with a larger definition of sustainable development.

[10] While rebound effect stays possible. There is a "rebound effect" in energy use in the following situation (see Khazzoom, 1980): after improvements in the technical efficiency of energy use we note a cutting of their costs. Because the good or service has now a lower price its sales can be boosted. There is a gap between the micro economic level at which a more energy efficient product has been designed and the macroeconomic level at which it is used more intensively. As a consequence innovation though improving efficiency has a smaller energy-saving (macroeconomic) effect than those predicted (at microeconomic level).

[11] Different from labour-saving innovations involving a reduced number of workers.

Figure 1 summarizes the main findings as well as theirs relationships. It must be noted as emphasized by Weyrauch and Herstatt (2017) managers and researchers are not always aware of the sustainable quality of FI. By contrast our frame shows why and how FI enables to increase the sustainability of an economy.

3. Drivers and barriers to diffusion of FI as environmental Innovation

Mapping drivers and barriers to FI diffusion is the main aim of this section. It sets up a first step aiming to assess the economic consequences of FI as a kind of EI.

3.1. General considerations

As a new type of technology of technological change Frugality enters in competition with others. The evolutionary theory thinks the competition between an old technology and a new one as a progressive substitution in which the ability of the (often new) firms exploring the new technology to survive long enough to get that technology effectively launched depends on the existence of fringe markets (Windrum and Birchenhall, 1998; Malerba et al., 2007). Niche markets or experimental users can provide that fringe in which new firms using the new technology can survive without economic conflict with established firms and develop the new technology until the moment where it is competitive on the main market. One particular aspect of EI dynamic is its emergence and first development can be facilitated by the *creation of technological niches* that allow the experimentation through the co-evolution of technology, user practices and regulatory structures (Kemp et al., 1998; Schot and Geels, 2008).

Nevertheless this vision assumes the users have the same needs and revenues. We cannot apply it to frugal product that presuppose users with different levels of revenues. By contrast the market segmentation analysis matches the relevant approach. In effect with FI as a new technological paradigm we are in the frame of an industrial segmentation where consumers might purchase or consume a not too expensive product. FI opens a new market without any substitution with other types of technologies. We consider frugal product does not match the dominant design approach that stipulates a standard product takes place in the industry. FI at the core of new type of products shapes another design (frugal design). As a consequence there is no price competition between standard and frugal products. In other terms frugal product has no vocation to invade the industry as a whole.

Another issue is: Is frugal product in competition with other *green* products? First of all it may be frugal product is not acknowledged as an environmental or green product although it has positive consequences as a general rule (as said in the previous section). Secondly a true green product is located in a niche not a segment (Kemp et al., 1998; Schot and Geels, 2008). Following the evolutionary theory green product has vocation to conflict a day with no green products. Evidence show green products are sold with high prices while frugal products are related to another pricing system. This later aspect has important consequences for launching a discussion about drivers and barriers to FI diffusion.

We think it is important for discussing the economic consequences of FI to put at the core of the analysis the environmental properties of FI. The dynamic of diffusion of FI will benefit from the momentum in favor of EI. Of course barriers hindering this process do exist. For correctly analyzing the factors that drive and hinder the diffusion of FI it is important to note an innovation (whatever its type) is a part of a socio-technical system produces in a specific time period within of a particular territory (Freeman, 1987). Such a remark underlines the strong relevance of the notion of system of innovation (Edquist, 2004). As a consequence the rate of diffusion of an innovation depends not only on intrinsic economic performance of the new technology but also on systemic aspects.

3.2. Drivers of FI diffusion

For a firm in mature industry FI is clearly a way to enlarge its markets scale. The potential market enlargement shapes obviously a true driver of this type innovation. This argument is relevant for FI in general. Nevertheless it may be the strength of this driver crucially depends on the level of development of the economies (emerging versus developed).

Reverse innovation sets up a real economic potential for FI. This type of innovation is related to innovation from the South that is "transferred" to the North after incremental or larger changes. Brem and Ivens, (2013) consider reverse innovation matches a new product developed in emerging markets which is modified for sale in developed economies[12]. Reverse innovation is costly because development costs that are necessary for reconfiguring the product before it could be marketed worldwide. Although costly we expect it performs net economic benefits to the innovator. As a consequence it is a way to amortize the costs of the initial frugal innovation. FI implemented in developing countries could be valorized through

[12] In the same vein Zeschky et al. (2014) note "reverse innovations are cost, good-enough, or frugal innovations that find a market among customers outside of the emerging markets at which they were originally targeted".

its worldwide diffusion (Tiwari et al., 2017b). In such a frame reverse innovation opportunities could be seen as a factor creating incentives for the investing in the search of FI.

We have to consider now new drivers related to the environmental side of FI. For assessing the pace of the FI diffusion as an environmental innovation it is worth noting the following important points:

- **a.** FI as EI should be eligible to public financing (under some conditions) for supporting the diffusion of green products.
- **b.** If we retain now the institutional context we can conjecture there will be tomorrow a strong demand for innovation more socially acceptable as far as environmental goals are concerned (Hansen et al., 2009). As a consequence we can expect a growing market for products related to frugal environmentally conscious consumers.
- **c.** We do not exclude once many frugal products will be implemented a new technological system (Carlsson, 1995) based on frugality will be born. As a result a large variety of frugal technological options will be supplied included for materials and equipments. At this time it would be possible many frugal products enter in competition.
- **d.** The development of new forms of innovation production as fablabs and makers communities matters here. They set up a driver of FI besides others types of social innovation or grassroots innovations (Wang et al., 2015).
- **e.** New regulations on waste and recycling have favorable effects on FI development (Report of EU Commission, 2017).
- **f.** There are a number of reasons to conjecture the system of circular economy will grow. This trend will pull the propensity to implement FI standards. Moreover the increasing costs of raw materials give incentives to cut resources use (Bonini and Görner, 2011).
- **g.** Within developed economies there are many rationales acting in favor of circular economy performed by products relying on FI. The consumers are more and more aware of the importance of sustainable products and their capacity to fuel a circular economy having positive effects on the environment at large. Raw materials being more and more expensive and the regulation becoming tighter play in favor of a greener management of wastes and recycling. But as noted by a report of the European Commission (2017) “these factors alone are not enough to change the way companies do business” the consumers have a role to play in that story. The consumer markets for sustainable products, while growing rapidly, are still niches part of the overall market

for goods. Moreover the sustainable products may be too expensive for many consumers. By contrast the products based on FI are cheaper with the same quality in terms of sustainability. The majority of consumers are unwilling to pay a premium for circular products but certainly not a price too high. If they have an offering with two types products (green and frugal) matching the principles of Circular Economy with one which using resource constraints as an opportunity to create greater value for the customer supplies a product that is cheaper (the frugal option) it has an advantage for the consumers[13].

3.3. Barriers

We have to bear in mind barriers (or constraints) do exist to the FI diffusion as a new paradigm. We here count up some of them.

As a new technological paradigm FI enables to produce low cost products for low income people markets. As a general statement it sets up good profitable opportunities for firms because it is a mean for opening new markets. Nevertheless this view is a little abstract. In effect evidence show the firm aiming FI should necessarily *develop specific capacities costly to create* (see for the example of the Kwid car by Midler et al., 2017). As a consequence the constraints related to creating specific capacities shapes a barrier in terms of knowledge to the diffusion of FI. Frugality being a specific technological paradigm firm does not move without costs from standard technological paradigm to the new one (see still the case of Kwid exemplified by Midler et al., 2017). Secondly it would be important to operate the distinction between developing and developed countries regarding the potential of profitability stemming for the implementation of FI. The FI potential of diffusion appears larger in emerging economies (Tiwari et al., 2017b).

The diffusion of FI can be slowdown because the existence of other competitive technological paradigms. For instance with respect to raw materials, developed industrial economies produce advanced (or high tech or over-engineered) new materials that are able to enter in competition with materials that are incorporated in the frugal products. It may be the price of products made with these news materials stay low enough for attracting consumers accustomed to the segment of frugal products.

The existence of previous technological paradigms based on high tech culture it is a real obstacle to the implementing frugality principles (Tivari et al., 2017a). In effect the

[13] We summarize here ideas supported by European Commission Report (2017).

intellectual strengths of high tech paradigm can trigger 'an overwhelming reliance on high tech-driven and complexity-embracing innovation pathways' that strengthens the engineer culture.

The development of a circular economy meets real constraints[14] that play against the growth of frugal products markets. The effectiveness of regulations, for instance the eco-labeling practices designed to promote the sustainability and frugality is mixed at best (UNEP, 2005).

Our assumption would be in the developed economies frugality principles cannot rely on the same principles that those workable in emerging economy. The levels of development and the purchasing power of consumers are different. As a consequence the *frugality should have new features in developed world.* We argue business models based on services have important effects for the diffusion of frugality. We draw here on the report by the European Commission (2017) that outlines what might be new frugal products in the context of North economy: "…Philips' lighting as a service, where business customers pay a regular fee for the service of lighting, rather buying and running lighting equipment themselves. The frugal potential of the 'as a service' solution comes from the combination of product innovations and service innovations. Philips has developed this model to help customers transition from conventional analogue to more efficient, digital lighting systems. LED lighting systems reduce energy use and are cheaper in the long run, but the up-front costs can discourage customers from switching. By moving to an 'as a service' model, customers are able to transition to higher quality technologies but only pay for what they require, ensuring products are used optimally. Meanwhile, Philips as the service provider is better placed to repair, replace, reuse and upgrade components, and avoid lighting stock sitting idle or being sent to landfill. As a result, the lighting service becomes cheaper, more efficient and less wasteful when compared to purchasing new lighting technology outright".

In this empirical case the pivotal role of the business model of innovation is a service model that embodies a new sustainable product. This new business model tends to extend the working life of the lighting system. The system is cheaper and offers a better alternative than the resource intensive offerings. This example indicates what could be the frugal model of

[14] In relation to that the report of the European Commission (2017) notes: "While many products can now be made with almost 100% recycled material, or designed in a way which makes them easily repairable or reusable, innovations that take their starting point as constrained resources face a number of challenges in Europe. These include low consumer demand for sustainable products, partly as a result of the availability of ultra-low cost alternatives, issues around behaviour change required in the use of new sustainable products, lack of awareness of sustainable alternatives, issues around the difficulty of regulating a circular economy and the additional costs of creating reverse supply chains and repair networks".

innovation for the North developed. Its foundation rely on new service may be intensively using information technology saving energy and resources. What we wish to emphasize is the building of new business models based on services is necessarily costly for the firms. It sets up a barrier to the quick diffusion of FI.

Conclusion: Contributions, implications, limitations

In this paper our contribution is twofold. We define rigorously FI thanks to the notion of technological paradigm. It enables us to outline the problems at stake in particular the strategical importance of technological complexity. Secondly we develop the idea FI can be considered as an environmental innovation although this is not the primary intention of innovators. A framework is suggested outlining and interpreting some among the main positive impact on the sustainability of the economy.

Sustainability can be achieved through many ways. Frugal innovation an inclusive type of innovation sets up one (important) of them. We have shown how FI can contribute to drive firm sustainability performance when it designs new products with less functionality and less technological complexity for low income markets segments. As pointed out by Pisoni et al. (2018) the environmental sustainability of frugal innovation sets up a promising area of research [Pisoni et al., (2018), p.122). Firms are advised to harness frugal thinking and design in their products to ensure the longevity of the industry (Kuo, 2017).We hope this frame can provide useful inputs for better understanding how FI can contribute to a large sustainability.

In the Smithian model of industrial growth the increasing division of labour is the tool for cutting the average costs and the prices at which the products are sold on the market. As a consequence the demand for the industrial product increases. In the frugalist model of growth the growth of demand on any market is provoked by the "economic inclusion" of low income people through *a new design of the product*. Of course it does mean the division of labor no longer plays a role. The true engine of growth is no longer the division of labor but a frugality as a new technological paradigm.

As any analytical study ours has one important limitation: the context of the country (developed, middle-income, developing countries) in which FI is developed is missing (Haudeville and Le Bas, 2016). Until now only a few comparative international studies have been published. Therefore, more studies comparing firms adopting FI from different countries should be carried out[15].

[15] In the vein opened by Herstatt and Tiwari (2017).

The recent literature emphasizes the notion of '*frugal business models*' *(*see for instance Short et al., 2014). It means the issue of how low income consumers pay is important. In this frame the provision of products and services using less *financial* inputs appears crucial. Of course this aspect should deserve more attention in the future.

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Figure 1. Complex Interplay between Frugal Innovation Characteristics: a virtuous circle of positive environmental effects