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Green and competitive: who influences the development of advanced frugal product characteristics?

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ABSTRACT

The societal shift to a greener economy is subject to a trade-off. Green products are often more expensive than conventional products, making them less attractive and thus slowing down the transition. Advanced Frugal Innovations overcome this trade-off and are able to accelerate the transition through the inclusion of broader population groups. Based on a company survey, this research examines the influence of societal actors on green and cost-related product attributes that influence this trade-off using correlation analyses and meaningful illustrations. Using the German manufacturing sector as an example, this new database provides first empirical results that illustrate how societal and systemic agents affect the development of green and competitive products. The results indicate that the societal and systemic situation in Germany has an inhibiting effect.

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1. Introduction

Global emissions of CO2 and other climate-damaging and polluting gases continue to rise as well as the consumption of fossil raw materials. The transformation to green product development faces this critical situation, but creating green technologies and expanding green infrastructure is often expensive. High costs can inhibit the acceptance (Park 2019) and speed of an overall economic transformation process.

Overcoming this trade-off that Porter and Van Der Linde (1995a, 1995b) already address is key to a sustainable transformation in which the broad population of economies with different financial and technological starting conditions can be taken along. Frugality in product design through advanced technologies, salvaging from end of life, and simple design are able to resolve the trade-off (Rao 2017b, 2018, 2019, 2022). These principles lead to a form of innovation that is called advanced frugal innovation and offers green and competitive product features.

Previous research discusses that the conditions for the emergence of AFIs are not solely due to the capabilities in the development process but are also subject to social conditions (Barnikol and Liefner 2022). This makes them more complex than other frugal innovations, which primarily react to financial constraints in less developed countries (Gupta 2012, 2013; Prahalad 2012), where the environmental aspect is often ignored (Hossain 2021). However, since this combination of both involves specialised and comprehensive knowledge of the impact of technologies, highly skilled

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personnel and effective sharing of relevant knowledge are required (Rao 2017a). If this is successful, AFI helps to pave the way to a greener economy.

To take a closer look at the solution of the trade-off and the societal framework conditions, this article relies on an explorative research design. To this end, building on existing theoretical constructs, societal agents are identified from the literature and their influence on green and competitiveness-determining product attributes are. Two research questions are investigated: (RQ1) How does the systemic embeddedness of a company influence the development of AFIs? Do systemic agents have an inhibiting or facilitating effect (RQ2)?

To answer the research questions, primary data from a company survey in the manufacturing industry in the two German states of Lower Saxony and Hesse are examined. The results indicate that the societal environment influences the development of AFIs and the existing trade-off. The paper is structured as follows. First, section 2 discusses the theoretical background and identifies agents that can play a role in the development of AFIs in the manufacturing sector. Section 3 includes the formation of aggregates in terms of product costs and sustainability, which are related to the agents' efforts in section 4. In the discussion in section 5, these results are interpreted and placed in the context of existing literature. The main results, recommendations for action and the need for future research are the subject of Section 6.

2. Theoretical background

The term advanced frugal innovation (AFI) describes products with a more comprehensive degree of complexity in the research field of frugal innovation. Their development requires, among other things, acceptance of frugal design principles and technological capabilities (Barnikol and Liefner 2022b). Accordingly, the ability to develop AFIs is determined not only by factors internal to the company but also by external factors. This results from the characteristics of AFIs as well as the innovation system-related and institutional prerequisites for the development of this special form of innovation.

2.1. Advanced frugal innovation

AFI's technological claim is based on the agreement between environmental sustainability and competitive prices. Combining the claim of cost efficiency and environmental friendliness while maintaining the quality of products, AFI, can create an overall benefit for society. Accordingly, AFI also represent environmental innovations, which can enable, accelerate and simplify the transition to a sustainable economy through lower or competitive prices.

However, these dimensions increase the demand for development and require fundamental knowledge of the product, the area of application and the customers (e.g. Jha and Krishnan 2013) as well as technical capabilities with a highly skilled workforce (Rao 2017a). Based on a simple design, modern technologies and materials, adjustments in the production process, and application of the 4R principles, the material input of a product can be optimised, thus realising significant cost savings (Rao 2017b, 2018, 2019, 2022). The resulting products are often lighter and have a longer life span, which in turn reduces energy consumption (Rao 2019).

2.2. Relevance of innovation systems, socio-technical regime and institutional embeddedness

Frugal design principles can be applied to all physical products, and their philosophy may go beyond them. Nevertheless, the need for suitable materials, specified knowledge and technologies limits the range of users and scope of application nevertheless. Knowledge about potential materials and technologies, and the necessary infrastructure must be available but can be expensive. These conditions vary geographically and between industries and require not only technological capability but also a societal and innovation system perspective (Barnikol and Liefner 2022b).

For the emergence of AFI, two types of innovation systems as particularly relevant: Territorial Innovation Systems including National (Freeman 1995) and Regional Innovation Systems (Cooke, Uranga, and Etxebarria 1997), and Technological Innovation Systems (Carlsson and Stankiewicz 1991). For both types of innovation systems, different agents indeed influence the possibilities and characteristics of the final product. The more agents support the development of AFI in an innovation system, the higher is the probability that they will be actually realised (Barnikol and Liefner 2022b).

In the context of AFIs, Barnikol and Liefner (2022) identify five agents as relevant: Customers, suppliers and cooperation partners, research institutes, governments and the innovating companies themselves. The basic idea is that the more of these agents support the development of AFIs, the more frugal the products of the companies involved in the corresponding innovation systems will be. Especially in a specialised business environment, this is due to the need for suitable technologies, materials, knowledge, infrastructure and institutional conditions. The individual agents not only influence the innovating company and its products but also their environment and other agents in the innovation system (Cooke 2001; Cooke, Uranga, and Etxebarria 1997). That makes the innovation system more akin to a network of an innovation-supporting or -hindering environment. This can go to the extent of forming a kind of mission-oriented innovation systems (MIS) that pursue a clear aim (Hekkert et al. 2020; Wanzenböck et al. 2020).

In addition to the provision and availability of technological properties, legitimacy must also be created for new products and technologies, or for the application and necessity of frugal design principles in development processes. Individual agents can create legitimacy for their application in this context (Bergek, Jacobsson, and Sandén 2008; Hekkert et al. 2007). Policymakers can legitimise the orientation of research institutes (Fischer et al. 2021) and support them through funding. Companies can develop products that serve as a flagship for this type of product. In the case of AFI and the combination of green and competitive product features, this is a significant factor. For example, the widespread conviction that green products are premium products and must therefore be more expensive than conventional ones is prevalent (Berger 2019). In this context, the mechanisms of product development and those of training and education are relevant factors to consider, whereby, the development and market penetration of AFIs would have to be accompanied by a institutional change.

The existence of institutions is influenced by regional conditions, among other factors. Climatic conditions, natural disasters, topography and biogeography can influence the rules of living together in a society. The resulting institutions can constitute a significant locational advantage for the economic development of a region (Olsson 2005). In particular, economic conditions and the concomitant need for more modest consumption shaped the capacity for simplification in countries such as India, making it a lead market for frugal innovation (Tiwari 2017). The cultural-cognitive perspective on the products' socio-economic benefits is therefore particularly pronounced in emerging economies (Ananthram and Chan 2021; Gupta 2012), while in contrast, technological and systemic capabilities are still stronger in industrialised economies (Barnikol and Liefner 2022b).

Conducive institutions and the ability to generate relevant knowledge, transfer it to suitable recipients, and transform it into new products are primarily regional. This leads to the assumption that these characteristics and capabilities, which are necessary for the emergence of AFIs and for overcoming the trade-off between monetary and environmental costs, differ geographically and are determined by the support of systemic agents.

2.3. Choice of agents considered

The choice of agents considered is based on the combination of institutional framework conditions and the agents of the innovation system. It should be noted that the survey was only conducted among companies. For this purpose, company-related motivation and the ability of agents external to the company are relevant. The choice of influencing agents beyond the company under consideration is essentially based on the agents relevant to AFIs mentioned by Barnikol and Liefner (2022).

Among the company-related variables, the influence of shareholders, product developers, and the companies brand are taken into account. The consideration of these three agents is interesting regarding the coverage of different aspects of the companies orientation. Shareholders, for example, can change the focus of a company. Also the capabilities and aspirations of product development teams, who share values and convictions and have gained experience and behaviour in respective companies or training institutes, matter. The brand represents the internal and external perception of the company, and may also determine the design of the products and competitiveness through pricing.

3. Afi measurement and aggregation

The methodology used in this paper is mainly based on the definitional work of Barnikol and Liefner (2022a). To understand the empirical results, it is helpful to clarify the two methodological steps: data collection, and AFI measurement and aggregation. The data set of this paper is the result of a survey from 2022 in the months of May, June and July. The questionnaire was tested in advance with company representatives and discussed with representatives of associations, ministries and consultancies. Survey participants were recruited via e-mail and in various newsletters from the Lower Saxony Business Association, RKW Hessen and other associations and consulting firms. The survey mainly targeted companies from the manufacturing industry in Hesse and Lower Saxony. A total of 96 responses were received, of which 63 questionnaires were usable for the purpose of this research.

At present, many approaches to measuring frugal innovation exist, but they are not suitable for measuring AFIs (e.g. AlMulhim 2021; Dost et al. 2019; Iqbal, Ahmad, and Li 2021; Kline and Rosenberg 1986; Kronemeyer, Draeger, and Moehrle 2021). Barnikol and Liefner (2022b) therefore propose their measurement concept to capture AFI. This concept defines AFI as a continuum along the aggregated societal benefits. This is based on the dimensions of environmental benefit (EB) and socio-economic benefit (SEB), which constitute the objectives of AFI described in Section 2 and are in a trade-off in the case of non-AFIs. These two dimensions also represent latent variables that must be captured with the help of proxy variables. The advantage of this approach is that these variables can be flexibly adjusted between sectors and product types, and that the higher levels of environmental and socio-economic benefit remain comparable. The same applies to the aggregated societal benefit (ASB), which represents the degree of innovation and efficiency between the two dimensions, and the market novelty in terms of overcoming the trade-off. In general, all products with a positive ASB can be considered as AFIs due to the newly created efficiency compared to competitors.

Within the scope of the survey, the respondents were asked to compare the characteristics of their products to the average products of the competition. The results were plotted on a 7-point Likert scale from much lower (1) to equal (4) to much higher (7). Finally, the results were transformed into a scale from −3 to 3 for further statistical processing. The aggregation of the three dimensions socio-economic, environmental and aggregated societal benefit is calculated as follows:

$$\text{Socio-Economic Benefit} = \overline{\text{SEB}} = \frac{-1}{n} * \sum_{i=1}^{n} SEB_i = \frac{-SePr - MOCU}{2} \tag{1}$$

$$\text{Environmental Benefit} = \overline{\text{EB}} = \frac{1}{n} * \sum_{i=1}^{n} EB_i = \frac{EFPU + SMPU + Ao4R}{3} \tag{2}$$

$$\text{Aggregated Societal Benefit} = \overline{\text{ASB}} = \frac{1}{n} * \sum_{i=1}^{n} ASB_i = \frac{\overline{EB} + \overline{SEB}}{2} \tag{3}$$

The expression of the dimensions can be interpreted similarly to the initial variables. Increasingly negative values signal a negative effect compared to the competition. Negative effects can be higher

product costs (SEB), higher environmental damage (EB) and a negative combination of both (ASB). Zero signals a similar effect as the competition. In the case of ASB, this can also happen if the EB is higher but is accompanied by a similar negative SEB resulting in no societal added value. Increasingly positive values signal a positive effect of a product compared to products of the competition. The location and distribution of the products by dimensions and proxy variables are shown in Table 1.

Based on the formulas (1) to (3), the influence of the agents considered on the individual product characteristics can also be determined. The influence of individual agents on the respective variables, from extremely reducing (−3) to negligible (0) to extremely reinforcing (3), was also queried from the companies. The aggregates calculated from this show the influence of the agents on ASB, EB and SEB (see Table 2).

4. Results

The aggregation of the data enables the explorative investigation of the influence of different internal and external agents on the AFI-related product characteristics. For this purpose, the statistical correlations are examined and the orientation of the different agents is considered with regard to the direction of the effect and the strength of the influence. For a sufficient interpretation of the systemic components, it is first necessary to consider the distribution of products in the context of AFIs.

Figure 1 shows the distribution of the products of 63 companies regarding the two dimensions of environmental benefit and socio-economic benefit. The upper half includes products with a positive environmental benefit while the lower half shows a negative environmental benefit compared to the competition. From a socio-economic perspective, products on the right generate a positive benefit while products on the left generate a negative benefit. The diagonal line distinguishes products with a positive from products with a negative aggregated societal benefit. All products above this diagonal can be described as AFI. It is apparent that the distribution of products in the manufacturing sector in the population of German companies tends towards positive environmental but negative socio-economic benefits. There seems to be a trade-off between these two dimensions in most cases. Nevertheless, some products have high ASB and express their innovativeness through a significantly more successful combination of both dimensions compared to the competition.

The detection of the systemic influence on the development of AFIs indicates a first tendency in the case of the manufacturing sector in Lower Saxony and Hesse. In this context, Table 3 shows the correlation between the ASB-related aspirations of the individual agents and the ASB-related actual properties of the product and each other. Interpretatively, this represents the extent to which the individual agents support (positive correlation) or counteract (negative correlation) the AFI-related innovativeness of the product. Although it is evident that not all influencing agents surveyed have a connection with the product characteristics, at least a direct and indirect connection of the agents with the product characteristics can be drawn. Especially in the case of significant ($p < 0.05$) correlations, the product characteristics are more in line with the agents' expectations. In detail, the brand is the only significant company-related agent influencing product characteristics. The external agents, customers, suppliers, cooperation partners and science have a significant

Table 1. Measurement variables for environmental and socio-economic benefits.

	Mean	*Standard Deviation*	*Span*
Aggregated-Societal Benefit (ASB)	**0.11**	**0.58**	**3.83**
Socio-Economic Benefit (SEB)	**−0.29**	**0.80**	**4.00**
Selling Price (SePr)	0.56	1.23	6.00
Maintenance and Operation Cost in use (MOCU)	0.02	0.81	4.00
Environmental Benefit (EB)	**0.51**	**1.02**	**5.67**
Environmental Friendliness of Production and use regarding energy (EFPU)	0.79	1.21	5.00
Use of Sustainable Materials in Production and Use (SMPU)	0.41	1.12	6.00
Use of 4R Mechanisms (Ao4R)	0.32	1.09	6.00

$N = 63$.

Table 2. Distribution of the agents' influence on ASB, EB and SEB.

	ASB			SEB			EB		
	Mean	SD	Span	Mean	SD	Span	Mean	SD	Span
Costumer (C)	−0.10	0.68	4.08	−0.70	1.04	5.50	0.50	0.98	5.00
Supplier and Cooperator (SCo)	−0.16	0.63	4.25	−0.70	1.17	5.00	0.38	1.00	5.33
Science (Sc)	0.16	0.45	2.75	0.16	1.05	5.00	0.16	1.07	6.00
Government (Gov)	0.10	0.44	2.50	−0.26	0.93	6.00	0.46	1.29	6.00
Shareholder (Sh)	0.06	0.52	3.00	−0.78	1.28	6.00	0.90	1.35	6.00
Product developer (Pd)	−0.01	0.56	3.00	−0.83	1.13	6.00	0.82	1.25	6.00
Brand (B)	−0.07	0.53	3.00	−0.88	1.07	6.00	0.74	1.07	6.00

$N = 63$.

direct influence. Shareholders, product developers and the government have no significant connection with the AFI-related product characteristics, but shareholders and product developers show evidence of positive correlations with the other directly to the product variable connected agents. Government shows only significant correlations with shareholders and product developers (Table 3).

The individual analysis of the SEB (Table 4) and EB (Table 5) dimensions shows that the strength and significance of the individual relationships deviate significantly from the aggregate. Concerning the SEB (Table 4), only the supplier and cooperation partner and the company's brand correlate significantly. This suggests that pricing is largely influenced by the company itself rather than being

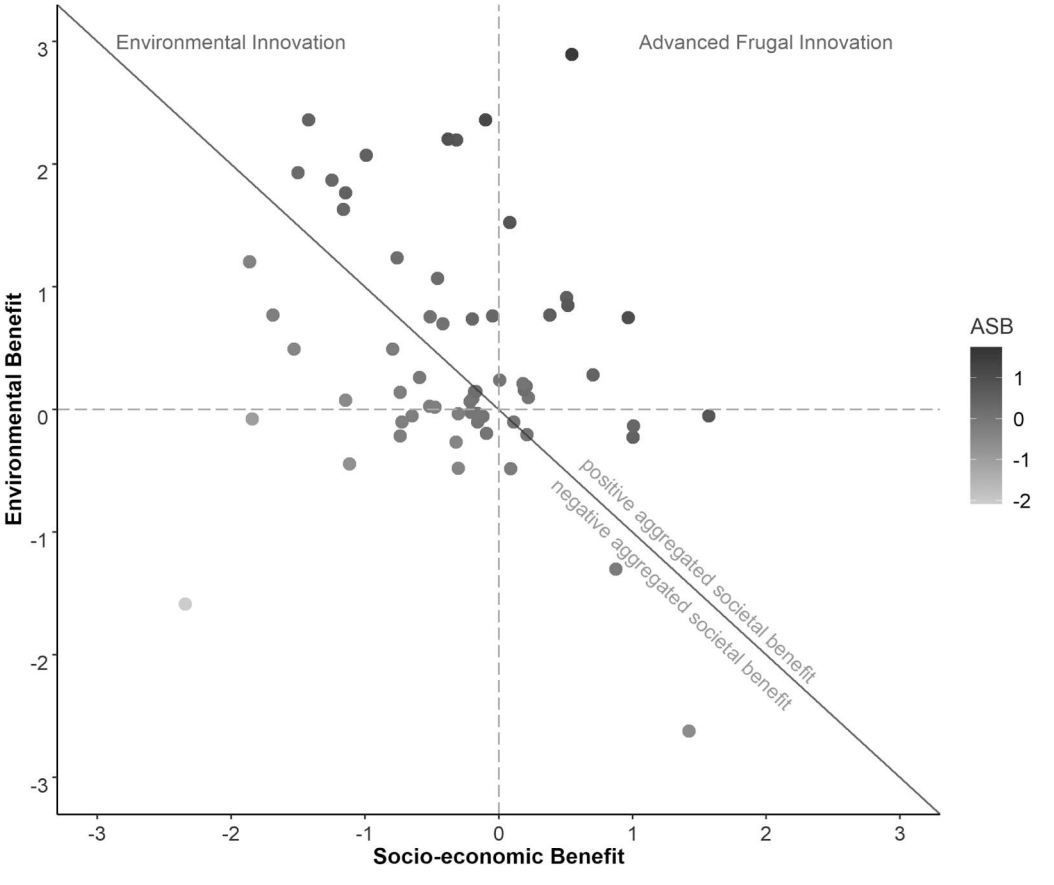

Figure 1. Aggregated societal benefit and trade-off between environment and socio-economic benefits in the manufacturing industry.

Table 3. Correlation between internal and external agents and the ASB of the product.

	P	*C*	*SCo*	*Sc*	*Gov*	*Sh*	*Pd*	*B*
Product (P)	1							
Costumer (C)	**0.35*** **	1						
Supplier and Cooperator (SCo)	**0.50*** **	**0.65*** **	1					
Science (Sc)	**0.33*** **	**0.38*** **	**0.47*** **	1				
Government (Gov)	−0.23*	0.08	0.03	−0.21*	1			
Shareholder (Sh)	0.24*	**0.41*** **	**0.38*** **	**0.26****	**0.27****	1		
Product developer (Pd)	0.18	**0.42*** **	**0.43*** **	0.10	**0.34*** **	**0.51*** **	1	
Brand (B)	**0.45*** **	**0.44*** **	**0.54*** **	**0.40*** **	0	**0.51*** **	**0.40*** **	1

$N = 63$, * < 0.01, ** < 0.05,*** < 0.01 according to Pearson.

externally driven. The scalability of the products and the market segments in which the company operates could have a greater influence. The situation differs about environmental benefits (Table 5). All variables, apart from government, show a significant correlation. Therefore, the environmental benefit of a product depends more on internal and external agents than the socio-economic benefit. A general comparison of Table 5 with Table 3 and Table 4, shows that the correlations are stronger in the case of the EB and weaker in the ASB due to the weaker and absent correlations of the SEB.

In addition to the actual correlations, the data also provide information on the direction of influence. Figure 2 shows the position of the systemic indicators in terms of environmental support and socio-economic support. The expression of the individual variables is the result of mean values across the data set. It conveys to what extent individual agents or the company's brand exert pressure on the product characteristics. Positive socio-economic pressure signals that agents demand or favour lower product costs, while negative pressure represents a favour for higher product costs. Positive environmental pressure marks environmentally friendly behaviour, such as the use of sustainable materials and energy, while negative pressure stands for environmentally harmful behaviour. Except science, all agents are located in the second quadrant and accordingly exert positive pressure on environmentally friendly behaviour, but simultaneously favour a negative socio-economic effect. This relationship is stronger in the case of internal agents' brands, shareholders, and product developers, but in the case of external agents' consumers, governments, suppliers, and cooperation partners. Science is particularly noteworthy as it only slightly favours the environmental friendliness of a product as well as its affordability.

While Table 5 only shows the correlation and Figure 2 shows the direction of the actual influence, Figure 3 shows a synergy of both findings. The AFI-related pressure and the strength of the influence are compared. The AFI related pressure represents the direction like Figure 2, whereby the illustration of the agents indicates the expression regarding EB and SEB according to the legend. The current strength of leverage represents the correlations with the product characteristics from Tables 4 and 5. It should be noted that these are only positive correlation coefficients. Accordingly, the figure shows if an agent has an influence and whether this influence favours or hinders the development of AFIs.

Table 4. Correlation between internal and external agents and the SEB of the product.

	P	*C*	*SCo*	*Sc*	*Gov*	*Sh*	*Pd*	*B*
Product (P)	1							
Costumer (C)	0.17	1						
Supplier and Cooperator (SCo)	**0.29****	**0.51*** **	1					
Science (Sc)	0.05	0.20	0.18	1				
Government (Gov)	−0.03	**0.29****	0.23*	**0.52*** **	1			
Shareholder (Sh)	0.15	0.23*	**0.47*** **	0.08	**0.42*** **	1		
Product developer (Pd)	0.04	0.23*	**0.27****	0.10	0.05	0.22*	1	
Brand (B)	0.35***	0.09	0.38***	0.13	0.07	0.34***	0.32**	1

$N = 63$, * < 0.01, ** < 0.05,*** < 0.01 according to Pearson.

Table 5. Correlation between internal and external agents and the EB of the product.

	P	*C*	*SCo*	*Sc*	*Gov*	*Sh*	*Pd*	*B*
Product (P)	1							
Costumer (C)	**0.65*** **	1						
Supplier and Cooperator (SCo)	**0.60*** **	**0.76*** **	1					
Science (Sc)	**0.32*** **	**0.37*** **	**0.54*** **	1				
Government (Gov)	0.21	**0.34*** **	**0.45*** **	**0.36*** **	1			
Shareholder (Sh)	**0.55*** **	**0.53*** **	**0.59*** **	**0.30** **	**0.33*** **	1		
Product developer (Pd)	**0.37*** **	**0.27** **	**0.31** **	0.23*	**0.32** **	**0.31** **	1	
Brand (B)	**0.63*** **	**0.67*** **	**0.61*** **	**0.39*** **	0.22*	**0.49*** **	**0.49*** **	1

$N = 63$, * < 0.01, ** < 0.05,*** < 0.01 according to Pearson.

An aid to interpretation is the consideration of the quadrants. Quadrant I represents agents and factors with a high and facilitating influence. Quadrant II includes AFI supporting agents and factors with weak or no influence. Quadrant III represents AFI adversaries with no or weak influence. Quadrant IV contains high-influence counterparts. The company's brand and the agents are located entirely in quadrants I and II in respect of environmental benefit, while they are predominantly positioned in quadrant III in respect of socio-economic benefit. In an ideal systemic situation that supports AFI, all agents and dimensions would be positioned in the I quadrant in a systemic AFI-supporting situation. Decision-makers who want to develop or promote AFIs should consequently try to shift their position in this direction.

4. Discussion

Despite the low number of cases, the results presented in Section 4 show significant and reliable results. Nevertheless, it must be minded that the questionnaires were filled out by company representatives and therefore capture their perspective on the individual agents. The results show that the systemic prerequisites for the development of AFIs and the creation of the highest possible ASB turn out different.

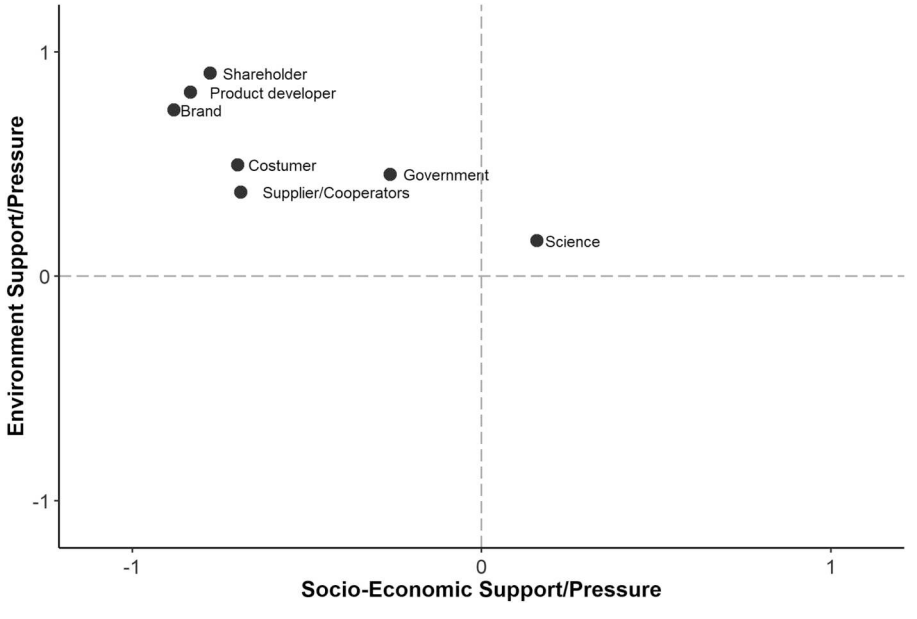

Figure 2. Agent-side trade-off between environment and socio-economic benefits.

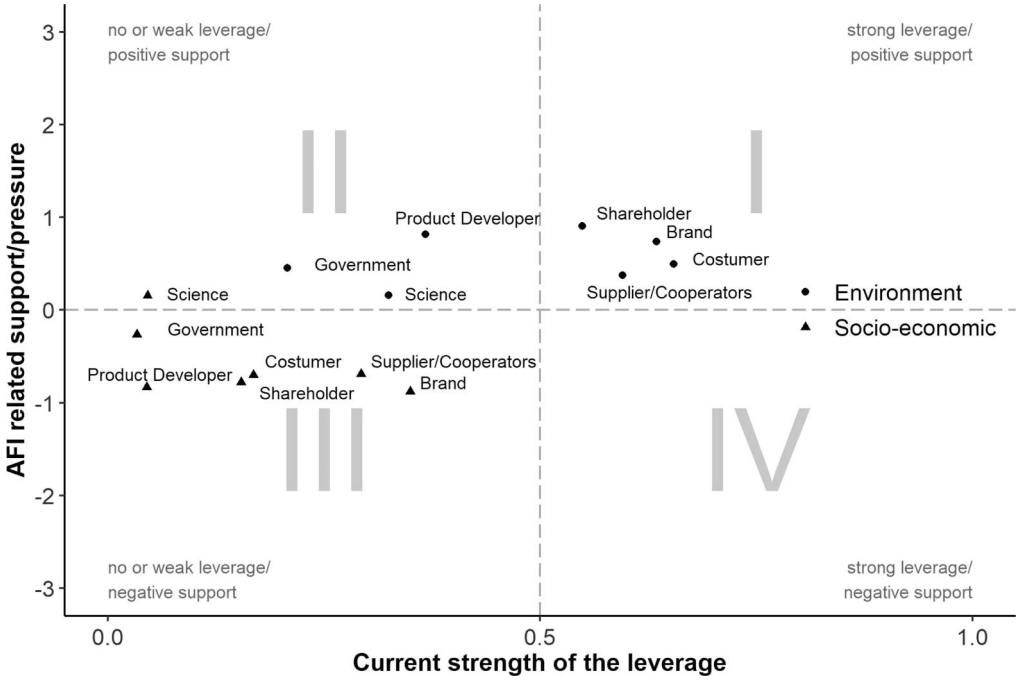

Figure 3. Strength and direction of support for AFIs by societal agents.

Superficially, the development of AFIs from a systemic perspective benefits from a general movement towards environmentally friendly product characteristics of individual agents, which is evident in Figure 2 and Table 5. In the case of the Socio-Economic Benefit (Table 4), this can be observed to a much lesser extent. The trade-off between the two dimensions thus appears to be institutionally supported. This explains why the companies in their overall competitive dispersion predominantly position themselves along the trade-off line of the ASB, and why the pattern in favour of the environmental benefit is like that of the systemic agents (see the comparison between Figures 1 and 2). Recent work supports this finding, noting that for green product innovation, cooperation with civil society and market influence are critical (Cassetta, Dileo, and Pini 2023). The ability to innovate in relation to the development of AFIs is thus clearly diminished.

From an external perspective, this result fits society's aspirations towards a climate-friendly and environmentally-friendly economy. The environmental awareness has been increasing in Germany (Umweltbundesamt 2022) whereby green products are often understood as premium products entailing higher prices. Berger (2019) essentially justifies this with the signal theory, which explains the consumption of green products as a status symbol. Schwirplies and Ziegler (2016) show that environmentally conscious consumers in Germany are more motivated to spend money on carbon offsets than consumers in the United States, which indicates that this mechanism varies regionally and might be strong in Germany and explain the positioning of customers.

The introduction of higher environmental standards is often accompanied by higher costs (Tognetti, Grosse-Ruyken, and Wagner 2015). An example for this trade-off are particulate filters in cars. The additional technology serves to increase environmental compatibility, but may result in higher product prices due to the passing on of the additional costs for upgrading a previously not used technology.

Research institutes and universities are the only agents in the Hessian and Lower Saxon manufacturing sector that have a positive impact on both dimensions. Compared to governments and

customers, this could be due to the kind of systemic and societal relationship. While companies must follow laws and regulations and react to customer demand rather than generate it on a large scale, the cooperation between universities and companies is more strongly oriented towards profitable mutual added value (Chais, Ganzer, and Olea 2018). This kind of competitiveness-inhibiting legislation has already been noted by Porter and Van Der Linde (1995a) three decades ago.

The company-related variables and the agent supplier and cooperation partner can be interpreted similarly as a totality of the companies. The current positioning of the products (Figure 1) and the company-related influencing factors as brand, shareholders and product developers (Figure 2) are linked to the systemic influence. The reputation as a premium product is often reflected in a price premium and is protected by this unique selling proposition (Berger 2019). Increasing competition and better market transparency or consumer knowledge could counteract this. The similar positioning of suppliers can also be explained by this, as market knowledge is shared more easily, especially among cooperation partners (Bathelt, Malmberg, and Maskell 2004), and should result in similar behaviour.

In addition to discussing reasons for the current systemic situation, the question arises which constellation is necessary for the development of AFI, and to what extent the current situation can be changed. The results from Figure 3 are particularly interesting in this regard. While – except for science – the agents predominantly have a medium to strong and supportive influence on environmental benefit, the support turns negative with no to weak influence on the socio-economic benefit. The potential mobility of individual agents in terms of strength of influence is largely dependent on the economic and social system in which they are embedded. For the creation of green and competitive products an ideal constellation would be a positioning of all agents in the I. and II. Quadrants (see Barnikol and Liefner 2022b). This is a static perspective though; in the course of the innovation process and life cycle, the importance of the individual agents and the need for their support may vary (Dewald and Fromhold-Eisebith 2015).

The current constellation in Lower Saxony's and Hesse's manufacturing sector suggests that the positive environmental benefits of many products are integrated into and subordinate to an overarching systemic and societal aspiration. Nevertheless, it can be assumed that the socio-economic benefits are lower for companies that see themselves as premium manufacturers and demand a price premium (Chais, Ganzer, and Olea 2018; Figge and Hahn 2012). A change in the societal acceptance of green products towards the demand for affordability, as Schwirplies and Ziegler (2016) found out for the U.S., could result in a shift to the I or II quadrant in the framework of Figure 3. This Mindset shift could have a similar effect on shareholders, suppliers and cooperators as well as product developers and governments.

From an international perspective, the current situation can be both: a strength and a weakness. Although there does not seem to be any price-reducing pressure in the observed systemic-social constellation in Lower Saxony and Hesse, it may exist in other countries, regions, sectors, companies or individual customer groups. The literature on classical frugal innovation underlines this by prioritising the reduction of monetary costs to supply low-income consumer groups (Hossain 2017; Lim and Fujimoto 2019; Weyrauch and Herstatt 2017; Zeschky, Widenmayer, and Gassmann 2011). Barnikol and Liefner (2022b) argue that, principally, the ability to develop both green products and low-cost products is a strategic starting point to create an competitive advantage for companies and regions.

Companies, especially in the German market, could strategically develop green products that are perceived as premium in the short to medium term, and use the resulting revenues to expand competitiveness in the direction of lower-cost products (see Barnikol and Liefner 2022a). In the medium to long term, however, they will need to generate environmentally friendly and low-cost products to prevail international and re-conquer applications traditionally occupied by Far East products. It also offers companies the opportunity to use a first-mover advantage. Since AFI, in contrast to FI, addresses a broader spectrum of markets and customer groups, the advantage could turn out to be greater than Zeschky, Widenmayer, and Gassmann (2014) find for FI. One way to leverage this

strategic advantage for Western companies could be to cooperate with companies from emerging economies that have experience in reducing costs and simplifying product design (Lim, Han, and Ito 2013).

To facilitate this strategy for companies, regions and countries need to create an innovation infrastructure that supports the combination of environmental and socio-economic benefits in product development, including education and training of labour as well as support in dissolving unfavourable networks (see Kyllingstad 2021; Rycroft and Kash 2002). It is crucial to apply measures that are low-cost but at the same time ensure optimal transparency. One possibility would be an institutional framework in which environmentally harmful behaviour is internalised in prices across all products in a market, as is the case with European emissions trading.

5. Conclusion

The conducted explorative study shows the influence of individual system agents on the characteristics of a product with regard to socio-economic and environmental benefits. The results indicate that a trade-off between these properties is strengthened by many agents in favour of green product properties and that higher prices are accepted or promoted. While science or research-related cooperation enable a simultaneous promotion of both benefits, the sustainability efforts are particularly driven by consumers, the brand and suppliers who accept and charge higher prices. From a systemic and societal perspective, it appears that the trade-off is also favoured by institutional factors.

Based on the data used there is a relationship between the innovation system and societal expectations and perceptions of the characteristics of a product. The systemic situation in the manufacturing industry in Germany hinders the resolution of the trade-off between green and affordable product characteristics in general. Nevertheless, the strong and consistent efforts of systemic agents to influence the environmental benefits point to a green technology development path.

Whether the solution approach is essentially technologically or cultural driven or a combination of those cannot be finally determined with this research. In addition to available research, this article does support the assumption that societal perceptions of pricing in the context of a green economy have a negative feedback effect, slowing and hindering the transition towards a green economy and the development of AFIs. Expressed differently AFI efforts do not fail because of missing motivation to generate green products but because of the disability to reduce or remain the price level simultaneously.

The results of this article contribute to theoretical discussions on the strategic positioning of technologies in markets under green transition by providing empirical evidence. In doing so, this work underpins the importance of AFIs in creating an competitive advantage for companies and regions. The influence of societal and systemic agents on the development of green and affordable products was uncovered separately by direction and strength from a theoretical perspective. This enabled the identification of stakeholders' interests and degrees of impact. Furthermore, the research results offer first-time observations on the societal and systemic influence on the development of advanced frugal innovation and frugal innovation in general. From a practical perspective, this work offers an evaluation framework for the establishment of technologies with specific characteristics in specific societal frameworks. The development of AFI in markets undergoing a green transition can represent a unique selling proposition and strategic competitive advantage for companies.

However, the classification of the results is limited by the small sample size and the lack of comparable surveys and measures. Nevertheless, the dataset is unique and the results show expressive new empirical findings. To allow a better comparison of results, further research with a larger sample size, other industry or country focus has to be conducted. This would also allow to evaluate the influence of the agents regarding the question of whether they are already exploiting their potential or need to develop it further. The present study can serve as an orientation framework that leaves room for expansion and adaptation. Nevertheless, implications can already be derived from this

study. Since agents influence the development of advanced frugal product characteristics and determine the degree of a trade-off, they should use their influence to increase systemic competitiveness. In addition, the overall constellation of agents should be considered and, ideally, adjusted. It is advisable for Western companies in particular to relearn the ability to develop low-cost products while remaining existing quality standards. A strategic decision could be the participation in the competition of markets under more supporting conditions for AFI.

There is still a great need for broad interdisciplinary research. Above all, there is a need for further studies that offer companies transparent and agile guidelines for creating AFI in innovation processes. The effective integration of green and affordable products into existing business models and organisational structures is also largely unexplored. In both contexts, comparative geographical studies can also make a necessary contribution to identifying transferable prerequisites for the emergence of supportive conditions from the respective systemic conditions and agent constellations of different countries and sectors.

In conclusion, AFIs can contribute to a greener economy and green business models, through their competitive and affordable character. However, the societal and systemic conditions must change, and the monitoring and identification of possible adjustment mechanisms requires further research.

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