De-Locking Regional Trajectories: The Intricacy of Using Industrial Design in an Engineering Region

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Abstract

Design is a crucial element in today`s engineering and technical innovation. Although its economic benefits have been demonstrated and the number of design award applications has been rapidly increased, especially small and medium sized firms are still reluctant to integrate design in their innovation and development processes. This paper seeks to answer why manufacturing firms resist industrial design. To explore this question, we focus on a successful growth region in Southern Germany – Heilbronn-Franconia – which is dominated by a strong legacy of industrial engineering. Based on in-depth interviews with internal as well as external designers, we first develop a typology of differential depths of design integration into the engineering process in order to demonstrate the limited use and integration of design in traditional engineering. Secondly, we identify important barriers to recombining the distinct domains of engineering and design knowledge at the level of epistemic communities as well as on organizational and regional levels. We thus offer a critical perspective on path-dependence and contribute to the understanding of regional lock-in mechanisms. Finally, we illustrate ways to break these lock-ins and open up for a successful integration of industrial design in engineering innovation.

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FIRST DRAFT (work in progress)
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Abstract: Design is a crucial element in today`s engineering and technical innovation. Although its economic benefits have been demonstrated and the number of design award applications has been rapidly increased, especially small and medium sized firms are still reluctant to integrate design in their innovation and development processes. This paper seeks to answer why manufacturing firms resist industrial design. To explore this question, we focus on a successful growth region in Southern Germany – Heilbronn-Franconia – which is dominated by a strong legacy of industrial engineering. Based on in-depth interviews with internal as well as external designers, we first develop a typology of differential depths of design integration into the engineering process in order to demonstrate the limited use and integration of design in traditional engineering. Secondly, we identify important barriers to recombining the distinct domains of engineering and design knowledge at the level of epistemic communities as well as on organizational and regional levels. We thus offer a critical perspective on path-dependence and contribute to the understanding of regional lock-in mechanisms. Finally, we illustrate ways to break these lock-ins and open up for a successful integration of industrial design in engineering innovation.

1. Introduction

Half of all failed innovations do so because firms lack of sufficient market or customer orientation (Wolf 2009). Conversely, those firms that invest in product design and adopt a customer perspective have been found to be more successful in sales and exports (MacPherson 2000). Industrial design is one proven way to enhance market orientation, to tailor products to customer preferences and raise the value-added of services and goods. However, there has been a major lack of research on industrial design in the context of SMEs (Perks et al. 2005; D'Ippolito 2014; Melkas and Pekkarinen 2016) and especially in geographical perspective. Only a few studies have addressed industrial design, such as in debates on the creative class, the creative industries (Florida 2004) and global cities (Sassen 2005). These studies focus on design as a creative profession (Vinodrai 2006) or industry O'Connor, 1996), more generally, and discuss its role in cultural production systems (Sunley et al. 2008). However, the role of design in engineering and technical innovation has hardly been studied – despite its increasing role as a source of additional value-added. In addition, there is more research necessary to explain the specific requirements which support industrial design and "the conditions to be met in order for this potential to be realized" (Ravasi and Stigliani 2012, 481). Thus, this paper focuses on the difficulties that design faces when being integrated in technical innovation and production.

We choose the case of Heilbronn-Franconia to ask how differently design is actually used by engineering SMEs, and secondly, how design faces resistance to its use and further integration in the innovation process. Located in Baden-Württemberg, Heilbronn-Franconia has been one of the fastest growing economies, is home to a considerable number of so-called hidden champions and world-market leaders in mechanical engineering, equipment manufacturing and the automotive industry (Industrie- und Handelskammer Heilbronn-Franken 2014). At the same time, however, it is doing poorly in industrial design: both the profession of designers as well as the business sector of industrial design are disproportionately underrepresented in the context of Germany. We draw on over thirty in-depth interviews with internal and external designers to develop a typology of differential depths of design integration into engineering and to present evidence of several lock-in mechanisms that hinder design to grow at the levels of the profession, the organization and the region. We thus relate evolutionary arguments of path-dependence with concepts of social realms of knowledge production, such as epistemic communities, knowledge domains or thought collectives.

2. Theoretical Background

2.1 Path-dependence and lock-in mechanisms

An evolutionary perspective has been useful in research on economic development to interpret the quality of change. Change is seen as evolutionary whenever future events are both dependent and contingent upon past development and current context (Nelson 1995). A key concept to account for the constraining yet contingent influence of the past on future development is path-dependence (David 1985; Arthur 1989). Path-dependency describes a presumable process which is channeled by moments in the past and the performance of these possibilities in the present. In other words, the future of technologies, organizations and industries is contingent upon historical events and the status of the socio-economic system they are and have been embedded in (Martin and Sunley 2006). The sequence of these events thus describes a relatively consistent trajectory of economic development. In a geographical perspective, different starting conditions and specific regional trajectories thus help to explain

enduring differences in economic performance and inter-regional disparities (Martin and Sunley 2006; Henning et al. 2013).

The literature has identified important mechanisms of cumulative development, such as increasing returns to scale and technological externalities (David 1985; Arthur 1989), as well as institutional hysteresis (Setterfield 1993). Whether path-dependence is good or bad for a regional economy cannot be assessed a priori. Often, successful practices are reinforced and increasing specialization in these sets of practices become dominant logics of action which in turn define and solidify a consistent and cumulatively developing trajectory. While the creation and growth of development paths is often beneficial in the short and mid run, it may prove inefficient or even obstructive for enduring growth and development in the long run (Jacobs 1969). How do firms and regions respond to new technologies, new regulatory and institutional opportunities, and new ways of thinking?

We would like to go beyond the ambiguous assessment of whether path-dependence is good or bad, to help exploring the mechanisms that conserve existing trajectories and work against the opening toward, integration of and co-evolution with new development opportunities. These mechanisms have been broadly identified as lock-ins. The evolutionary literature suggests several types of lock-ins (Grabher 1993; Frenken et al. 2007; Boschma and Iammarino 2009). The most common type is the technological lock-in (David 1985). It describes a situation in which an organization (or a region) is not able to change its technological base although worthwhile alternatives are available (Martin and Sunley 2006). Technical interrelatedness, economies of scale and quasi-irreversibility of investments are claimed as rational causes to explain the endurance of existing technologies.

Apart from these incurred costs, there are also social dimensions of cumulative development and potential lock-in. In his analysis of the rigid specialization in the coal, iron and steel industry of the German Ruhr area, Grabher (1993) identified three non-technological types of lock-in. Together these lock-ins were found responsible for intraregional constraints on the flexibility and adaptability of the regional economy. The industry and the political administrative system pursued a highly cooperative strategy which creates an environment (alliances, unions, etc.) of consensus and implicit agreement of not opening the regional economy for new industries (political lock-in) (Grabher 1993). Stable personal and supply relationships lead not only to an efficient way to reduce transaction cost, but also increases intraregional innovation activities (functional lock-in). A cycle of common understanding, personal cohesiveness, and group thinking constructed a 'common worldview' (cognitive lock-in) which framed the decision making processes. The awareness of new innovation possibilities were ultimately constrained by the shared worldview (Grabher 1993). This example shows how a development trap is constituted, and it furthermore highlights the social hysteresis beyond technologies or sectors. Yet, in order to be able to detect possibilities of de-locking encrusted trajectories, more research is needed about the underlying beliefs that frame a common worldview and about the social mechanisms that reinforce their validity in a regional context.

2.2 The social framing of collective thought and learning

Rather than analyzing the technological externalities leading to a lock-in, we are interested in social mechanisms that invigorate established regional trajectories. Concretely, we examine how firms in a region dominated by export-driven engineering and mid-tech innovation fails to make better use of industrial design in their innovation process. While the concept of domains characterizes marked differences in the constitution of a field of knowledge, the

concept of the thought collective (Fleck 1979) or the epistemic community (Knorr-Cetina 1999; Cohendet et al. 2014) define the social group of practitioners enacting such a domain.

A domain in general is a construct which is used as description tool to differentiate areas or subsystems from each other and to make their characteristics visible. In mathematics a domain defines a set of elements which are included in a calculation. The idea of domains is used interdisciplinary: in psychology (Gigerenzer and Hug 1992; Gigerenzer 1996; Buehl et al. 2002; Strack and Deutsch 2004), in sociology (Cook et al. 2004), or in computer science (Gennari et al. 2003). Even if it is not possible to define the boundaries of a domain exactly (Sternberg 2009), it defines a specific field of meaning characterized by its own language, norms, values, and requirements for actors (Gruber and Mandl 1996; Meusburger et al. 2011). Recent findings suggest that key beliefs underlying the epistemic value, the types and certainty of knowledge, as well as strategies for the justification of knowledge vary by knowledge domain and thus display contextual differences between academic disciplines (Greene and Yu 2014). Overall, this line of research supports the notion that knowledge is at least partially domain-specific and thus develops contextual logics and rationales for the value, validity and justification of knowledge.

While a domain refers to a field of knowledge the concept of epistemic community refers to the social collective of actors that shares the underlying beliefs, logics and rationalities and that develops with common practices new knowledge within the domain (Knorr-Cetina 1999; Miller and Fox 2001; Cohendet et al. 2014). Such a community is not just a group of creative people but a group of knowledge-driving agents with a common object: the epistemic movement (Cohendet et al. 2014). In other words, its members have the common goal to solve a problem. It is characterized by experts of a specific domain (Haas 1992), specific arrangements and mechanisms which "make up how we know – what we know" (Knorr-Cetina 1999,1). This presupposes that all members share a common understanding and practice of how problems of a class should be solved. This shared belief is entailed in a kind of common codebook (Cowan et al. 2000) or a common orientation system (Holzner 1968).

Thinking in categories of domains and epistemic communities has two motivations: one is to understand how commonly shared mental models, dominant logics and taken-for-granted beliefs as well as knowledge emerge within a social collective; second, to analyze how learning across domains and between communities is possible. One extreme scenario is that learning between domains is impossible and fails altogether because of incommensurability. Members of distinct knowledge domains, scientific paradigms (Kuhn 1962) and thought collectives (Fleck 1979) may fail to communicate to each other about the truthfulness of a common matter if there is no shared logic between their epistemic systems which allows for the articulation of one paradigm in the language of the other (Latour 1987). These debate about was motivated to argue against universal truth, infinite scientific progress and cumulative knowledge. When a new paradigm challenges rather than adds to an incumbent one, then the summative notion of knowledge accumulation becomes obsolete. Although this argument contributes to relativistic science (Shapin 1998), the very claim of incommensurability has been seriously challenged. In his reconstruction of the opposition between Einsteinian relativity theory and Newtonian physics – the fundamental example of Kuhn to illustrate incommensurable paradigms – Toulmin demonstrates how physicists gradually converted to relativity theory by way of conviction and reason in the period between 1890 and 1930 (Toulmin 1972): the example on which Kuhn puts greatest emphasis, actually does not comply with his definition of incommensurability.

The controversy about the commensurability between paradigms and thought collectives reveals the importance and contingency of the social process of recombining between domains. Knowledge is not only created in specific social, cognitive, and institutional contexts, its successful reproduction also depends on social strategies of representation

(Shapin 1998). The knowledge creation process is the result of cognitive interpretations in a unique context which leads to the fact that knowledge becomes bounded and more difficult to communicate between rather than within domains. Consequently, adding new knowledge to the existing stock of knowledge does not necessarily create more value (Barnes 2004). New knowledge (domains) cannot simply be added to the existing knowledge base (Bathelt and Glückler 2011). Instead it needs to be actively recombined. This recombination may be a major source of unlocking path-dependent development. It is not enough to know the codes of the other community (Håkanson 2010). Instead it requires adjustments within both communities (Baldwin 2008). Since knowledge creation and learning are social processes, the question of recombining knowledge between domains and communities becomes an empirical question rather than one of theoretical possibility. This empirical contingency has been crucial, for instance, to understand the success or failure in the diffusion of controversial innovation (McGrath and Krackhardt 2003; Glückler 2014; Glückler and Panitz 2014): Commensurability, controversy and the odds of successfully recombining new knowledge are ultimately contingent upon the social process of representing and communicating knowledge, of raising interest and consensus, and of interacting in social networks and specific spatio-temporal contexts.

2.3   Industrial design as a domain, designers as a thought collective

There is no universal definition of industrial design (Gemser and Leenders 2001) since it is often conceived as a process, a practice or even a result (Ravasi and Stigliani 2012). An industrial designer (synonym to product designer) focusses on the human-machine interaction while combining the form, the function and the context (Ravasi and Stigliani 2012). In the organizational context, industrial design aims to bring together all professions and departments that work on and contribute to the development of a new product or technology. In line with such a perspective, we understand industrial design as a catalyzer of different demands regarding a product – be they aesthetic, technical, functional, or commercial – with the aim to satisfy the consumer needs (Valencia et al. 2013).

While the early design activities in the 19th and early 20th century were mainly directed to the arts, industrial design began to become more and more product oriented in the first half of the 20th century. However, design was still a kind of stylistic and aesthetic add-on for consumer products (i.e. vacuum cleaner) (Perks et al. 2005). In the 1950 and 1960 the first idea of industrial design as a specialization in design was born in Germany. Dieter Rams, a German industrial designer and head of construction at BRAUN GmbH, became famous for the purity and functionality of his products. He helped to establish the idea of industrial design as an interplay of craft arts and engineering. At about this time, industrial design began evolving toward an institutionalized profession. In Germany, the first professional association of industrial designers (Verband Deutscher Industriedesigner) was founded in 1959 (VDID 2016), and many other professional associations were founded around the industrial world in the same period, such as the Society of Industrial Designers (SID) in the U.S. (ISDA 2016), or the British Council for Industrial Design in the UK. Moreover, universities began to offer the first courses on industrial design in Germany, and by 1950 the first formal university degree in industrial (product) design was established (Bundesagentur für Arbeit 2016). Today, eighteen universities offer a degree in industrial or product design in Germany (VDID 2016). The evolution of industrial design as a profession helped to formalize, legitimize, identify with and train the constitutive set of skills and knowledge necessary to create the foundation of design as domain and of the beliefs, proficiencies, perspectives, values, and rationalities of a legitimate member of an epistemic community or a though collective. These included, for instance, to work creatively, to solve problems from the perspective of the user, to spot and

build on technological, social, and functional trends, to transform abstract ideas into concrete visualization, and to communicate these solutions to the rest of the development and production teams (Blaich and Blaich 1992; Valencia et al. 2013).

A key feature defining the specificity of the thought style (Fleck 1979) of the epistemic community of industrial designers is the disruptive approach to create original solutions. Designers are trained to challenge the entire product and its usability by interrupting the production process again and again. Instead of focusing on continuous technical improvement or complying with initial production plans, the industrial designer instantly brainstorms and irremissibly seeks conversations with involved parties to explore and solicit creative alternatives to established ways of thinking and doing the product (Sutton and Hargadon 1996, p. 703): Product designers "insisted that the only way to avoid major mistakes, or at least make fewer mistakes, is to talk to a lot of smart people". By using both analytical or engineering knowledge and symbolic knowledge industrial designers conceive themselves as generalists (Verganti 2013). In contrast to graphic designers industrial designers interact with the physical product, its material features, and they are trained in software (CAD) and other techniques to develop proto-types (Valencia et al. 2013). Industrial designers have the capability to embody and visualize the abstract object in the problem-solving process of product development (Ewenstein and Whyte 2009). This explicit role of intermediation between many other involved parties has inspired scholars to sometimes understand industrial design per se as a multi-domain knowledge community (Ravasi and Stigliani 2012). Institutionalizing industrial design as a profession with its own curriculum and associations laid the foundation of what Fleck considered crucial for a thought collective to emerge and formalize: a system of apprenticeship to be inaugurated and socialized into a dominant thought style, and the affiliation with associations to experience and enact thought solidarity (Fleck 1979).

Moreover, government and other political organizations noticed the potential value of industrial design for the innovativeness of regional and national economies. The proliferation of publicly commissioned studies reflects the interest in assessing the state of the art of industrial design in a specific territorial jurisdiction in promoting its use in industrial manufacturing (i.e. Wirtschaftsministerium Baden Württemberg 2009; Hessisches Ministerium für Wirtschaft Verkehr und Landesentwicklung 2013). Today, there is an increasing number of applications for product design awards (Zec and Jacob 2010) and Registered Community Designs (Filitz et al. 2015).

Despite the evident rise of industrial design in the economy, its causal effect on commercial and financial success is hard to measure in tangible ways (Hesket 2009). By trying to quantify design some authors argue that design increases the economic profitability, the return on investments and the profit rate (Hertenstein et al. 2005; Zec and Jacob 2010). However, this effect cannot easily be attributed to the impact of design, and it is usually estimated for large corporations, only. The ambiguity of assessing the tangible cost and benefit of value design for product performance has been claimed as one explanation for the underutilization and resistance to design by smaller enterprises. This is possibly one reason why industrial design has been suffering from the contempt of SME manufacturing firms (Veryzer 2005; Högberg 2007). In what follows, we examine how design knowledge gets either recombined with or locked-out of engineering and technical innovation in the regional context. Such blockages of knowledge and thinking external to a though collective will be considered as a case of epistemic and cognitive lock-in. They are likely whenever the different actors do not share trans-epistemic competencies (Knorr-Cetina 1984) or their knowledge domains are lived and enacted as if they were incommensurable. Such processes of cognitive lock-in can occur at the level of epistemic communities (e.g. professions), organizations (firms and associations) and the regional economy as a whole and may in sum

reinforce an established development path. We therefore analyze cognitive barriers toward the domain of design knowledge at different levels: the profession, the organization, and the region.

3 Research design and methods

3.1 A regional case study: Industrial design in Heilbronn-Franconia

The region of Heilbronn-Franconia is located in the state of Baden-Württemberg in Southern Germany. The region enjoys nearly full employment and is the second fastest growing region in all Southern Germany. The regions' gross value-added per capita has increased by 44 percent in only 12 years since 2000 (Statistsches Bundesamt 2014), and the region reports the highest income per capita throughout Germany. The economic base of the region is predominant mid-tech industries such as mechanical engineering, equipment manufacturing and the automotive industry. The export rate reaches as high as 51 percent compared to only 44.3 percent of GDP in Germany (Industrie- und Handelskammer Heilbronn-Franken 2014). A total of 99 percent of all the 41,000 firms are small and medium sized enterprises and making up the so-called Mittelstand in the German economy (Statistsches Bundesamt 2014). The Mittelstand is well known for its family-run businesses, traditional managements and its high-quality technical tinkering. Family firms are often strongly regionally rooted and build the backbone of the regional economy. Despite its recent growth, however, regional experts fear the challenges imposed by increasing global competition, regional shortage of highly-qualified labor force and the demographical change toward an ageing population. The sustainability of its economic growth thus depends on the ability of firms to adapt to the fast changing markets and to satisfy more differentiated customer needs.

As a consequence of its long and successful trajectory of economic growth, the region is strongly focused on engineering. In contrast, industrial design seems nearly absent in the region, and statistically it is clearly underrepresented (Table 1). In terms of a business sector, just 57 of all 354,000 employees subject to social security contributions worked in the design sector in 2013. Since the design sector includes also ateliers of jewelry and art factories, the true number of industrial designers is even lower. In fact, there are only three design agencies registered in all Heilbronn-Franconia. In terms of a profession, 565 designers were employed in the profession "product designer and artisan", a share of .16 percent in the regional labor market (Bundesagentur für Arbeit 2014). By any means of statistical comparison in Southern Germany, the location quotients of .38 for the sector and .36 for the profession reflect the marked underrepresentation of industrial design in the region. There is growing evidence of a long shadow of a successful development path of engineering in Heilbronn-Franconia, which now seems to convert from a positive to a negative lock-in (Martin 2006). In other words, the strength of technological tinkering may evolve into an encrusted trajectory posing a risk to the future development potential of the region.

Table 1: Industrial design in numbers (sectors, jobs)

	No. of employees	Share in labor market	Location quotient (in Southern Germany)
Design sector	57	.02%	.38
Design profession	565	.16%	.36
Total	354,000		

3.2 Observations

We first collected official data from German labor and industry statistics on all employed industrial designers in the region (Bundesagentur für Arbeit 2014; VDID 2015). In addition, there are also designers who work as freelancers and who do not appear in official statistics. We therefore sought support by the Design Center in Stuttgart and the association of German industrial designers (VDID) to identify the number of freelance designers (self-employed) in the region and thus produced a near-to-complete dataset on industrial design in Heilbronn-Franconia. We used these data to assess the statistical distribution of design in the region as reported in the previous section.

Drawing on this dataset, we contacted three groups of actors for personal interviews: designers employed with design agencies, freelance designers, and in-house designers employed with manufacturing and engineering firms. These firms operated in distinct sectors of mechanical engineering and manufacturing, such as automotive electrics, engines and ventilators, gearboxes, measurement/control technics, polymer processing, valves, fluid control systems, and seat manufacturing. The distribution of in-house designers is highly skewed in the regional population. While a handful of large firms with a labor force around 1,500 people employed design teams of 8 to 16 professionals who equally participated in design and technological functions during the product development process, most other firms employed only one designer or engineer being responsible for design in the entire firm. As a consequence, we decided to also have interviews with engineers in those cases where they had explicit design tasks and responsibilities.

Overall, we conducted 33 semi-structured interviews with the four types of design practitioners (Table 2). All interviews lasted between 45 minutes and 120 minutes, were recorded and transcribed completely. The anonymized transcribed data were loaded in the software program MAXQDA which is designed for computer-based text analysis. Following the approach of qualitative content analysis (Mayring 1988), we coded interview transcripts into several categories and over a few iterations of re-reading and re-coding. The code system is constructed around four main code topics: characteristics of industrial design, the design process and work, areas of conflict, and regional context. Each main code includes up to 15 sub codes cascading over three levels. In total, our content analysis builds on more than 800 interview codings.

Table 2: Interviews with industrial designers in Heilbronn-Franconia

Firm type	Number of interviews
Designers in design agencies	5
Freelance industrial designers	10
In-house industrial designers	13
In-house engineers (making design)	5
Total	33

4   A typology of the depth of design integration in innovation

A key focus in our semi-structured interviews was to reconstruct how industrial designers had been involved in particular innovation and product development projects. Overall, we collected 52 project examples covering a wide range of product developments, such as automotive electrics, furniture, fluid control systems, seat manufacturer, snow-/skateboards,

engines and ventilators, gearboxes, measurement/control technics, automotive electrics, polymer processing, and gas valves. Analyzing the roles that industrial designers had taken in these projects, we were able to abstract the empirically observed involvement into three types of what we call depth of design integration in technical innovation (Table 3): (1) shallow design with only little or no integration in the technology development process; (2) aesthetic design which focuses on the design as the final product itself, and (3) pervasive design with profound integration in and a key driver of technical innovation. We argue that the relationship between design and technology is more than a dualism of "form follows function or function follows form": it rather is a continuum of interdependence between design and technical inputs.

Table 3: A typology of depth of design integration into technical innovation: Empirical examples

Type of design integration	Shallow design	Aesthetic design	Pervasive design
Product designed by…			
…in-house-designer	automotive electrics bearings engines fluid control systems gearboxes gas valve long-/skateboards measurement control technics water valve	plastic foil	automotive seats aircraft seats special furniture
…agency/ freelance designer	case for dialysis machine (r) drilling machine (r) ventilators (r) screws (r) liquid pump (tap) (r)	pen (n) watch (i)	ambulance (n) automotive for disabled (r) people

The letter indicates the location of the client company, (r) regional, (n) national, (i) international.

4.1 Shallow design: The nice jacket to the product

A shallow depth of design integration refers to using industrial merely as the optical appearance or the nice jacket of a product. In this case, design is added to a final product as an additional package completely isolated from the product development process itself. Despite its separation from research and development of a product, shallow design is useful and leverages the product value. A nice looking product can create an attractive image in the consumers' mind (Bloch 1995). The majority of projects reported in our interviews referred to products which were first developed independent of industrial design and then dressed into shallow design afterwards: screws (looking stable), longboards (looking fancy), drilling machines (looking resistant), displays of fluid control machines (looking modern), or the case of a dialyze machine (looking clean). The visual appearance can also signal otherwise invisible technological, functional improvements inherent in a new product, e.g. a new automotive with an electric rather than combustion engine which is purposively transmitted by the design (Eisenman 2013; Glückler and Bathelt 2017) or Edison's electric light bulb which needed an redesign to meet institutionalized expectations (Hargadon and Douglas 2001). In addition, design can offer an incentive to pay a higher price (Desai et al. 2001; Talke et al. 2009) and can so increase corporate revenues (Appleton 2011).

However, "functional" design (Perks et al. 2005) results from only a shallow degree of integration into the new product development. The quote of an engineer talking about a new instrument of a fluid control system illustrates the first depth of design integration. The engineer of a large family firm illustrates this in the case of developing a new instrument of a luid control system. Although the firm employs over a thousand people, there is just one industrial designer on the payroll. This designer is consulted only at the very last stage of product development and usually, there is very limited communication between construction and design. The engineer explains: "blueprinting the hand wheel is usually done before we ask a designer to create a fancy look" (02 in-house engineer). Another way of employing shallow design is branding and to generate visual distinction from competitor products. Design serves as a functional add-on to the technical product itself. In the case of screw production, an in-house industrial designer states:

> "There are two reasons, why they need design. Firstly, to differentiate from their competitors. I produce obviously a different screw than the competitors. And secondly, maybe, the functionality, that the screw is easier to assemble" (03 in-house industrial designer)

This serial, linear division of labor precludes any integration of design at earlier stages of research, construction and proto-typing. Moreover, this process makes it difficult to introduce consumer needs in the development process. The majority of projects and case we observed in the interviews corresponds with shallow design. Mirroring the peripheral role and status of industrial design, we made the following experiences in the field: when contacting and visiting the firms, we repeatedly talked to people, e.g. receptionists or middle managers, who had no clue that actually an industrial designer was employed with their firm. This illustrates how industrial design is not only underutilized in the process, but profoundly unknown or almost ignored within even those firms who actually employ a designer. Most of the product examples in this category are produced with in-house designers.

4.2 Aesthetic design: Design as innovation

The second type of design integration is aesthetic design. Not the technical part of the product innovation is the novelty, it is the appearance itself. Aesthetic innovation (Eisenman 2013), stylistic innovation (Tran 2010), or the innovation of meanings (Verganti 2009) here is the innovation itself. Although the design activity has an important influence on the product and the development process, there is still very little interaction and integration between the distinct knowledge domains: designing and engineering largely remain separated activities. Similar to shallow design integration, common project meetings are rare and communication between designers and engineers is scarce. Instead, the process is almost completely design-driven (Perks et al. 2005; Verganti 2013). In our examples we observed that the industrial designer often leaves ones associated designing activities and used engineering methods to test prototypes or materials and to produce the product by one's own.

We identified three projects in our interview sample: a pen, a watch, and a plastic foil. Interestingly, only one of the products was actually manufactured within the region of Heilbronn-Franconia. There is almost no demand for this type of products or know-how in the region. One industrial designer employed with a design agency had formerly worked in-house an automotive firm before he started his own business. He reported the case of an idea to develop of a premium watch with a bracelet built of ceramics. The interesting aspect is that the client company had contacted him first to create the new bracelet:

> "I made a watch which was more different. Additionally, I do not only want to replace the old material in the bracelet with the new one. I think it was ceramic. The company just want to replace the metal with the ceramic and proceed with the watch how they have ever done before. If you are thinking about a pearl

> necklet. The pearl is the material, the pearls are connected with the necklet, a ribbon. And the company just thought about to replace the metal with ceramic, but keep the metal connections between them. I said I will not use metal anymore; the entire watch should be made of ceramic. I made a blueprint and they really liked it. However, they said they could not manufacture it." (05 agency industrial designer)

Despite their interest, the client firm had no experience how to manufacture such a watch. Therefore, the designer tried it himself, applied a patent and had sorted out the technical production two years later:

> „But two years later the company Rado with its new general manager approached me again and said that they had seen this and that they wanted to realize it after all. We have a company in Japan, they can produce the ceramic parts for us, in Switzerland they weren't able to do it at that time; and they also want to have the patent of this bracelet which was the foundation actually to be able to produce this in the first place. This Rado, its called Keramika, is still in the market today, in the most different versions actually. " (05 agency industrial designer)

In this examples, the design itself is the innovation. Engineering only serves to put the design into practice. Not technical functionality is not the important factor, it is the aesthetic element. The face-lift of a car is another example where the visual and aesthetic elements of an existing technology justify a new model (Eisenman 2013). Some technologies are very hard to change in their exterior, so technological novelties need to comply with traditional dominant designs to get accepted (Abernathy and Utterback 1978).

4.3 Pervasive design: Design as a driver for technical innovation

Pervasive design, the third depth of integration into the innovation process, is the one with the highest potential to foster the innovation process. If consumer needs are integrated into the product development process right from the beginning (Gemser and Leenders 2001; Veryzer 2005), the process becomes more effective, sparing evitable loops of trial and error (Valencia et al. 2013) in meeting customer demand. Pervasive design integration means that the process is neither exclusively driven by design nor by technology. In these cases, domain knowledge of industrial design is accepted and plays an equally legitimate role as technical engineering from the very beginning of pre-construction. Pervasive design integration is so valuable because it enables an open atmosphere of recombining knowledge between domains and thought styles. Designers, engineers and managers challenge each other during the entire development process and thus create new products that surpass many pitfalls usually overseen when the different domains are ignored in early phases of development. Apple's iPhone illustrates such innovation because the smartphone was not characterized by the best technical interior but a novel usability and thus best suited customer needs (Brown 2008). During the entire process, engineering and design work together and discuss each modification. Contrary to the literature (Rampino 2011) we found that the higher the technological complexity of a product, the more important is it to involve a user perspective at every stage of development. An industrial designer of a design agency illustrates this in the context of a special purpose vehicle: Interestingly, the designer reveals that their client initially started to talk only about shallow design requirements. Then, they noticed that they needed to introduce the design team as soon as possible in the development process:

> "We have a lot of requirements concerning this ambulance, we have to handle all this factors and bring them together: while the interior should be maximum high, the exterior should be at a minimum, the whole light machine, the legal regulation, technical possibilities for production. We can just go on and say we are making a nice exterior." (03 Design agency)

After further follow-up meetings, the industrial designer had become part of the development team. As valuable this kind of integration is, as conflictive is it. Frictions and controversies

challenge the innovation process, but help to improve product quality and even set the standard for a market niche:

> "A local firm produces vehicles for people with disabilities. [...] For this you need to have certain tools in the vehicle so that you can drive at all. Before these were only rod systems. They didn't look nice and implied risks of injury. Now we as designers have consciously shaped them, have developed them further technically together with the company, have made them in a new way, and now the company is the market leader in the market." (04 agency industrial designer).

The client-company of this industrial designer was located outside the region of Heilbronn-Franconia. Only two firms within our study region were found to integrate industrial design pervasively in their R&D processes: a firm that produces aircraft seats and a special furniture manufacturer. Only in these cases did the two firms employ teams of industrial designers rather than just one person. Whereas Perks et al. (2005) observed that external designers were mostly consulted by firms pursuing radical innovation projects in early stages of product development, we observed that especially for external industrial designers it is not easy to get involved in the development projects from the very beginning. Not only had the empirical observation shown that a pervasive integration of industrial design is necessary to realize the full potential of industrial design. But also the skills of the designers and frequent involvements are very important at the early phases of the product development (Sutton and Hargadon 1996). To summarize, the depth of design is low in the engineering SMEs in Heilbronn-Franconia. It is mostly used as a nice jacket and has a low degree of integration into the production. In addition, most firms were found strongly biased toward an engineering-only model of innovation failing to deeply integrate a market-oriented perspective in the innovation process.

5 Learning between domains?

5.1 Collaboration between professions

Our content analysis of how the integration and thus recombination of design and engineering is inhibited points to cognitive lock-ins at three levels: the profession or epistemic community, the organization and its dominant logic of innovating, and the regional context in which a dominant worldview is institutionalized and uncontested. At the level of the professions, we found recombining knowledge across domains substantially difficult due to different thought styles (Fleck 1979) or epistemic cognitions (Greene and Yu 2014).

A first instance of limited commensurability is an incongruent set of mutual expectations about tasks between engineers and industrial designers. Whereas designers restricted the role of an engineer to perform only the technical core of a product, engineers viewed design as a face-lifting activity creating a beautiful cases. This ends in a deep misunderstanding and generates a sense of opposition and conflicting interests when claiming their stake in a new product. However, from an epistemic view they might fight for a common goal (Cowan et al. 2000, 234), a kind of "manifesto" (Cohendet et al. 2014).

Across all interviews, this clear-cut sequential division of engineering first and shallow design thereafter turned out to be the consistent worldview among engineers, but also managers and people more generally. The downside of the unquestioned boundary of engineering domain implies the disadvantage that firms in the region did not see the necessity in integrating design deeply into technical innovation in order to satisfy consumer needs. Although firms orally confirmed the important of market-orientation, it became very clear from the interviews that it is illegitimate and unaccepted at early stages of technical innovation. The head of R&D in a firm producing high-end individualist valves said:

> "Well, then you realize that it's too expensive, this valve. Because a lot of maintenance is necessary. The customer would like to spend as little as possible on maintenance, he doesn't want to replace the entire valve every year. Therefore we have had to adjust our production." (14 in-house engineer)

The consumer needs were not satisfied because the valve could not be maintained correctly. Designing knowledge could have perfectly helped to avoid the problem in the first place. But this would presuppose a designer be seen as a problem solver rather than artist. Although, both kinds of professions are experts in problem solving (Higgs et al. 2008), they pursue markedly different, domain-specific thought styles that begin at opposite ends of the development cycle: While the engineer begins new creation with technological opportunities, the designer begins new creation from customer utility and demand. Designers and technical persons feel threatened because they work on the same issue and do the same with contrasting goals.

5.2   Organizational level: Governance and resource conflicts

Apart from barriers in recombining knowledge across professions, there are further challenges at the organizational level to implementing design into the organizational structure and established innovation processes. A single designer cannot have pervasive impact on the innovativeness of the company and its development processes. In one case, the management decided to bring in design but underestimated the resistance and hysteresis regarding acceptation and integration of design in its innovation process. It took two years until design had become sufficiently accepted. There are often two streams inside a company: design and technology fail to synthesize in new product developments, mainly because of departmental thought worlds and organizational product routines (Dougherty 1992):

> "It was communicated pretty well in the company that a designer would be introduced. It was quite some effort to prepare the employees in advance. It's really not that simple in a traditional company like this. I would say that I worked a lot in the first two years to reach this kind of acceptance." (03 in-house industrial designer)

A second important hurdle is the access to resources and the knowledge how to distribute them. Design incurs extra costs on a development project. These resources have to be mobilized in two ways: by restacking existing and by using new resources. For firms it seems difficult to generate more financial or personal resources for something that is more or less invisible intangible. It is very difficult to calculate the right balance of design and technical parts. First, if design is to rare, it is not value-driven. Second, if the value cannot be linked to the designer, he might be perceived as unimportant part. Third, if design will be introduced to fast and with a big amount of resources it will probably fail in acceptance. These constraints lead to lock-in at an organizational level.

Another hurdle are established and taken for granted organizational routines which have evolved over long periods of time and are deeply embedded in the organization structure. Organizations are a kind of adaptive systems in which the employees follow "dominant logics" (Bettis and Prahalad 1995) or "mental models" (Bathelt and Glückler 2005). This interpretive framework gives the opportunities for action and the common meaning about the way of working and frames the epistemic systems, as well. To integrate designers correctly it is necessary to break up the mental models and overcome cognitive barriers (Chesbrough and Rosenbloom 2002). It is more a strategic decision. "Design has to flow through the whole company, through every project structure, and through every strategic decision", as an in-house industrial designer pointed out. A traditionally grown Mittelstand firm that led by a technical manager will be likely to get locked-in the thought style of engineering innovation.

5.3 The regional level: Interdependencies and de-locking

Finally, we observed elements of a regional thought style or worldview (Grabher 1993) in support of the incumbent engineering trajectory of Heilbronn-Franconia. The lock-ins at the community and the organizational level are embedded in this regional system. As already known from a technological perspective (Sydow and Schreyögg 2010) a regional path influences the organizational routines and its sloth for change. Without doubt, the technological know-how in mid-tech production combined with a traditional way of tinkering are a key element of the performance of Heilbronn-Franconia (Wuttke and Glückler 2016). The question is whether this rigid focus converts from a positive into a negative trajectory (Martin 2006), when failing to open innovation toward customer orientation. We observe a missing competence to transform their structure and own systems. Cohendet et al. (2014) describe three different spatial layers which influence the success of an epistemic process: an informal underground where lose creative ideas where produced, a rich and heterogeneous middleground where the agents of the epistemic community transform knowledge and creative ideas into an epistemic movement by using a common codebook (Cowan et al. 2000), and the formal upperground where organizations and firms legitimize the transformation and bring the innovations on the market. The firms located in Heilbronn-Franconia's upperground do not have a paragon or critical mass of firms using industrial design (Witt 1997). In addition, the labor market is highly specialized on technical skills and professions and lacks in highly qualified and service labor. Due to a missing educational infrastructure it is impossible to build competencies endogenously within the region.

While talking about how to de-lock the situation of the regional development path and the knowledge creating system, we would like to clarify why it seems necessary to integrate designers in such a successful regional economy. Without adopting a more market-oriented understanding of innovation and product development, the engineering competitiveness may suffer in the long run. There are noteworthy exceptions: a firm has already integrated design very successfully. This has been possible because it is a local subsidiary of a global corporation with a strong culture of industrial design developed and practice in the parent plant. This shows that in order to de-lock this situation external action and impulses are helpful to overcome limitations in the regional worldview. Change from within is also possible yet much more difficult for the many mechanisms of cognitive lock-ins and contextualized thought collectives. To bring a new epistemic movement to success, game changers both within firms and at the regional level are necessary.

6 Conclusion

We have analyzed the sluggish integration of industrial design in the product development process of engineering SMEs in the industrial region of Heilbronn-Franconia in Southern Germany. We have identified characteristics of epistemic lock-ins and the role of regional context in the reproduction of path-dependent development trajectories. Apart from the statistically obvious absence of industrial designers in the region the cognitive barriers at the individual and organizational level undergird the necessity to rethink a purely technological understanding of innovation. Building on over thirty interviews we have proposed a typology of the depth of design integration in engineering and product development, and we have distinguished three major types of design integration: shallow design as the nice jacket to the product, aesthetic design as design-driven process, and pervasive design as a deep recombination of technology and design in developing new products. Empirically, most firms used only shallow design integration to market their products but failed to reap additional value from more pervasive form of design in the innovation process.

Moreover, we identified two cognitive lock-ins preventing deeper forms of design integration into engineering and technical innovation. First, we observed partial incommensurability between the diverse meanings of design in the two thought collectives of engineers and industrial designers. This became evident in reciprocal misunderstanding and unsatisfied mutual expectations between engineers and designers. Rather than being a nice toolbox to make things look pretty, industrial design is essentially about driving technical innovation from a market and customer oriented perspective. Second, we identified governance restrictions and resource conflicts between various departments within the SMEs which reinforced the asymmetry between engineering and design and thus blocked off either the use or the progressive integration of design in the development process.

These lock-ins are both constituted in distinct thought styles (Fleck 1979) or mental models shared within the epistemic community (profession) or the organization (firm routines). Moreover, these cognitive lock-ins are reinforced by and embedded in a regionally encrusted development path. The regional context, e.g. the specialized labor market, socio-economic factors, and the lack of a critical mass, sustains and reinforces an established thought solidarity (Fleck 1979) and thus legitimate ways of thinking and dominant mental models at the individual and organizational levels. Yet learning across domains and recombining knowledge from diverse domains are important elements of innovativeness in the long run. As several studies have shown (Narver et al. 1998; Hargadon and Douglas 2001; Wolf 2009) innovation always includes a market-oriented component to meet consumer needs. Industrial design is crucially valuable to increase customer sensitivity in research and development of new technologies and products.

As a consequence, it may not be sufficient to overcome cognitive lock-ins at just one level. Until now, Heilbronn-Franconia has performed very well. However, there is a threat of losing ground in innovation on the long run if the region misses to broaden its understanding of the innovation process. Further research in the geography of innovation should not limit its scope of innovation to technical features only. Instead, our analysis demonstrates that other knowledge domains such as design offer rich potential for even more successful innovation processes. To unlock such an encrusted trajectory will be necessary to unleash further innovation and economic opportunity especially for SMEs and regional economies.

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