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Abstract

India's automotive sector has grown tremendously in the post-liberalization period. The growing domestic market, increased export opportunities and greater emphasis of vehicle manufacturers on high-quality, innovative solutions have created a context for component suppliers to ramp up their innovation capabilities as well. For about past 20 years the auto component industry has consistently acted as a key enabler of various frugal vehicles launched in India. Our multi-level and multi-approach study, making use of firm and sector-level data while combining case studies with expert interviews, seeks to investigate the prevalent innovation pathways and trajectories in India's Auto Component Industry. The results indicate that firms often engage in designing and developing components making use of modern, digital technologies, and manage to reach very high levels of process and resource efficiency. The huge domestic market, and the rising global demand, for affordable, high quality products provide good incentives for investments and openness for external knowledge. Cooperation between Indian and global companies as well as mergers and acquisitions have accelerated the development of innovation capabilities in India. The focused approach on developing concrete applications within requisite parameters gives rise to "appropriate solutions" that balance economic, ecological and technological performance. The study discovered a remarkable set of innovation pathways that makes use of collaborative development, avoids over-engineering and is often driven by economies of scale. All this is also stimulated by the state that developed into a key promoter of innovations.

Keywords

Innovation Pathways; Innovation Trajectories; Automotive; Auto-Components, India



1. Introduction

“The real message of the new concepts in science [is] that change and disequilibria are probably more ‘natural’ than equilibrium and stasis. Those who can adapt and learn will survive. And this will depend on their ‘creativity’. [...] In other words, technical change and economic evolution are related to factors such as originality, risk-taking and creativity in a population.” (Allen, 1988: 117)

The quote above can be applied, probably very befittingly, to the automotive component industry in India, which in its relatively young history has managed to thrive and gain global competitiveness in the face of several strong and even existential challenges. Its resource-constrained settings have inspired it to achieve high levels of operational efficiencies; the generic lack of cutting-edge technological capabilities in many firms has motivated quite a few firms to engage in open innovation to overcome the innovation deficit; and the after-shocks of economic liberalization have induced firms on a path to achieve global standards and even expand abroad to become active and dynamic global players. The entrepreneurial spirit shown by firms, including domestic affiliates of foreign-owned enterprises,¹ has been instrumental in creation of several frugal innovations at components level that in turn have enabled vehicle manufacturers in India to come up with various highly successful frugal vehicles, as is exemplarily documented in Table 1-1.

The auto components industry in its present form in India emerged only in the 1960s when the government as a part of its industrial policy decided to limit the number of auto components that vehicle manufacturers were allowed to manufacture in-house. A “reserved list” of around 80 auto parts was created that could only be sourced from small scale companies (Tiwari et al., 2011). As a result original equipment manufacturers (OEMs) were induced in investing “greater resources in searching for and developing new suppliers, particularly in the small-scale sector” and they were made to bear current costs “in return for the longer term benefits of cheaper supplies” (Lall, 1980: 213). The core idea behind this industrial policy, thus, was to reduce “inefficiencies in production” as well as to “reduce costs and improve quality” by sprucing up domestic competition (Tiwari et al., 2011: 31).

Despite these best intentions the desired efficiency and quality effects took some time to materialize. When the very first batch of cars came out of the factory of the Indo-Japanese joint

¹ For the purpose of this study we define the Auto Component industry in India as consisting of all auto component supplier firm having business operations in the country, irrespective of whether the firm is owned domestically or its (majority) stakeholders are based abroad.

venture Maruti in December 1983, they “were almost entirely Japanese cars, with only the tyres and batteries being Indian” due to unavailability of auto parts with satisfactory quality and the indigenization languished at less than 2.8% (Bhargava & Seetha, 2010: 191). Growing market size, improved quality consciousness and policy-induced encouragement for technical collaborations with foreign entities, however, soon led to fast upgradation of manufacturing and technological capabilities (Tiwari et al., 2011). Merely 10 years later when India decided to open its automobile industry to global carmakers, the strengths of the component industry reportedly acted as a key incentive for inbound investments by vehicle manufacturers and India moved on to get “recognized as an automobile component manufacturing hub” (Bhargava & Seetha, 2010: 241).

Market conditions in India have traditionally favoured vehicles that befit frugality (Tiwari, 2017; Tiwari & Herstatt, 2014). Concerted efforts, including on the policy front, have been made to ensure high affordability of vehicles with “good enough” quality for general public demand. Economies of scale as well as high levels of efficiency have been used as key instruments for achieving that goal (Tiwari et al., 2011). Long before the term “frugal innovation” came into existence, Bhargava (1991: 29) noted that India’s “car industry has not only made available comfortable, spacious and efficient cars to a large desirous population within the country but has also attracted a sizeable number of buyers outside the country”. He cited the examples of countries in Africa, West Asia and South East Asia which were the largest importers of India-made cars (Bhargava, 1991), providing an early indicator for India’s lead market potential for frugal vehicles, especially small cars (cf. Tiwari & Herstatt, 2014).

Innovation capabilities of auto component suppliers in India have grown successively marking a slow yet steady change in innovation pathways of the local automotive industry and have started to act as a catalyst in the successful creation of frugal vehicles. For example, no significant contribution on part of the component suppliers has been mentioned in the development story of the Tata 406, the first successful, indigenously-designed commercial vehicle by an Indian OEM in the 1980s (cf. Maira, 2015). On the other hand, some of the more recent successful innovations in both passenger and commercial vehicle segments point towards a well-documented and even critical role of the component suppliers in enabling these vehicles’ core value proposition, i.e. affordable mobility solutions fulfilling all prevalent safety norms while catering to aspiration of the targeted customer groups and providing specific functionalities for the local market conditions, such as ruggedness (see Table 1-1).

The role of component suppliers in developing the Tata Nano, the world's most affordable car which is often cited as a prime example of frugal innovations, is well documented.² According to Chacko et al (2010: 62), "Suppliers were, from the start of the Nano project, factored in as critical to its success", since around 80% of its roughly 2,000 components were sourced from suppliers to reduce development and manufacturing costs. Cost-reduction ideas were generated by Tata Motors through an "early and intense engagement with vendors" (Chacko et al., 2010: 68). In case of the Indica, too, the Tatas reportedly "gave the component makers a target cost for each items and asked them to amortise tooling costs [...] over the first 100,000 sets" (Sen, 2015: 134). This "success sharing" formula was used to turn component suppliers into stakeholders of the project.

Vehicle model	Year of launch	Examples of role of India-based component suppliers	Source
Tata Indica	1998	Development of several indigenously designed parts using target costing and "success sharing"	(Sen, 2015)
Mahindra Scorpio	2002	All major systems designed directly by suppliers based on performance specifications and cost limits set by Mahindra	(Khanna et al., 2005; Wielgat, 2002)
Tata Ace	2005	Suppliers' significant contribution in reducing costs by ~20% and creating solutions that allowed the vehicle to meet emission standards while reducing maintenance complexity	(Palepu & Srinivasan, 2008)
Maruti A Star	2008	Weight reduction in the air intake filter system with resultant cost cutting	(Kulkarni, 2009)
Tata Nano	2009	Suppliers contributed with "breakthrough prices" and "the lowest possible development costs on components"	(Chacko et al., 2010: 63)
Renault Kwid	2015	Design-to-cost approach implemented for collaborative development with suppliers	(Midler et al., 2017)

Table 1-1: Selected examples for contribution of frugal solutions by India-based component suppliers

The present study seeks to identify innovation pathways that are typical for auto component suppliers operating in India and which enable them to create frugal solutions that in turn help vehicle manufacturers to create frugal cars and commercial vehicles. The objective of the study is to identify if certain elements of innovation pathways are particularly useful while developing frugal innovations. For the purpose of this study we work with the following definition of frugal innovations proposed by Tiwari, Fischer and Kalogerakis (2017b: 24):

² The commercial failure of the Nano is a different matter and has been attributed primarily to non-technical factors such as market positioning, see, e.g. Chakravarti and Thomas (2015).

“Frugal innovations seek to create attractive value propositions for their targeted customer groups by focusing on core functionalities and thus minimizing the use of material and financial resources in the complete value chain. They substantially reduce the cost of usage and/or ownership while fulfilling or even exceeding prescribed quality standards.”

The study has been conducted in a three-stage process based on a mix of quantitative and qualitative methods. In a first step, we have made use of publically available, quantifiable data to gain an understanding of trends and developments in the auto component industry, e.g. by analysing annual reports of publically listed companies. As a second step, case studies have been conducted on select firms to enable in-depth understanding of typical innovation pathways. Finally, insights generated in these two steps have been validated and complemented with expert interviews in India.

The study is structured in 7 sections. After this introduction in section 1, the concept of innovation pathways is explained in section 2. Section 3 familiarizes the reader with the auto component industry in India and includes information on its historical developments and the status of innovation activities. Section 5 provides two detailed case studies to illustrate typical innovation pathways. Results of the expert survey are presented in section 5, while section 6 contains a detailed discussion of results. The study concludes with section 7.

It may be also noted that all values available only in Indian rupees (INR) have been converted to international currencies such as euros (€) or dollars (\$) using the official average annual exchange rates for a given fiscal year as published by India's central bank, the Reserve Bank of India (RBI). All dollar values in this report, unless specified otherwise, refer to United States dollars (USD).

2. Innovation Pathways

Innovation pathways characterize factors that influence innovation activities and in a way determine the outcome of the innovation process. They can be analysed from a company's internal perspective as well as from the perspective of an entire industry or country (external perspective). They are constituted by path dependency which can be explained on a technological level, on an organizational level, but also on a cognitive level (cf. Dosi, 1982; Thrane et al., 2010).

Organizational path dependence is an organizational process approach explaining the emergence of organizational persistence (Schreyögg & Sydow, 2011). Path dependency is an increasingly popular concept applied in social sciences as well as in economics “to show how ‘history matters’ in producing persistent institutional, regional, technological, or organizational

patterns” (Dobusch & Schüßler, 2013: 618). Self-reinforcing mechanisms leading to lock-in situations can be disadvantageous for companies, because they are at risk of becoming dysfunctional and inflexible. If they lose their “capability to adapt to new circumstances or to better alternatives” they will be “confined to the existing path that replicates inefficient solutions” (Schreyögg & Sydow, 2011: 325).

Thrane et al. (2010) empirically show that innovative path dependence can be distinguished from technological path dependence. They stress the cognitive basis of path dependency influencing innovative as well as technological pathways as innovation approaches that result of decisions with, for example, respect to chosen problems or selected principles. In addition to internal factors such as strategies, business models, prior knowledge and competencies (Thrane et al., 2010), companies’ innovation pathways are also influenced by external factors.

Development of Innovation Pathways	
Internal Factors	External Factors
Business model and strategies	Established standards and conventions
Organizational structure	Cultural concepts and norms
Corporate culture	Economic developments
Established innovation processes	Regulatory requirements
Prior knowledge and competencies	Political context
Applied technologies	General technology development

Table 2-1: Influencing factors of innovation pathways

Mitra et al. (2015: 181) define product development pathways “as the full range of activities required to bring a product from conception to end use, including design, production, marketing, distribution and support to the final consumer”. Furthermore, they emphasize that these internal factors “are embedded within an innovation ecosystem that includes the economic, regulatory, societal and political contexts that are beyond the control of the innovator, with either positive or negative impacts on the product business plan” (Mitra et al., 2015: 181). Based on these lines of thought, we also consider diverse internal as well as external factors when analysing innovation pathways of companies (see Table 2-1).

Taking the example of the Tata Nano, the most-radically cost-effective car in the world, Chacko et al (2010: 5) stress that in implementing such an innovation project “some automobile engineering orthodoxies would have to be overcome, doubters within the organization would need to be convinced, and a new kind of thinking would have to take root”. Hence, analysing path dependency in innovation processes can deliver valuable insights when comparing the new emerging concept of frugal innovation with traditional innovation practices in the automotive component industry.

3. Auto Components Industry in India

3.1. General Profile

The auto components industry can be seen as an ancillary industry to the automobile industry and developments in the automobile industry have a direct bearing on its growth prospects.³ It would be, therefore, useful to take a brief look at the key indicators of the overall developments in the automobile industry comprising of OEMs.

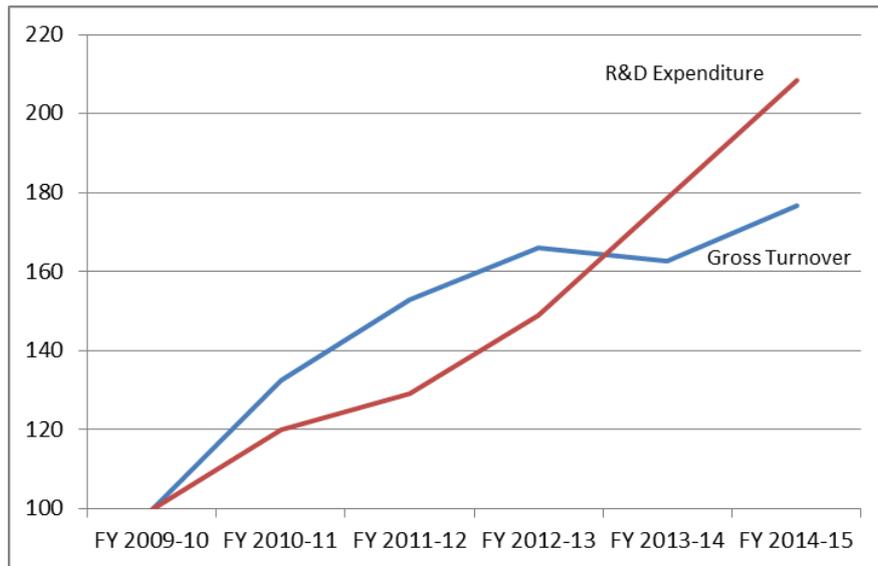


Figure 3-1: Normalized growth patterns in India's automobile industry (base FY 2009-10 = 100)⁴

A longitudinal analysis of SIAM (2012a; 2014; 2016a) data reveals that in the six years between FY 2009-10 and 2014-15, the gross turnover of the automobile industry grew by 77% in rupees terms, while the R&D expenditure increased by 108% and lately R&D expenditures have grown on a faster pace than gross turnover (see Figure 3-1). In FY 2014-15 OEMs spent close to INR 62 billion on R&D, which amounts to a little over \$1 billion in the average exchange rates of that fiscal year.

In recent past, India's automotive industry has gone through a period of impressive growth and expansion (see, e.g., Figure 3-2). In 2016, with a combined production of about 4.5 million passenger and commercial vehicles, India was worldwide the fifth largest producer of four-wheelers behind China, USA, Japan and Germany (OICA, 2017). This is a remarkable development, as at the turn of the millennium India was only 15th placed with a combined four-

³ We use the term automotive industry as encompassing both the automobile industry (i.e. vehicle manufacturers or OEMs) as well as the auto-component industry (Tiwari & Herstatt, 2014: 105). Firms in the auto components industry are often also referred to as "vendors" in India.

⁴ Source: Authors' illustration based on an analysis of SIAM (2012a; 2014; SIAM, 2016a) data

wheeler production of 0.8 million units in 2001 (OICA, 2002). India is also the second-largest producer of motorized two-wheelers, such as scooters and motor cycles, and the largest producer of three-wheeled vehicles (SIAM, 2012b). Four-wheeled vehicles constitute less than 18% of the Indian motor vehicle market, while close to 80% of the produced vehicles are two-wheelers (SIAM, 2017a).

The automotive industry plays an important economic role in India's economy accounting for about 7% of the country's gross domestic product (IBEF, 2017a). Whereas the turnover of vehicle manufacturers stood at \$58.9 billion in fiscal year (FY) 2014-15 (SIAM, 2016a); the auto-component suppliers, excluding tyre manufacturers, contributed \$38.5 billion (SIAM, 2016b).⁵ About 40 firms engaged in manufacturing tyres, accounted for another estimated \$8.5 billion (ATMA, 2016).⁶

Table 3-1 depicts the total turnover as well as exports and imports of the Indian auto-component industry (excluding tyre manufacturers) for FY 2006-07 to 2015-16. As is evident, in the 10 years between FY 2006-07 and FY 2015-16 the total turnover, exports and imports have all increased significantly. The involvement in the global auto-component industry has also grown rapidly in this period. Import intensity increased from 21% to 35%, while export intensity grew from 16% to 29%. Aftermarket business contributed \$6.5 billion in FY 2014-15 to the total turnover (SIAM, 2016b).

⁵ Fiscal years in India run from April of a given calendar year to March of the following year. FY 2015-16, as an example, refers to the period from April 2015 to March 2016.

⁶ These firms are organized under the umbrella of Automotive Tyre Manufacturers' Association (ATMA) and their data is generally not included in the ACMA data on the status of the auto-component industry in India.

Fiscal Year	Total Turnover	Exports	Imports
FY 2006-07	23.0	3.6	4.8
FY 2007-08	27.2	4.5	7.1
FY 2008-09	24.1	5.1	8.2
FY 2009-10	30.8	4.2	8.0
FY 2010-11	41.3	6.7	10.9
FY 2011-12	42.2	8.8	13.8
FY 2012-13	39.7	9.7	13.7
FY 2013-14	35.1	10.2	12.8
FY 2014-15	38.5	11.2	13.6
FY 2015-16	39.0	10.8	13.8

Table 3-1: Growth of the Indian auto-component industry (numbers in billion \$)⁷

Comparing these figures, however, to the global auto component market which is estimated at \$1.75 trillion (ET Auto, 2016), the Indian contribution with its \$39 billion turnover, so far, represents only about 2.2% of total market volume. Nevertheless, high growth expectations are stated in the Automotive Mission Plan 2026, which sets the goal to expand market size and exports by five times within the next 10 years.

3.2. Historical Development

In the first three to four decades after Independence, India's industry was governed in a very restrictive and protectionist fashion. Substantial parts of the Indian economy were reserved for state-owned enterprises (Kumaraswamy et al., 2012). Especially in the pre-1980s period a domestic market for automobiles was deliberately nurtured, but remained relatively small. A complex policy of industrial licences and permits was set in place that reduced competition, put barriers on demand and effectively created quasi-monopolies, resulting in relatively high prices and low-quality of products. Innovation was not high on firms' agenda, and in words of Kumar and Puranam (2012: xi):

“[...] innovation in India [...] contorted itself mainly into an ingenuity to overcome import, licensing, and other bureaucratic controls. The most popular concepts in industrial innovation were the CKD (completely knocked down) units that were imported and subsequently assembled in India using ‘screwdriver technology’ and ‘reverse engineering’.”

In order to provide supporting structure to the automotive industry, the Automotive Components Manufacturers Association (ACMA) was established in 1959 and the Society of Indian Automobile Manufacturers (SIAM) in 1960 (Kumaraswamy et al., 2012). Then in the

⁷ Data source: FY 2006-07 to FY 2014-15: SIAM (2016b: 268); FY 2015-16: ACMA (2016)

early 1980s, India's government started a modernization program with relaxations concerning the automotive industry. Furthermore, the government of India and Suzuki Motor Corporation of Japan formed a joint venture by establishing Maruti Udyog Limited (MUL) in 1984 which also initiated diverse changes to the industry. MUL introduced some Japanese standards and technologies to the Indian automotive industry and thereby incentivized domestic auto component suppliers to improve their competences (Bhargava & Seetha, 2010; Diebolt et al., 2016). Besides, the passenger car segment was expanded as it was "identified as a core industry of national importance" (Tiwari & Herstatt, 2014: 109). However, indigenization of the automotive industry continued during this phase as all joint ventures with foreign companies had to "achieve 95% indigenization within 5 years of start of production" (Tiwari & Herstatt, 2014: 109).

After a severe economic crisis in 1990-1991, a new phase of industry liberalization was initiated by then Prime Minister P.V. Narasimha Rao (cf. Ahluwalia, 2002).⁸ Since then, the Indian automotive industry has been developing dynamically. In a phased process by 2002 import restrictions were removed and customs duties were cut (Diebolt et al., 2016). However, some minor exceptions still exist to protect the domestic industry. For example, as of 2017 a high import duty of 125% was still due for importing used cars (SIAM, 2017b). In 1993, the passenger car industry of India was delicensed and foreign automotive companies were allowed to set up manufacturing facilities in India if they established a joint venture with Indian companies.⁹ Consequently, overseas OEMs entered the passenger car and utility vehicles market in India mostly focusing on the mid or premium car segments. At that time, Premier Automobiles Limited and MUL were OEMs manufacturing small cars in India (Diebolt et al., 2016: 107).¹⁰

New car manufacturers such as Hyundai entered the Indian passenger car market in the year 2000 resulting in a huge growth of 59.7% (Diebolt et al., 2016: 107). In 2002, the Indian government "announced a new auto policy to make India a major source of small cars for the global market and also an Asian hub for auto components." (Kumaraswamy et al. 2012, p. 374) A further liberalization of the auto and auto components market followed and foreign direct

⁸ For some recent and in-depth accounts of the political and ideological resistance to the process of economic liberalization see Ramesh (2015) and Baru (2016).

⁹ "The overseas entities were permitted to own up to 51% of the equity of such joint ventures until 1995 and more than 51% after 1995." (Diebolt et al. 2016, p. 107)

¹⁰ For detailed accounts of the historical development of the automotive industry in India, see, for example, Kathuria (1987), Narayana (1989), D'Costa (1995), Narayanan (1998), Tiwari, Herstatt and Ranawat (2011), and Sen (2015).

investments were fostered, as now 100% foreign ownership was permitted with only a minimum of investment requirements (Kumaraswamy et al., 2012). These policy changes as well as a raising middle class in India caused a rapid growth of the small car segment in India. India's passenger car segment is dominated by compact hatchbacks. The small car segment, consisting of micro, mini and compact cars, accounted for 83.6% of all passenger cars and 62.8 % of all passenger vehicles sold in India in FY 2014-15 as an analysis of SIAM (2016b) data shows. Such a strong demand for small cars in the domestic market and the subsequent success of such cars in the overseas markets has led India to emerge as a lead market for small cars (Tiwari & Herstatt, 2014). Figure 3-2 shows how the penetration of different vehicle types has changed enormously between 1951 and 2015. The number of all registered motor vehicles grew from less than half a million (306,000) to over 182 million in this period. Two-wheelers are the largest constituent of this pool, accounting for over 76% of all motor vehicles, while passenger vehicles account for another 14%.

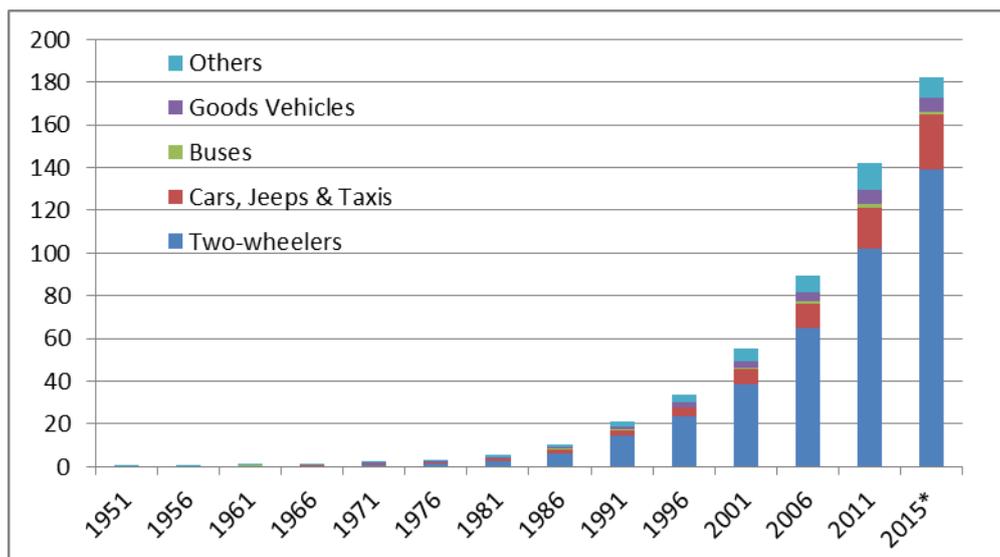


Figure 3-2: Registered motor vehicles in India (million units)¹¹

Altogether, the liberalisation process of the Indian automotive industry constitutes a positive example of globalization and its potential for unleashing economic growth. Apart from market forces it has been the state with its activist intervention that has clearly shaped the automobile industry in India (D'Costa, 1995; Tiwari & Herstatt, 2014). Furthermore, some domestic Indian suppliers have engaged in outward FDI activities and acquired companies in industrialised nations to secure growth opportunities, gain access to advanced technologies and to improve

¹¹ Authors' illustration based on SIAM (2012b; 2016b) data. * Data for 2015 is based on SIAM estimates.

their position in global competition (Kumaraswamy et al., 2012; Tiwari & Herstatt, 2010).

3.3. Industry Structure

The automotive component industry in India can be divided into an organized and an unorganized sector. 758 companies were registered with ACMA at the end of FY 2015-16.¹² These companies represent around 85% of the industry turnover in India. The rest turnover is generated by about 10,000 more small companies active as tier-3 or tier-4 auto component suppliers, many of them in the so-called unorganized sector, which “caters mostly to the aftermarket category” (IBEF, 2017a). Automotive clusters exist in India in four geographical regions. The largest cluster is in the northern India (Delhi/Gurgaon) which is the base for 348 registered auto component suppliers. The second largest cluster is in the western India (Pune/Aurangabad) with 222 registered auto component suppliers, followed by the south (Chennai; 154 companies) and the east (34 companies). Within these clusters, the auto component suppliers are distributed around the principal automotive manufacturers. Despite the regional nature of the industry, Diebolt et al. (2016) showed via a network analysis that the buyer-supplier network in the automotive industry spans across all regional clusters in India. Most of the auto component suppliers are involved in the production of engine parts (31%). The distribution of the companies concerning their manufacturing focus is given Figure 3-3.

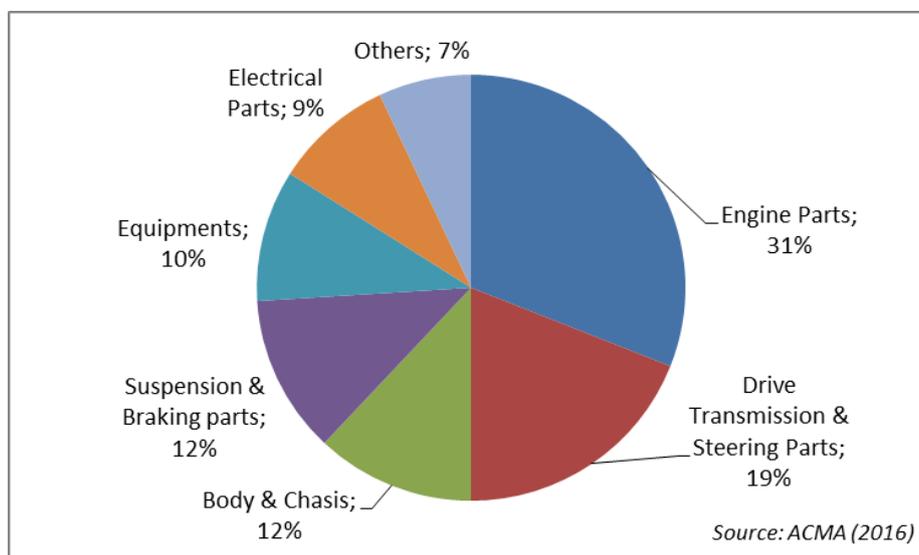


Figure 3-3: Auto component suppliers' production focus

In April/May 2016 we created a database that contained basic profiles of all member companies and institutions registered with ACMA. Data was available in public domain for 733 members

¹² Source: ACMA, March 2016

of ACMA, 9 of which represented institutional bodies such as the Automotive Research Association of India (ARAI) and the Mahratta Chamber of Commerce, Industries & Agriculture (MCCIA). The rest 724 were for-profit companies active in different segments of the auto components industry. An overwhelming majority (77%) were wholly-owned domestic firms, whereas 15% were wholly-owned affiliates of foreign-based firms. About 8% had a varying degree of foreign ownership, but the ownership structure (majority / parity / minority stakes) for around half of them could not be ascertained (see Table 3-2). About one-third (249) of the 724 companies were public limited companies, even though only 94 of them were actually traded at the stock market.

Category (as per ownership structure)	No. of companies	R&D activities as per firm's own representation	DST-recognized R&D activities
Wholly-owned domestic firms	557	39.7%	21.0%
Majority-owned domestic firms	14	78.6%	50.0%
50:50 Joint Ventures	5	60.0%	60.0%
Majority-owned foreign subsidiaries	8	75.0%	37.5%
Wholly-owned affiliates of foreign firms	105	39.0%	13.3%
Joint Ventures with unclear ownership structure	35	57.1%	42.9%
All companies	724	41.7%	22.0%

Table 3-2: No. of auto component sector firms in India's organized sector¹³

Altogether 302 firms (41.7%) reported some form of formal R&D activities in their annual reports and/or on their Internet pages. While in 1991 only two auto-component sector companies out of 99 in the Prowess Database of Centre for Monitoring Indian Economy (CMIE) were reported to have had a formal R&D budget (Nath et al., 2006), a study by Ramamoorthy and Tiwari (2009) found that 174 out of 425 member companies of ACMA (41%), whose R&D activities could be assessed, had established formal, in-house R&D activities (cf. Tiwari & Herstatt, 2014).¹⁴ It thus shows that more companies in a growing set of players are engaging in formal R&D activities. Generally speaking, the propensity to engage in R&D was significantly higher when domestic and foreign firms held a joint stake in the firm (shared ownership) than when they were wholly-owned domestically or otherwise. A probable reason could be that R&D related activities are a key reason for such joint investments that seek to

¹³ For member companies of ACMA; based on own research.

¹⁴ Also see Pradhan and Singh (2008) for an in-depth analysis of R&D activities between 1991-2007 based on the Prowess database. The study, however, is based on a varying sample size limiting its generalizability.

benefit from each other's strengths.

The results were also matched against entries in a directory of officially recognized R&D-performing organizations published by the Department of Scientific and Technology (cf. GOI, 2015). In 160 of 303 cases R&D activities were officially recognized. Absence of an entry in this directory, however, may not be construed as absence of formal R&D in a firm. It just means that the firm does not seek to benefit from government incentives (e.g. tax exemptions) for R&D. Some small firms with non-substantial R&D expenditure may perceive the potential benefit to be too small to go through the official recognition process. The directory is, therefore, at best non-exhaustive. It is, however, interesting to note that foreign-owned firms are less likely to take efforts to get their R&D activities recognized by DST, which would actually enable them certain tax benefits. With increasing stake of FDI firms apparently tend to forego the benefits of an official recognition by DST.

In the next section, we describe in detail the innovation activities which we could observe in the auto component sector in India.

3.4. Innovation Activities

In the early protectionist phases, innovation activities were not stimulated. The most important determinant of firm performance was rather a positive relationship management with government actors (Kumaraswamy et al., 2012). In the absence of competitive pressures, "domestic auto manufacturers had little incentive to perform consequential research, product development or quality improvement" (Kumaraswamy et al., 2012: 372). This trend also suppressed innovation activities at auto component suppliers, because OEMs mostly based their purchasing decisions on price and did not ask for innovation or did not provide assistance in this regard. Furthermore, suppliers were rather small companies that often could not afford employing a highly-skilled workforce. Kumar and Puranam (2012: 73) state:

"Historically, the combination of available cheap manual labour and high capital costs led Indian companies to make an archaic trade-off: instead of investing in technologically sophisticated production equipment, they employed a massive blue-collar workforce in labour-intensive manual production processes."

However, when in the aftermath of liberalisation global assemblers and large component suppliers entered the Indian market, dynamics of the industry changed. New "stringent operational requirements in terms of cost, quality, delivery and flexibility" were set for the auto component suppliers and new technologies were introduced, e.g. processing of composite parts (Diebolt et al., 2016: 78). It was in this context that "[s]ome Indian auto parts companies

embarked on drives to improve their manufacturing quality and productivity. Over the next fifteen years, the largest numbers of winners outside Japan, of the Deming Quality Medal,¹⁵ the highest prize for quality in the world perhaps, were India auto parts producers! Not only did they win prizes, they successfully won orders in the US, Europe, and even Japan, and made large profits in the process too” (Maira, 2015: 192). In the meantime, the Indian “auto component industry has transformed itself from a traditional job fulfiller role to an integrated organization role” (Sahoo et al., 2011: 10).

3.4.1. Study of Annual Reports of Publically-listed Companies

In order to gain deeper insights into innovation activities of auto component suppliers in India, we conducted an analysis of annual reports of 123 publically-listed companies in this sector for FY 2009-10 to FY 2014-15. The idea was to conduct a study of firms whose official data was available in public domain for a consistent period of 6 fiscal years.

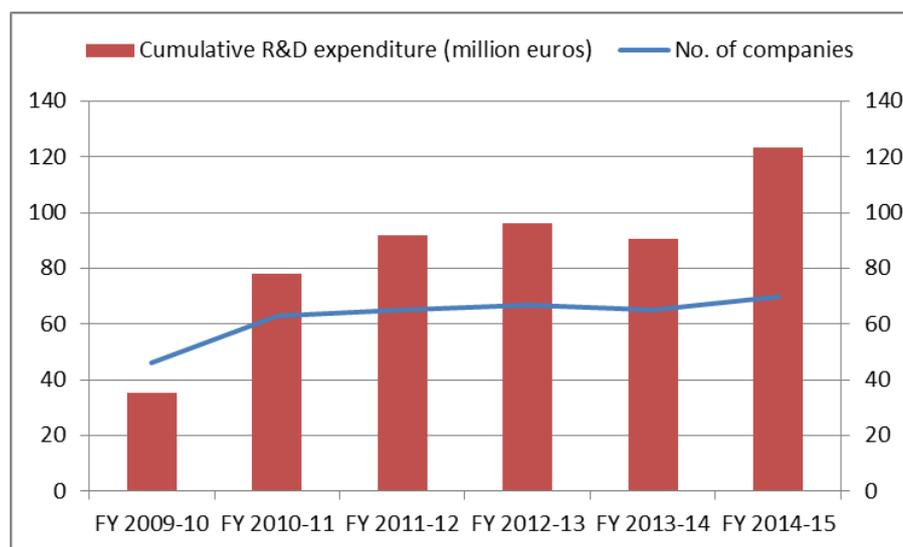


Figure 3-4: Cumulative R&D expenditure by publically-listed component suppliers

We discovered that a total of 70 firms reported a cumulative R&D expenditure worth €123.5 million in FY 2014-15, while just 6 years back only 46 firms had formally reported R&D expenditure to the tune of €35.5 million (see Figure 3-4). Average annual expenditure per firm has also continuously increased in this period from €0.77 million to €1.76 million signifying increasing R&D engagement of certain firms.

Top domestic players regarding R&D expenditure in FY 2014-15 were Apollo Tyres (€11

¹⁵ The Deming prize is awarded in “recognition of a firm’s efforts in improvements in products/processes, minimization of costs, improve quality and productivity, involving every person in the firm from research, design, sales and production as team, movement toward single supplier etc.” (Nath et al., 2006).

million), Escorts Group (€9.8 million), Kirloskar (€8 million), Minda (€6.1 million), and Bharat Forge (€5.4 million). However, compared to western countries the R&D intensity is still rather low and averaged only 0.52%, while the median value languished at as low as 0.17%. Above average R&D intensity of Indian auto component suppliers can be observed at:

- Kinetic Engineering Limited: 4.36%
- ANG Industries Limited: 3.90%
- Rane (Madras) Limited: 2.96%
- Sundaram Brake Linings Ltd: 2.70%

The Indian affiliate of Germany's Bosch (Bosch India Limited) had the highest R&D spending in the industry (€27 million), but its R&D intensity reached only 1.8%. Another German-origin firm ZF Steering Gear (India) Limited spent €0.48 million reaching an R&D intensity of 1.13% in India.

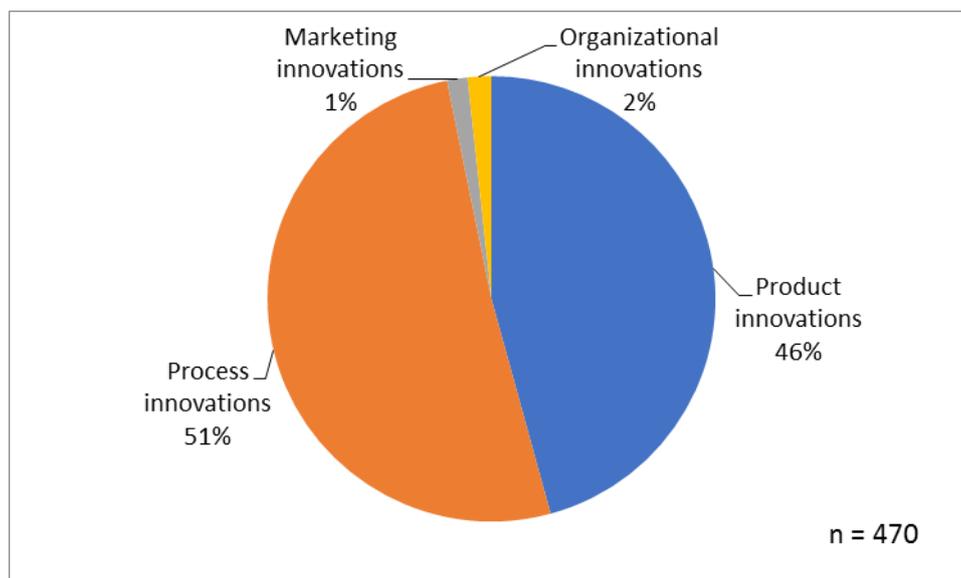


Figure 3-5: Types of innovations observed in India's publically-listed auto component firms

The annual reports were also scanned for all reported instances of innovations. Using methods of content analysis (keyword identification) all reported innovations were first collected and then analysed in order to categorize them into different innovation types and wherever feasible also according to degree of innovations. The number of reported and identified innovations per year showed a relatively stable pattern, ranging between 64 and 87 a year on average adding up to altogether 470 innovations reported by the companies in the period 2010-2015 (see Figure 3-5). An interesting insight was that process innovations were the dominant type of innovations accounting for over half of all observed innovations (51%). A closer observation of the distribution of these two innovation types revealed that process innovations seemed to have

gained increasing importance in India's auto components sector, at least in publically-listed companies. This is an interesting observation as it can be interpreted as an indicator of the great importance attached to resource efficiency by the observed firms.

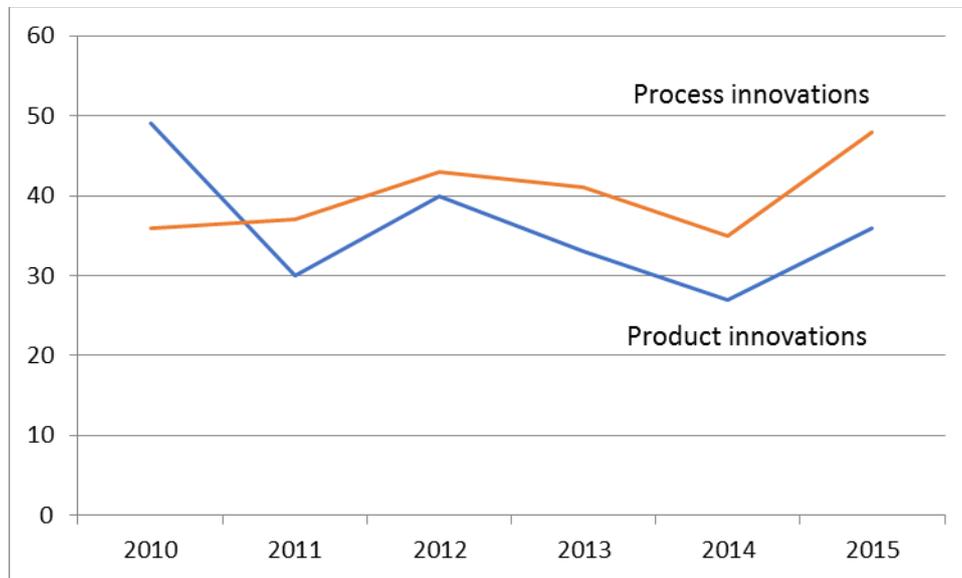


Figure 3-6: Dominance of process innovations in India's auto components industry

The degree of innovativeness could be assessed for 111 reported innovations in the period 2010-2015. An overwhelming majority (86%) could be categorized as “new to firm”, while only 14% were identified as being “new to market”. We did not discover any innovation qualifying as “new to world”. Apart from this, companies reported filing 179 patents and having imported 92 technologies in this period.

3.4.2. Role of Engineering Services Providers

Information technology (IT) industry and digital technologies in general are contributing significantly to product development processes in the automobile industry and engineering, research and development (ER&D) service providers have emerged as disruptive innovators in the traditional automotive value chain. Automotive ER&D is estimated to have constituted about 16% of the \$700 billion global ER&D industry, and the volume grew by \$20 billion between 2009 and 2013 (NASSCOM, 2015). There are more than 1,500 firms in India providing ER&D services to their global customers (NASSCOM, 2017).

Example: HCL Technologies Limited

HCL Technologies is a part of India's HCL Group, which was founded in 1976. In 2016 it continued to grow and generated revenues worth \$6.7 billion, of which \$1.23 billion came from its ER&D business. The company employed over 111,000 persons in 32 countries and had about 500 points of presence in India. Its automotive business centers on Embedded Systems, Driver Information Systems, Powertrains, Engineering Design, and Infotainment. The company states to have over 14 years of experience in the automotive industry and partners with organizations such as Rockwell Automation, SAP, Oracle, Microsoft, Natrip, Oesa and Genivi to deliver industry-specific solutions. Examples of solutions HCL Technologies reports to have developed relate to significant reduction in costs, better performance and next-generation technologies with the means of alternative design, alternative components and alternate sourcing. According to HCL (2017), "Our customers (Tier 1 and Tier 2 automakers, OEMs, and dealers) are achieving collaboration, visibility across their supply chains, and faster time to market through our integrated services and industry technology consulting approach across automotive IT, engineering, electronics and embedded services, and plant automation."

Box 3-1: An example of automotive ER&D: HCL Technologies Limited¹⁶

ER&D companies provide a very valuable support system to automobile manufacturers in India by enabling a speeded-up time-to-market, defect reduction and saving component costs by around 20-25% (NASSCOM, 2015). The key capabilities of the Indian ER&D industry, as per this report, lie in realising cost savings and providing flexible capacities, followed by factors such as localising products to different markets, decreasing time-to-market and helping firms gain access to cost-sensitive emerging markets with differing needs. On the other hand, the report also shows that providing access to completely new technologies is not perceived as a core strength of India's ER&D sector (NASSCOM, 2015).

Automotive ER&D exports from India stood at \$2.5 billion in 2015 having grown 3 times within 5 years and the country's share in the global Automotive ER&D was estimated to have stood at between 35-40% in 2013 (NASSCOM, 2015). Key contribution of automotive ER&D lies in enhancing security, achieving superior performance, ensuring greater reliability and enabling better fuel economy. It is estimated that India's exports of automotive ER&D could grow to as much as \$9 billion by 2020 in the wake of increasing fuel costs, rising emission

¹⁶ Constructed based on (HCL, 2017; HCL, n.d.-a; HCL, n.d.-b)

standards and the push for weight/friction reduction (NASSCOM, 2015).

India has also emerged as a major destination for R&D activities of many MNCs “owing to its large domestic market, huge base of research and talent and significantly lower costs of conducting research” (Tanuku, 2011: 112). There were 62 R&D centres of global MNCs from the automotive sector reportedly operating in India as of 2015 (IBEF, 2017b). According to Mashelkar and Chinchure (2016: 30) there is a perception that R&D partnerships with India can help firms generate “specific mutants of an existing technology or create a new technology that is fully adaptable to the distinctive conditions prevailing in India”.

Overall, it seems that the presence of a very significant and globally active ER&D scene in India is enabling Indian auto components industry to gain access to next generation digital technologies that can act as enablers of frugal (high quality, affordable) solutions.

4. Select Case Studies¹⁷

4.1. Bharat Forge Ltd.¹⁸

4.1.1. General Overview of the company

Bharat Forge Ltd. (BFL) is a leading powertrain and chassis component manufacturer headquartered in Pune, India. It was incorporated in 1961 and is a part of the Kalyani group, which is a conglomerate with a reported annual turnover of \$2.5 billion and having a global workforce of about 10,000 (Kalyani Group, n.d.). The group, as per its own statement, “is a market leader in all its respective business segments” and it is the largest forging company in the world, holds the No. 1 position in Engineering Steel as well as in Axle Aggregates in India, and it is also the largest Indian exporter of wheels (Kalyani Group, n.d.). BFL has successfully established itself as a tier 1 supplier in the global automotive market (Kumaraswamy et al., 2012). It has 10 manufacturing locations spread across India, Germany, France and Sweden and employed 4,766 permanent employees in March 2016.

At the end of FY 2015-16, BFL had 13 wholly-owned overseas subsidiaries, 8 of which are located in Germany; while one subsidiary each exists in France, Sweden, Hong Kong (SAR),

¹⁷ A total of 6 case studies representing various ownership structures and firm size were conducted (see Appendix 1). For reasons of space, we are providing here two most elaborate cases that provide detailed and in-depth insights on innovation pathways in India's auto component industry. One case represents an Indian-owned large firm, while the other one is a global German multinational company (MNC).

¹⁸ This section is based on information of Bharat Forge's website (bharatforge.com) and annual reports published by Bharat Forge unless explicitly stated otherwise.

the United Kingdom, and the United States of America. In addition, it has 9 subsidiaries and associate companies (with varying levels of stakes) in India. In FY 2015-16, 91% of its €596 million revenues as a standalone company were generated in the automotive sector, while exports accounted for 57% of the revenues. With a share of 36% Europe was the most important export region for BFL. For consolidated revenues (including those of the subsidiaries and associate companies) of €1.06 billion, Europe was the single-most important region with a market share of 39%, while the domestic market in India accounted for 36%. Automotive sector generated 84% of the consolidate revenues.¹⁹

Fiscal year	Performance of company				R&D expenditure			
	Total revenues	Export revenue	Profit before tax	Net worth	Capital	Re-curring	Total	Intensity
2001-02	112	26	8	24	-	-	-	-
2002-03	134	57	24	36	-	-	-	-
2003-04	158	62	48	47	-	-	-	-
2004-05	217	90	59	78	-	-	-	-
2005-06	303	122	58	216	0.88	0.64	1.52	0.50%
2006-07	335	129	62	229	0.02	0.80	0.82	0.24%
2007-08	400	168	70	258	0.11	1.10	1.21	0.30%
2008-09	324	154	24	232	0.00	0.56	0.56	0.17%
2009-10	282	105	27	228	0.00	0.43	0.43	0.15%
2010-11	497	202	74	331	0.23	1.02	1.25	0.25%
2011-12	569	263	83	325	0.22	1.13	1.35	0.24%
2012-13	463	226	64	330	0.24	1.86	2.10	0.45%
2013-14	419	228	71	332	0.33	2.83	3.15	0.75%
2014-15	587	351	140	451	1.77	3.66	5.44	0.93%
2015-16	596	340	150	504	0.72	4.95	5.66	0.95%

Table 4-1: Financial performance and R&D expenditure of BFL (monetary values in million euros)²⁰

Overall BFL has grown outstandingly between FY 2001-02 and 2015-16; see Table 4-1. Revenues have increased over four-folds in 15 years, from €112 million to €596 million, not including revenues generated by overseas subsidiaries and other associate firms. Export revenue has grown exponentially from €26 million in FY 2001-02 to €340 million in FY 2015-16, which is around 12 times higher. Exports contribute a significant part of total revenues. Export intensity has risen consistently from 16% in FY 2000-01 to 57% in FY 2015-16. This

¹⁹ Data used in this case study pertain to BFL as a standalone company, unless specified otherwise.

²⁰ Self-calculated & constructed based on data collected from annual reports of BFL. A hyphen (-) indicates non-availability of data.

exemplifies the progress of BFL from a large domestic into a significant global player. Also annual profit before taxes has grown from €8 million in FY 2001-02 to €150 million in FY 2015-16 giving the firm substantial options to enhance its capacities and acquire assets globally. The firm's net worth, defined as the sum of paid up capital and free reserves, has grown from €24 million to €504 million in this period, signifying the immense potential of frugal innovations ("affordable excellence") in the global automotive market.

BFL's core competences in forging and metallurgical knowledge have been complemented by general design and engineering know-how in diverse industry sectors, such as other areas of automotive, power, oil and gas, construction and mining, rail, marine as well as aerospace. After its incorporation in 1961, it took four years to get a government license to actually start business and it was only in 1966 that the first plant could be set up (Ramachandran & Mukherji, 2005). The government license mandated it "to produce engine parts to meet India's domestic automotive production needs" (Kumar et al., 2009: 84 p.). Due to non-availability of technical expertise for setting up a forging plant in India in the 1960s "technology was obtained through a technical collaboration with a Cleveland, US, based company", which deputed 10 engineers to Pune for a period of 5 years (Ramachandran & Mukherji, 2005: 3).

Since then BFL has undergone an impressive cultural change and knowledge transformation. At the beginning, a focus on customer service, quality and innovation was generally lacking, and even difficult to implement, in India as a result of the centrally planned socialist environment. However, due to "a period of growth and consolidation within the Indian forgings industry [...] Bharat Forge emerged as the undisputed leader throughout the 1980s" (Kumar et al., 2009: 85). When the liberalization process of India's industry started, BFL's chairman and managing director Baba Kalyani²¹ developed a new and courageous global strategy for the company and pushed BFL to develop from "an 85 percent blue-collar workforce in 1989 to an 85 percent white-collar workforce in 2000, with more than 700 engineers" (Kumar et al., 2009: 87). He envisioned that his company could only compete in the global automotive market, if its products reached high quality and precision based on sophisticated and advanced machinery instead of until-then-prevalent manual processes with cheap low-skilled workers. In the late 1980s BFL, therefore, went on to acquire "several new, state-of-the-art, fully automated press lines for manufacturing forgings, even though the existing manual workforce in hammer shop did not know how to operate them" (Kumar & Puranam, 2012: 74).

²¹ BFL was set up by Dr. Neelkanth Kalyani, father of Baba Kalyani. The current chairman joined BFL in 1972 after completing a study of engineering from MIT in Boston (Ramachandran & Mukherji, 2005).

Still, it was a long and difficult way to establish confidence in BFL's competences outside India. To achieve this, BFL has over the years acquired various quality certifications, such as ISO 14001, ISO 9001, ISO/TS 16949, and the "EC Certificate of Quality System Approval". In its presently last available annual report (FY 2015-16) Industry 4.0 is taken up as an important topic. It is expected that a change towards Industry 4.0 will "increase manufacturing productivity, improve efficiency, shift economics and foster industrial growth". BFL wants to reap benefits of these advantages and thereby further reduce costs.

"We have started this journey in areas of connected enterprise, big data, mobility, augmented reality (human-machine interface) and additive manufacturing. We aim to apply this initiative across the entire value chain and create a cohesive manufacturing ecosystem."

In the opinion of Baba Kalyani, "Low cost, high technologies, and speed of delivery have all helped us to be accepted in the Western markets" (Kumar et al., 2009: 89). Ramachandran and Mukherjee (2005: 2) cite Kalyani with the following words comparing his company with its competitors in the industrialized nations, "My cost even 25 years ago was lower than theirs, but I was not able to match their quality. Today our manufacturing side is on par with best anywhere in the world and at a cost that is lower by almost 20-25%!" The company has achieved this by following an aggressive global acquisition strategy to ensure inorganic growth in global markets. BFL's "journey towards becoming an international player", as per Annual Report 2003-04, "began in 1997". For this journey the company cited three reasons. Apart from the desire to tap new avenues of growth and reduce over-dependence on the domestic market, the decision was primarily driven by the appreciation of globalisation as an opportunity for "improving quality, delivery, costs, supply chain, R&D, productivity and business processes". In its annual reports, cooperation or acquisition agreements with different companies from India and abroad are well documented. These acquisitions and joint ventures were motivated by the desire to seek advanced technical know-how, to improve the efficiency of manufacturing processes and to establish manufacturing locations close to customers abroad. Here, we cite one prominent example from FY 2003-04:

"We were always clear in our minds that to be an international player, Bharat Forge would have to proactively pursue international acquisition opportunities — and to complement our export thrust with inorganic growth. To this end, in January 2004, your company acquired the assets, intellectual property and the labour force of a reputed German forging company called Carl Dan Peddinghaus GmbH & Co. KG. The new entity — CDP-Bharat Forge — is a 100 per cent subsidiary of your company. With this acquisition, Bharat Forge has become the world's second largest forging conglomerate."

"CDP-BF and Bharat Forge have complementary production capacities and excellent market

synergies. Moreover, CDP is a key supplier to European auto majors such as BMW, Volkswagen, Daimler Chrysler and Audi, which should help your company build further bridge heads in Europe and enter the passenger car business.”

“CDP is the company’s first significant overseas acquisition. As a part of its strategy to increase its global footprint, we are continuously examining other international acquisition opportunities.”

Today, BFL has a strong customer base in India (e.g., Tata Motors, Mahindra, Ashok Leyland), but it also delivers to well-known OEMs from other countries (e.g., Audi, BMW, Toyota, Chrysler, Renault or Volvo).

4.1.2. Innovation Profile

Formal R&D started to gain attention at BFL only after the turn of the millennium in the face of economic liberalization and the resultant competitive pressure, as is evident from a statement in Annual Report 2002-03:

“In the past, we have done some work in the ‘development’ side of R&D. For instance, in 2002-03, we upgraded our computer aided design systems, and actively used a new three-dimensional software for simulating metal flows and validating product designs. Going forward, we are allocating clear-cut budgets to build a much more significant R&D platform for new product development. We see this as a critical tool in maintaining a competitive edge.”

Next year (FY 2003-04) the company followed up with a statement on the *leitmotif* of its R&D mission. The annual report stated that the “R&D efforts are aimed at reducing costs; making improvements in products and processes; developing new product development capabilities; achieving higher value addition; enhancing quality, speed-to-market and safety benchmarks; and scaling higher levels of productivity”. With this mission statement the firm decided to move on a process which would be targeted at ensuring affordable excellence in its innovation activities.

Table 4-1 shows the development of BFL’s R&D expenditure. A positive upward trend can be identified from FY 2009-10 onwards. It seems as if this year is a turning point and increased importance is given to expansion of R&D activities since then. The most striking point in the analysis seems to be the near phenomenal growth (albeit at a low level) in the recurring expenses on R&D (see Figure 4-1).

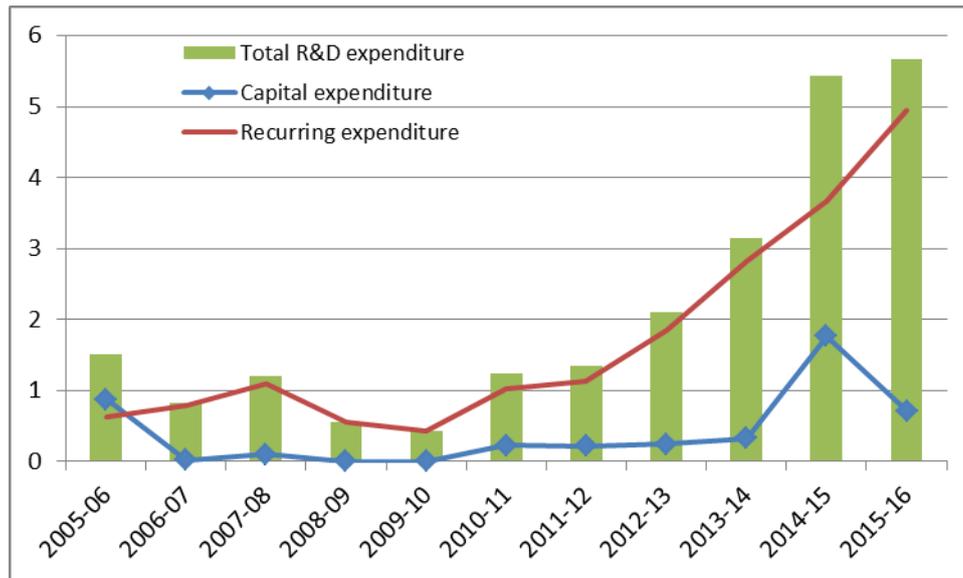


Figure 4-1: Development of R&D expenditure at BFL (million euros)²²

It is apparent that BFL has strongly intensified its R&D activities necessitating the recurring expenses on materials and salaries, whereas considerable capital expenses keep on occurring at specific points in time, when new facilities are created.

Since R&D expenditure alone is not a sufficient indicator of how much efforts a firm is undertaking in securing access to technical know-how and expertise, we analysed the annual reports for any mentioning of payment of royalties and technical service fees. In the period between FY 2004-05 and FY 2009-10, i.e. before significantly ramping up its in-house R&D activities, BFL spent a cumulative amount of €0.7 million on royalties. Between FY 2010-11 and 2013-14, it paid a total amount of €1.14 million for receiving technical services and technology licenses mainly to the Alstom group of companies. In FY 2015-16 the firm again reported royalty payments of about €70,000 to General Electric Technology GmbH.²³ This indicates a need-based approach to acquiring knowledge from external sources.

BFL's efforts for creating intellectual property and innovations within a global value-chain are worth mentioning here. The company's wholly-owned subsidiaries are also engaged in R&D activities. These activities lead to generation of technological know-how especially valuable for global business. For example, CDP Bharat Forge GmbH in Ennepetal (Germany) reported R&D expenditures worth €2.7 million (R&D intensity 1.6%) in its annual report for 2013. The

²² Source: self-construction based on data in BFL's annual reports

²³ Annual reports did not provide any useful information on payments for receiving professional and consultancy services, as that data was reported at an aggregated level including legal services availed overseas. As a result it was not possible to distinguish expenses incurred while securing access to intellectual property (IP).

company stated that its R&D activities mainly focus on implementing customer requirements and specifications in forging products which can be mass-produced in a reliable manner with high quality and cost-effective manner. The report said that the company continuously strives to optimize existing processes, in particular plants and cycle times as well as products, especially with the purpose of reducing weight (CDP-BF, 2014). Another group company in Germany, Bharat Forge Aluminiumtechnik GmbH while not disclosing monetary expenses incurred on R&D activities in 2015, mentions a project for industrialized production of continuous cast material. The new process, as per firm's statement, enables better mechanical properties than conventional castings, fosters circular economy with utilization of forged scrap and reduces dependence on suppliers of primary material. The new process also cuts down the number of requisite production steps leading to reduction in CO₂ emissions. It has opened new business avenues for selling "green technology" to environment-conscious customers (BFAT, 2016). A third German subsidiary, Bharat Forge Daun GmbH, states that it does not carry out its own R&D but collaborates closely with its sister concern CDP Bharat Forge, universities and providers of product development services for process optimization and application of new technologies (BFD, 2016).

On its website BFL presents itself as an innovative company and states: "The company believes that its next round of growth will be propelled by creating opportunities through innovation". Special attention is given to technologies for minimizing carbon footprints and lightweight products which support lower energy consumption. In 2014, the Confederation of Indian Industry (CII) awarded Indian companies concerning their innovative output for the first time. In this context BFL is mentioned as one of the 26 most innovative companies in India.²⁴ In 2010 the Kalyani Group established its new R&D centre – Kalyani Centre for Technology and Innovation, which fosters innovation capabilities at BFL. The centre offers advanced technical training, advanced academic courses and is endowed with advanced R&D capacities. BFL's engineering and design centre uses "State-of-the-art CAD / CAM / CAE infrastructure for 3D modelling, NC tool path generation and FEA analysis to accelerate response time in developing new parts." Furthermore, the company offers value analysis and value engineering (VAVE) based on customer needs. Thereby, "components with higher strength to weight ratio" are developed and tested.

Results of increasing investments in innovation and technical knowledge are also reflected in

²⁴ <http://innovationawards.ciiinnovation.in/>

technical papers published by BFL. Beginning with its annual report 2011-12, BFL reports scientific technical papers in rising numbers that the company presents and publishes. In the report of 2015-16 thirty-one such papers are listed. The company also states explicitly its intention to “create strong in-house innovation capability & IPR repository through R&D” and to use those R&D capabilities “to develop breakthrough processes and solutions”.

Furthermore, BFL has started to focus on patents “as the key driver of IP within the group”. Patent activities are presented in the annual reports starting in FY 2012-13.

Fiscal Year	Statement in the Annual Report
2012-13	“Your Company has filed six Patents during the financial year 2012-13.”
2013-14	“Filing of seven patents is in progress.”
2014-15	“Seven patents applications were filed.”
2015-16	“12 (Twelve) patents filed.”

Table 4-2: Overview of patents filed by BFL since FY 2012-13

Altogether, BFL has filed 48 patents in the past 15 years among which 24 were related to automotive applications. Twenty-one of these 24 automotive-related, patented inventions were developed in cooperation with its overseas subsidiaries and other firms. Almost all patents were developed outside India. Table 4-3 shows three different patents registered by BFL at the European Patent Office (EPO) in fiscal year 2014-15.

Fiscal Year	Title/Description	Purpose	Characteristic advantages
2014-15	An ultra-high strength thermo-mechanically processed steel (WO2016063224 A1)	“To increase mechanical strength, toughness, ductility and reduce weight of components”	Product robustness; Weight reduction
2014-15	A forging process for manufacture of aluminium alloy wheel disc (WO2016027209 A1)	“To produce complex shaped alloy wheels that has superior strength and low wear and tear. It helps to offer high quality products at low cost”	Product robustness; cost reduction
2014-15	A method of forging complex parts from continuous cast billets (WO2016027208 A1)	“This process reduces manufacturing cost and number of defects and increases quality and strength of complex geometry components”	Cost reduction; product robustness

Table 4-3: Patents registered by BFL at European Patent Office (EPO)

Looking at the purpose of the patented innovations, it is striking that they all are targeted at increasing the strength/robustness and thereby the quality of the product. At the same time, an achieved cost reduction is explicitly mentioned twice.

Industry/Academia collaboration: BFL has also developed interesting models of industry/academia collaboration, e.g. creation of a complete study course with the Indian Institute of Technology Bombay (IIT-B) in Mumbai with a direct connect to firm-specific project works. The course is open to all employees. Annual report 2009-10 states:

“During the year, there was shift towards renewed focus on learning and development across the Company. This philosophy has been extended across all management and operational levels. To promote talent management, BFL launched an M.Tech programme for employees in collaboration with IIT Mumbai. This has a strong R&D focus, and is geared to develop the Company's own capabilities. The first batch of 25 students attended the course in FY2010. During the second year of this course, all engineers will have to do their project work at BFL, under the supervision of professors at IIT and senior management of BFL. This is a process where employees are not only developing their skills but also contributing to BFL's operations. This cycle will be repeated to maintain an R&D oriented workforce. The Company is in the process of sponsoring some of the PhD students at IIT Mumbai, subject to their taking up projects related to BFL's business. Other learning initiatives with BITS, Pilani and Warwick University, UK continued during the year.”

4.1.3. Analysis of Innovation Activities

We evaluated the last six annual reports (FY 2010-11 to FY 2015-16) concerning described innovation and R&D activities by analyzing information provided in the recurring section “Technology Absorption” in the respective annual reports.

In the FYs 2010-11 until 2013-14 a rather extensive list of “specific areas in which R&D [is] carried out by the Company” can be found. On average 11.5 areas are mentioned per year. Product as well as process innovations are described. Recurring themes are increase in strength and weight reduction of materials. Benefits derived from these activities are repetitively stated as: “Customers' satisfaction and new business opportunities because of cost, quality and speed.” In addition, in 2012-13 and 2013-14, “IP Generation by way of Patents and Technical papers” is complemented. Furthermore, in all six annual reports “efforts, in brief, made towards technology absorption, adaptation and innovation” as well as benefits derived thereby are listed. Remarkably, in the last three years two points are repeated: “Development of precision forging (Near net shape forging)” and “additive manufacturing for metals”. Connection of these two technological development points with the business and innovation strategies of BFL is characterized in the following

Precision forging (PS) can be characterized as a “forging operation which generates *high quality* parts concerning surface quality and dimensional accuracy. [...] In particular high-duty automotive components offer a wide application field for the PF technology. Advantages like

shortened production cycles which are achieved by eliminating machining operations and the *saving of raw material* contribute to the ongoing *cost-saving* trend in the automobile industry” (Behrens et al., 2007: 139; emphasis added). It shows that advanced technologies can be employed to achieve high precision and efficiency gains leading to “affordable excellence”, a hallmark of frugality. Forging industry has been faced with challenges, such as increased competition, need for technological upgradation and cost pressures necessitating innovative solutions in both process and product design. PF can be employed to achieve “enhanced geometrical and dimensional accuracy [...] in large quantities and with reasonable cost” (Milutinovic et al., 2008: 73). Key success factors for PF applications “are the process design, die design and die manufacturing. [...] Therefore, a new approach in process planning as well as support of computers and engineering design tools are needed” (Milutinovic et al., 2008: 73). About 5 years after discussions of this new forging trend appear in scientific journals, BFL also adapts this process. High quality products with reduced cycle time and costs owing to innovations in processes fit well into its competitive strategy.

Additive Manufacturing (AM) can also be called 3D-printing and has evolved for serial production of metal parts only lately. Layer-by layer building-up of parts has recently turned into a viable option for serial production. Essential engineering materials, such as steel, aluminum and titanium, can be processed today “to full dense parts with outstanding properties” (Herzog et al., 2016: 371). AM shortens lead times and the manufactured parts are reported to be “25% lighter and stronger than the previous conventional design” turning it into “not only a valuable method for rapid prototyping but more and more also for rapid manufacturing” (Herzog et al., 2016: 388). According to Frazier (2014: 1917), “AM has the potential to revolutionize the global parts manufacturing and logistics landscape. It enables distributed manufacturing and the productions of parts-on-demand while offering the potential to reduce cost, energy consumption, and carbon footprint”. Here, it seems as if BFL is following a new trend which has the potential to transform manufacturing and logistic processes radically. It very clearly is following a high-tech strategy to enable frugality in its innovative products, processes and services.

Benefits of technology absorption, adaptation and innovation are reported by BFL in its annual reports. Five statements are repeated throughout 2011-12 until 2015-16:

1. Product improvement by way of light weighting and better fatigue strength
2. New processes developed
3. First time Quality with reduced development cycle time for new part development

4. Improved die life
5. Customer satisfaction and new business opportunities

This shows again that products as well as processes are being improved. The focus on light weighting and strength is also stressed. Interestingly the third point reflects the goal of BFL to compete with reduced development cycle time for development activities of high quality parts.

4.1.4. Case Summary

BFL is an outstanding Indian company that has successfully transformed itself into a global player. BFL has realized that affordable innovations with high quality and speed-to-market are essential to its long-term global success. Its R&D spending is rising constantly, but is still rather low compared with companies from industrialized countries. At any rate, BFL seems to be making very smart use of its limited R&D expenditure to generate high levels of benefit in terms of innovation output. Its innovation activities, that include collaborations with academia and firms at home and abroad, are designed to let it fairly leverage external knowledge and expertise. BFL and its affiliate firms proactively engage in creating solutions that use process optimization and new technologies to create high-quality, environment-friendly and cost-effective solutions. The overall objective seems to be to generate and secure long-term competitive advantage with the means of cost-effective, high-quality products using a high-tech strategy.

Process innovations seem to play an important part for BFL to deliver customer value in global competition. Very interestingly, a key benefit described is “first time quality with reduced development cycle time for new part development”. The analysis points to a frugal strategic approach. The emphasis seems to be on marrying high-tech with affordability in the entire value chain to ensure excellent quality and reduce input costs of all kinds.

4.2. Bosch India Ltd.²⁵

4.2.1. General Overview of the company

Bosch was established as a “Workshop for Precision Mechanics and Electrical Engineering” in Stuttgart, Germany in 1886. Today, the company is present in more than 150 nations. Its business operations in India go back over 95 years, and its first manufacturing unit in India was established in 1953 (Tiwari, 2014b). Robert Bosch GmbH holds 71.18% stake in Bosch India

²⁵ This section is based on information of Bosch India Limited's website (boschindia.com) and annual reports published by the company, unless explicitly stated otherwise.

Limited (BIL). The Bosch Group in India, however, apart from BIL consists of five additional companies, namely Robert Bosch Engineering and Business Solutions Pvt. Ltd., Bosch Rexroth India Ltd., Bosch Chassis Systems India Ltd., Bosch Automotive Electronics India Private Ltd., and Bosch Electrical Drives India Private Ltd. (BIL, 2015a). BIL has also entered joint ventures with other organizations in India. For example, in 2006 it formed a joint venture with Mann and Hummel Filter Pvt. Ltd., a wholly owned subsidiary of MANN+HUMMEL GmbH, Germany. The resulting new manufacturing facility MHB Filter India Pvt. Ltd. is tasked to deliver filters for automotive as well as industrial applications for the Asian market (Mann-Hummel, 2016).

The Bosch Group has grown significantly in India, especially in the post-liberalization phase. As of 2015, the Bosch Group in India employed over 28,500 associates, generating revenues worth €2.53 billion (INR 195.11 billion) in the fifteen months period ending on March 31, 2015.²⁶ It also maintained 11 manufacturing sites and 7 development centres (BIL, 2015a). This is a remarkable development as the number of development centres, apparently, increased from 3 in 2012 to 7 in 2015 and the group-wide headcount in India increased by 6,000 in this period (cf. Tiwari, 2014b). This case study, however, unless specified otherwise, concerns only the flagship company BIL.

BIL is active in various sectors such as mobility solutions, industrial technology, consumer goods, and building and energy technology (BIL, 2015a). It is engaged in manufacturing and trading products “as diverse as diesel and gasoline fuel injection systems, automotive aftermarket products, starter motors and generators, special purpose machines, packaging machines, electric power tools, security systems, and industrial and consumer energy products and solutions” (BIL, 2015a: 7). BIL’s very active engagement in India’s automotive sector may be judged by the following company statement (BIL, 2015a: 7)

“It also has a strong presence in the Indian automotive services sector, with networks spanning across 1,200 towns and cities with around 3,400 service outlets which ensures widespread availability of both products and services. Apart from this, we have a strong automotive training network that spans over 10 cities thereby covering Parts, Bytes, Services and training under one roof.”

Automotive Technology business of BIL is organized in 5 divisions that take care of the following areas: Diesel Systems, Gasoline Systems, Starter Motors and Generators, Car Multimedia, and Automotive Aftermarket. Its customer base includes practically all important domestic and global vehicle manufacturers in India in two-, three- and four-wheeler segments.

²⁶ The revenues of BIL as a standalone company stood at € 1.5 billion (INR 117.4 billion).

Especially the two-wheeler segment with its vast market size and still large growth potential has been getting increasing attention from Bosch in India.

Year	Performance of company				R&D expenditure			
	Net sales	Export revenue	Profit before tax	Net worth	Capital	Re-curring	Total	Intensity
2001	343	46	31	150	-	-	-	-
2002	338	54	44	154	-	-	-	-
2003	360	62	73	174	-	-	-	-
2004	413	71	100	223	-	-	-	-
2005	542	77	96	283	-	-	-	-
2006	665	110	140	359	-	-	-	-
2007	756	119	151	453	-	-	-	-
2008	713	107	134	486	-	-	-	-
2009	705	87	118	502	-	-	-	-
2010	1,093	139	198	675	8	11	19	1.7%
2011	1,222	159	243	729	5	12	18	1.4%
2012	1,226	137	196	812	5	15	20	1.6%
2013	1,093	136	161	808	3	18	21	1.9%
2014-15#	1,447	180	241	905	2	25	27	1.8%
FY 2015-16	1,413	151	257	1,147	2	22	24	1.7%

Table 4-4: Financial performance and R&D expenditure of BIL (monetary values in million euros)²⁷

Since 2001 BIL's sales revenues have impressively grown four-fold, from €323 million to €1.4 billion in FY 2015-16 as shown in Table 4-4. Exports grew in a similar fashion from €46 million in calendar year 2001 to €257 million, accounting for 10.7% of total revenues, in FY 2015-16. Germany, China and Brazil are top export destinations which contribute significantly to export revenue. In terms of profits, its profits before tax increased more than 8 times from €31 million in 2001 to €257 million, signifying a ratio of over 18% to net sales in a cost-sensitive market. BIL's net worth too registered an extraordinary growth in this period, growing almost 8-times, from €150 million to €1.2 billion.

4.2.2. Innovation Profile

Bosch has been a key contributor to several frugal vehicles launched in India. For example,

²⁷ Source: Self construction based on data collected from annual reports of BIL beginning 2010. # Data for 2014-15 concerns the period of 15 months from January 2014 to March 2015. The period from 2001 to 2013 concerns calendar years; currency exchange rates for these years are the average annual exchange rates for the respective calendar year. For 2014-15# and FY 2015-16 average annual exchange rates for FY 2014-15 and FY 2015-16 respectively have been used for calculating the euro values. A hyphen (-) indicates non-availability of data. Figures have been rounded off to their nearest digit.

Tata Motors relied on Bosch to supply the Nano's electronic engine management system and 90% of the development work was performed by Bosch (Chacko et al., 2010). Table 4-4 shows R&D expenditures of BIL as far as they could be retrieved from the annual reports.²⁸ Since 2010, BIL's total expenditure on R&D has shown a modest increase from €18.8 million to €24.2 million, while the R&D intensity (as a percentage of net sales) has remained largely unchanged hovering around 1.7%. Nevertheless, three points are worth closer attention.

Growth in intensity of R&D engagement: While BIL's capital expenditure (e.g. investment in machinery) on R&D has decreased in this period (from €8.1 million to €1.9 million), its recurring expenses (e.g. on salaries of R&D personnel) have more than doubled from €10.6 million to €22.2 million) within six years signifying significantly higher levels of actual R&D work being carried out, see Figure 4-2.



Figure 4-2: Composition of R&D expenditure by Bosch India Limited (million euros)²⁹

High level in national comparison: BIL's R&D expenditures in absolute amounts still constitute considerably higher levels in comparison to other automotive component suppliers operating in India (see section 3.4.1).³⁰

Need for a holistic approach: An exclusive focus on R&D expenditure blends away the fact that technological advancement may also be occurring by *gaining* access to technologies

²⁸ BIL's official annual reports were only available from 2010 onwards and did not contain historical data on R&D expenditure.

²⁹ Authors' illustration based on data retrieved from BIL's annual reports. Data for 2014-15# refer to a 15-months period from Jan. 2014 to March 2015. Data for 2010-2014 refer to respective calendar years.

³⁰ However, Bosch globally reports €6.4 billion of R&D expenditure for 2015 which is a rate of 9% as a ratio to sales (€70.6 billion).

developed elsewhere (Tiwari, 2014a; Tiwari & Herstatt, 2012). In case of BIL it is striking that the company spent €22 million on royalties and for availing technical services and another €35 million on “professional and consultancy charges” in FY 2015-16. The total amount spent on *creation and usage* of intellectual property (including R&D expenditure), thus, should be seen as €82 million, which leads to an *intellectual property (IP) intensity* of BIL to 5.8%.

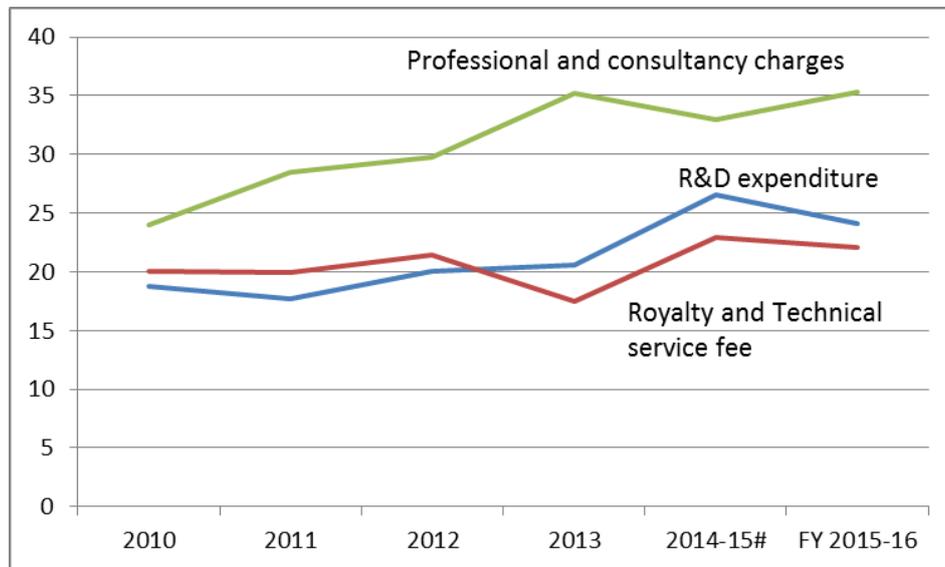


Figure 4-3: Expenditure on creation and usage of IP at Bosch India Limited (million euros)³¹

As Figure 4-3 shows fees paid for royalties and technical services as well as for professional and consultancy charges constitute a very significant expenditure in comparison to R&D expenditure and are probably a core source of innovation impetus. R&D expenditure and expenses for royalties and technical services can be combined as “total expenditure on technical know-how”. Combining this indicator with expenses on professional and consultancy charges leads us to a composite indicator for “total expenses on intellectual property” and *inter alia* to IP intensity in the company.

BIL has established a “futuristic Technical Centre” in Bangalore that is reportedly the first globally-mandated development centre for Bosch outside Europe and is expected to provide high-quality solutions to India’s automotive industry matching global standards (Tiwari, 2014b). India is the location of the largest development capacities for Bosch outside Germany dealing with end-to-end engineering and technology solutions. BIL develops electronic diesel

³¹ Authors’ illustration based on data retrieved from BIL’s annual reports. Data for 2014-15# refer to a 15-months period from Jan. 2014 to March 2015. Data for 2010-2014 refer to respective calendar years

control and petrol injection systems to match specific needs of new generation vehicles in India, while it also acts a global hub for designing, developing and manufacturing single cylinder pumps, multi-cylinder pumps and mechanical distributor pumps for the entire Bosch group (Tiwari, 2014b). In 2015, the Group in India filed for over 200 patents. Apart from own R&D activities BIL has also regularly imported technologies as listed in its annual reports.³²

BIL cooperates with local partners including research institutions. For example, it formed a Memorandum of Understanding (MoU) agreement with the Indian Institute of Science (IISc) in 2015. Statements by company officials given on this occasion are interesting in that they give some insight into the company's thinking. For example, Dr. Steffen Berns, president of Bosch Group in India, was quoted by a company press release as saying (BIL, 2015b):

“Based on this MoU we intend to develop solutions that address key India centric requirements. Innovation has always been a special strength of Bosch. This partnership between industry and academia further enforces our ties with the IISc and underlines our commitment towards local innovations, according to our slogan ‘Invented for life’. We expect to see positive results as we collaborate in research on areas of strategic interest, such as mobility, healthcare, energy and water.”

Another company official, Vijay Ratnaparkhe, president of Bosch Engineering and Business Solutions, was quoted by a news report (Srivastava, 2015) as saying:

“These partnerships symbolize Bosch's innovation focus in India. It will increase our problem solving capabilities, and at the same time the collaboration will result in sharing our learnings for the benefit of society. I believe it is absolutely essential for the growth of innovation in India [...]”

BIL's innovation activities to improve products and processes have been also recognized by several automotive OEMs, such as Mahindra and Mahindra, TML or Maruti Suzuki, as well as the Government of India. Annual reports of BIL mention forty awards that the company has won between 2006 and 2016. Especially worth mentioning here are a “Supplier Excellence Award from Mahindra & Mahindra for Best Cost Management Performance” (FY 2015-16), and an Innovation award from Mahindra & Mahindra for “introducing an ‘Innovative, Overall Cost Effective & Field Fuel Efficient A-Pump System’” (2014-15).

4.2.3. Analysis of Innovation Activities

According to our procedure in the previous case study, we evaluated the last six annual reports

³² In the “Annexure to the Report of the Directors”, section B Technology absorption. We found entries for each year from 2002 to 2016 except 2007 and 2015.

(2010 until FY 2015-16) concerning described innovation and R&D activities in the recurring section “technology absorption”.

For the five reports 2010 to ‘2014-15’ BIL describes “specific areas in which R&D was carried out” which are divided into five sub-sections: (1) Fuel Injection Equipment: Diesel; (2) Gasoline Systems; (3) Starters Motors and Generators; (4) Spark Plugs and (5) Glow Plug & Glow Control Units. For each of these sections there are on average three topics mentioned per year.

In the Fuel Injection Equipment – Diesel area, one recurring topic is innovation to fulfill Bharat stage 5 norms that were expected to come into force 2019.³³ Bharat stage emission standards and their timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment, Forests and Climate Change. They refer to the respective Euro Norms of the same number and were first introduced in the year 2000. These legal requirements seem to foster innovation activities in the auto component sector in India. Further topics are innovations addressing the Low Price Vehicle segment (mentioned three times), and cost effective/ low cost strategies for the Indian market or emerging economies in general (in 2013 and 2014-15).

“Segment specific local approach pursued for whole Indian market with strong focus on total cost of ownership giving a competitive advantage.” (2014-15)

In the area of Gasoline Systems it was twice stressed that “System engineering and component development capability [was accomplished] with corporate support and local expertise for specific market requirements” (2010 and 2011). The term “low cost” was here only mentioned once.

In the Starter Motors and Generators segment product development for low-cost vehicles is mentioned twice. Furthermore, recurring themes here are adaptations for “abnormal operating conditions” in India or “Off-Highway” applications. Hence robustness as well as localization of products seems to have played an important role. Cost effectiveness and durability of innovations are also mentioned in the area of spark plugs. Glow plug and glow control units were developed especially for emerging markets, but also for the European and American aftermarket.

In all six annual reports that we analyzed benefits are described resulting from these innovation

³³ The government has in the meantime decided to leapfrog the Bharat Stage V emission norms (comparable with EURO V) that were to be implemented by 2020 and to directly advance the introduction of Bharat Stage VI emission norms (comparable to EURO VI) from 2024 to 2020 (SIAM, 2017c).

activities. In the first two years fulfillment of requirements for the Indian market are emphasized as well as the fulfillment of emission norms. Then from 2012 until FY 2015-16 only three points are mentioned repetitively:

1. Reducing Emissions
2. Improving fuel economy and consequent reduction in CO₂
3. Optimum cost/benefit ratio for system solutions

Furthermore, in all annual reports except for the last one a future plan of action regarding innovation activities is described. Several points are repeated throughout the years.

Future plan of action	2010	2011	2012	2013	2014-15
Build up competence in engine management solutions for technologies <i>beyond Bharat Stage-5 norms</i> .					
Projects on <i>energy conservation</i> to enable reduced carbon dioxide emissions thereby reducing the carbon foot print.					
Product portfolios <i>relevant to the low price vehicle segment</i> .					
Increase the depth of <i>localization</i> .					
Increase in competencies across business sectors to take advantage of the potential in the Indian market through <i>efficient processes and systems</i> .					
Improve <i>cost competitiveness</i> across all areas and business divisions.					
Improve <i>performance levels</i> of spark plugs in terms of acceleration/drivability.					
Work for low priced markets for doing away with the spurious spark plugs.					

Table 4-5: Future plan of action BIL

Table 4-5 provides an overview of the topics mentioned in BIL's future plan of action. In all five annual reports a focus on products for the low price vehicle segment as well as localization efforts are stated. Furthermore, four times efficient processes and systems are seen as enablers to participate successfully in the Indian market. And in the last three years, carbon footprint reduction as well as preparations for emission norms beyond Bharat Stage-5 are added in the future plan of action. Hence, ecological sustainability seems to become more important in India recently.

4.2.4. Case Summary

BIL is an important subsidiary of the Bosch Group concerning the Indian and other similar markets in Asia. It has been a key contributor to frugal vehicles that have been launched in the

Indian market. The company follows a strategy that puts emphasis on utilizing local knowledge and resources and pursues product adaptation for addressing market-specific demands instead of relying solely on its global product portfolio. R&D spending is at a relative high level for India, but still only marginal compared to other locations in industrialized countries. But interestingly enough, BIL seems to infuse technology and know-how from its global operations, which is apparent by the relatively large expenses for royalties and other technical services enabling access to external intellectual property. This is an indicator for the importance of external sources of knowledge, providing access to reliable, existing technologies, in innovation pathways leading to affordable excellence.

The company has been pursuing a strategy of addressing the low-price segment as a key market. It strives to create solutions that have an optimum cost/benefit ratio while enabling access to next generation technologies in terms of environment-friendliness and emission norms, as becomes apparent in the analysis of its annual reports. This strategy of offering its customers affordable excellence seems to be at the heart of its innovation policy for India and has very clearly paid rich dividends for the company ensuring extraordinary growth in sales, exports, profits and net worth since 2001.

5. Results of Expert Survey

5.1. General Overview

Innovation pathways in India's auto-components industry were sought to be identified and the results of the desk-research and the case studies validated through personal interviews with persons representing various sectoral stakeholders. For this purpose an interview guideline for conducting semi-structured interviews of 60-90 minutes duration was created. This guideline contained questions on innovation pathways taken by companies (e.g. objectives pursued in the product development and innovation activities and the integration mechanism for internal and external sources of knowledge), the influence of external factors, such as regulatory standards, on innovation processes, and the general importance of frugal innovations. Altogether 17 interviews were conducted in December 2016. While 9 respondents represented Indian firms, 5 were working for Indian affiliates of multinational companies, and in 3 cases the respondents represented institutional bodies. Three of the 14 respondents representing firms were working for OEMs and could thus enable a perspective from the customer side. This was especially important because product development in the auto-component industry is often mandated by OEMs limiting the space of own initiatives by component suppliers.

5.2. Innovation Autonomy

Interview partners were asked, to what extent it was usual for clients (OEMs) to “set” the development goals on the component suppliers. A mixed picture emerged in this respect. While there was a consensus that OEMs very often have a very clear idea of their needs and provide more or less exact specifications to the suppliers for the parts they would like to source from them.³⁴ Some suppliers also engage in proactive creation of new solution ideas, which they present to their clients. If a client signals in-principle interest, or if the supplier itself is convinced of the idea's future prospects, then the idea is pursued further. A clear consensus was that creating proactive solutions was limited to a handful of large domestic companies and to affiliates of foreign companies.

Most domestic firms preferred to stick to OEM specifications to reduce operational risks and R&D expenditure on uncertain innovation projects. One interview partner, representing a large tier-1 component supplier said that the “Indian auto component industry is used to working on specifications and on fitting the envelope of what the customer wants.” This possibly points to the industry's expertise being mostly driven towards efficiency and creativity in achieving a set target. That includes finding novel ways to achieve the specified target. Another interview partner also representing a large tier-1 supplier suggested that open-ended mandates like the one in the case of the Tata Nano are not regular. In his words: “In the forging industry it is not often that OEMs give an open mandate as in the case of the Tata Nano. But there are concrete situations where we enhance the product features proactively, as there are not many people in the industry who have those capabilities.”

5.3. Key Aspects of a Typical Innovation Project

Asking interview partners to evaluate certain aspects of a typical innovation project as high, medium, low or irrelevant revealed an interesting picture (see Table 5-1). The most important aspects were “technological performance” and “customer adaptation and customization”. Here several interview partners emphasized the need for appropriateness. Many felt the need to qualify their evaluation by stressing that in their opinion high technological performance is *not an objective unto itself*, rather it is about achieving the requisite levels of technological performance in a given costs/resources framework. In the words of an expert, who acts as an innovation and process implementation consultant after having worked for several years in

³⁴ This was also true for suppliers operating at the different levels of the value chain. A tier-1 supplier was likely to pass on very specific details about its sourcing needs to a tier-2 supplier, which would act similarly when dealing with a tier-3 supplier.

Germany: “If technological performance means ‘meeting the need of the end user’ then this has a very-very high importance”. Low costs, quality and usability/convenience were also rated relatively high. Novelty and design were rated as medium (2.2), which is probably not surprising since the components were often meant to be used as an invisible part of the overall vehicle and the specifications were mostly supplied by the OEMs. It is interesting to see that low costs were evaluated as lesser important than customer adaptation and technological performance.

Aspects	Relevance	High (1)	Medium (2)	Low (3)	Irrelevant
Novelty			2.2		
Technological performance		1.2			
Customer adaption and Customization		1.2			
Design			2.0		
Low costs		1.7			
Quality		1.7			
Usability / Convenience		1.7			

Table 5-1: Perceived relevance of innovation aspects by respondents³⁵

5.4. Impact of Firm Size

It was suggested that Indian SMEs are less likely to engage in product innovation whereas MNCs (including Indian MNCs) are often more proactive on this front. The reason cited was that MNCs generally have a larger resource and customer base and can afford to engage in futuristic planning, whereas SMEs are more often integrated as tier-2 or tier-3 suppliers in the value chain and are geared towards achieving very high levels of process efficiency. Many of them engage in purchasing state-of-the-art manufacturing facilities and try to be innovative in their use of resources in their complete value-chain by optimizing processes to their fullest extent possible.

5.5. Strong Focus on Process Innovation

Interview partners emphasized that they cannot often come up with radical innovations due to the very strong need to follow norms (“fit to function”) and as many standard interfaces would have to be changed if they came up with something completely new. In the words on an

³⁵ Arithmetical average, N=17.

innovation manager from a smaller-sized component supplier, “we cannot temper around with that too much”. R&D Head of a large supplier said, “We rather tend to improve the functions. We focus often on aspects of lightweighting and process innovations.” He explained that the size of the physical shape is coming down because of lightweighting and the strength requirements are going up because of various factors. In his words, “that’s where we come-in, in terms of our expertise. That’s where process innovation comes in because the components are getting very complex and the ability to make those in series without any significant cost premium is a key factor. This is where process innovation comes in.” The statement shows that creating high-quality solutions and having the capacity to mass-manufacture those, while maintaining a strong focus on affordability necessitates significant process innovations. These have, therefore, turned into a critical success factor in the auto components industry.

5.6. Openness for External Collaboration

Openness to absorb knowledge and technical know-how from firm-external sources was mentioned often as a widespread practice. The interviewed experts confirmed that many auto parts suppliers in India acquired external knowledge through licenses from national and international technology leaders. In some cases, the extent of the practice was very high. For example, one firm reported a “very active university collaboration process in a wide range of fields including a full Ph.D. program with permanent seats in some universities”. There were also reports of working together with institutions of excellence in foreign countries, such as the Fraunhofer Society in Germany and the Warwick University in the United Kingdom. Even closely working together with OEMs was seen as a part of that, as mentioned by one interviewee, who said, “Indian auto component industry is used to working on specifications and on fitting the envelope of what the customer wants.” The iterative component development process in a project conducted together with a concerned vehicle manufacturer, characterized by very high emphasis on cost-saving while maintaining regulatory norms, necessarily lets external knowledge flow-in.

5.7. Role of Policies & Regulations

Regulatory impact was evaluated as positive. For example, several interviewees mentioned the rising emission standards that were necessitating technologically more complex components leading, in turn, to a greater need for process innovations including material changes in their composition. One interviewee from a large component supplier, however, also cautioned that suppliers were less affected at the component level. In his words, “It is basically OEMs that set the design; we only have to see how we achieve that. At the end of the day we are supplying a

component that goes in a product. The only role that we play in this is how we make that process more efficient.” The important role of OEMs in incorporating sustainability and environment friendliness in auto parts was confirmed by several interview partners. For example, an R&D manager with a large component supplier stated that “[s]ustainability is increasingly becoming an important issue in India. Leaving aside the regulatory aspects, too, we see a growing awareness in Indian OEMs to be responsive to environmental needs.”

5.8. Question of Mind-set

Almost all interview partners emphasized the role of mind-set in implementing and ensuring a frugal approach. “We are more cost-minded than our German colleagues”, said one interview partner, while emphasizing that it was “by no means a criticism of my German colleagues. But here we tend to be a little more practical in terms of how one would go about doing things. In Germany, you know, they expect that you have to have the best of the best available at your fingertips before you start doing it. Then it obviously becomes more expensive as a process.” He also added that “[t]o a large extent, I think, in India in our facilities we can do this much more cost effectively than possibly anywhere else in the world”. An expert connected this to the Indian philosophy of *samyak* living, which can be translated as balance/appropriate way of life. Nevertheless, some experts also saw this mind-set as leading to fewer investments in in-house R&D around the country. According to a representative of an industry association, due to lack of sufficient facilities within the country “[a]ny product development done has to go to Japan or Korea for validation. It takes a lot of time. We cannot compete with the global players.” It seems as if there is a need for creating testing and validation infrastructure that can be jointly used by firms. Advantages or disadvantages of the approach aside, it does seem that on average component developers in India's auto parts industry often operate with a mind-set that leads them to a frugal innovation pathway.

6. Discussion of Results

Synthesizing the results from the previous three chapters it appears that the price-sensitivity of the domestic market has helped India turn into a global lead market for vehicles that offer a value proposition befitting frugal solutions (cf. Herstatt et al., 2008). The remarkably high price sensitivity of the Indian automobile market necessitates very cost-effective solutions from auto component suppliers to fully exploit the potential of the domestic market, while the increased competition and the tightening of regulatory norms force firms to continually raise their quality standards. Target costing and value engineering are often applied in the context of frugal

innovations (Agnihotri, 2015; Herstatt & Tiwari, 2015). This is also corroborated by studies in other industries. For instance, Guillermo Wille, managing director at General Electric in India is cited by Kumar and Puranam (2012: 106) with the following words: “the beauty of the Indian market is that it pushes you in a corner ... it demands everything in the world but cheaper and smaller”.

The budget-constrained customers in India and the demand conditions resulting from their needs have given rise to the emergence of capabilities for a certain kind of innovation and the associated mind-set in India (Kumar & Puranam, 2012). In our interviews, experts have suggested that there exists a mind-set in India which is especially conducive to reducing costs and avoid “unnecessary” features. This is in accordance with the published literature where researchers have pointed towards the need for a frugal mind-set to create frugal solutions. According to Agnihotri (2015: 405), “A firm cannot innovate cost effectively unless it changes its corporate mind-set”. She also suggests that MNCs generally have been more successful in innovating frugally when they established innovation capacities in low-cost countries such as India. A mind-set that leaves room for a certain ambiguity in planning also creates a certain space for organizational responsiveness and flexibility to unforeseen problems and challenges arising at a short notice. Personal motivations and commitments also play a big role. For example, Maira (2015) and Chacko et al (2010) show how personal commitments played a key role in holding the end-prices and thus forcing the product developers to look for unconventional solutions that can enable such prices while maintaining the requisite quality standards.

Nevertheless, the expert interviews also show that even though low costs play an important role in the success of frugal innovations, they do not constitute the sole or even the primary core of frugal solutions. Delivering quality products, often in conjunction with high-tech, organizational flexibility and a fastened speed-to-market constitute the critical success factors for frugal innovations in the auto component industry. This fits with an earlier study by Tiwari and Herstatt (2012: 267), which came to the conclusion that the “affordable price is a *necessary* but *insufficient* condition” for the commercial success of frugal innovations. R.C. Bhargava, the former managing director of Maruti, narrates two instances how in the pre-liberalization period some Indian OEMs tried to introduce “new” models in the car, which were based on old engines and badly flopped in the market. The customers conveyed a message “that they wanted technology which was up to date and relevant to Indian conditions” (Bhargava & Seetha, 2010: 105). The role of high-quality and advanced solutions, which can cater to customers’ aspirations has thus become crucial.

Despite the low R&D intensity and the general weakness in terms of other traditional indicators of innovation, such as patent applications, “surveys confirm India’s outstanding framework conditions with regard to human resources, technological absorptive capacity and innovation friendliness” (Walz et al., 2008: 137). Apart from this, many Indian auto-component suppliers have tried to augment their capabilities by investing overseas and acquiring assets in the industrialized world to accelerate growth by inorganic means and to secure access to global markets and technological know-how. This has also helped firms forge a positive image and gain access to beneficial “country of origin” effects. Accordingly, firms often show great willingness to access and absorb external knowledge, e.g. through technological collaborations and licensing. Partners include domestic and global entities from varying backgrounds, such as universities, research institutions and other firms. This indicates a general openness in the innovation process. Indian auto-component suppliers often do not claim to have enough technological competencies to succeed on their own. However, as the example of Bharat Forge has shown, large players have realized the importance of in-house innovation knowledge and have started to increase R&D investments in recent years.

Some India-based auto component suppliers have been able to compete globally with various strategies that, apart from competitive prices, include approaches such as “time-to-market”. Such firms are able to design & deliver a component on a very fast basis leveraging the availability of skilled labour and by extensive use of digital technologies in engineering. Aruna Maira, a former top executive at Tata Motors,³⁶ narrates a story how Tata conceptualized and implemented a highly-effective yet low-cost “innovative learning system” to increase “the skills available in the workforce tremendously” and how this system was successfully utilized in creating one of the best-selling trucks, the Tata 407, in the face of the Japanese competition in the 1980s (Maira, 2015: 61). According to him:

“The combination of flexible, precision machines and versatile, highly skilled workmen enabled a huge reduction in product development times. Multiple resources could be deployed at each stage so that bottlenecks could be prevented. The same resources – machines and people – could be used in multiple steps, thereby transferring knowledge between steps in typical product development processes. This was a strategic advantage provided by the company’s human resources strategy [...]. An audacious goal, with very high levels of cooperation within the team, enabled TELCO to produce a very successful 4-tonne commercial vehicle, the Tata 407, within eighteen months. This was a world record in new product development time” (Maira, 2015: 61 p.).

³⁶ Tata Motors was then known as TELCO (Tata Engineering and Locomotive Company).

Likewise, most innovations in the component industry are concerned with increasing efficiencies of processes, reduction in cost & weight of components, as well as with increasing robustness. Process innovations constitute, therefore, a crucial part of the innovation strategy and are at least as important as product innovations. Kumar and Puranam (2012), too, have found that Indian companies tend to often engage in process innovation that remain rather invisible to the outside world but “stimulate the creation of new products and services for global B2B markets” (Kumar & Puranam, 2012: 70).

The bulk of innovations emanating from India's auto components sector may be classified as “new to firm”. Solutions that are “new to market” are rather rare and solutions that are completely “new to the world” are even more seldom. This, however, need not be specific to India. Rather, in this highly regulated industry dominated by product development to specifications set by the customers and where many parts have to be integrated in a system solution, this may be specific to the given situation in the industry.

Nevertheless, the Indian innovation landscape is not uniform. While smaller-sized domestic firms are often less concerned with product innovations and mostly concentrate on process innovations to supply manufactured products as per demands and specifications of OEMs and tier-1 suppliers, larger companies and those with overseas roots also show proactive engagement in coming up with their own innovative product ideas. Most companies, however, stress that as an ancillary industry the ultimate decision whether or not to utilize an innovation remains with the OEM. This also means that the OEMs are a key driving force of the innovation scene in India's automotive industry.

Indian vehicle manufacturers have traditionally focused on markets in the global south, where low-cost vehicles are preferred. Ecological aspects, therefore, have not been high on the innovation priorities of Indian OEMs in the past (Walz et al., 2008). However, our study shows that regulatory policies have increasingly sought to overcome this deficit. As our interviews confirm, these policy moves are mostly rated as positive by the industry. They provide guidelines and set incentives for innovations in the industry. More stringent safety norms and rising emission standards are often mentioned as key drivers of innovation. Altogether, an increasing ecological awareness could be observed in the auto-component industry, also from smaller-sized Indian component-suppliers. Their ecological efforts are often combined with efficiency improvements that also reduce costs.

Figure 6-1 provides an overview of the “drivers of frugality” that we identified for the Indian auto-component industry. It seems that the prevalent (macro-economic) market conditions,

requirements of OEMs increasingly engaged in a global competition, the advent of digital technologies and the ever-more stringent regulatory norms in terms of safety and emission standards are the driving forces behind innovations in India's auto components industry and constitute a virtuous cycle of frugality in its innovation pathways.

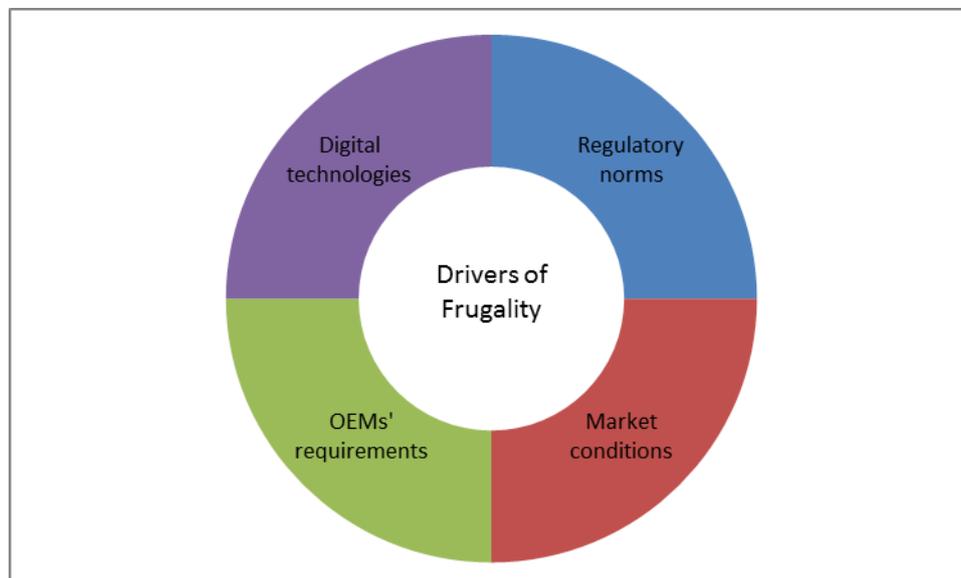


Figure 6-1: A virtuous cycle of frugality in innovation pathways of India's auto components sector³⁷

Peter M. Allen (1988) in his work “Evolution, innovation and economics” introduced the concepts of “Stochasts” and “Cartesians” to describe the innovation behaviour of firms. While the former refers to risk-takers that form the vanguard, the latter are more efficiency-driven seeking to optimize their processes. Stochasts tend to go beyond the present system and are generally not satisfied reaping “the present returns on effort”, while Cartesians constitute the “backbone of the system”. They represent “normality” and “push any particular activity to its ultimate in excellence” (Allen, 1988: 116). “The success of the overall system”, according to Allen (1988: 116), “will be determined by the balanced existence of the two types”. The Indian auto components industry seems to be endowed with both types of innovators. While there is a small vanguard of Stochasts – both foreign and domestic players operating in the country – there is a huge reservoir of Cartesians that – with their emphasis on process efficiency – are acting as enablers of frugality. Presence of a critical mass of Cartesians is crucial to ensure that technological progress is also leading to concrete applications and is not turned into a mere self-

³⁷ Source: Authors' illustration

objective.³⁸

Limitations

Our study was aimed at identification of initial insights and makes, except for the interviews, use of publically available data. Hence, the identified innovations do not necessarily provide a complete list of actual innovations and their categorization might not always be accurate. However, we could address these shortcomings to a certain extent by validating the data and the generated insights by conducting interviews with industry experts.

We have depicted financial data in euros and dollars for the sake of better comprehension through international readers. A limitation that arises with this approach, however, is that the values are prone to show “distortions” in the growth path due to variations in exchange rates.

Nevertheless, since the results do not show any apparent inconsistency and they are compatible with recently published research (Diebolt et al., 2016; ICRA, 2015; Kumaraswamy et al., 2012; Parthasarathy et al., 2016; Sahoo et al., 2011), there is, in our opinion, justified reason to believe that the study results are robust enough to provide direction for future research.

7. Conclusions

The growing domestic automobile market, export opportunities and the increased emphasis of OEMs on high-quality, innovative solutions have created a context for component suppliers to ramp up their innovation capabilities. Our findings indicate that the Indian auto component industry has developed unique frugal innovation pathways that manage to circumvent the various shortcomings of India's innovation ecosystem, by building on some key strengths of that very ecosystem. The firms often engage in designing and developing products making use of modern, digital technologies, leapfrogging certain stages of technological development and reaching very high levels of process and resource efficiency in order to cater to market-specific demand aspects. The huge domestic market and the rising global demand for affordable, high quality products provide a large incentive for investments and openness for external knowledge. Cooperation between Indian and global companies as well as mergers and acquisitions have accelerated the development of innovation capabilities in India.

Innovations in India's auto-component industry, which we observed in this study, are generally

³⁸ It has been, for example, pointed out that in context of industrialized nations technological progress is sometimes leading primarily to extension of the current frontiers of science. It does not necessarily always lead to concrete applications with a focus on appropriateness of solutions (cf. Tiwari et al., 2017a)

aiming to achieve a specific, desired and/or required quality level with robust features and to improve process efficiency. The focus on concrete application within requisite parameters gives rise to “appropriate solutions” that balance economic, ecological and technological performance. Companies do not hesitate to engage in less-technology intensive innovation projects, if required for targeting satisfactory, “good enough” results. All this indicates a frugal culture in India's auto-component industry.

The study discovered a remarkable set of innovation pathways that makes use of collaborative development, avoids over-engineering and is often driven by economies of scale. All this is also stimulated by the state that developed into a key promoter of innovations. By analysing factors influencing innovation capabilities and innovation pathways in the Indian auto component industry this study enables valuable inputs for practitioners, policy makers as well as researchers regarding the creation and shaping of innovation.

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Appendix 1: List of conducted case studies

Firm nationality	Company name	Company size
India	Bharat forge Ltd.	Large
	Motherson Sumi Systems Ltd	Large
	Menon Bearings Ltd.	Small
	IP rings Ltd.	Small
Germany	Bosch India Ltd	Large
	Hella India Lighting Limited	Small