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Ibrahim Semih Akçomak and Serkan Bürken

Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)
email: info@merit.unu.edu | website: http://www.merit.unu.edu

Boschstraat 24, 6211 AX Maastricht, The Netherlands
Tel: (31) (43) 388 44 00

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The Middle-Technology Trap:

The Case of the Automotive Industry in Turkey*

İbrahim Semih Akçomak

Science and Technology Policies Studies (TEKPOL), Middle East Technical University

Serkan Bürken

Science and Technology Policies Studies (TEKPOL), Middle East Technical University

Abstract

This paper argues that Turkey has fallen into a middle-technology trap on the borders of a weak innovation system (IS) and strong global value chains (GVCs). Detailed information from a primary R&D and innovation funding agency is used to show that the technological characteristics of the funded automotive R&D and innovation projects remained reasonably stable between 1995 and 2011. This result is cross-validated with two qualitative designs on beneficiary firms and automotive industry experts. The qualitative designs aided in identifying three mechanisms that explain how the Turkish automotive industry has fallen into a middle-technology trap. Analysis at the project, firm, and expert levels indicate that despite extensive upgrading and learning in manufacturing, the automotive industry has failed to build innovation capabilities. Turkey's delegated role in the automotive GVC, the joint venture (JV) structure and the lack of complementarities collectively work in creating a trap that impedes further technological development.

Keywords: Middle-technology trap, automotive industry, technology, innovation, Turkey

JEL codes: O12, O25, O33, L62

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1. Introduction

A group of engineers produced three functioning prototypes of the first domestic car in Turkey in 1961 through reverse engineering. The project *Devrim* ("Revolution") was a short-lived but commendable effort. The Turkish automotive industry has developed extensively since and is an automotive base hosting the manufacturing operations of global brands such as Ford, Toyota and Renault, a large supplier network and research centres that started operation recently. Turkey manufactures approximately 1.7 million vehicles annually and ranks 15th in terms of car and 9th in terms of commercial vehicle production in the world (OICA, 2018). This paper investigates whether manufacturing success created an impetus for technological learning and to what extent the sector has gained R&D and innovation capabilities.

Globalisation creates various opportunities for developing countries many of which are constrained by weak Innovation Systems (IS) and strong Global Value Chains (GVCs). Technological learning occurs in a local "natural" interactive process where knowledge diffuses and actors learn. In most developing countries, IS produces innovations that are predominantly incremental because of capability and interaction problems (e.g., Viotti, 2002; Alcorta and Peres, 1998; Pietrobelli and Rabellotti, 2011). GVCs may provide an "artificial" global environment where domestic firms can learn through foreign interaction (e.g., Gereffi and Kaplinsky, 2001; Gereffi et al., 2005; Morrison et al., 2008; Callegari et al., 2018; De Marchi et al., 2018). During technological upgrading, however, developing countries may stuck in a middle-technology trap between a weak IS and strong GVCs.

Initial impetus after the 1980s led by the Joint Venture (JV) and Foreign Affiliate (FA) structure and extensive production support (and to some extent R&D and innovation) served to enhance learning in manufacturing and create a wide local supplier chain in Turkey compatible with the export-led growth strategy. Strategic policy choices favouring short-term gains over long-term capability building created a home-grown state-industry agreement on gaining manufacturing capabilities, which created a vicious circle within the weak IS. On the other hand, increased integration to automotive GVCs with strong entry-exit barriers and pre-determined profit margins (e.g., Sturgeon et al., 2008) meant delegation. The interplay of these national and global forces created a middle-technology trap for the Turkish automotive industry.

To identify and understand how this occurred, we followed a mixed research design with both quantitative and qualitative analyses. Data is collected on the automotive sector-specific technology development projects from 1995 to 2011 using the Turkish Technology Development Foundation (TTGV) database. This unique longitudinal data enables the comparison of certain characteristics of the R&D projects over time. The quantitative part was complemented by two qualitative designs based on 13 detailed face-to-face interviews with beneficiary firms on the specifics of R&D and innovation process and 14 interviews with experts: R&D managers, CEOs of automotive firms and industry professionals. The expert interviews are instrumental in presenting a micro to macro framework of the Turkish automotive industry. This novel research design presents information at the project, firm and macro levels providing internal and external validity and robustness to our findings.

Section 2 of this paper briefly discusses learning in the IS and the GVCs. Section 3 describes the methodology with details of TTGV data and firm and expert interviews, followed by an overview of the Turkish automotive industry. Section 5 presents the primary results, emphasising the three mechanisms that collectively created the middle-technology trap followed by a synthesis of the results. Policy implications contextualising the Turkish automotive sector globally conclude the study.

2. Middle-technology trap on the borders of IS and GVC

Development requires industrial upgrading and technological learning (Kim, 1999; Lee and Kim, 2001; Giuliani et al., 2005; Bell, 2006; Altenburg et al., 2008; Lema et al., 2015). Current technology, economy and geography create opportunities for the developing world as well as local and global barriers for learning (Archibugi and Pietrobelli, 2003).

Technological learning occurs in IS where actors and interaction between actors are significant. IS provides a "natural" interactive process of learning where firms and formal and informal institutions blend (e.g., Lundvall, 1992). The system's inherent locality is conducive to technological learning but may also create lock-in situations (Narula, 2002; Bathelt et al., 2004). Contrariwise, GVCs provide an "artificial" organised global environment where local firms can learn from their foreign counterparts. However, GVCs may also hinder technological learning depending on how much knowledge the lead-firms are willing to transfer and the capability of local firms. Lee et al. (2018), for instance, conclude that building a strong local IS is key to upgrading while integrating into the GVCs, which only some developing countries such as South Korea have accomplished. Sampath and Vallejo (2018) and Amendolagine et al. (2019) further highlight the role of capabilities and a strong IS in benefiting from GVCs. Thus, developing countries may face a middle-technology trap on the borders of local natural systems such as the IS and global artificial organisations such as the GVCs.

2.1. Learning in IS

Innovation occurs in a socially embedded learning system where actors interact (Lundvall, 1992; Freeman, 1995; Edquist, 1997). Part of the extensive literature on IS pertains to developing countries (e.g., Arocena and Sutz, 1999; Edquist, 2001; Lundvall et al., 2009).

Pietrobelli and Rabellotti (2011) argue that innovation in developing countries is predominantly incremental and occurs in weak IS where external knowledge is important. To reach technological maturity, firms have to absorb new knowledge by creating significant new-to-the-firm knowledge that entails incremental steps (Bell, 1984; Ernst et al., 1998). Countries that govern the learning-by-doing and learning-by-using phases can increase active learning where transition to an innovative environment is possible (Viotti, 2002; Chiarini et al., 2017).

Technological learning in developing countries occurs in weak IS where either the actors or their interactions are missing, which creates barriers for successful firms. Comparing India and Brazil, Guennif and Ramani (2012) argue that how actors in an IS perceive windows of opportunity determines divergence that reduces to forming new capabilities. In another comparative study of Brazil, China and India, McMahon and Thorsteinsdóttir (2013) observe that the capabilities of local actors are pivotal for learning. Various studies show that actors in developing countries lack capability, and their interactions are low (Alcorta and Peres, 1998; Dantas and Bell, 2011; Crespi and Zuniga, 2012).

An important difference in IS between the developed and developing worlds is the quantity and quality of knowledge in the system. Limited technological knowledge of actors in the system and non-existent or weak interactions, interrupts the knowledge diffusion process. Introducing external knowledge in the system helps alleviate the knowledge diffusion process to enhance learning and technological upgrading (Carlsson, 2006; Fromhold-Eisebith, 2007; Iammarino et al., 2008). Thus, GVC is viewed as a form of learning through interaction with foreign firms (Lundvall et al. 2009; Pietrobelli and Rabellotti, 2011) compared with others such as learning from exporting (e.g., Wagner, 2007) and learning from spillovers as a result of Foreign Direct Investment (FDI) (e.g., Navaretti and Venables, 2004). Local firms can learn from foreign firms participating in GVCs and upgrade their technologies, thereby enhancing the variety and quality of knowledge in IS. When the government actively enables interactions and/or when local firms demand such soft policies, even upgrading of IS is a possibility.

Literature on automotive industry has emphasised the importance of capability building in weak IS where learning is difficult. Research on Argentina (Albornoz and Yuguel, 2004), South Africa (Lorentzen, 2005), Thailand (Brimble and Doner, 2007), South Korea (Oh and Rhee, 2010), Central and Eastern Europe (Pavlinek and Zenka, 2011), India (D'Costa, 2004; Lim et al., 2013), China (Zhao et al., 2005; Motohashi and Yuan, 2010; Nam 2011) and Turkey (Özatağan, 2011) illustrate that indigenous capability building is affected by capability gap, localisation strategies under active and passive governments and various forms of learning opportunities from foreigner firms that the next subsection discuss.

Brimble and Doner (2007) highlight the role of weak university–industry linkages to explain why learning and technological upgrading in weak IS is difficult. Similarly, Albornoz and Yuguel (2004) report weak knowledge flows within the automotive network while Pamukçu and Sönmez (2012) and Sönmez (2013) suggest poor backward and forward linkages. Given the capability gap, successful learning is possible if local firms collaborate with foreign firms in an early stage of technology and product development, focus on niche products and actively demand climbing the value chain (Okada, 2004; D'Costa, 2004; Oh and Rhee, 2010; Ray and Ray, 2011; Karabağ et al., 2011; Pavlinek, 2012; Lim et al., 2013).

Finally, weak IS demands a more active government policy. While the government in developed countries focuses on fixing systemic failures, developing countries have to actively create the system. Barnes and Kaplinsky (2000) for South Africa, Park (2003) for South Korea, Catalan (2010) for South Korea and Spain, Depner and Bathelt (2005), Chu (2011) and Hu, Xiao and Zhou (2014) for China show that active government policy (i.e., localisation strategies, active JV policy, late liberalisation, policy experimentation, creating forced competition, active deregulation) is an important determinant of successful learning and approaching higher value-added segments of the GVC.

2.2. Learning in GVC

Essentially, the concept of GVCs is related to how global production is organised. Technological advancement and a favourable political climate enabled large firms to divide the production process and distribute the pieces geographically based on cost and quality standards. Multinational Corporations (MNC) view this vertically integrated and fragmented production as a value chain where stages of production is performed in a network of firms globally (Gereffi and Kaplinsky, 2001; Gereffi et al., 2005; Pietrobelli and Rabellotti, 2007). This governance of global production provides various technological learning opportunities for developing countries (Morrison et al., 2008).

GVC may transfer technical and managerial knowledge to local firms. When such knowledge is combined with local capabilities, developing countries can climb the value ladder (Pietrobelli and Rabellotti, 2007; Amendolagine et al., 2019). Such development entails a significant amount of technological learning and capability building. When GVC meets a fairly developed IS, firms can obtain new higher value-added skills such as design and R&D and can even learn to tap into new value chains (Humphrey and Schmitz, 2002; Pietrobelli and Rabellotti, 2011).

Gereffi et al. (2005) list various forms of learning mechanisms in GVCs. Developing countries can access global markets via GVCs to leverage the learning effects from exporting. For instance, Kumar and Subrahmanya (2010) show that the subcontracting relations of Indian firms with MNCs can help firms to upgrade technology. Meeting standards, regulations and technical specifications of the lead firms is an important learning mechanism that forces firms to adopt certain skills just to tap into the value chains. Okada (2004), Pavlinek et al. (2009), Motahashi and Yuan (2010) and Oh and Rhee (2010) identify this channel of learning in the automotive industry for various countries. Another form of learning is via technical and managerial knowledge transfer. This can be a by-product of interactions or can be deliberately organised by the lead firm. Training and turnover of key employees can also help local firms to learn from the lead firms in the GVC. For instance, Contreras et al. (2012) show that the spin-off process of locally established lead firms in Mexico can result in the emergence of knowledge-intensive firms within the automotive supply chain. By transferring complex manufacturing, managerial and knowledge-related tasks, GVCs can boost the development process, assuming that firms learn from and/or imitate their counterparts and that knowledge spreads to local firms through spillovers and further imitation (e.g, Dutrenit and Vera-Cruz, 2005). The idea of development enhancing GVC is based on the assumption that local firms and supplier industry learn from the subsidiaries, FAs and JVs to the extent of creating backward and forward linkages (Pavlinek, 2018).

Automotive industry is an example of GVCs with complex and dynamic interactions. Sturgeon et al. (2008) define the industry as global in codified knowledge (i.e., production) but local in tacit knowledge (i.e., design and R&D). Though technical (and even R&D) centres of lead firms are located in developing countries such as China, core design, R&D and engineering remain centralised. After completing conceptual design and modularisation, suppliers that meet technical specifications are integrated into the value chain. Pietrobelli and Rabellotti (2011) refer to GVCs in the automotive sector as "modular chains" where capable suppliers produce technical modular parts under highly complex codified transactions. Usually, lead firms readily provide specs and force the suppliers to commit to stringent technical specifications and standards (Barnes and Morris, 2004; Hassler, 2009; Pavlinek et al., 2009; Nam, 2012; Simona and Axel, 2012; Pavlinek, 2012). To fulfil the standards, suppliers need to learn and acquire certain technological and managerial skills. Automotive GVCs are considered as captive and quasi-hierarchical value chains in which lead firms drive the value chain and decide whom to support and what to produce (Gereffi et al., 2005; Pavlinek and Zenka, 2011, Nam, 2011). Such conceptualisations define a well-structured value chain driven by lead firms where tacit knowledge is centralised and codified knowledge is decentralised only if certain standards and specifications are met.

The process of learning and technological upgrading that enables climbing the value ladder in a well-structured GVC seldom includes active involvement of the lead firms. As in Argentina (Albornoz and Yuguel, 2004), Brazil (Quadros, 2004), Central and Eastern Europe (Pavlinek et al., 2009; Pavlinek and Zenka, 2011), South Africa (Barnes and Morris, 2004; Lorentzen, 2005), Thailand (Brimble and Doner, 2007), Turkey (Özatağan, 2011) and even in the JV case of China (Nam, 2011; 2012), suppliers and local firms upgrade to an extent but mostly in a particular direction to become a "technology colony" (Barnes and Morris, 2004). Learning and technological upgrading at such a stage is possible depending on the firms' capability and the state of IS in the developing countries (Pietrobelli and Rabellotti, 2011), active government policy such as in China (Liu and Dicken, 2006; Chu, 2011) and South Korea (Park, 2003; Catalan, 2010) and ownership of the technology (Lorentzen, 2005).

2.3. Middle-technology trap

We conceptualise middle-technology trap in a narrative where IS meets GVC (e.g., Pietrobelli and Rabellotti, 2011). To our knowledge, the term was initially used by Robert Wade to refer to situations where firms in middle-income countries are stuck in low-value added segments of the global production chain (Wade, 2010). A variation of the concept "middle innovation trap" has recently been used to highlight the role of innovation capability to explain the source of middle-income trap (Lee, 2017)

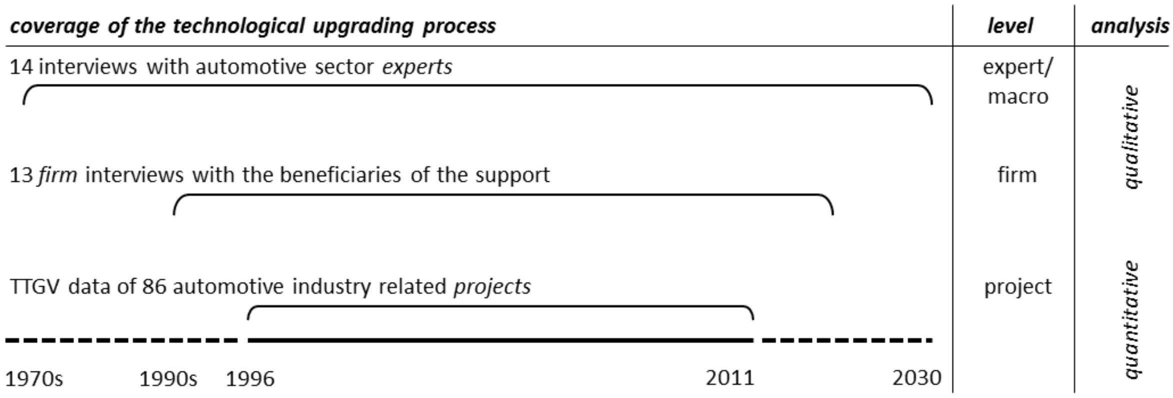
Weak IS with capability and interaction problems limits technological learning in developing countries. Local firms engage in GVCs to create new learning opportunities but face strong reluctance from the foreign lead. Thus, firms in developing countries are internally (i.e., the weak IS pulls down such firms to average), as well as externally (i.e., pushed away by the GVCs) constrained. Literature on the automotive industry reports that GVCs delegate roles to developing countries and allow learning to an extent that further supports the position of the lead-firms in GVCs (Barnes and Morris, 2004; Okada, 2004; Brimble and Doner, 2007; Petison and Johri, 2008; Pavlinek and Zenka, 2011; Nam, 2011, 2012; Contreras et al., 2012). We argue that developing countries can be trapped in producing middle-technology products from which it is difficult yet not impossible to escape because a weak IS coupled with strong GVCs create a vicious circle.

Thus, a strong middle-technology trap fosters on the borders of IS and GVC where both restrict technological learning opportunities. The concept is related to transition from a passive by-product "doing-based" learning to a more active "non-doing-based" learning where firms deliberately invest in technological upgrading (Bell, 1984). A similar transition occurs from active learning to building innovation capabilities (Viotti, 2002), but most developing countries are trapped between the two.

3. Methodology

We employ a mixed-methodology approach that includes both quantitative and qualitative analyses. The quantitative part is based on TTGV data that provides information at the project level. Detailed information on technology development at the firm level is gathered by conducting face-to-face semi-structured interviews. Expert interviews assess the position of Turkish automotive industry globally. Variety within the selected firms and experts is ensured for internal validity and robustness (e.g., Yin, 2003). We follow an explanatory sequential design where the qualitative part is employed to further interpret and contextualise the findings of the quantitative part (Creswell and Plano Clark, 2011). Figure 1 depicts the research design.

Figure 1: Research methodology



There are two primary advantages to using mixed research designs. First, mixed designs provide complementarity. In our setting, TTGV data provides compelling evidence that proved instrumental in reaching interim findings but also provided space for further analysis. The two case study designs provide information on the aspects that TTGV data could not corroborate, thereby proving complementary in nature. A second advantage of using mixed design is triangulation. The three research designs provide information at the project, firm and expert levels. The main findings and three mechanisms identified are mostly validated at all three levels that contributed to the novelty of this research.

3.1. TTGV data

Technology Development Foundation (the Turkish acronym being TTGV) was founded as a non-profit organisation in 1991 to support technological development by providing seed capital and R&D funds to Turkish industrial firms.

TTGV's funding is the antecedent of all R&D support mechanisms in Turkey. The data set covers the entire R&D support period of Turkey, starting from the early 1990s, thereby enabling comparisons over time. Data on automotive projects is sourced from the Technology Development Support Program of TTGV that provides R&D loans of up to one million US dollars for industrial firms. The repayment commences one year after the project is officially completed and continues for three years. By 2011, there were approximately 2400 project applications and 938 of these were supported. The total amount of contracted support under this scheme was approximately 320 million US dollars. With the development of firm and entrepreneurship support programs in TUBITAK by 2010, TTGV support gradually turned inconsequential and eventually stopped by 2012. Previous research has showed that TTGV support was successful in creating awareness for R&D and innovation (Özçelik and Taymaz, 2008).

The project reports detail the R&D activities provided by the performer firm that seeks approval from the field committee members who evaluate the projects. Within approximately 500 projects that may be related to automotive, 102 projects were identified by carefully examining the fact sheets and the evaluation reports. However, due to missing information, only 86 projects were analysed. The first project was initiated in 1996. There were, in total, 86 projects on automotive till 2011. Our data set comprises information on firm characteristics (size, capital structure, location, etc.) and project characteristics (budget, involvement in design, technology field, target markets, targeted automotive component, innovation level, etc.). Table 1 summarises these projects' information.

Table 1: Summary of TTGV automotive projects, 1996-2011

SMEs	52	(0.60)
Has R&D department?	57	(0.66)
Applications by domestic firms	73	(0.85)
Applications from Doğu Marmara region	50	(0.58)
Firms having quality certificates (ISO9001; ISO16949 etc.)**	67	(0.81)
Firms that are involved in R&D activities before application	61	(0.71)
Core business of applicants		
OEMs and JVs	19	(0.22)
Auto-suppliers	53	(0.62)
Engineering and consulting firms	8	(0.09)
Core business other than automotive	6	(0.07)
Projects by auto-component classification		
Body & body equipment	30	(0.35)
Power transmission	13	(0.15)
Electronic component	1	(0.01)
Safety component	1	(0.01)
Engine	6	(0.07)
Whole Vehicle	16	(0.19)
Others	19	(0.22)

Note: The numbers in parentheses are the percentages (over 86 projects).
** indicates that the percentages are calculated over 83 projects because of data availability.

Despite the program being primarily aimed at increasing the capability of the SMEs, big firms, OEMs and JVs also benefitted from the R&D support. Table 1 shows that approximately 60% of automotive projects are initiated by SMEs. Most firms are suppliers, but OEMs and JVs constitute one-fourth of the project applicants. Beneficiaries are mostly domestic, have quality certificates such as the ISO9001 and ISO16949 and are involved in R&D activities before applying to TTGV. The firms are generally located in the Doğu Marmara Region (Bursa, Istanbul, Gebze and Izmit), which is the heart of the Turkish automotive industry.

We additionally matched each R&D project to an automobile component to verify whether over time there is an inclination towards contemporary technologies such as safety technologies, electronics component, software, engine, etc. rather than traditional technologies such as body and body equipment. Table 1 shows that over the years, most project applications involved traditional technologies. Approximately, one-third of all project applications were on body and body equipment. Only 8 projects (i.e. approximately one-tenth of all applications) in the whole period were on electronics, safety component and engines. This subtly indicates towards the technological sophistication level of the Turkish automotive industry.

3.2. Firm and expert interviews

Two separate designs are used to cross-validate the findings of the TTGV data. In both designs, we presented the interviewee brief information regarding the research project but did not specifically mention the interim results obtained from the TTGV data.

The qualitative part focuses on three aspects. First, firms are asked to evaluate their last five R&D projects to understand the evolution of R&D content. The interviews are tailored to investigate whether the R&D activities of firms are based on more design-oriented contemporary automotive technologies. Second, we focus on the content of innovation and decision-making in commercialisation. Finally, the impact of foreign presence on decision-making in domestic firms is examined. The presence of design-oriented R&D activities in contemporary technologies in which the decision-making power on commercialisation activities is retained by domestic firms is perceived as a sign of increased technological sophistication.

Firm interviews aim to collect detailed information regarding the R&D context (content of R&D, novelty, OEM presence in decision-making etc.), R&D output (customers, decision-making in commercialisation, etc.) and firm strategy on R&D and innovation. 15 firms that benefitted from the TTGV support mechanism were selected on the basis of size, location, capital structure (domestic, JV, FA) and core competences (suppliers, design and engineering firms, etc.). 13 of these firms responded our interview request (5 SMEs, 6 big firms, 1 JV and 1 FA). The face-to-face semi-structured interviews with the R&D managers (or top-level managers) of these firms lasted for one and a half hours on average. The firms vary in terms of size, location, capital structure, core competency and type of end-product. Table A.1 in the appendix summarises information regarding the selected firms.

To complement the project and firm level information, we conducted interviews with experts to gather information on the development of the Turkish automotive industry, its position in the GVC and the future of the industry with reference to R&D and innovation activities. 20 names were initially drafted of which 14 responded. Table A.2 in the appendix presents the general characteristics of the selected 14 experts. Interviews averaged 45 minutes. Interviewees have either previously worked in automotive firms or automotive NGOs or still actively work in automotive firms and organisations. The backgrounds of the experts vary in terms of job status (e.g., managerial position), past and current work experience (from production, engineering and design activities to top-level management) and background (policy-makers, consultants, R&D managers etc.).

4. Turkish automotive industry at a glance

In the 1960s' closed economy, infrastructural limitations, political and bureaucratic problems as well as shortage of physical, human and intellectual capital prevented industry formation. Before the 1960s, only minor attempts were made such as Ford assembling trucks by 1930s, the

Otomarsan assembling buses and Turk Tractor assembling tractors by 1950s in very small quantities. Traces of the first organised governmental intervention can be located in the five-year development plans (DP). The import substitution, credits to manufacturing industry, ban on bus imports (1963–67 DP), creating national automotive industry and especially domestic supply industry (1968–1972 DP), increasing scale and capacity usage ratios (1973—77 DP) and various other policies were emphasised in DPs, most of which were rarely implemented. Unlike other developing countries such as Argentina, China, South Africa and South Korea, the government did not even administer a local-content ratio. Most strategies, targets and policies remained on paper except the import substitution.

The government supported the industry by subsidising business groups to foster (automotive specific) capital accumulation. Backed by the import substitution policies, this process led to the first organised attempts at production by the late 1960s and the emergence of JVs such as Tofaş-Fiat and Oyak-Renault in the early 1970s. By investing and accumulating financial, physical and human capital, the import substitution period from 1960s to 1980s attempted to build capabilities. By mid-1980s, Turkey started implementing export-oriented policies aimed at establishing a fully-functioning market economy. The industry reached a commendable level of capital accumulation in the 1990s, which together with increased investment in assembly production meant expertise in manufacturing. The customs union with the European Union in 1996 tested ability to survive in global competition. The industry passed this test by obtaining licenses from foreigners to produce cars that can sell immensely in the domestic market and even exported at a later stage (e.g., Fiat-Tempra produced by Tofaş-Fiat). In the last 40 years, Turkish share in global vehicle production rose from a mere 0.1% to approximately 1.8%.

Table 2 depicts the current state of the Turkish automotive industry. Three phases of production can be observed from the table: 1960s' assembly of trucks, busses, midi-busses and tractors; 1970s' creation of JVs Oyak-Renault and Tofas-Fiat that produced passenger cars; and the establishment of fully or partially foreign-owned production facilities of Ford, Honda, Hyundai and Toyota in the second-half of the 1990s. In 2018, a total of 1.58 million vehicles were produced in Turkey while the maximum production was achieved in 2017 with 1.75 million units. The utilisation rate in 2018 in passenger car producers is 81% that is higher than non-passenger vehicle producers (73%). 64% of total production are passenger cars and 27% are pick-ups. The automotive industry exports reach 21.9 billion dollars in 2018, which is approximately 13% of Turkey's total exports. The firms in Table 2 altogether employ approximately 52,000 employees, of which 12% are engineers. The ratio of engineers in the total workforce reached a maximum of 14% in 2014 and has since declined.

Table 2: The current state of automotive industry in Turkey

Firms	Production place and starting year of production	License	Ratio of foreign capital (%)	Type(s) of vehicles produced	Total production capacity (2018)	Total production (2018)
Anadolu Isuzu Otomotiv Sanayi	Kocaeli – 1966	ISUZU	29.74	Truck, Pick-up, Bus, Mini-Bus	19,012	4,461
Ford Otosan	Eskişehir - 1983 Gölcük/Kocaeli - 2001 Yeniköy/Kocaeli – 2014	Ford	41.04	Passenger Car, Truck, Pick-up, Mini-bus	455,000	373,702
Hattat Traktör	Tekirdağ – 2002	Valtra, Hattat	0.00	Tractor	25,000	3,572
Honda Türkiye	Kocaeli – 1997	Honda Motor Europe Ltd.	100.00	Passenger Car	50,000	38,319
Hyundai Assan	Kocaeli – 1997	Hyundai Motor Company	70.00	Passenger Car	245,000	203,000
Karsan	Bursa – 1966	Hyundai Motor Company, Breda Menarini Bus	0.00	Pick-up, Bus, Mini-bus, Midi-bus	52,225	6,724
M.A.N. Türkiye	Ankara – 1966	MAN Truck and Bus AG	99.90	Bus	2,400	2,558
Mercedes Benz Turk	Istanbul – 1968 Aksaray - 1985	Mercedes Benz	84.99	Truck, Bus	22,000	20,856
Otokar	Sakarya – 1963	Land Rover, Fruehauf	0.00	Pick-up, Bus, Truck Midi-bus	10,300	2,369
OYAK Renault	Bursa – 1971	Renault	51.00	Passenger Car	375,000	336,778
TEMSA Global	Adana – 1987	TEMSA	0.00	Truck, Bus, Midi-bus	10,500	2,549
TOFAŞ	Bursa – 1971	Fiat	37.80	Passenger Car	450,000	301,750
Toyota	Sakarya – 1994	Toyota	100.00	Passenger Car	280,000	257,084
Türk Traktör	Ankara - 1954 Sakarya - 2014	New Holland	37.50	Tractor	50,000	34,114

Source: Automotive Manufacturers' Association (OSD) in Turkey. Statistics in 2018 and 2019 http://www.osd.org.tr/sites/1/upload/files/2018_YILLIK-3299.pdf . http://www.osd.org.tr/sites/1/upload/files/2019_YILLIK-5401.pdf Accessed 25.02.2019.

The average foreign ownership in non-passenger automotive production industry is 33%. There are 9 producers, 4 of whom are fully domestically owned (Hattat Traktor, Karsan, Otokar and TEMSA). Considering only foreign companies, average foreign ownership in non-passenger automotive industry is 73%. There are six passenger car producers with average foreign ownership of 66%. The passenger car industry is concentrated in the Marmara Region (Bursa, Kocaeli and Sakarya), whereas the non-passenger automotive industry is more distributed since production occurs in various cities such as Aksaray, Ankara, Adana, Eskisehir and Kocaeli.

5. Results

The analyses start by considering 6 indicators that reflect the quality of the R&D projects: *(a)* R&D content (whether the R&D involves modelling and design activities), *(b)* auto-component the project addresses (traditional vs. contemporary), *(c)* the users of the R&D results (OEMs & JVs, domestic firms), *(d)* market orientation of the projects (domestic vs. abroad), *(e)* type of intended innovative activity (process, product or both), and *(f)* intended level of innovation (new to the firm, country, world). To observe development over time, TTGV data is divided into 2 sub-periods. The first period (1996–2003) characterises the strengthening of the manufacturing capabilities with the first examples of R&D activities. In this period, TTGV supports were instrumental in not only funding the industrial automotive R&D but also in improving the image of the participants since obtaining funding from TTGV signalled capability. The latter (2004–2011) characterises a period where the number of automotive R&D performers increase and funding opportunities expand.

Table 3 summarises the results. Since more projects are available in the second period, we present absolute numbers as well as column percentage shares. Intended level of innovation that reflects novelty does not display a clear pattern. In the entire 16 years' period, only 5 projects can be classified as new-to-the-world. 3 of these belong to foreign OEMs and JVs. Initially, the R&D projects predominantly aimed at product innovation while in the second period, process as well as product innovations were in focus. Process innovations are considered as a trigger of productivity increase. In this manner, Turkish automotive R&D projects are more inclined towards augmenting productivity at the expense of increasing product variety. This result agrees with earlier findings reporting that process upgrading is integral to integrating with GVCs while product upgrading is mostly limited (Okada, 2004; Pavlinek and Zenka, 2011; Simona and Axele, 2012).

Considering the content of R&D projects, we assessed the presence of design-oriented and market-signalled R&D activities independent of foreign partners. Design and design confirmation processes are considered as significant determinants of technological capability (Barnes and Morris, 2004; Nam, 2012; Ray and Ray, 2011). The project may involve domestic efforts of modelling, design and design verification or such activities can be in the form of readily available specs, know-how and foreign technology transfer. Table 3 indicates design components in almost all projects. However, performers are increasingly inclined to obtain know-how from abroad in the second period compared to the first. This pattern became more apparent after the global crisis; more than 40% of the R&D projects used ready specs and know-how sourced from OEMs and JVs. Moreover, approximately 60% of automotive R&D projects are intended for foreign OEMs and JVs. This signifies foreign dependency that may affect strategic R&D and commercialisation decisions of domestic firms.

Table 3: R&D, innovation and technology in automotive projects, 1996-2011

	1996-2003	**column %**	**2004-2011**	**column %**	**row total**
R&D content					
modelling, design and design verification (domestic)	12	0.75	45	0.64	57
know-how, specs and technology transfer from abroad	3	0.19	23	0.33	26
no design activity	1	0.06	2	0.03	3
Type of intended innovation					
process	1	0.06	12	0.17	13
product	15	0.94	42	0.60	57
process and product	0	0.00	16	0.23	16
Intended level of innovation					
new to the firm	5	0.31	32	0.46	37
new to the country	11	0.69	33	0.47	44
at the world frontier	0	0.00	5	0.07	5
Projects by auto-component classification					
traditional	11	0.69	48	0.69	59
contemporary	4	0.25	22	0.31	26
both	1	0.06	0	0.00	1
Intended use of the R&D output					
OEMs and JVs	10	0.63	40	0.57	50
other (end users, subcontractors, firms etc.)	6	0.38	30	0.43	36
Market orientation of projects**					
domestic	4	0.25	13	0.19	17
abroad	5	0.31	8	0.11	13
domestic and abroad	6	0.38	48	0.69	54

Note: columns 1, 3 and 5 present the project numbers in two different time periods and the row total. Columns 2 and 4 present the column percentages such that the column sum of each indicator panel sum to 1.00.

Matching each R&D project to an automotive component can show how contemporary the R&D projects are. 70 sub-groups of automotive components belong to 2 main groups: *(i)* contemporary—electric and electronic component, safety component, engine and emerging engine technologies such as recyclability and telematics and *(ii)* traditional—body, body equipment and power transmission technologies. As Table 3 shows, almost 70% of the automotive R&D projects are in traditional components and there is no difference between the two periods.

Two important findings emerge from the TTGV data. First there is no significant difference in the projects between the two time periods regarding R&D content and output, auto-component technology and innovation type and level. Project portfolio around 2010 resembles the project portfolio around 2000. Second, Turkish automotive firms depend on global OEMs and lead firms in GVC on strategic R&D and innovation decisions. Automotive R&D in Turkey is usually sustained with the provision of specs from foreigners that may restrict domestic R&D efforts to traditional technologies and components with less value-added

Why Turkish automotive R&D efforts are stuck in low value-added components and the role of foreign presence in explaining this can be comprehensively understood by exploring the role of Turkey in automotive GVCs. Current global automotive industry has a well-organised structure with high entry/exit barriers and pre-determined profit margins that are consolidated by lead firms in GVCs, allowing little space for latecomers such as Turkey. *INT1* describes the current state referring to the value chain and the role of JVs in Turkey: "*A branded car is manufactured at a cost of 75 percent of its sale price. JV has rights to sell it to a dealer or export it with 3-5 percent margin. Main branch of the JV is determining what part of the production is sold abroad and what part will remain inside. JV has rights to sell the part that is left for the domestic market with a margin of extra 12 percent. For a car sold in domestic market, the profit margin for JV is reaching nearly to 17 percent. The last 8 percent is acquired by the dealer. The growth of domestic market refers more value-added for JVs.*"

In such a well-organised scheme, foreign firms establish branches in developing countries mainly for reasons of exploitation of the domestic market and manufacturing (e.g., Barnes and Morris, 2004; Okada, 2004; Liu and Dicken, 2006; Brimble and Doner, 2007; Nam, 2011; Contreras et al., 2012). Interviewees agree that Turkey gained competence in manufacturing over the years (see also Table 5 in section 6). For instance, *INT3* argued that "*With about 50 years of experience, we learned how to produce efficiently in good quality, how to implement production methods and produce a ready-made product.*" In a similar manner *INT7* argues that "*Reaching a certain level of intellectual capital has been an accumulated process during the past 50 years. Turkey has reached this level by manufacturing. Now, manufacturing has reached a certain level of maturity. On tier 2 (supplier industry), quality, planning and lean manufacturing is well-developed. Before 2000, no one was expecting this kind of development*". *INT8* emphasises further that Turkey gained capabilities primarily on manufacturing but not on technology development. "*Turkey is highly capable of automobile mass manufacturing. But this is the least profitable part. Government frequently refers to the association between the automotive industry and export performance. However, we are manufacturing cars without absorbing R&D and developing technology.*"

Our initial analysis leads us to argue that Turkey has become an excellent manufacturing centre but Turkish automotive R&D as well as production efforts are stuck in low value-added components, which is very difficult to recover from. We identify three mechanisms to further explain how this has occurred. (1) The delegated manufacturing role within the GVC has been accepted by the governments for job creation and export revenue, which shapes the content of R&D activities and binds them to incremental innovations that further strengthens the position of lead firms; (2) lack of indigenous electronics and/or ICT sector that complements the automotive sector; (3) foreign presence enhances technological upgrading at a decreasing rate and saturates well below the frontier.

5.1. Automotive manufacturing as a delegated role

Being part of GVCs may create an industry with stable employment and export prospects but can hinder further development of the industry as in the case of Turkey. Especially for developing countries, manufacturing or process upgrading is a delegation problem rather than a choice. *INT7* illustrates this emphatically, stating "*Common transport is still on four wheels. Boundary conditions are certain and in this well-organised industry, corners are held by big players. The needs are determined and the prices are fixed. Turkey has accepted the rules that the western counterparts has established and has no power to change them. Developed countries are continuously changing and developing these rules in order to protect their leadership.*"

Neither the government nor the firms and NGOs could design strategies and policy tools transforming manufacturing capabilities to innovation capabilities. Especially in the 1990s, the governments left the playing field void which strengthened the position of lead firms in the GVCs and tied Turkish firms to the lower segments of value chain. The governments could have retaliated, but this delegated position in the GVC was accepted because the automotive sector created jobs and export revenue that had political connotations especially in the 1990s where both elections and economic crises were frequent. We argue that this delegated role shapes the content of R&D and innovation that Turkish firms conduct.

Approximately half of the firms in the TTGV sample indicated that their products involve solely traditional technologies and little R&D effort has been invested in producing knowledge at the world frontier. Knowing why firms perform R&D, how R&D process is initiated and how much decision-making power firms have on commercialisation is vital to assess the potential for further development. Firms perform R&D either for cost reduction (i.e., improving production processes) or to achieve higher quality or produce new (and niche) products. As a quality check, we specifically seek concept design and design confirmation processes.

The R&D and innovation processes in Turkish automotive firms are not nurtured by basic and experimental R&D accompanying design and design confirmation processes. Most ideas emerge from foreign partners/firms or outsourcers. Incremental R&D and innovation for survival are common elements. To illustrate further, I*NT3* argued that the source of innovation is not basic or experimental R&D that is an important handicap for the industry's further growth. "*Turkish firms are performing R&D for survival. Turkish firms are investing on projects involving lower risks…one of the weakest side of the innovation system is that experimental R&D is* *not supported…Turkey also seems weak in basic research. In contrast, newly developed countries such as Taiwan are highly specialised in generic and advanced contemporary technologies such as nanotechnology and in basic sciences.*" If not basic and experimental R&D, what is the source of R&D in the Turkish automotive industry?

The first step towards answering this is locating the source of ideas i.e., whether R&D initiatives are initiated by market signals or by (direct commissioning of) foreign firms, JVs and FAs. Using market signals is an important phase of nurturing concept design capabilities unless the domestic firm is assigned for this process by the foreign lead. As *INT1* puts it, "*design and design confirmation are the most eminent processes of automotive manufacturing today. If you have presence in design, you take royalty and as a result, higher positions in the GVC.*" *INT8* emphasises this, stating "*Designing concepts requires collecting data from the field – signals from markets, passengers, car users, dealers, manufacturers etc., so that you are able to design brand new models accompanying the needs of the stakeholders. Data help you design new concepts. However, developing countries such as Turkey are skipping this phase since the designs have been readily served by JVs. Without market analysis, it is impossible to develop concepts.*" *INT5* similarly argues that design and innovation capabilities are of instrumental in the automotive industry, "*Given the ease of reaching capital, investment, technology and resources today, design and innovation are of vital importance to provide competency in the global industry.*"

Though data collection for concept design and design confirmation processes are vital for gaining design and innovation capabilities, *INT8* argues that most Turkish firms are far from reaching such understanding. "*We lack in design and design confirmation. We cannot develop concepts maybe because the industry is highly dependent on JVs. We are not even developing engine or power transmission*." *INT3* also emphasises the significance of designing concepts rather than designing whole vehicles (or components). Interviewers usually associate concept designs with a sophisticated phase of technological development that is nurtured by market signals. Firm interviews further corroborate this finding. Table 4 shows that firms seldom adopt signals from the market but rather depend on foreign partners and outsourcers.

Table 2 and 3 (TTGV data), Table 4 (firm interviews) and quotes from expert interviews show that design and design confirmation processes are usually skipped because firms use ready specs made available by foreigners. Most firms rely on signals (and mostly delegation) from the outsourcers to determine the technological area and content of R&D activities. Only one firm in the interviews (*BIG1*) states that they completely rely on market signals to conduct R&D. Some firms use mixed R&D strategies where the original idea either comes from the JV, OEM, FA or the market. Thus, Turkish firms (domestic, FA or JV) are missing a vital step in routine formation for developing technology. This finding parallels the findings of Ölmezoğulları (2011), citing a lock-in situation in Turkey on co-designing activities. Özatağan (2011) also argues that using ready specs and neglecting the concept design phase makes the performing firm more dependent on the lead firms in GVC. The only exceptions to this rule are large firms (*BIG1*, *BIG4* and *BIG5*, see Table 4) that conduct R&D in niche technologies apart from their core areas.

In conclusion, the delegated role of being a manufacturing centre shapes the main characteristics of R&D and innovation. Turkish firms conduct R&D and innovation for survival, hardly participate in basic and experimental R&D and mostly skip concept design and design confirmation processes. These findings support literature on automotive industry in India (Okada, 2004), South Africa (Barnes and Morris, 2004), Thailand (Brimble and Doner, 2007; Hassler, 2009), Central and Eastern Europe (Pavlinek et al., 2009; Pavlinek, 2012) and on automotive JVs in China (Nam, 2012).

5.2. Lack of complementarities

The reason for the Turkish automotive industry's inability to ascend the value-ladder can be the accompanying developments in the electronics industry. *INT11* cites the lack of physical infrastructure, qualified workforce and intellectual capital as the main reasons behind Turkey's failure to establish a strong electronics industry. "*By 1980s, there was a critical threshold; unfortunately privatisation had slowed down the national efforts towards electronics. We speeded up in automotive but Turkish electronics declined. I strongly think that the failure in the adoption of electronics technologies in automotive has decreased the value-added being created in national automotive industry, particularly the suppliers'. This has also impeded the system design processes. The result is products with lower value-added."* The initial attempts at establishing R&D labs and conducting R&D in state-owned (electronics) companies were interrupted by privatisation attempts (e.g., the Teletaş case – see Yücel, 2016).

Similarly, *INT8* emphasises the role of electronics in engine design and in designing and integrating smart systems in automobiles. *"Electronics industry is a prerequisite for producing 'smart automotive systems.' Without a good electronics and software industry, it is impossible to design and produce engine control unit." INT1* approaches the issue with a wider perspective, arguing that there are hardly any domestic producers of components predominantly involving electronics and software. "*We have no manufacturers in automatic transmissions, engines, vehicle control units, software integrating with mechanic parts, brake systems. Furthermore, Turkey has no manufacturer producing boards and cards that are being used in automotive software. Unless you are uniting mechanics with software, it is hard to have more value-added." INT9* emphasises the (future) role of telematics as well as electronics. "*Among international projects, the most important ones are from the technological fields of telematics and telecommunication…ICT-driven technologies are driving innovation in automobile industry*."

Table 4: Summary results of the firm interviews: R&D content, R&D output and innovation

Firm	Core specialisation	Core technology	How R&D projects are initiated?	Product/ process innovation	Ready specs from foreigners	Commercialisation decision	Projects in niche or sophisticated products	Innovation level	Diversified core competency?	Technological sophistication
SME1	Design and engineering firm of a domestic OEM	Contemporary	affiliated OEM and market signals	Product	Yes	Dependent on OEM	Yes	National	Yes	Yes
SME2	Supplier	Traditional	outsourcer	Both	Yes	Dependent on OEM	No	Firm	No	No
SME3	Supplier	Traditional	outsourcer	Both	Yes	Dependent on OEM	Yes	Firm	Failed	No
SME4	Supplier	Traditional	outsourcer	Both	Yes	Dependent on OEM	Yes	Firm	No	Yes (due to its phase of being a co-designer)
SME5	Supplier	Traditional	outsourcer	Product	Yes	Dependent on OEM	No	Firm	No	No
Procurer BIG1	Engineering firm / assembly line procurer for global OEMs	Contemporary	outsourcer and market signals	Both	Yes (niche projects - No)	Dependent on OEM	Yes	National	Yes	Yes
BIG2	Supplier	Traditional	outsourcer	Both	Yes	Dependent on OEM	Yes	Firm	No	No
BIG3	Supplier	Traditional	outsourcer	Both	Yes	Dependent on OEM	No	National	Failed	No
BIG4	End product manufacturer	Contemporary	market signals	Product	Yes (niche projects – No)	Independent	Yes	National/ international	Yes	Yes
BIG5	Supplier/end product manufacturer	Traditional/ Contemporary	outsourcer and market signals	Both	Yes (niche projects – No)	Dependent (for niche projects – independent)	Yes	National	Yes	Yes
BIG6	Supplier	Traditional/ contemporary	outsourcer and market signals	Both	Yes	Semi-Dependent	Yes	National	Yes	Yes
FA1	Supplier of an affiliated MNE	Traditional/ contemporary	affiliated MNE	Both	Yes	Dependent on headquarter	NA	National	No	No
JV1	Supplier of an affiliated MNE	Traditional/ contemporary	affiliated MNE and firm's own initiative	Both	Yes	Dependent on headquarter	NA	National	Yes	Yes

Almost all interviewers cite the importance of electronics and ICT especially with the developments in electric and autonomous vehicles. Moreover, most technologies related with customer-based tendencies on safety and comfort (such as heating, air-conditioning, entertainment, parking-assistance, ABS and ESP etc.) are predominantly related to electronics. Since customer satisfaction for the adoption of electrical vehicles and the attainment of rage extension targets seemingly increase the probability of substitution of internal combustion engine technologies with electrical engines, electronics could become axial to automobiles.

Turkey seems to have ignored the strong effect of electronics (and ICT) on the national automotive industry. Privatisation policies that emerged after the 1980s weakened the national electronics industry, particularly in hardware and component development. Thus, failure to establish a competitive electronics industry is a missed opportunity for Turkey, which thereby significantly hinders the automotive industry's technology development attempts.

5.3. Foreign dependence on strategic decisions

When the sources and content of R&D activities and decision-making in commercialisation are considered, our findings reveal that Turkish firms are highly dependent on foreign OEMs and JVs. The JV/FA structure in the automotive industry hinders Turkish manufacturers and suppliers from participating in decision-making processes. Firms are unable to participate in design confirmation, regulation and homologation processes.

The supplier industry in Turkey managed to survive in export-oriented market policy regime by merging with foreign firms and/or performing R&D and innovation led by foreign firms and JVs. This helped Turkish firms to survive amidst fierce global competition at the expense of independence on strategic decision-making. JVs took advantage of this structure by gaining R&D capabilities (up to the extent that lead-firms allow). However, the foreign-dependent structure in the industry affects the R&D efforts of the local suppliers. *INT3* summarises the current situation as *"Between 1995 and 2005, in addition to the main industry, the supplier industry integrated with the foreign markets through mergers and acquisitions. This impedes Turkey's presence on decision-making processes of the global automotive industry. R&D efforts have seriously been lowered because both JVs and the supplier industry are based on foreign partners… This situation has inevitably made Turkey dependent upon foreigners."* As discussed in section 5.1, Turkey accepted the delegated manufacturing role rather easily for short-term economic gains that inevitably increased foreign dependence of Turkish firms. As *INT5* argues, *"If you are highly dependent on the JV structure, it is not allowed to make your own R&D. Your innovations remain at the firm-level or at best national level."*

Involving R&D projects of the lead firms and head-quarters could enhance local in-house R&D capabilities. *INT6* presents an example for this. "*In TOFAŞ (JV of FIAT), Doblo was the very first car that was fully designed and manufactured in a JV in Turkey. TUBITAK supports were* *effective in manufacturing the prototype. R&D department in TOFAŞ started up with 10-15 persons and then dramatically increased to 350-400 persons*." The R&D performers, rather than "*dancing with foreign affiliates,*" as *INT3* illustrates, should be involved in comprehensive learning and interactions at an early phase in order to benefit from such commissioned R&D. Fiat Doblo and Ford Transit Connect cases reveal that when manufacturing cooperates with decision-making in design and design confirmation processes and when domestic firms are integrated in the process at a much earlier phase, sophisticated capabilities can be nurtured. Özatağan (2011) shows that for several suppliers in Bursa (central hub of the automotive industry in Turkey), a co-designer phase has created opportunities in the upper segments of GVC. Similarly, Ray and Ray (2011) argue that collaboration in design activities with suppliers in the early phase was important for the success of Nano in India. Lim et al. (2013) further illustrate the role of early phase collaboration for TATA.

Big firms try operating a dual structure; one related to their core areas that generates most revenue (survival) and another where they invest in niche technologies to penetrate into new markets (growth). In the former, the firms, though big, are primarily dependent on OEMs and outsourcers regarding technology production. In the latter, firms are more independent in decision-making. For example, *BIG1,* a design and engineering oriented firm, has developed R&D projects in niche areas such as electrical vehicle components but in their core business (building custom-made automation lines for Turkish JVs and global OEMs), they are highly dependent on foreign partners. Similarly, *BIG4* is rather independent in R&D and innovation decision-making because it works in niche areas that are not driven and guided by global OEMs and that the foreign partner has departed.

When we consider the commercialisation decisions on the performed R&D, the structure does not change. Table 4 shows that almost all firms are either dependent on the OEM or the head-quarter (in the cases of *FA1* and *JV1*) for commercialisation decisions. *INT9* bluntly states, "*Innovative projects are not being developed within the sector. For international projects, innovative ideas are coming from foreign firms and research centers. Main car manufacturers are operating as test-beds of these projects."*

Summarising, most Turkish automotive firms rely on ideas and specs readily available from lead-firms in the GVC that outsource non-core R&D activities. Local firms are not independent in commercialisation decisions even though such R&D activities produce incremental innovations. Firms that rely on market signals and invest in concept design and design confirmation processes are more likely to produce niche product innovations in which they have full authority on commercialisation. This, however, is an exception.

6. Synthesis of results

Table 5 summarises the findings of the analyses. The first column lists statements based on findings. The robustness of each statement is analysed by investigating whether the statements are supported at different levels (project, firm and expert) of analysis. In this manner, firm and expert interviews show within-level and Table 5 shows between-level robustness.

The between-level results indicate extensive learning in the industry being used for establishing excellent manufacturing capabilities. However, for catching-up (or leap-frogging) an IS should be formed based on manufacturing capabilities where the industry can indigenously design, commercialise and sell (radical or niche) new products/processes. Our results show that Turkish automotive industry is predominantly involved in R&D activities on traditional components; conduct applied R&D; invest in incremental (process) innovations; rely on ideas generated by foreign actors and possesses less power in strategic decision-making. Through gains in manufacturing capabilities after 2000, this structure prevailed in R&D and innovation activities. With this portfolio, expecting radical innovations or niche innovative products from the automotive sector is hard.

The delegated role of being a manufacturing centre has resulted in learning and increased capability. However, as our results reveal, the Turkish automotive industry did not succeed in making the next leap towards indigenous capability building in design, R&D and innovation that implies retaliation against delegation. Governments and the industry made strategic mistakes in the process that became the seedbed for middle-technology trap. Strategic policy choices that favoured short-term gains coupled with the acceptance of such choices by the firms fed a home-grown state-industry agreement led the industry to a position from which it is difficult or impossible to recover. It is rather difficult to recover from such a trap given the dual national and international forces that work in the same direction. Weak IS could not nurture and strong automotive GVC inherently prevents such forward leaps.

Complementarities among industries are crucial for the sustainability of the automotive industry. Privatisation attempts in the 1990s especially in the state-led electronics sector was an important strategic mistake, considering the increased convergence of electronics, ICT and automotive. Lacking complementarities coupled with the decision to maintain temporary competitive positions for export revenue and employment, the foreign presence that was crucial for learning gradually became a handicap. Thus, foreign presence initially enhanced technological upgrading. However, this effect decelerated through time and saturated significantly below the frontier. Current dependence structure impedes attempts to form indigenous technological capabilities.

Table 5: Consolidation of results at the project, firm and macro levels

Automotive industry characteristics	Project level data	Firm interviews	Expert interviews
Manufacturing excellence	Hard to observe from the data	Strong support	Strong support
Inclination from process towards product innovation (cost reduction versus product variety)	Increased number of recent projects with process innovation focus	Mostly process innovation but cases of niche product innovations	Mostly process innovation
Inclination towards contemporary technologies	Mostly traditional technologies. Almost no change through time.	Mostly traditional. Some cases of contemporary technologies in niche products	Mostly traditional. Existence of exceptions (niche products)
Existence of basic and experimental R&D	Weak support. Some exceptions.	Weak support. Number of exceptional cases niche products with new technologies.	No support
Existence of domestic local concept design and design confirmation processes	Weak support. No significant differences through time.	No support. Some exceptions.	No support
Independence (from foreigners) in strategic decisions on R&D and innovation	Hard to observe from the data	No support. Some exceptions.	No support. Except cases of transport vehicle companies with niche products
Signs of increased technological sophistication	The project characteristics did not change between two time periods.	Weak support in the case of firms with niche products	Almost no support. There are cases which are by and large exceptions

7. Conclusion

This research shows that on the borders of weak IS and strong GVCs, the Turkish automotive industry has fallen into a middle-technology trap. Our novel research design involves both quantitative and qualitative methods to improve the validity of the findings. The main finding is that the manufacturing capabilities gained over the years have not been translated into innovation capabilities and national and global forces work in the same direction, making indigenous technological and innovation capabilities difficult to form.

We identified three mechanisms explaining middle-technology trap in the Turkish automotive industry. Weak national IS coupled with state-automotive industry agreement favouring short-term economic gains at the expense of forming long-term indigenous technological capabilities left the playing field void, creating scope for increased GVC operations in Turkey. However, as evident from other cases such as Thailand (Petison and Johri, 2008), China (Nam, 2011; 2012), Mexico (Contreras et al., 2012), South Africa (Barnes and Morris, 2004), Central and Eastern Europe (Pavlinek and Zenka, 2011), GVCs seldom care about the local industry unless building local capabilities strengthen the position of lead-firms. Weak IS that lacks complementarities, passive governments and strong GVCs that increased foreign presence all together weakened the bargaining power of the Turkish automotive industry. In its current state, the Turkish automotive industry is an excellent manufacturing centre that fulfils the delegated role. This result is compatible with the findings of Timmer et al. (2019), claiming that Turkey plays a "fabrication only" role in functional specialisation on trade. Furthermore, recent findings suggest that position rather than participation in GVCs determines success in productivity gains and local sourcing (Mantalbano et al., 2018; Amendolagine et al., 2019).

Our research reveals four important lessons for developing countries. First, complementarity among sectors is crucial for long-run sustainability that entails technology production. We show that lack of a strong electronics industry hindered technology development in the automotive industry. Park (2003) argues that capability building in electronics and automotive industries was a combined effort in South Korea and was aggressively supported by the government. Similar complementarities can be found in China (automotive-electronics-IT). Second, firms that can diversify especially in niche products and markets become more independent in terms of R&D, innovation and commercialisation. Our results are comparable to earlier findings on India regarding the importance of niche products and markets for indigenous capability building (D'Costa, 2004; Lim et al., 2013). Third, firm interviews reveal that joint product development in which domestic firms involve in initial stages is not only important for capability building but also for bargaining power over strategic decisions. Motohashi and Yuan (2011) and Ray and Ray (2011) report similar findings for China and India, respectively.

Finally, the findings hint at the difficulty of escaping the middle-technology trap without active government involvement. Several cases are available where governments actively created, governed and restructured the automotive industry. Catalan (2010) argues that early liberalisation attempts in Argentina as opposed to South Korea and Spain were decisive in forming an indigenous automotive sector. A similar story can be found in South Africa (Barnes and Kaplinsky, 2000; Barnes and Morris, 2004). Part of the success in creating indigenous technological capabilities in South Korea and China is due to the state's active regulation and structuring of the industry (Park, 2003; Depner and Bathelt, 2005; Liu and Dicken, 2006; Chu, 2011; Nam, 2012; Hu et al., 2014).

Considering between-sector complementarities, success in producing niche products and penetrating into niche markets, involvement in joint production at an earlier stage and active government policies, a divide between the Latin American and East Asian experience is traced in building indigenous technological capabilities in the automotive sector. Our results show that Turkey resembles to the Latin American case.

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Table A.1: Characteristics of selected firms

Firm	Description of the firm	Category	City	Position of the interviewee
SME1	A domestic design and engineering firm affiliated with the domestically owned midi-bus and military vehicle manufacturer.	SME	Kocaeli	R&D Manager
SME2	A domestically owned clutch procurer for automobiles and buses.	SME	İzmir	R&D Manager
SME3	A domestically owned brake components manufacturer for the global brands under foreign license.	SME	İzmir	R&D Manager
SME4	A domestically owned front/rear axle procurer for global OEMs.	SME	Bursa	R&D Manager
SME5	A domestically owned procurer manufacturing plastic assembly parts for automobiles.	SME	Bursa	Vice Manager
BIG1	A reputable company specialized in automation and installing robotics on mass production lines in JVs.	Big Enterprise	Kocaeli	Vice Manager
BIG2	A reputable domestically owned spring supplier for heavy vehicle OEMs.	Big Enterprise	Manisa	R&D Manager
BIG3	A domestically owned supplier for global heavy vehicle manufacturers that operates in a niche market.	Big Enterprise	İzmir	R&D Manager
BIG4	A renowned accumulator and battery producer that is operating worldwide. (former shareholder was foreign).	Big Enterprise	Manisa	R&D Manager
BIG5	A domestically owned tractor, customised automobile, wagon parts and heavy parts manufacturer.	Big Enterprise	Eskişehir	R&D Manager
BIG6	A globally owned domestic cord fabric manufacturer for international tire brands.	Big enterprise	Kocaeli	R&D Manager
FA1	A foreign-affiliate of a renowned bus manufacturer.	Foreign Affiliate	Ankara	R&D Manager
JV1	A joint venture, which is a sub-branch of a globally renowned automobile manufacturer.	Joint Venture	Bursa	R&D Manager

Table A.2: Expert characteristics

Interviewee	Title	Firm/Institution	Rationale behind selection
INT1	General Manager	University test/homologation centre	Highly qualified expert
INT2	General Secretary	An umbrella organization	Experienced and well-known in the auto industry
IINT3	General Manager	An R&D design/engineering firm affiliated with an OEM.	Experienced specialist in the auto industry.
INT4	R&D Director	A JV in Turkey	Specialized experience in automotive R&D
INT5	Technology Consultant	Former R&D director of a bus manufacturer	Experience in automotive industry, entrepreneur and consultant
INT6	Professor	Former R&D director and an academic member in a university	One of the first R&D managers in Turkish automotive industry
INT7	R&D Director	R&D director in a Turkish manufacturer	Experienced specialist in the auto industry.
INT8	Technology consultant and specialist	Former senior expert in R&D funding, Automotive Specialist, Technology Policy Maker	Respected in the automotive industry; former policy-maker of the very first R&D grant program
INT9	General Manager	Former manager in an EU program, General Manager in a consulting firm	Specialized in networking and clustering.
INT10	General Secretary	Technology specialist, business developer, General Secretary in a former R&D-funding institution	Possession of wide array of knowledge and vision about several sectors and technologies
INT11	Former Board President	The founder of one of the first R&D departments in electronics in Turkey	Expert in a complementary sector to automotive
INT12	General Manager	Manager in an automotive procurer	Experienced in auto supplier industry
INT13	Vice Manager	Financial manager in an engineering firm	Experienced professional in the automotive industry
INT14	Former General Coordinator	An umbrella organization of Turkish Automotive Suppliers	Experienced professional in the supplier industry

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