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DRIVERS, INSTRUMENTS AND CHALLENGES OF KNOWLEDGE AND TECHNOLOGY TRANSFER IN THE AUTOMOTIVE SECTOR

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Abstract. This study comprehensively analyzes the drivers, instruments, and challenges that facilitate knowledge and technology transfer (KTT) in the automotive sector. The review was conducted with a focus on the regions of the Czech Republic and the German Free State of Saxony. It examines the evolving landscape of the automotive industry from a KTT perspective, driven by motivators of the three key stakeholders: government, academia, and the industry. The study explores how KTT expedites the adoption of safer, cleaner, more economical, and sustainable technologies in this sector. Key instruments from KTT intermediaries are highlighted, and their challenges and obstacles are discussed. A best practice case study involving the interplay of the three stakeholders is presented.

Keywords: Knowledge and technology transfer, automotive, innovation ecosystem.

1. Introduction

The automotive industry is undergoing a multifaceted transformation driven by various factors reshaping the future of transportation. The growing need for ecological practices, stemming from initiatives like the European Green Deal [1], in combination with the increasing integration of high-tech solutions in vehicles, is driving this change. The European Green Deal and country-specific regulations seek to bring a paradigm shift in vehicle driving. By 2050, Europe aims to be the first carbon-neutral region where green sources power vehicles. For this transition, large-scale research and development (R&D) initiatives involving equivalent investments are necessary to find technical solutions. Therefore, knowledge and technology transfer (KTT) instruments are crucial in effectively transferring innovation investments into the market.

While R&D in the automotive sector is trending from hardware innovation toward software innovation, an increasingly interdisciplinary approach to technology development is evident. High-tech innovations like advanced sensor technology are crucial in enhancing safety and enabling features like collision avoidance, adaptive cruise control, and autonomous emergency braking systems. Concepts like artificial intelligence (AI), the Internet of Things (IoT), augmented reality (AR), and 3D printing include a much more diverse set of skills than the traditional car manufacturer.

KTT can facilitate the exchange of knowledge and innovations between research institutions, universities, and the industry, enabling the swift adoption of cleaner and more sustainable technologies. The transfer can expedite the development of electric and hydrogen-powered vehicles, sophisticated sensor systems, autonomous driving capabilities, and more. Moreover, KTT can help bridge the gap between research breakthroughs and practical applications, leading to safer, more efficient, and eco-friendly vehicles for the future.

What are the triggers, instruments, and concepts driving KTT, and what obstacles are encountered in the process? The following study examines these questions with a focus on the region of the Czech Republic and the German Free State of Saxony (Saxony), neighboring regions both prominent in car manufacturing. This study aims to encourage scientists involved in R&D for the automotive sector to understand better the concept of transfer, government strategies, and the possibilities for transferring innovation to the market.

The current state of knowledge shows that KTT plays an essential role in the innovativeness of a country and its efficient use of resources, leading to economic success. KTT's role is to share the resources spent within academia, resulting in know-how that serves the socio-economic well-being. It includes both science and personnel transfer. Whereas science transfer implies the transfer of new results in some form of IP rights, personnel transfer implies the exchange of staff with tacit knowledge [2]. KTT serves mainly to generate innovation for small-medium enterprises (SME) that need to be able to invest resources into R&D, thus gaining a competitive advantage for their enterprise. However, large corporations have also found value in outsourcing research, hence utilizing resources more efficiently and involving KTT.

KTT takes place in various forms, on various levels, and in various organizations. According to Reinhard and Schmalholz, KTT occurs not only between producers and users of knowledge and technology in direct exchange but also through indirect exchange using transfer agents [3]. A transfer agent or intermediary is close to the research institute or the industry partner (see Figure 1). Considered an incomplete model, the author has adapted it by adding the government

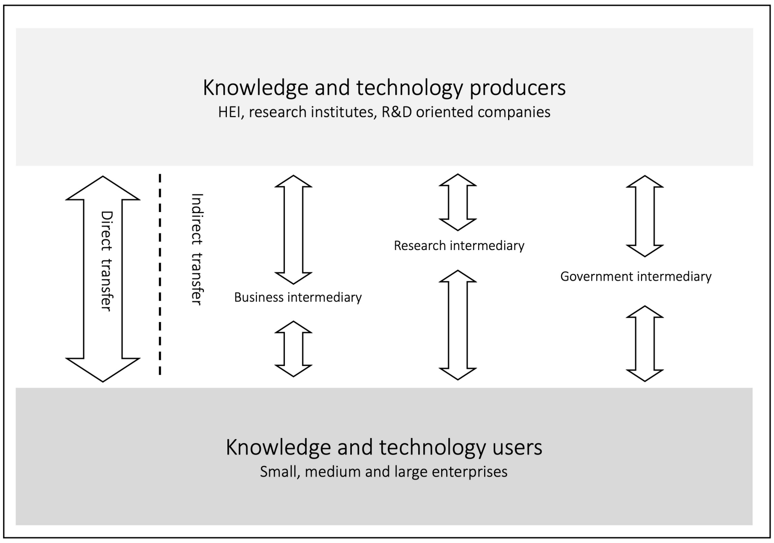

Figure 1. KTT transfer model involving direct and indirect transfer.

as a KTT intermediary. Government initiatives involving the transfer between academia and industry are widely used, whether on a European, national, or regional level.

The triple-helix theory outlines a collaborative innovation approach involving interactions among the key stakeholders, government, academia, and industry. This theory postulates that various levels of cooperation can occur between any two or all three stakeholders, often depicted by partially overlapping circles representing the areas of collaboration [4]. The same is evident in the model shown in Figure 1.

2. Materials and methods

This research follows a quantitative approach, leveraging scientific resources for a literature review and online resources for data acquisition. The literature review aims to synthesize the existing knowledge and provide insights into the concepts of KTT within the automotive sector.

Firstly, the drivers of KTT are laid out based on the three stakeholders: academia, industry, and government. Secondly, the research delves into investigating KTT instruments at various levels: national, regional, and institutional. This exploration extends to the Czech Republic and Saxony, facilitating a comparative analysis of the findings. By examining the diverse instruments and approaches employed in these regions, this research identifies variations, similarities, and the effectiveness of KTT strategies. Finally, specific challenges are highlighted.

The outcomes of this analysis are contextualized within the automotive sector, shedding light on their relevance and implications for the industry. Through this examination, the research strives to draw meaningful conclusions and offer valuable insights into the evolving landscape of KTT within the automotive sector.

3. Results

KTT is pivotal in driving innovation, improving competitiveness, and ensuring sustainable growth in the automotive industry. It involves exchanging knowledge, innovations, and technologies between research institutions, universities, and the automotive sector. The following sections will provide an overview resulting from an extensive review of the concepts of KTT, the critical drivers of KTT in the automotive sector, KTT's approach in the Czech Republic and Saxony regions, and a best practice example.

3.1. Drivers of KTT

As in other industry sectors, technology transfer in the automotive industry is driven by various factors and incentives. Key drivers for technology transfer in automotive involve the three stakeholder groups mentioned in the introduction. Firstly, government drivers for KTT encompass identifying strategic areas of economic specialization, establishing conducive regulatory frameworks for innovation, and providing incentives.

- National smart specialization strategy: The European Union (EU) requires the implementation of a National RIS3 Strategy, the Regional Research and Innovation Strategies for Smart Specialization, for all EU member states (for purposes of the funding periods). The National RIS3 Strategy is a framework designed to guide research and innovation activities to enhance a country's or region's competitiveness and sustainable development [5]. During the current funding period (2021–2027), the Czech Republic's RIS3 focus areas include
    a) photonics and micro-/nano-electronics,
    b) advanced materials and nanotechnology,
    c) biotechnology,
    d) advanced manufacturing technologies,

Governmental	Czech Republic	Saxony (Germany)
	National Level	**National Level**
Legal framework	ACT No. 130/2002 Coll. (Support of Research and Development from Public Funds)	Higher Education Act (HochschulG) Research Framework Act (Forschungsrahmengesetz) Innovation Act (Innovationsgesetz) Patent Act (PatentG) Trademark Act (MarkenG) Copyright Act (Urheberrechtsgesetz)
Government agencies/initiatives	Technologická agentura České republiky (TAČR – Funding agency for applied research) Grantová agentura České republiky (GAČR – Funding agency for basic research) Czechinvest (incl. CzechAccelerator, CzechStartup) Agentura pro Podnikání a Inovace (API – Business and Innovation Agency) Transfera (partnership platform for KTT) Technologické Centrum Praha (TCP) Various regional centres	Federal agencies • SPRIND – agency for disruptive technologies • DATI – agile innovation agency **Regional LEVEL** State agencies • Sächsische Aufbaubank (SAB – development bank) • FuturSax (innovation platform) • Technologiegründerfonds Sachsen (seed-investors)
Innovation council	Rada pro výzkum, vývoj a inovace	Innovationsbeirat Sachsen
Innovation strategies	Czech Republic – Innovation Strategy (2019–2030)	Innovationsstrategie des Freistaates Sachsen

Table 1. Governmental KTT instruments.

e) artificial Intelligence,

f) digital security and connectivity [6].

In Germany, the federal states focus on individual specializations. In Saxony, the focus lies on

a) environment,

b) raw materials,

c) digitalization,

d) energy,

e) mobility,

and f) healthcare [7].

In both cases, parts of the specializations can be directly translated to the automotive sector, indicating the high importance to the region (Czech Republic: a), b), d), e), f); Saxony: a), b), c), d), and e).

- Regulatory compliance: Stringent environmental and safety regulations, such as emissions standards and safety requirements emerging from national or EU strategies, drive the automotive industry to adopt new technologies to comply with legal mandates. The European Green Deal, also referred to as the Green Industrial Revolution, employs legally binding climate targets that call for the elimination of CO_2 emissions by 2050 [1]. This EU climate law fosters innovation and hence drives research, development, and innovation (R&D&I) [8] in areas such as automotive, aerospace, energy, construction, and manufacturing [1]. These regulations effectively promote the transfer of innovative sustainable technologies, such as electric vehicles (EV) and fuel cell electric vehicles (FCEV), replacing those with combustion engines. From 2035, no new cars fueled with fossil fuels may be registered in the EU (except for combustion engines for e-fuels). It presents an essential catalyst for innovation and transfer.
- Government funding and incentives: For local and national governments to achieve goals of their innovation strategies and their RIS3 goals, programs for research funding, tax incentives, and subventions are employed. These incentives motivate and support technology transfer projects, among others, in the automotive industry while encouraging innovation and economic growth. While funding derives from various ministries, some government agencies further enhance fund formulation, administration, and distribution. See Table 1 for governmental KTT instruments.

Drivers for KTT	Czech Republic	Saxony (Germany)
Government drivers		
RIS3 (2021–2027)	a) photonics and micro-/nano-electronics b) advanced materials and nanotechnology d) advanced manufacturing technologies e) artificial intelligence f) digital security and connectivity	a) environment b) raw materials c) digitalization d) energy e) mobility
Regulatory compliance	EU member states are required to translate the European Green Deal into national legislation while enforcing the elimination of emissions among others in vehicles and fostering R&D&I.	
Funding and incentives	European, as well as national and regional government incentive programs provide research funding, tax incentives, and subventions. Specific (government) agencies are established in support.	
Academic drivers		
Applicable innovation	KTT strategies, KTTOs, Centre of competencies, UIC	
Commercial income	IP generation, support for start-ups and spin-outs, contract research	
Resource sharing	Joint research centers	
Industry drivers		
Competitive advantage	Access to state-of-the-art technologies and latest research	
Access to talent	Access to graduates and experienced researchers, dual study programs (Germany)	
Cost reduction	Reduce company R&D costs and enhance profitability	
Risk mitigation	Share financial and technical risks through collaboration	
Securing supply chains	Build supply chains involving local R&D and local sourcing	

Table 2. Drivers of KTT in automotive.

The academic drivers of KTT can be explained through the university's third mission, which is the university's involvement in the socio-economic development of society. According to Compagnucci and Spigarelli, the third mission "is currently both the most crucial mission and that which most requires innovation in the organization of universities" [9]. It highlights the importance of integrating strategies and systems for commercializing inventions within publicly funded research organizations. Entrepreneurial quality presents a new skill set for academic staff. The following vital drivers for KTT are laid out here and summarized in Table 2:

- Applicable innovation through research: With academia in need of engaging in the socio-economic contribution of society, the transfer of knowledge and technology for commercial purposes has become a strategic goal. Most research institutions and universities include the aspect of KTT in their organizational strategies and establish dedicated knowledge and technology transfer offices (KTTO) to promote and support projects for transfer. Collaboration with the automotive sector allows these institutions to bring their innovations to market, benefiting both parties. Examples are manifold. At Czech Technical University (CTU), for instance, the Centre of Vehicles for Sustainable Mobility, a competence center, focuses on collaborative research with national and international partners from the applied sphere around sustainable mobility [10]. This is an example of effective university-industry collaboration (UIC), a preferred tool for long-term KTT collaboration. As a result, the effectiveness of KTTOs plays a pivotal role in the success of an institution's KTT implementation.
- Sources for commercial income: As higher education institutions (HEIs) face growing pressure to generate revenue from research, creating intellectual property (IP) such as patents can open avenues for commercialization through licensing agreements or establishing start-ups and spin-offs, hence leveraging institutionally developed IP. The exploitation of IP presents challenges for most universities in terms of costs and marketing, and only small portions of the generated IP tend to be successfully commercialized. Another form of income is presented through contract research, where companies or other organizations commission research institutions, such as universities, to carry out R&D on their behalf or in collaboration for a fee.
- Resource sharing: Research institutions and the industry, particularly SMEs, often lack the resources for large-scale technology commercialization. Collaboration and sharing of resources provide access to broader resources, including funding, facilities, and expertise, leading to more efficient transfer. One example is the AIM.Lab, an artificial intelligence laboratory between Škoda Auto and the Technical

University of Ostrava (2021). The collaboration will focus on data analysis, machine learning and AI applications, and optimization challenges in industrial practice while combining theory and practice [11].

Industry drivers for KTT are manifold and driven by an organization's competitiveness and economic growth. The following represent key industry motivators.

- Competitive advantage: Staying competitive in the automotive market is a strong motivator for KTT in the industry. Companies aim to enhance their competitive advantage by incorporating state-of-the-art technologies developed through collaborations with HEIs. This collaboration grants them access to new and innovative technologies, including advancements in electric and autonomous vehicles. Every fourth European electric vehicle is made in Saxony [12]. Research collaborations are essential for the automotive producers and suppliers of this region to stay ahead of this trend.
- Access to talent: With the increasing implementation of complex technologies in car manufacturing, the industry requires access to a highly skilled workforce. Transfer of tacit knowledge from academia to the industry is essential. Collaborating with educational institutions provides access to talented graduates and experienced researchers who can contribute to technological advancements. A popular concept in Germany is the dual study programs. The Westsächsische Hochschule Zwickau (WHZ) offers higher education in cooperation with industry partners, where students learn about vehicle technology in theory and practice. The automotive industry has immediate access to a pool of trained graduates.
- Cost reduction: Technology transfer can lead to cost savings, particularly in companies needing R&D activities. KTT allows for a more economical and timely adoption of more efficient manufacturing processes, materials, and systems compared to involving own R&D activities. KTT can, therefore, enhance a company's profitability and market position.
- Risk mitigation: Technology transfer further allows companies to share the risks associated with R&D by cooperating with experienced scientists from research institutions while utilizing grants in the form of public funding. This situation is particularly true for SMEs who may otherwise not invest in R&D due to financial and technical risks and the need for more human resources. Collaborative projects with external partners can distribute financial, technical, and human risks.
- Securing supply chains: Stable supply chains and good relations with suppliers are vital in automotive manufacturing as the sector depends on logistical systems, including just-in-time delivery. Suppliers often play a crucial role in technology transfer by providing automotive manufacturers with specialized components, materials, and systems. Collaborative relationships facilitate knowledge sharing and innovation. For instance, the increasing integration of semiconductor technology in vehicles is transforming the automotive industry because it places a high dependency on it. Keeping R&D and production within the region helps eliminate the risk of losing access to the technology and the supply (i.e., through financial crisis, energy crisis, political unrest, pandemic). The recently enacted European Chips Act (September 21st, 2023) [13] plays a vital role in protecting and strengthening the European chip industry and several dependent industries, such as the automotive sector.

These drivers interact to shape the landscape of KTT in the automotive sector, promoting collaboration between academia, other research institutions, and the automotive industry. Governments find incentives to foster collaboration further. KTT not only accelerates innovation but also addresses key challenges facing the automotive sector (see Section 3.3).

3.2. KTT instruments in the regions

The study has researched the governmental and institutional KTT instruments, summarized in Tables 1 and 3. The instruments are compared between the Czech and Saxon regions and are categorized. Table 1 classifies the instruments into four sections: legal framework, innovation council, innovation strategy, and government agencies and initiatives. The institutions' instruments include the categories of KTTOs, special purpose vehicles (SPV) or venture capital (VC) funds of the institutions, and joint innovation centers.

While both regions prove a legal framework around R&D, the German framework seems more fragmented and widespread than the Czech approach. The Czech Ministry of Science is currently making efforts to amend its act to remedy the shortcomings of transfer and innovation support [14]. Both regions have implemented an innovation council of experts to advise the government on R&D&I. The Czech Council meets more frequently than the Saxon Council (monthly vs. bi-annually). The innovation strategies are clearly defined, yet a change in government in the Czech Republic may impose modifications (i.e., total investment in R&D). The government agencies and initiatives are multifaceted and range from funding or grant agencies to start-up advisories, from transfer centers to innovation centers. Notable is Germany's and Saxony's increasing focus on providing seed funding instruments. This is currently lacking in the Czech Republic.

On an institutional level, research shows that institutions related to technical studies have some transfer activities in the form of a dedicated department (KTTO). Table 3 highlights some key transfer offices

Institutional	Czech Republic	Saxony (Germany)
KTTOs incl. incubators and accelerators *(all university and non-university institutions have some kind of KTTO with various functions)*	CeTAV (Transfer Center at the Czech Academy of Science) Centre for Knowledge and Technology Transfer at Charles University CTT (Centre for Technology Transfer at CTU) *and others*	TUD|Excite – patents (IP advisor), innovate (transfer support), start-up (student/research advisor), talents (transfer education), Futurelab (R&I in tech transfer/entrepreneurship), facilitate (process optimization) TUC Transfer Office Technology Transfer Office at University of Leipzig
SPVs as investment vehicles and institutional venture capital funding	Institute of Organic Chemistry and Biochemistry of the CAS – IOCB tech s.r.o., I&I, I&I Biotech Fund Charles University Innovations Prague a.s. (CUIP) CVUT tech s.r.o. (CTU)	TUDAG (TU Dresden Aktiengesellschaft) TUCED (An-Institut für Transfer and Weiterbildung)
Joint innovation centres	South Moravian Innovation Centre (JIC) Moravian-Silesian Innovation Centre (MSIC)	Dresden I exists Saxeed SMILE

Table 3. Institutional KTT instruments.

that prove important concepts or are currently developing new strategies. Only some institutions established specific SPVs to ease the bureaucracy behind the institutional transfer, encourage the institutions' involvement in spin-offs, and improve their benefit from license agreements. Synergies are realized in several joint innovation and transfer centers, mainly initiated by universities, and include the collaboration between various institutions and, in some cases, the regional government.

3.3. Challenges of KTT in the automotive sector

KTT unfolds across both inter-organizational and intra-organizational dimensions [15]. Inter-organizational progresses through distinct developmental stages, transitioning from basic research to applied research, collaboration between academia and the industry, and ultimately finding practical applications in the market. This process is evident in the journey of knowledge transfer, where knowledge originating from academic research evolves into tangible market applications. Conversely, intra-organizational transfer characterizes knowledge and technology movement within a single organization from one unit, entity, or context to another. An illustrative example is transferring knowledge and expertise in electromobility from the Volkswagen concern as the mother company to Škoda Auto, its daughter company. This internal knowledge dissemination facilitates the seamless integration of insights and advancements across different segments within the organization, fostering collaborative growth and innovation.

While there are many motivators and instruments to support transfer on various levels, several challenges exist. Common challenges of KTT experienced by various industry sectors include the need for more motivation for researchers to act as entrepreneurs, the lack of skilled KTT professionals, and the unclear legislation around transfer [16]. Valid challenges experienced from the side of academia or public research institutions include the ability to detect suitable transfer partners from the applied sphere, for researchers to pinpoint technologies needed by the market, and for the institutes to turn around transfer agreements timely [17]. The following highlights essential issues experienced in the KTT process in automotive and similar industry sectors.

The automotive sector is defined by a high set of complex technologies involving an increasing number of new technologies. Key systems include advanced driver assistance systems (ADAS), connected cars, in-car entertainment (ICE), augmented reality (AR), self-driving cars, EVs, FCEVs, and more. Today, the average car consumes 1 400 to 1 500 integrated circuits (IC) and the so-called semiconductor chips, and some cars even require up to 3 000 [18]. It shows that the car manufacturing industry depends on many different skills, suppliers, and innovations. Incorporating cutting-edge technologies into an existing complex technological system presents a significant challenge. The balance between innovation and compatibility demands a multidimensional approach encompassing technical expertise, strategic planning, stakeholder collaboration, and a commitment to fostering a dynamic and adaptive technological ecosystem.

The need for infrastructure for game-changing technologies faces challenges. Amidst a wave of disruptive technological shifts, most notably the transition from combustion engine vehicles to EVs and FCEVs, a significant challenge emerged: the need for adequate infrastructure, in this case, charging or fueling stations. Initially encouraged by government incentives (i.e., through financial motivators for manufacturers and consumers) and subsequently enforced through regulations, the transition from conventional combustion engines posed a complex dilemma for global car manufacturers. They needed intensive research while selecting the most viable technology to resonate with a broader market audience. As evidence shows, the transition to EVs has so far outperformed FCEVs. The number of public electric charging stations (Czech Republic 1 710 [19]; Saxony 2 023 [20] as of November 16th, 2023) is significantly higher than that of fuel stations for hydrogen (Czech Republic 1; Saxony 3 as of September 16th, 2023 [21]). The number of registered vehicles in the EV and FCEV categories reflects the same. The initial market entry of EVs coincided with less advanced FCEV technology, leading to greater government support and infrastructure development for EVs. The KTT process for game-changing technologies faces the challenge of balancing the readiness of alternative technologies and their market potential with the level of government support. While the transition from combustion to electric vehicles appears to be the preferred path, research into fuel cell technology continues, as evidenced by "The Czech Republic's hydrogen strategy" [22] and the "Wasserstoffstrategie Sachsen" [22]. If FCEVs are to be adopted in more significant numbers, strong incentives, as seen with EVs, will be necessary to establish a robust infrastructure.

Regarding KTT efforts requiring fundamental changes in systems, the need for acceptance through regulatory frameworks and industry safety standards demonstrates notable challenges. Lawmakers face challenges keeping up with the rapid pace of technological change. Many laws become outdated as new technologies emerge, rendering even recently enacted laws obsolete. The slow pace of lawmaking further complicates the issue, as legislation often lags behind technological advancements. As a result, lawmakers struggle to address the evolving legal landscape effectively [23].

An example of tackling the challenge of adopting new technologies can be evidenced in autonomous driving. With the ambition to play a lead role in adopting autonomous driving, Germany was the first in the EU to accept legislative changes. The draft bill "to amend the Road Traffic Act and the Compulsory Insurance Act – Act on Autonomous Driving" (19/27439) was accepted on May 20th, 2021 [24], giving the green light to autonomous driving in Germany. The Society of Automobile Engineers (SAE), an automotive standardization body, defines six levels of autonomous driving, laying out a framework for "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles" [25]. Germany has been the first to adopt level 3 within Europe. EU regulations on autonomous driving are anchored in Regulation (EU) 2019/2144 of the European Parliament and the Council [26].

3.4. KTT in automotive – The case of Silicon Saxony

In light of the modern automotive industry's profound reliance on IC supply, the recent global supply chain disruptions and Europe's surging IC demand underscore the urgent need to establish a robust development and manufacturing ecosystem for semiconductors within the European economy. This endeavor necessitates both geographical proximity and a well-trained workforce. Today, Silicon Saxony is Europe's largest microelectronics cluster. Today, every third chip in Europe is made in one of the four fabs in Saxony [27].

Why this ecosystem has evolved in and around Dresden was no coincidence. During the GDR (German Democratic Republic) times, the state-owned company Robotron pioneered microelectronics-producing computer technology. After the fall of communism in 1989/90, the microelectronics industry in Saxony faced significant challenges. Many companies had to reorient themselves or were closed down. To promote the industry, the Saxon state government responded with a series of measures by introducing subsidies, tax breaks, and investment in R&D. These measures led to a successful relaunch of the microelectronics industry in Saxony. In the 1990s, new companies, including Infineon, US-based, and AMD (later GlobalFoundries), settled in the region. Today, 3 650 companies involved in microelectronics employ ca. 76 000 people in Saxony [28]. The industry contributes around 11.5 billion EUR to Saxony's gross domestic product [25].

Nevertheless, this is not all. Current expansion plans for most existing fabs are underway, while the Taiwanese semiconductor TSMC is finalizing plans to start the construction of a 10 billion EUR investment on the outskirts of Dresden [29]. TSMC's launch in Germany is subsidized by the federal and state governments, making it attractive for the Taiwanese investor to take this step. This news has triggered global attention and further interest in the region. To satisfy the increasing demand for skilled labor, an educational center for microelectronics, namely the Sächsischen Ausbildungszentrum für Mikrotechnologie (SAM), is planned to be supported by the chip industry and financially by the state [30]. Knowledge transfer will take place from the companies and research centers to the trainees and then back into the industry. Furthermore, agreements were concluded to train Saxon students in Taiwan through TSMC to bridge the talent gap in Saxony [31].

Underscoring the critical need for a stable supply of semiconductors manufactured within Europe and continued investment in R&D of chips, Saxony has joined forces with 26 other regions from 12 EU member states to form the European Semiconductor Regions Alliance (ESRA) in 2023 [32].

Silicon Saxony's success can be attributed to four key factors involving the three pivotal stakeholders: industry, government, and academia. Firstly, the region benefits from a well-established research landscape comprising excellent university research, non-university research, and research-focused companies actively engaged in R&D&I of microelectronics and semiconductor technologies. The practice of KTT, from research to industry, propels advancements. Secondly, Silicon Saxony boasts a highly skilled workforce with a profound understanding of microelectronics and semiconductor manufacturing. This expertise has played a vital role in attracting global companies and positioning the region as a center of excellence. The offerings from universities, colleges, and vocational training centers significantly contribute to nurturing this skilled labor pool. Thirdly, government support has been instrumental in fostering and accelerating the development of the semiconductor industry in Saxony. This support has created a favorable environment for innovation and business development through programs and incentives provided by regional and federal governments. Lastly, close collaboration among industry partners has been a critical driver of success in Silicon Saxony. Companies, research institutions, and government agencies have collaborated closely, sharing knowledge, developing technologies, and collectively addressing challenges.

The lessons for the automotive industry are evident. As the demand for advanced technologies in this sector continues to surge, Silicon Saxony remains a driving force in shaping the future of mobility in the region and beyond. Contributions to smart and connected vehicles, energy-efficient semiconductor components, battery management systems, and R&D in artificial intelligence and sensor technologies are clear examples of how Silicon Saxony is propelling the advancement of mobility. The success of this high-tech cluster serves as a testament to the critical role of innovation ecosystems in fostering economic growth and technological advancement. Silicon Saxony stands as a model for how collaborative efforts among industry, government, and academia can create a thriving environment that attracts global players and contributes significantly to the technological evolution of key industries, such as automotive.

4. Discussion

Many consider KTT to be a process between academia and the industry. Looking at the example of the automotive industry, it becomes evident that the government also plays a significant role. In the complex and technology-intensive automotive industry, the collaboration between academia, industry, and government is essential for fostering innovation, achieving sustainable growth, and maintaining a competitive position. KTT plays a pivotal role in bridging the gap between research, regulation, and commercialization, enabling the translation of cutting-edge technologies into viable products and services. Regulatory frameworks play a significant part in shaping the KTT landscape in the automotive sector. Governments are responsible for establishing clear and supportive policies that encourage innovation, protect intellectual property, and promote responsible technology development. Such frameworks include defining the scope of public funding, establishing guidelines for using new technologies, and implementing measures to address global challenges such as climate change. Government intervention can significantly accelerate the adoption of new technologies and expedite the transition from one technological paradigm to another. However, it is essential to balance government involvement and market forces. Overly prescriptive regulations or excessive government funding can also stifle innovation, while a laissez-faire approach may fail to address market failures and societal needs. In the case of the extensive support for EVs, the push for FCEV, possibly the more sustainable solution, may have suffered.

To maximize the impact of KTT initiatives, governments should focus on supporting large-scale, high-impact projects that align with their national and regional development strategies. These projects should address critical societal challenges and aim to generate significant economic returns.

The review of government KTT instruments in the two regions has shown various similarities. The main difference can be seen in Germany, where state-initiated venture capital funds provide access to seed funding. It seems a valuable tool to overcome the need for initial funding for high-potential projects. Breaking down administrative and financial barriers through bridging funding for institutional or joint (institution and industry) R&D projects helps encourage researchers to remain involved until market launch. The so-called project hopping, which derives from the ongoing need to secure recurring funding, placing close-to-completion projects in the draw, is a pattern often seen within academia. This leaves an unknown number of promising projects to be unexploited. This situation needs to be tackled through proper measures, such as innovative and sustainable public funding tools.

One instrument proven helpful is the foundation of SPVs of universities, which break down the administrative barriers for transfer projects and, at the same time, allow the university to maintain a role and, therefore, responsibility within the transfer projects. Often, the administrative burden in spin-outs can, in this case, be assigned to the university KTTOs, allowing the researchers and entrepreneurs to focus on the technology and the preparation of market entry.

While governments play a vital role in promoting KTT, transfer effectiveness depends on the capabilities and efficiencies of the institutions and organizations involved. The level of research should be aligned with the level of transfer. For instance, excellence in research requires excellence in transfer. However, not every KTTO must be equipped to produce the next unicorn. Instead, KTTOs should focus on their core competencies and effectively transfer knowledge and technology to support innovation within the scope of their institution's strategy. While some KTTOs may have the resources and expertise to identify and nurture high-potential start-ups, others may be better suited to facilitating collaborations between academia and industry, providing training and support for SMEs, or promoting regional innovation ecosystems. The success of a KTTO should not be solely measured by its ability to produce high-valued start-ups but rather by its overall contribution to the advancement of knowledge and technology and the transfer of innovative products, services, and processes. This is an impact that is hard to measure and serves as a topic for further research.

The identified key KTT challenges for the automotive sector include the technology change in complex technological systems, the lack of infrastructure for game-changing technologies, and the need for changes in legislation. While the compatibility of technology is considered an issue between the academic and industrial stakeholders, challenges related to infrastructure and legislation require the involvement of the government. While time to market is of high importance in the high-tech sector, these two barriers hinder the fast adoption, and the government will need to act on the importance of time.

The strategic inter-organizational transfer in automotive companies tends to flow from the home base to production sites abroad. In the case of Volkswagen, there are several reasons why it was chosen to transfer technology for EVs initially in its home market. Firstly, the company has a strong base of engineering expertise in Germany and is able to realize the transition of technologies. Secondly, the German market is the largest automotive market in Europe, with a high potential for the adoption of EVs. Thirdly, the German government has created mechanisms to support the development of EVs and incentivize the purchase of EVs so that a critical mass of EVs can enter the market. The focus on new technologies will likely flow from the strong automotive countries with government support to those with less of an automotive lobby. Therefore, countries with a high automotive dependence will likely implement more robust KTT mechanisms for relevant technologies and know-how, and others will follow.

5. Conclusion

Europe, including Germany and the Czech Republic as automotive nations, has a solid economic and social dependency on the automotive sector. With increasing international competition advancing in the ongoing fundamental changes in mobility, Europe aims to remain in a leading competitive position. KTT is essential for staying ahead of the curve, yet the right motivators and instruments need to be in place for a successful transfer process. Drivers include the framework for the transfer on the governmental level, containing national smart specialization strategies, innovation strategies, and public funding programs tailored to the needs of the country's strategies. Further drivers include government agencies carrying out transfer strategies and laying the basis of a legal framework that enforces and administers these acts. On an academic level, the focus lies on aligning institutional strategies with those for transfer while building transfer capacities. This includes placing new technologies within the applied sphere, establishing infrastructure such as KTTOs, combining legal skills, mediation, advising, and more to foster collaboration between industry and science. Innovation agencies deriving from academia and seeking to foster entrepreneurship are finding synergies as they combine efforts from various institutions in geographic proximity.

The challenges of KKT are manifold. Those key challenges specific to the automotive industry include enforcing a technology change in complex technological systems requiring harmonized systems integration. The lack of infrastructure for game-changing technologies, as seen in the initial state of EVs, requires the contribution of corporate and government investment to expedite the process and reduce the business risk for companies. With new inventions, such as autonomous driving, legislation will require fundamental changes, challenging the transferrable knowledge or technology entering the market. Also, the human factor plays a role in the available expertise to carry out the full spectrum of the transfer. Clearly defined focus areas are crucial for R&D&I success. Of equal importance is the need for collaboration among different stakeholders, interdisciplinary actors, and international partners.

As seen in the case of Silicon Saxony, a significant contributor to the automotive industry in Europe and abroad, collaboration among industry, government, and academia helps embed a long-term ecosystem combining R&D activities, education of skilled labor, attracting foreign investment, and securing a stable supply of parts for the automotive industry.

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