CHAPTER 11

THE LANDSCAPE ANALYSES OF SEMICONDUCTOR RESEARCH TRENDS OF MIDDLE POWERS: MAPPING THE COLLABORATION NETWORKS OF JAPAN, SOUTH KOREA, TÜRKİYE, AND MALAYSIA

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Abstract

The semiconductor industry is at the heart of core case studies related to the understanding of broader dynamics of technological developments and international competition in the 21st century. Much has been written about the superpower rivalry between the United States (US) and China, but this chapter highlights significant and growing contributions from middle powers in research, development, and production of semiconductors. This chapter compares the changing role of middle powers in the global semiconductor industry, drawing examples from Japan, South Korea, Türkiye, and Malaysia. The book chapter makes a comparative analysis of research output, patent data, policy initiatives, and industry development in the countries under study and their respective positions. Also, the chapter makes a deeper analysis of Türkiye's semiconductor research and development efforts. The results suggest diversified strategies and capacities of the established middle powers, Japan and South Korea, compared to the emerging middle powers, Türkiye and Malaysia. In this research, network analysis is used to map patterns of international collaboration and to identify nodes of influence within global semiconductor research and innovation networks. Our results reveal significant differences between well-established middle powers, such as Japan and South Korea, and emerging ones like Türkiye and Malaysia. Japan and South Korea have strong research output and are leaders in patent applications in semiconductor production. While their research impact is relatively much lower, Türkiye and Malaysia are building emerging strengths. Much of the work in Türkiye aims toward defense and strategic applications. In Malaysia, an existing position in semiconductor assembly provides the opportunity for moving up the value chain. In terms of publications, the output of both countries increased linearly since the beginning of the 2000s. In terms of patent applications, Japanese and South Korean companies dominate the patent application network, particularly in semiconductor production and intermediate products. The study helps to further our understanding of how middle powers can pursue various roadmaps in an era of technological innovation and economic competitiveness in the semiconductor industry.

Keywords

Semiconductors, Middle Powers, Japan, South Korea, Türkiye, Malaysia

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Introduction

The global semiconductor industry has emerged as one of the main areas of technological competition and geopolitical rivalry in the 21st century (Park, 2023; Shattuck, 2021). While so much attention has been given to the contest between superpowers like the US and China (Bown, 2020; Miller, 2022), this chapter turns to the rising contribution of middle powers in research, development, and production of semiconductors. As the industry grew in complexity and became globalized, countries outside of the top tier have been driven to establish niches and build capabilities in this strategically vital sector.

The chapter examines middle powers —Japan, South Korea, Türkiye, and Malaysia— from a comparative lens within the changing global semiconductor landscape. By considering indicators like research output, patent filings, and international collaboration, we attempt to systematically map established and emerging middle power contributions and strategies in this high-tech domain. The semiconductor industry will be an interesting and important case to understand how middle powers can balance great power competition with technological autonomy and economic development.

We also anchor our analysis on the theoretical underpinnings of middle power literature. Even though many definitions exist, a middle power is mainly characterized by its mid-range material capabilities and the penchant for multilateral solutions and niche diplomacy on the international stage. We separate the traditional middle powers— Japan and South Korea, who have their semiconductor industries established for quite a while—from the ranks of emerging middle powers trying to build their capabilities, as in the cases of Türkiye and Malaysia. This will allow comparison of several strategies and trajectories when countries at different stages of development engage with this critical technology sector. In addition to comparative study, we make a deeper analysis of Türkiye's semiconductor research and development efforts.

In fact, the global semiconductor industry has gone through dramatic changes in the last few decades due to the emergence of fabless design firms and the growing prominence of foundries, with the ever-increasing complexity of chip manufacturing processes. The new landscape can force middle powers to adjust—typically through specialization in subsectors or applications in which they can develop competitive strengths. Meanwhile, such emerging geopolitical tensions and supply chain vulnerabilities have motivated a growing list of countries to pursue greater self-sufficiency in semiconductors for both economic and national security reasons.

The chapter also combines quantitative analysis of research publications and patent data with the qualitative inquiry into national policies and industry developments. In the following section, we will apply network analysis techniques to map out patterns of international collaboration and identify main nodes of influence. In this way can we go beyond simple metrics to an understanding of the relational position that various middle powers occupy within global semiconductor research and innovation networks.

Our results underline the high and increasing contributions of middle powers to semiconductor R&D but point to divergent strategies and capabilities. Having leveraged their incumbent positions within the industrial base, Japan and South Korea have remained at the forefront in the development of many semiconductor technologies and become close collaborators with their Western counterparts. Coming from a lower base, Türkiye and Malaysia have focused on special niches and pursued domestic design and manufacturing competencies through strategic investments and collaboration.

Government policy thus comes to the fore as a major determinant of engagement with semiconductors by middle powers. From the Leading-edge Semiconductor Technology Center in Japan to the development of the national processor in Türkiye, state support and coordination have been instrumental in creating capabilities and guiding research priorities. But it is international collaboration that still has to be at the core of their efforts, as middle powers seek to manage cooperative and competitive relations in the global arena.

The chapter contributes to an important lacuna in the global semiconductor industry literature and the nation-state technological rivalry. While much of scholarship focused either on the US-China rivalry or the strategies of the top-tier firms, we provide a broader picture by examining diverse contributions from the middle powers. In doing so, we shed light on how countries beyond the superpowers position themselves in this strategically vital sector and, conversely, how they actually shape the future of semiconductor technology.

The semiconductor industry is an especially valuable lens for understanding broader dynamics of technological development, economic competitiveness, and geopolitical realignment during the 21st century. This chapter is, therefore, relevant to map the evolution of the roles of these middle powers in this critical domain and deepen our understanding of the changing nature of global innovation networks and strategies that countries have pursued in order to upgrade technological capabilities. Their importance for how the industry develops further will likely increase as the industry further evolves amid deepening international competition.

The chapter first will provide a historical background to the development of semiconductors. Afterward, the chapter will provide a broad picture of global semiconductor policies. We provide a theoretical framework of middle powers. Then, we show the results of data analysis of research outputs and patents of middle powers. Following the comparative lens, we offer a deeper analysis of Türkiye's efforts in the field of semiconductors. Lastly, we discuss the implications of the results and conclude our research.

Historical Background of the Semiconductor Industry

The global semiconductor industry is a cornerstone of modern technological progress (Clark & Gibson, 2024; Tan & Mathews, 2010, pp. 346–347). It is a rich terra incognita of groundbreaking discoveries and relentless innovation. The exploration of the industry's historical journey traces its evolution from a nascent field to its current position as a powerful driver of technological progress (Sydow & Müller-Seitz, 2020). The year 1947 marked a pivotal moment with the invention of the transistor at Bell Labs. As indicated by scholars, this revolutionary device, made from readily available materials such as silicon, ushered in a paradigm shift in electronics (Riordan et al., 1999). The transistor's ability to miniaturize electronic circuits paved the way for exponential advances in computing power and functionality. The following decades were a period of exponential growth for the industry. In the 1950s, 60s, and 70s, the industry saw the invention of the ICs, which further revolutionized electronics (Dickson et al., 1982). These devices integrated multiple transistors and components onto a single chip, laying the foundation for the digital revolution that transformed our world (LaDou & Rohm, 1998). From powerful computers to sophisticated telecommunications equipment and ubiquitous consumer electronics, ICs catalyzed transformative change.

Governments played a critical role in nurturing this technological saga. Strategic investments and supportive policies by nations such as the US, Japan, South Korea, and Taiwan fostered a thriving semiconductor research, development, and manufacturing environment (Chen & Bandyopadhyay, 1996; Rasiah et al., 2016). These policies included targeted funding for research institutions, financial incentives for semiconductor companies, and the establishment of industry-specific regulations and standards. By fostering a supportive ecosystem, these nations strategically positioned themselves as key players in the global semiconductor landscape. Industry leaders have also played a significant role in shaping the industry's trajectory. Companies such as Intel, Samsung, and Taiwan Semiconductor Manufacturing Company (TSMC) have consistently demonstrated a commitment to research and development, consistently pushing boundaries (Shattuck, 2021). Their competitive strategies, including mergers, acquisitions, and strategic collaborations, have reshaped market dynamics and propelled the industry forward at an unprecedented pace. The historical evolution of the semiconductor industry stands as a testament to the power of continuous innovation and strategic foresight (Brown & Linden, 2010). From the invention of the transistor to the development of ever-more sophisticated ICs, the industry's growth has been fuelled by technological breakthroughs, supportive government policies, and the vision of industry pioneers. An understanding of this historical context provides a vital lens through which to analyze the current dynamics and future trajectory of the global semiconductor landscape.

Present Nature of National and International Policies and Regulations

National policies and regulations exert a profound influence on the global semiconductor industry, influencing competitive landscapes, technological advancements, and geopolitical dynamics. The policies in question exhibit considerable variation across the key regions, reflecting the national priorities and strategic considerations of the countries in question. Many established companies and newcomers in semiconductor manufacturing are growing their operations to seize the rising opportunities across the entire value chain. This includes areas such as wafer manufacturing, chemical supply, packaging, capital equipment, and more. Worldwide, companies intend to invest approximately $1 trillion in semiconductor fabs by 2030. While most of this investment is concentrated in Asia and the US there is also an increasing amount of funding for projects in Europe (McKinsey, n.d.; SIA, 2024).

Semiconductor investments and innovations are transforming the sector, revitalizing both large and mid-market companies. These advancements are crucial for enhancing chip technologies and staying competitive. Large firms leverage cutting-edge solutions to improve their offerings, while mid-market companies benefit from new technologies that boost their product differentiation and performance. This progress is essential for meeting the rising demands of various industries and driving the tech landscape forward (Clark & Gibson, 2024; Sourcengine Team, 2024). As Chris Miller from Tufts University indicates, while numerous countries have made investments in domestic semiconductor production, it is evident that technological superiority is a significant factor in this field. China has made notable advancements in the localization of its Artificial Intelligence (AI) chip supply chain, whereas the US has not yet achieved comparable progress. China has successfully developed its supply chain, thereby challenging global power dynamics. In contrast, the US faces challenges from its sanctions and China's internal issues affecting innovation. The semiconductor industry is evolving rapidly, with AI driving demand for advanced chips. Companies such as Nvidia are leading the way with specialized AI processors, while traditional players such as Samsung and SK Hynix are adjusting their strategies to meet new market demands (Miller, 2024).

The US enacted the CHIPS and Science Act of 2022, which represents a significant investment in domestic semiconductor manufacturing and innovation (Rep. Ryan, 2022). Under the U.S. CHIPS Act, major semiconductor companies have outlined substantial financial commitments to bolster domestic production capabilities. Intel, for instance, has received $8.5 billion in grants and plans to invest $100 billion. TSMC has been allocated $6.6 billion and is set to invest $65 billion, while Micron has received $6.1 billion with an anticipated investment of $50 billion. Samsung, also benefiting from $6.1 billion in grants, aims to invest $45 billion. GlobalFoundries has secured $1.5 billion and will contribute $12 billion in anticipated investments (Lu, 2024). This robust financial backing underscores the U.S. government's strategic push to strengthen the domestic semiconductor industry and reduce reliance on international sources.

China's strategic ambitions are evident in its recognition of the strategic importance of semiconductors. China has initiated its ambitious "Made in China 2025" initiative, which aims to achieve self-sufficiency in critical technologies such as semiconductors (MIIT, 2015). China's semiconductor industry is making significant strides. Huawei's Pura 70 series features the Kirin 9010 processor, produced by SMIC with a 7nm N+2 process, showcasing Huawei's resilience amid US export restrictions. This advancement strengthens Huawei's position in the Chinese market against competitors like Apple. Concurrently, Beijing is promoting AI chip self-reliance with subsidies for companies using domestic AI chips, aiming for complete autonomy in smart computing by 2027. These initiatives reflect China's strategic push to advance its semiconductor industry and mitigate the impact of US technology restrictions, striving for a self-sufficient and competitive global position (Mokhtari, 2024). This initiative encompasses significant investments in domestic semiconductor production facilities, talent acquisition programs, and intellectual property development.

A prominent strategy employed by governments to support domestic production is the fostering of domestic semiconductor capabilities through targeted initiatives. For example, in 2022, the Japanese Ministry of Economy, Trade and Industry established the Leading-edge Semiconductor Technology Center (LSTC). The objective of this initiative is to reinforce domestic research and development

(R&D) activities, thereby accelerating innovation and ensuring a competitive advantage in advanced chip technologies (METI, 2024). In 2023, Japan embarked on an ambitious plan to revitalize its semiconductor industry, investing heavily in new plants and extensive support measures. This initiative reflects a global trend where countries strengthen their semiconductor capabilities to secure supply chains and address geopolitical risks. A key element of Japan's strategy is the government-backed Rapidus initiative, which aims to establish a competitive semiconductor hub comparable to Silicon Valley, attracting major players such as ASML Holding (Satoh, 2024). Additionally, industry giants like TMSC, Samsung Electronics, and Mitsubishi Chemical Group are making substantial investments in Japan's chip sector.

The Japanese government plans to allocate around $7 billion to boost domestic production and research, while Sony and other Japanese chipmakers are set to invest $30 billion to enhance manufacturing technologies and expand production capabilities. Despite these efforts, Japan faces challenges in regaining its former prominence due to intense competition and the need for continuous R&D and talent development. Historically, Japan was a leading player in the semiconductor market but lost ground due to trade tensions and shifting dynamics. Recent developments, including substantial subsidies for companies like Samsung and the creation of research hubs such as the LSTC, indicate progress (Beattie, 2024). Japan's planned investment commitments with Intel and Kumamoto's ongoing investments with TMSC are important in this regard. Japan has become increasingly active on the international stage, reflecting a subtle shift from "exclusive bilateralism [with the US] to modest multilateralism" (Mulgan, 2008) in the semiconductor domain. Japan is working with the US, South Korea, and Taiwan on semiconductor technology now. In terms of U.S. cooperation, this will be achieved by strengthening the partnership between the Japan LSTC and the U.S. National Semiconductor Technology Center. The objective is to cultivate expertise in the field of semiconductors. In 2022, a commitment was made to accelerate collaboration in the area of semiconductors, and a joint research center for new chips was established. The Economic Policy Consultative Committee Meeting concentrated on pivotal technologies, including semiconductors and electric vehicle batteries. In May 2023, the U.S.-Japan University Partnership for Workforce Advancement and Research & Development in Semiconductors (UPWARDS) was launched, a $60 million initiative involving eleven higher education institutions (Glosserman, 2024; Tsuzuki & Tanaka, 2023).

South Korea announced a record $19 billion package to boost its semiconductor industry amid global competition and supply chain challenges. The government will provide financial support, tax incentives, and regulatory reforms to encourage domestic chip production and innovation. This initiative aims to strengthen South Korea's position as a leading chipmaker, reduce reliance on foreign technology, and enhance national security. Key measures include increasing R&D funding, expanding facilities, and developing advanced manufacturing capabilities to compete with global giants like the US and China (AFP, 2024).

Malaysia is aiming for over $100 billion in investments in its semiconductor industry, according to Prime Minister Anwar Ibrahim. The country, already a significant player in semiconductor testing and packaging, is enhancing its sector with a $5.3 billion fiscal support package. The plan includes boosting integrated circuit design, advanced packaging, and semiconductor manufacturing equipment, and establishing at least ten local companies with significant revenue targets. This strategy aligns with Malaysia's goal to become a global manufacturing hub and move up the value chain in high-end semiconductor design and production (Azhar, 2024).

Türkiye has introduced the HIT-30 High Technology Investment Program (2024), a major initiative offering $30 billion in incentives to elevate the country's status as a global technology hub. This comprehensive program is designed to drive significant advancements across several high-tech sectors. It allocates $5 billion specifically for electric vehicle (EV) production, to ramp up Türkiye's EV output to 1 million units per year. In addition, the program includes $4.5 billion to attract investments in battery production, aiming to achieve a production capacity of 80 GWh by 2030. Another $5 billion is earmarked for semiconductor investments, addressing the needs of diverse industries such as automotive, electronics, and defense. Recent strides in this initiative include the opening of Türkiye's first domestic EV plant, Togg, and the establishment of a new EV battery production facility. These developments are complemented by significant investments from international players like BYD, which has committed nearly $1 billion to establish an EV and hybrid plant in Türkiye (S&P Global Commodity Insights, 2024). This strategic investment package is a key part of Türkiye's effort to enhance its technological capabilities and position itself as a leading player in the global high-tech industry.

International collaboration and regulatory frameworks acknowledge the intricate nature of global supply chains, prompting international efforts to address competition and security concerns. Initiatives such as the European Union Chips Act exemplify this trend by focusing on investments in research, development, and manufacturing capacities (European Commission, 2024). European companies, despite generating less than 10% of global semiconductor manufacturing revenue, lead in producing essential equipment, capturing 28% of the $30 billion global equipment market and 34% of the $20 billion subsystem market. Firms like ASML, ZEISS Group, and Edwards Vacuum excel in advanced technologies like EUV and DUV lithography. With a technological lag in advanced logic manufacturing, Europe is advised to focus on specialty markets with strengths. The EU Chips Act aims to bolster the sector, with European suppliers thriving in high-growth markets and maintaining strong positions in patterning, deposition, and metrology (West & Eloy, 2024). The EU Chips Act is designed to reinforce Europe's standing in the global semiconductor industry and diminish its reliance on external actors, particularly in the context of intensified competition with the US and China. Ultimately, the objective is to achieve strategic autonomy in critical technology sectors.

The current geopolitical landscape presents significant challenges for navigating trade disputes and geopolitical tensions. Such tensions and disputes can have the effect of disrupting international collaborations and compromising market access and supply chain stability. The establishment of regulatory frameworks by entities such as the World Trade Organization (WTO) and regional trade blocs plays a pivotal role in maintaining fair competition and resolving disputes. To navigate these evolving regulatory environments, it is necessary to adopt a strategic approach that fosters vibrant innovation ecosystems, promotes transparent and predictable policies, and ensures long-term industry growth amidst global uncertainties (WTO, 2022).

The future of semiconductor policy requires a balance between national security and global prosperity. Achieving this balance requires an appreciation of the interdependent nature of the global semiconductor industry and the formulation of policies that can respond to emerging technological innovations, evolving geopolitical circumstances, and the imperative for sustainable and environmentally responsible manufacturing practices (Ferreira et al., 2023). Middle powers represent a significant grouping of states with the potential to shape the dynamics of great powers' technology rivalry. Next section will examine the capacity of Japan, South Korea, Türkiye, and Malaysia to function as middle powers within the theoretical framework.

Theoretical Framework: Middle Powers

The concept of middle powers is based on their international power, capacity, and influence, as well as their propensity to promote global cohesion and stability (Carr, 2014; Jordaan, 2003). Middle power theory encompasses positional and behavioral approaches. The positional approach regards global politics through the prism of the international hierarchy of states. According to this approach, middle powers "can play a consequential role regionally and exert some degree of influence on global affairs beyond that of small or weak states" (Cooper, 2011a, p. 319). Material factors such as population, GDP, military power, and geography are among the bases of middlepowerness as per positional definitions (Carr, 2014).

The behavioral approach regards middle powers by "their tendency to pursue multilateral solutions to international problems, their tendency to embrace compromise positions in international disputes and their tendency to embrace notions of 'good international citizenship' to guide their diplomacy" (Cooper et al., 1993, p. 19). Robertson (2017) argues that the behavioral characteristics include active diplomacy, which involves the innovative and entrepreneurial use of diplomatic methods, niche diplomacy, which concentrates resources on specific goals, building alliances with similar states, and promoting good international citizenship by advocating for cooperation to solve global issues.

Middle powers are further distinguished as 'traditional' and 'emerging' middle powers (Jordaan, 2003). Traditional middle powers such as Canada, Australia, Netherlands, and Norway are stable, democratic, and wealthy countries that came to prominence during the Cold War (Cooper et al., 1993; Cooper, 2011b; Jordaan, 2003). On the other hand, emerging middle powers like South Africa, Türkiye, Malaysia, and Mexico have mid-range military and economic capabilities and have played a growing role in the post-Cold War era (Aydin, 2021; Öniş & Kutlay, 2017; Schoeman, 2000). These emerging middle powers reflect coalition-building, multilateralism, and the adoption of niche diplomacy in their foreign policies. Additionally, emerging powers have diplomatic ambitions on the path to obtaining higher status in global politics and participating in international institutions such as the G20.

Based on its material capabilities and behavior, scholars located Malaysia as a middle power. Malaysia is considered an emerging middle power in that Malaysia did not have an established position of middle power for a long time (Hossain & Shukri, 2021; Jordaan, 2003; Nossal & Stubbs, 1997). Malaysia's foreign policy is marked by mediation efforts, active participation in multilateral institutions, and expanding trade ties. Nossal and Stubs (1997) argue that Malaysia has attracted attention due to its economic growth since 1988 and has become an example for other regional countries. Ping (2017) analyzes the middle powers from a statistical perspective. Accordingly, Malaysia is classified as a middle power based on its GDP, GDP per capita, military spending, and value of exports. Lowy Institute Asia Power Index (2023) also lists Malaysia as a middle power by using comparable statistics and additional indicators such as defense networks. Burton's (2021) analysis of middle powers also asserts that Malaysia is a middle power based on material capabilities such as economy, population, and military spending. Emmers and Teo (2015), in their analysis of security strategies of middle powers, define Malaysia as a middle power even though they argue Malaysia's middle powerhood has fluctuated in terms of behavioral perspective. Malaysia has a GPD of $399 billion (World Bank, 2023). In terms of military power Malaysia ranks 42 out of 145 states (Global Fire Power a, n.d.). From a behavioral perspective, Malaysia portrays middle power features. From also a behavioral perspective, Malaysia portrays middle power features. Malaysia is an active participant in multilateral diplomacy and organizations such as such as ASEAN and the Organization of Islamic Cooperation (OIC).

Türkiye has emerged as a significant middle power due to its economic growth, expanding military capabilities, and active involvement in multilateral foreign policy. Geopolitically, Türkiye possesses substantial economic strength and is a member of international organizations such as the G20 and MIKTA, which unites both established and emerging middle powers (Müftüler & Yüksel, 1997; Öniş & Kutlay, 2017). In terms of behavior, Türkiye has pursued proactive diplomacy and coalition-building, indicating its readiness to pursue a more assertive foreign policy. The concept of Türkiye as a middle power is explored through its 'unusual activism' (Kutlay & Öniş, 2021; Soyaltin-Colella & Demiryol, 2023), its role in the liberal international order (Aydin, 2021), conflict mediation (Altunisik & Çuhadar, 2010), foreign policy towards international institutions (Dal, 2019; Dal & Kurşun, 2016) and humanitarian diplomacy (Gilley, 2015).

South Korea is a traditional middle power with a stable, wealthy, and democratic state and society. Cooper (1997) states that traditional middle-power diplomacy focuses on niche diplomacy, and underlines normative agendas of low politics such as international development and environment. The reason is middle powers possess limited diplomatic resources compared to great powers. Lee Myung-bak government (2008-2013) emphasized middle-power diplomacy to justify Korea's role as a mediator, and influential participant in international debates and multilateral organizations such as G20, OECD, and Nuclear Security Summit. Lee's niche diplomacy concentrated on issues such as international development, and environmental and economic cooperation, leveraging Korea's development experience and technological advancement (Kim, 2016). Korea's GDP is 1.7$ trillion and it has 50 million population. Korea ranks 5th out of 145 states in the world in terms of military power in 2024 (Global Fire Power b, 2024). South Korea as a middle power attracted a great deal of scholarly attention due to its importance in regional and global politics (A. F. Cooper, 2015; Emmers & Teo, 2015; Kim, 2016; Lee, 2017; Shin, 2016).

Japan is considered as a middle power according to Lowy Institute's Asia Power Index (2023). Japan's power score is considerably below that of the US and China, which are categorized as superpowers. Nagy (2022) uses World Bank and SIPRI data to examine traditional middle powers and from a positional approach, based on quantitative indicators such as GDP, GDP per capita, population size, and defense spending, categorizes Japan as a middle power, particularly in comparison with China and the US. Nagy states that the term "middle power" may not perfectly encapsulate Japan's economic prowess, but Tokyo's foreign policy aligns with a preference for multilateralism and a rules-based system. This is evident in its initiatives to advance multilateral frameworks in the Asia-Pacific region and, more recently, in its promotion of the Free and Open Indo-Pacific (FOIP) vision (Aki & Hiroshi, 2021).

The literature on technological rivalry concentrated heavily on great power rivalry (Kennedy & Lim, 2018; Malkin & He, 2024). It has legitimate reasons as the US and China top the lists in investments and developing critical technologies. Yet, middle powers' behavior becomes more important as the great powers implement export controls, increase investments, and take steps to increase their production capabilities to take the lead. However, there is a gap in the literature examining the middle power behavior in critical technologies such as semiconductors. Middle powers' investments in critical technologies such as semiconductors can also indicate their policies. Also, their scientific collaborations might imply R&D policies and institutional ties with other countries. Studying the middle powers' scientific production can also show what areas they have focused more on and in what areas they have spent less attention on.

The chapter will examine two established middle powers and two emerging middle powers. This will help offer a more nuanced analytical perspective on the middle power behavior in research and development efforts in the field of semiconductors. Japan and South Korea will examined as an established middle power and Türkiye and Malaysia will be examined as an emerging middle power. This analytical perspective will help examine similarities and differences among middle powers.

Scientific knowledge production can influence international relations in several ways. First, developments in science can make people aware of important issues and help put them on the international agenda, such as climate change. Second, scientific cooperation and competition "may on occasion affect international relations, as for example when agreements on scientific cooperation are a first step toward broader bilateral relations between states" (Weiss, 2005, p. 298). Third scientific knowledge also impacts the development of technologies that are crucial to national security. This becomes more important in today's weaponized interdependence and technological rivalry between superpowers. Technological innovation impacts international relations as can be exemplified by "how the development of nuclear weapons and inter-continental ballistic missiles (ICBM) changed the nature of warfare and of geopolitics" (Weiss, 2005, p. 298). The field of international relations is influenced by advancements in technological management and innovation, whether at the organizational, regional, or national levels. The ability to innovate technologically plays a significant role in determining both economic and political power (Weiss, 2005, p. 298).

There is a gap in the literature examining the scientific knowledge accumulation and collaboration networks of middle powers in the technological fields. The state of scientific development and knowledge accumulation also influence their power capabilities and technological innovation capacities. Thus examining middle powers' scientific knowledge accumulation, collaboration networks, and patents can have multiple implications. First, it will map the accumulation of existing scientific knowledge in the middle powers. This will help portray the state of R&D in middle powers in semiconductors and help spot the developed and underdeveloped areas of scientific concentration in middle powers. Second, this research can show which states collaborate with which state in terms of institutions. The institutional ties can imply bilateral and multilateral relations that can interact with states' strategic aims regarding semiconductors. Third, the middle powers' position in scientific knowledge can imply in which countries they have closer ties in the technological rivalry between the US and China. The next section will examine the semiconductor literature growth in middle powers.

Literature Growth Analysis on Semiconductors

Evaluating countries according to their AI capabilities has become a widely studied subject. These evaluations typically aggregate indices and metrics related to essential AI technology elements, including expertise in computer engineering, existing scientific infrastructure, investment accessibility in AI, government policies, and the commercial environment (Mousavizadeh et al., 2019; Ünver & Feldstein, 2022). However, our focus is on a research ecosystem specifically centered around semiconductors considering its wide range of use and importance for the global economy.

The methods used in this section are based on information obtained from two main data sources to provide an in-depth examination of scientific and technological trends: Web of Science (WoS) and Lens.org. These sources were used for bibliometric analyses and patent analyses, respectively. Bibliometric analysis allows for a quantitative examination of scientific literature, and the Web of Science database was preferred for this study. WoS is an important bibliographic database that provides a comprehensive index of scientific articles and other academic documents worldwide. The information obtained from this database was used to determine which topics are popular in a particular field of research, which researchers dominate the field, and which countries are active in these fields. In the analysis process, data was extracted from WoS using specific keywords and subject headings. This data was examined to determine publication trends over time and the most cited articles. Scientific research trends were analyzed using various metrics such as the distribution of publications by year, international collaborations, keyword networks, and the development of subject headings. In this process, we focused on specific countries (e.g. Türkiye, Japan, South Korea, and Malaysia) and specific research areas. The basic metrics used in the bibliometric analysis included citation counts, h-index, collaboration networks, and keyword distributions.[1]

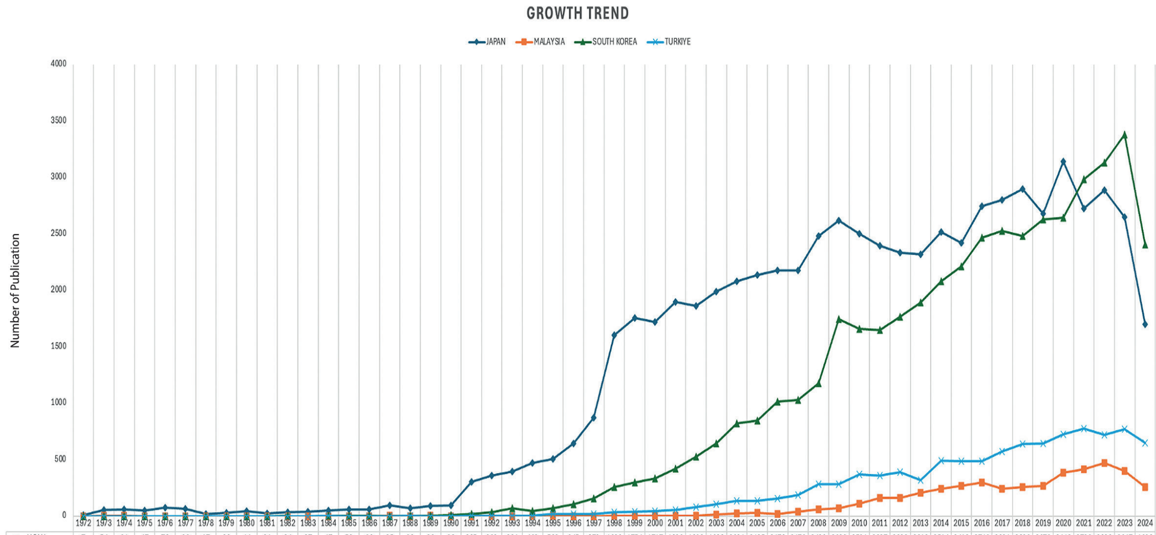
As illustrated in the accompanying growth trends table 1 below, Japan exhibited the most pronounced growth in terms of economic expansion between 1972 and 2024, particularly during the early 1990s. In 1997, Japan exhibited a near-complete vertical growth, followed by a return to a linear growth pattern from 2001 onwards. Towards the end of the 1990s, South Korea began to increase its publications, with a notable surge in 2008. South Korea continued to demonstrate consistent growth, attaining the top position among these four countries in 2020, surpassing Japan for the first time. In line with the middle powers' emergence, Malaysia and Türkiye emerged in the early 2000s and exhibited a linear growth line.

Table 2 presents data on the h-index, citations, and publications, offering a quantitative approach to mapping the collaboration networks of countries engaged in semiconductor research. As indicated by the data, Japan, the US and South Korea are identified as the countries with the highest h-index in the field of semiconductor research, reflecting a considerable volume of research output in this domain. The US has the highest total number of citations, while the China has also received a considerable number of citations in the field of semiconductor research. These findings highlight the significant influence of these countries on global semiconductor research and their pivotal role within collaborative networks. Moreover, the data indicates that middle powers such as Japan, South Korea, Türkiye, and Malaysia have made significant contributions to the field of semiconductor technologies, as evidenced by their collective output of 127,648 publications and 4,027,718 citations. These countries' robust performance in this domain serves to reinforce their competitive standing within the global semiconductor ecosystem, thereby underscoring their strategic importance in scientific and technological advancements.

Japan is the most prolific country in terms of citations, with an h-index of 69,717. South Korea and Türkiye also demonstrate high levels of research impact, with h-indices of 438 and 128, respectively. Malaysia exhibits a comparatively lower h-index of 111.

1 The criteria and scales of the analyzes: The criteria and scales of the Analyzes: TS=semiconductor, Web of Science Core Collection, Editions = A&HCI, BKCI-SSH, BKCI-S, ESCI, CPCI-SSH, CPCI-S, SCI-EXPANDED, SSCI.

Table 1
Literature Growth Trends



	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
JAPAN	7	54	61	47	73	66	17	30	44	21	34	37	47	59	60	95	68	90	93	305	360	394	469	506	645	870
MALAYSIA	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	0	2	3	0	0
SOUTH KOREA	0	0	0	0	0	0	0	0	0	0	1		3	2	1	0	5	5	8	19	34	67	43	68	104	157
TURKIYE	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	3	2	1	4	18	18	17

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
JAPAN	1600	1754	1717	1896	1860	1988	2081	2135	2178	2176	2480	2620	2501	2397	2332	2319	2514	2419	2746	2801	2896	2679	3142	2726	2888	2647	1698
MALAYSIA	2	2	1	2	4	12	24	28	16	39	58	69	111	159	162	204	242	265	298	243	257	266	384	413	469	398	256
SOUTH KOREA	255	297	331	419	524	645	822	846	1014	1028	1176	1745	1660	1649	1767	1890	2080	2211	2465	2525	2482	2627	2645	2985	3133	3381	2407
TURKIYE	34	39	43	55	81	102	136	134	153	184	284	283	371	359	390	316	491	485	486	573	638	645	725	773	718	772	649

Year

Table 2
Countries h-Index

Rank	h-index	Unit	Citation sum within h-core	All citations	All articles
1	505	*JAPAN*	697173	2427424	67742
2	438	*USA*	533747	985391	11273
3	368	*SOUTH KOREA*	281890	1255925	45526
4	245	*PEOPLES R CHINA*	145575	335331	6850
5	182	*UK*	148677	217004	2480
6	180	*GERMANY*	149282	229526	2941
7	135	*TÜRKİYE*	69015	237282	9985
8	128	*FRANCE*	71302	105250	1641
9	120	*MALAYSIA*	44248	107087	4395
10	111	*AUSTRALIA*	51067	71653	987
11	108	*INDIA*	21781	70315	2956
12	108	*SINGAPORE*	58999	75680	781
13	106	*ITALY*	105108	124716	967
14	98	*SWITZERLAND*	48495	59222	618
15	97	*SPAIN*	42483	54727	650
16	84	*CANADA*	47660	60463	687
17	83	*TAIWAN*	28312	45805	1191
18	77	*RUSSIA*	40435	58469	1161
19	77	*NETHERLANDS*	32580	39228	405
20	75	*SWEDEN*	27026	33925	450

Japan also holds the highest total number of citations (2,427,424), followed by South Korea (1,255,925), Türkiye (237,282), and Malaysia (107,087). These metrics indicate that Japan is the most influential country in semiconductor research, followed by South Korea, Türkiye, and Malaysia. The contributions of middle powers to semiconductor research are notable, as evidenced by their considerable number of publications and citations. This suggests that middle powers are increasingly playing a crucial role in shaping the global landscape of semiconductor research.

Middle Powers' Cooperations

To assess the contributions and collaborations of middle-power countries in the field of semiconductors, the table presents four distinct columns ranked according to various network metrics: "All Degree," "Betweenness Centrality," "High Aggregate Constraints," and "Low Aggregate Constraints.". These metrics are commonly used in network analysis to evaluate the role and position of countries or organizations within a network (Hajian & White, 2011; Tang et al., 2009; Varlamis et al., 2010; Yalcin & Daim, 2021; Zamani et al., 2022). These network metrics can be used as a tool for understanding the network position and strategic advantages of countries engaged in semiconductor research. Countries with high rankings have a wide cooperation network and are at the center of information sharing; those with high betweenness centrality play a critical role in mediating information and building bridges between different groups. While a high aggregate constraints value indicates that countries are more dependent on certain connections and flexibility is limited, a low aggregate constraints value indicates a more independent and flexible collaboration structure. Considered in this respect, when making strategic decisions in the field of semiconductor research, it can help determine which countries should be cooperated with, how to optimize the flow of information, and how to take a more central position in the network.

All Degree

All degree indicates the total number of connections a country has in the network (Hajian & White, 2011; Varlamis et al., 2010). This metric is also important in terms of determining how central a country is in the network and how many direct connections it has with other countries. When the table 3 is analyzed in terms of this indicator, it is observed that countries such as Japan, South Korea, and Türkiye stand out in terms of the number of connections. This shows that they have a wide interaction network.

Betweenness Centrality

This metric indicates how much a country acts as a mediator or bridge in the network. A high betweenness centrality value indicates that a country plays a critical role in the flow of information and connects different groups (Brandes, 2001; Kourtellis et al., 2013; Zhang & Luo, 2017). In this respect, it is seen that institutions such as Japan, South Korea, Türkiye, and China have a high betweenness centrality indicator, in other words, they play a critical role in the flow of information in the network.

High Aggregate Constraints

High aggregate constraints indicate less flexibility and more dependency on a country's relationships in the network. In other words, this metric shows how constrained a country is in its connections with other organizations (Brandes, 2001). Countries such as Japan, North Macedonia, the USA, and Saudi Arabia are highly constrained and have more dependent or less flexible relationships with other countries in the network.

Low Aggregate Constraints

This metric is an important indicator that shows how flexible and independent a country is in its network relationships. Low aggregate constraints indicate that a country has a wider range of action and fewer dependencies (Ansell et al., 2017). Countries such as Albania, Cambodia, North Korea, and Algeria stand out because they have low restrictions and have more flexible and independent relationships with other countries in the network.

Table 3
Contribution of Middle Powers to the Field and Levels of Cooperation between Countries

Rank	All Degree	Betweenness Centrality	High Aggregate Constrains	Low Aggregate Constraints
1	*JAPAN*	*JAPAN*	*CUBA*	*ALBANIA*
2	*SOUTH KOREA*	*SOUTH KOREA*	*NORTH MACEDONIA*	*CAMBODIA*
3	*TURKIYE*	*TURKIYE*	*USA*	*NORTH KOREA*
4	*USA*	*PEOPLES R CHINA*	*SAUDI ARABIA*	*ALGERIA*
5	*PEOPLES R CHINA*	*INDIA*	*U ARAB EMIRATES*	*PAKISTAN*
6	*INDIA*	*USA*	*CROATIA*	*SINGAPORE*
7	*UK*	*MALAYSIA*	*IRAN*	*VIETNAM*
8	*FRANCE*	*SAUDI ARABIA*	*PALESTINE*	*IRAQ*
9	*GERMANY*	*PAKISTAN*	*FINLAND*	*THAILAND*
10	*MALAYSIA*	*VIETNAM*	*LITHUANIA*	*FINLAND*
11	*SAUDI ARABIA*	*ALGERIA*	*BANGLADESH*	*MEXICO*
12	*ITALY*	*FINLAND*	*CAMEROON*	*TANZANIA*
13	*AUSTRALIA*	*IRAQ*	*MEXICO*	*MALI*
14	*CANADA*	*UK*	*MALAYSIA*	*BOSNIA & HERCEG*
15	*POLAND*	*FRANCE*	*KUWAIT*	*BURUNDI*
16	*RUSSIA*	*IRAN*	*PEOPLES R CHINA*	*BUNDES REPUBLIK*
17	*SPAIN*	*TAIWAN*	*TURKIYE*	*SERBIA MONTENEG*
18	*SWITZERLAND*	*MEXICO*	*LATVIA*	*HONG KONG*
19	*SWEDEN*	*SINGAPORE*	*TAIWAN*	*COSTA RICA*
20	*NETHERLANDS*	*BANGLADESH*	*QATAR*	*TIMOR-LESTE*

In the patent analysis we conducted on Lens.org data to show patent trends and network collaborations of institutions and companies from middle powers between the years 2012 and 2024. We wanted to monitor technological innovation and applications. Lens.org is an open-access platform that provides global patent information and allows researchers to learn about patent applications and technological trends. In the patent analysis process, patent applications made in specific technological areas (semiconductor technologies) were examined. This analysis was conducted to reveal which countries filed more patent applications in this field, which companies or institutions were leaders in this field, and in which directions technological developments were progressing. In addition, parameters such as patent application dates, applicants, and international patent collaborations were analyzed. The data obtained from Lens.org was processed in detail to understand which innovations emerged in the field of technology and which areas were concentrated. In this process, the distribution of patent data over time, national and international collaborations of patent owners, and the density of patents in different technology areas were examined. This analysis was also used to understand the geographical and sectoral distribution of technological innovations. In this context, the bibliometric and patent analysis methods used in our study provided a comprehensive framework for understanding the evolution and geographical distribution of scientific research and technological developments over time.

Table 4 below shows that Japanese and South Korean companies, including the Toshiba Group, Samsung Electronics, SK Hynix, and Renesas, are prominently listed. It is noteworthy that the overwhelming majority of companies included in the patent application table are based in Japan and South Korea. These companies are involved not only in semiconductor production but also in the production of intermediate products. The fact that Turkish and Malaysian companies in the emerging middle powers group have not yet established an international presence in this context indicates that they possess significant flexibility and the potential for new areas of collaboration. However, cooperation with Japanese and South Korean companies in this process will facilitate rapid progress in international connectivity.

Table 4
Network Collaborations of Institutions and Companies on the Basis of Patent Applications

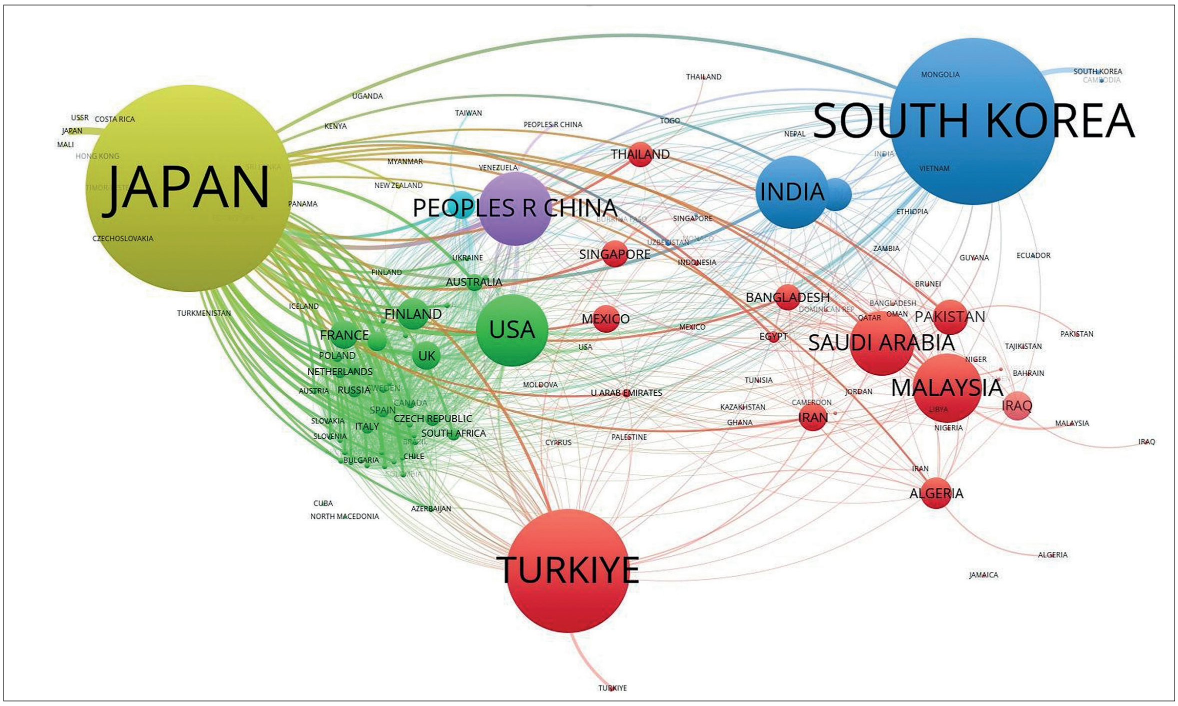
All Degree	Betweenness Centrality	High Aggregate Constraints	Low Aggregate Constraints
Toshiba Corp	*Samsung Electronics Co Ltd*	*Samsung Electronics Co Ltd*	*Auto Network Gijutsu Kenkyusho Kk*
Samsung Electronics Co Ltd	*Toshiba Corp*	*Renesas Electronics Corp*	*Sumitomo Electric Industries*
Denso Corp	*Sk Hynix Inc*	*Sk Hynix Inc*	*Sumitomo Wiring Systems*
Fuji Electric Co Ltd	*Univ Tokyo*	*Univ Tokyo*	*Toshiba Electronic Devices & Storage Corp*
Sk Hynix Inc	*Univ Tohoku*	*Fuji Electric Co Ltd*	*Citizen Electronics*
Toyota Motor Corp	*Fuji Electric Co Ltd*	*Tokyo Electron Ltd*	*Kia Motors Corp*
Univ Tokyo	*Nat Inst Of Adv Ind & Technol*	*Univ Osaka*	*Nitto Seiki Kk*
Nat Inst Of Adv Ind & Technol	*Denso Corp*	*Sumitomo Chemical Co*	*Univ Qinghua*
Toyota Central Res & Dev	*Univ Tokyo*	*Sumitomo Electric Industries*	*Hon Hai Prec Ind Co Ltd*
Aist	*Tokyo Electron Ltd*	*Rohm Co Ltd*	*Dow Global Technologies Llc*
Univ Osaka	*Univ Osaka*	*Univ Kyoto*	*Toshiba Infrastructure Systems & Solutions Corp*
Univ Tokyo	*Univ Osaka*	*Univ Tohoku*	*Toshiba Materials Co Ltd*
Samsung Display Co Ltd	*Nat Inst Materials Science*	*Nippon Telegraph & Telephone*	*Toshiba Energy System & Solution Corp*
Sumitomo Chemical Co	*Sharp Kk*	*Univ Tokyo*	*Citizen Holdings Co Ltd*
Nissan Motor	*Fuji Electric Co Ltd*	*Univ Osaka*	*Kia Corp*
Renesas Electronics Corp	*Renesas Electronics Corp*	*Tokyo Inst Tech*	*Hitachi Power Semiconductor Device Ltd*
Sanken Electric Co Ltd	*Sumitomo Electric Industries*	*Tokyo Inst Tech*	*Sophia School Corp*
Sumitomo Electric Industries	*Tokyo Ohka Kogyo Co Ltd*	*Nissan Motor*	*Shinetsu Handotai Kk*
Univ Osaka	*Tokyo Inst Tech*	*Mitsubishi Electric Corp*	*Ntt Electronics Corp*
Fuji Electric Co Ltd	*Tokyo Electron Ltd*	*Tokyo Electron Ltd*	*Aisin Seiki*
Univ Tohoku	*Mitsubishi Chem Corp*	*Fuji Electric Co Ltd*	*Univ Meijo*

Tokyo Inst Tech	*Aist*	*Sumitomo Bakelite Co*	*Nippon Micrometal Corp*
Tokyo Electron Ltd	*Sanken Electric Co Ltd*	*Fujitsu Ltd*	*Nippon Steel Chemical & Mat Co Ltd*
Mirise Tech Corp	*Research & Business Found Sungkyunkwan Univ*	*Sharp Kk*	*Rohm & Haas Elect Mat*
Sharp Kk	*Toyota Motor Corp*	*Asahi Kasei Corp*	*Sedi Inc*
Tokyo Inst Tech	*Hitachi Ltd*	*Mitsubishi Electric Corp*	*Dainippon Ink & Chemicals*
Fujitsu Ltd	*Samsung Display Co Ltd*	*Samsung Display Co Ltd*	*Tokai Rika Co Ltd*
Univ Kyoto	*Rohm Co Ltd*	*Sanken Electric Co Ltd*	*Kwangju Inst Sci & Tech*
Hamamatsu Photonics Kk	*Hyundai Motor Co Ltd*	*Nat Inst Of Advanced Ind Scien*	*Kobe Steel Ltd*
Mitsubishi Chem Corp	*Toyota Central Res & Dev*	*Tokai National Higher Education & Res System*	*Dongwoo Fine Chem Co Ltd*

A detailed examination of the table reveals a crucial network analysis of semiconductor research and patents, highlighting the centralization, mediation, or independence of various countries. It also outlines the patent application implications for companies from these nations. This analysis is essential for understanding research collaborations, information flows, and strategic planning, offering valuable insights into the capabilities and roles of different countries in the semiconductor field.

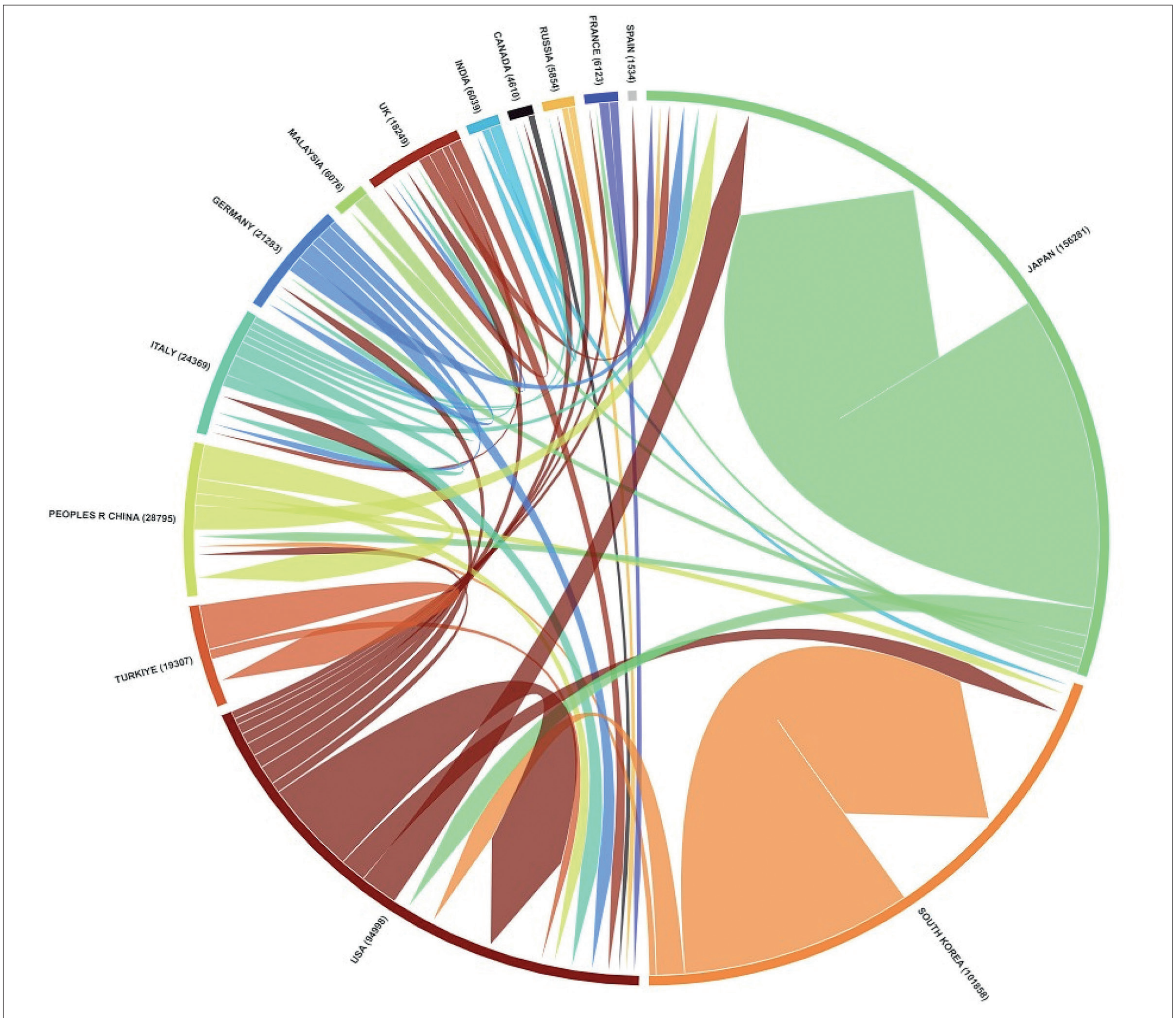
Figure 1 illustrates the cooperation map of the countries, providing a clearer view of the intensive network relations previously mentioned. Japan demonstrates a strong presence in research and scientific influence, as well as production cooperation with both the US and European countries. South Korea, while not as prominent as Japan, maintains notable ties with the US and India. China remains a central player within the network, positioned between the US, Japan, India, and South Korea. Despite the US Chip Act sanctions, China's integration into the network persists.

Figure 1
Country Collaboration Map



The map highlights Türkiye's relatively low level of network engagement, which presents an opportunity for growth. This position allows Türkiye the flexibility to form partnerships with various actors. The potential for Türkiye to collaborate with countries such as Japan, Malaysia, South Korea, and European nations appears significant (Figure 2). Conversely, Malaysia is actively engaging with Asian countries but has yet to establish strong connections with Middle Eastern nations.

Figure 2
Detailed Country Cooperation and Interaction Map



Data obtained from Web of Science and Lens.org show which fields are prominent in both academic and technological terms and which countries are leaders in these areas. These methods provide important insights for the direction of research and development policies.

Sectoral Practices in Türkiye

Over the past two decades, Türkiye has witnessed significant advancements across various sectors, including health, defense, the economy, and education. The National Technology Initiative (Kacır et al., 2022) has been a pivotal driving force behind these developments, with even niche areas such as blockchain receiving heightened attention (Doğrul & Yalçın, 2022). However, the history of semiconductors in Türkiye is not a new trend, and even earlier semiconductors, classified as "high-tech products", were considered as a strategic technology. In this regard, Türkiye initiated a series of strategic initiatives in this field, starting with the National Security Council meeting held on May 18, 1964, which was documented as Decision No. 42. The objective of this decision was to reduce Türkiye's reliance on external sources for strategic integrated circuits and to underscore the significance of semiconductors in developing a resilient production infrastructure. An analysis of the pivotal events in Türkiye's semiconductor industry reveals that the foundational framework for its advancement was established during the 1960s (Töken & Ukav, 2024). During this period, the establishment of companies and research units invigorated the sector. NETAŞ, founded in 1966 through a partnership between the Canadian company Northern Electric and Türkiye's PTT, was initially tasked with semiconductor production. NETAŞ started production in 1969. Although the company no longer engages in semiconductor manufacturing, it continues its operations as part of the Chinese firm ZTE (*NETAŞ*, n.d.).

In his presentation titled "A Critical Review of 50 Years of Semiconductor Technology in Türkiye" delivered on September 14, 2023, at the Istanbul Fair Center, Prof. Duran Leblebici characterized the 1970s as both "independent beginnings" and "intense and dynamic" periods. During this time, there were notable initiatives such as Philips' attempt to establish a transistor factory in 1971 and Siemens' effort to set up an RF power transistor factory in the same year. The ITU Microelectronics Laboratory was established in 1974, and it produced its first thick-film integrated circuits in 1975, followed by the development of the first MOS transistor in 1977. ASELSAN and TELETAŞ later acquired significant "know-how" from this laboratory. In 2004, the ITU-ETA ASIC Design Center was founded under the name Mikroelektronik Ltd., and its majority shares were acquired by ASELSAN in 2010. Since then, the center has been engaged in designing strategic integrated circuits to meet ASELSAN's needs (Leblebici, 2023).

In the 1970s, TESTAŞ (Türkiye Elektronik Sanayi ve Ticaret A.Ş.), a state-owned initiative, was established for the production of semiconductor components and collaborated with Exar (Pektaş, 2022). However, the project did not achieve the expected success. In 1983, YİTAL (Semiconductor Technologies Research Laboratory), established within TESTAŞ, was incorporated into TÜBİTAK BİLGEM. By 1998, TESTAŞ's factory in Ankara was transferred to METU (Middle East Technical University), where the METU MEMS Center was established in 2008 (*MEMS*, n.d.). In 2017, this center gained legal entity status and continued its activities as the "Advanced Research Laboratory." In 2015, Ermaksan A.Ş. established Türkiye's first chip factory in Bursa and conducted various R&D activities in collaboration with several universities (Ermaksan, n.d.). In 2017, a company named YİTAL Mikroelektronik Sanayi ve Ticaret A.Ş. was established with a partnership structure comprising 51% ASELSAN, 29% TÜBİTAK, and 20% the Undersecretariat for Defence Industries (YİTAL, n.d.). At YİTAL, the goal is to reduce the chip production technology scale from 250 nanometers to 65 nanometers (TÜBİTAK, 2023). In 2019, incentives for the semiconductor industry were announced as part of the 11th Development Plan (Presidency of the Republic of Türkiye, 2019). In 2023, TÜBİTAK and Qatar's Hamad Bin Khalifa University signed a cooperation agreement to establish a chip production facility (Ministry of Industry and Technology, 2023a). Additionally, it is estimated that the number of personnel working in the semiconductor sector in Türkiye has reached around a thousand. The Ministry of Industry and Technology has launched a project titled "Integrated Circuit Design Call" with a budget of 270 million Turkish lira. This initiative aims to bring together large companies and SMEs involved in chip design, offering 50% grant support. It focuses on priority areas such as electrical-electronics, automation, and digital transformation technologies, to enable the domestic production of Türkiye's first national processor, Çakıl (Ministry of Industry and Technology, 2023b). In collaboration with ASELSAN and TÜBİTAK BİLGEM, Türkiye's first national processor, ÇAKIL, has been developed. Produced by TSMC using 65-nanometer (nm) technology and packaged at the prototype level, the ÇAKIL processor operates at a speed of 400 MHz and supports the RISC-V IMAFD instruction set.

ASELSAN's subsidiary working on semiconductor technologies, ASELSAN Bilkent Micro Nano Teknolojiler Endüstri ve Ticaret A.Ş. (AB Mikro Nano A.Ş.), established in Ankara stands out as one of Türkiye's most significant microchip production facilities. On December 23, 2014, the groundbreaking ceremony for Türkiye's first commercial electronic chip factory was held with the participation of the Minister of National Defense, İsmet Yılmaz. The AB-MikroNano factory is a joint venture between ASELSAN and Bilkent University, located in the Bilkent Cyberpark Technopark area. It began producing micro/nanotechnology-based integrated circuits for the defense, space, communication, and energy sectors. This $30 million investment and partnership have played a significant role in enhancing Türkiye's defense capabilities and have actively contributed to increasing efficiency and advancing technology in the communication and energy sectors (*AB-MikroNano*, n.d.).

With an annual production capacity of 20 million chips, the factory is equipped with cutting-edge technology for the development and production of RF and photonic semiconductor technologies. Mikroelektronik Ltd. Şti. (MKR-IC), founded in Istanbul, offers application-specific integrated circuit (ASIC) solutions and aims to achieve cost optimization and efficiency through custom designs. TÜYAR Mikroelektronik Sanayi ve Ticaret A.Ş., established in Gebze in 2017, produces micro and nano-sized semiconductor devices and operates in collaboration with ASELSAN, TÜBİTAK, and the Secretariat of Defense Industries (SSB) (ASELSAN, 2024).

The other company is ElectraIC, which was established in 2010. The company specializes in the design and production of high-performance integrated circuits (ICs) and custom semiconductor solutions. Its products cater to a range of applications, including automotive, industrial, consumer electronics, and telecommunications (*ElectraIC*, n.d.). Moreover, Yongatek Microelectronics was established in 2003. The company specializes in the design and production of high-performance integrated circuits (ICs) for various applications. Its product portfolio includes advanced microcontrollers, sensors, and power management ICs, all designed to meet the requirements of modern technology (*Yongatek Microelectronics*, n.d.).

University labs work with special focus on semiconductors and some well-known can be listed briefly. Sabancı University Nanotechnology Research and Application Center (SUNUM) which was stablished in 2008. SUNUM is a research and application center specializing in nanotechnology. It focuses on advanced nanomaterials, nanofabrication techniques, and applied nanotechnology. The center supports national and international projects and fosters collaborations between academia and industry to advance nanotechnology applications across various sectors. With its high-tech equipment and expert staff, SUNUM serves as a platform that promotes scientific research and produces innovative solutions (*SUNUM*, n.d.).

Middle East Technical University (METU) Micro-Electro-Mechanical Systems Center (MEMS) was established in 2000. MEMS focuses on the research and development of micro and nano-scale systems. The center works on the design, production, and applications of micro-electro-mechanical systems (MEMS) and offers cutting-edge technologies in this field. Its research activities include the development of sensors, actuators, and other microsystems. The MEMS Center aims to produce advanced micro-system solutions through academic and industrial collaborations (*MEMS*, n.d.).

Istanbul Technical University (ITU) Power Electronics Laboratory was established in 1972 and subsequently became a standalone facility in 1995, following its relocation to the Ayazaga Campus. It is one of Türkiye's most comprehensive laboratories in the field, utilized for undergraduate courses, as well as for Master's and Doctoral research. The laboratory is equipped with 16 multi-purpose test benches and three specialized educational setups. It provides support for both academic research and industrial projects, offering experiments on power electronics circuits such as rectifiers, converters, and inverters. The laboratory serves approximately 150 students per semester and shares a power supply matrix with the Electrical Machinery Laboratory (*Power Electronics Laboratory*, n.d.).

Sakarya University Biomedical, Magnetic, and Semiconductor Materials Application and Research Center (BIMAS-RC): Established in 2009, BIMAS-RC is a leading research center dedicated to the development and application of advanced materials in Türkiye. The center focuses on a broad spectrum of materials science, including biomedical, magnetic, and semiconductor materials. It researches the synthesis, characterization, and various applications of these materials. BIMAS-RC addresses complex issues in biomedical engineering, such as developing materials for medical implants and diagnostic devices (*BIMAS-RC*, n.d.).

One of the most significant indicators of Türkiye's increasing interest and commitment to domestic chip production is its participation in the first chip design competition at the Teknofest Aerospace and Technology Festival (TEKNOFEST). The competition saw participation from 921 teams. Despite the modest prize, this high level of involvement reflects a strong enthusiasm and dedication to advancing the domestic chip industry (TEKNOFEST, n.d.).

The Presidency of Strategy and Budget announced (2023) the 12th Development Plan for the 2024-2028 period. This plan includes new programs, incentives, and policies to advance the semiconductor sector. Key objectives include promoting the technological development of semiconductors and their components, supporting investments in this field, and strengthening the design and production infrastructure in microelectronics. Additionally, the plan emphasizes supporting collaborations between universities, the public sector, and private industry in semiconductor chip design and production. The Chip Industry Report (2024) of the Digital Transformation Office of the Presidency of the Republic of Türkiye was also published and offers recommendations for the future of the chip industry.

Although Türkiye has demonstrated a clear commitment to the advancement of national technology across numerous sectors, there is a growing necessity for more strategic initiatives in the domain of semiconductors, particularly in collaboration with other middle powers. In order to enhance the competitiveness of its semiconductor industry, Türkiye can benefit from a more active engagement with these middle powers, with a particular focus on areas such as academic research, patent applications, international partnerships, and domestic investments.

Discussion and Conclusion

The chapter has made two case studies. The first is a comparative study of established and emerging middle powers' research and patent performance. The second case study offers a deeper perspective on Türkiye's semiconductor research and development infrastructure. The study also finds that India is the most frequently mentioned country in various areas of comparative cooperation in both literature and research analyses. Japan and South Korea are predominant actors in semiconductor research and patent numbers. Established middle powers play a crucial role in publishing research on semiconductors and producing patents. They collaborate with regional and superpowers. Both countries have closer ties with the US than China.

The analysis of middle powers and their engagement with the semiconductor industry reveals a complex situation of technological development, economic strategy, and geopolitical positioning. Our study of Japan, South Korea, Türkiye, and Malaysia provides rich insights into the range of approaches and challenges that countries face in seeking to gain or retain ground in this pivotal sector. Japan and South Korea are established middle powers with mature semiconductor industries, demonstrating sustained investment and strategic focus as requisites for continued technological competitiveness. With robust industrial bases, well-endowed research institutions, and state support, both nations have been able to stay at the leading edge of semiconductor progress.

Japan's historic leadership in semiconductors, though challenged in recent decades, continues to resonate in research output and patent filings today. Its focus on niche areas like materials science and specialized equipment has helped the country to retain an important position in global supply chains. The establishment of the LSTC in 2022 underlines Japan's commitment to the revitalization of its position in cutting-edge chip technologies (Shivakumar et al., 2023). At the same time, its collaboration with the US exemplifies teaming up with Western partners against the growing Chinese influence in the sector.

The case of South Korea rising to become a powerhouse in semiconductors, driven by chaebols such as Samsung and SK Hynix, epitomizes how the country can leverage its very carefully done industrial policy and couple it with private sector dynamism to take a middle power to the very top ranks of any high-tech industry. This can be exemplified by its dominance in memory chips and its developing capabilities in logic semiconductors—the potential for middle powers to be ranked as global leaders in given technological domains (Yang & Park, 2024). The $19 billion deal announcement for a package to boost the semiconductor industry in South Korea further shows the ongoing commitment to keeping the competitive edge against ever-more-global competition.

Both Japan and South Korea face identical challenges in their struggle to maintain their position, as Chinese competition is looming large with continuous innovation required in an increasingly complex technological environment and the securing of critical materials and equipment.

Their strategy is to deepen collaboration with Western allies while keeping on with economic engagement with China. It represents a delicate balance for a middle power in today's geopolitical environment.

Türkiye and Malaysia offer two distinct approaches to the building of semiconductor capability from a lower initial base for emerging middle powers. The experiences of these countries underpin the opportunities and challenges that exist for countries trying to make their way into an extremely competitive and capital-intensive industry.

The case of Türkiye attempting to build a national semiconductor industry, with the national processor development program and research centers and companies like ASELSAN & AB-MikroNano, shows the presence of strategic will for technological self-sufficiency. Its interest in defense and strategic applications corresponds to broader geopolitical aspirations and ambitions of autonomy. Our network analysis, however, reveals that the case of international research collaboration in semiconductors is rather low for Türkiye, which may indicate that opportunities to improve its global links and knowledge transfer are not being tapped.

Malaysia is building on its natural strengths in semiconductor assembly and testing to push an ambitious strategy up the value chain into chip design and advanced manufacturing. Its more than $100 billion of targeted semiconductor investments, and the creation of local champions in this sector, evince an ambitious and comprehensive attitude toward industrial development. Malaysia is therefore much stronger than Türkiye with respect to integration into Asian research and production networks, and it derives the relative advantages accruing thereto in knowledge spillovers and market access.

Both Türkiye and Malaysia are in a challenging environment vis-à-vis closing their respective technological gaps with established players, attracting sufficient investment, and developing the specialized workforce required to make for a competitive semiconductor industry. Their experiences underline the need to build capabilities in this sector and the role of sustained policy commitment and strategic focus over the long term.

There are a number of key themes that arise from our comparative analysis of middle powers in the semiconductor industry. The first concerns the critical role of government policy. While examining the semiconductor story across the four countries, one element that crops up as playing an important role is government support, be it in the form of funding, building infrastructure, and strategic coordination in ushering in capability-building and its sustenance. These middle powers demonstrate that in any high-capital, strategically important industry, the state often has to play a catalytic role if it is to be developed and compete with larger economies.

The second is related to balancing autonomy and integration. There is a delicate balance that middle powers have to establish between making something technologically autonomous and fitting into the global value chains. While domestic capability building was strongly brought out by all four countries, international collaboration and knowledge exchange form part of the imperatives. Only strategies that blend elements of these two approaches can be successful, building strategic autonomy while engaging global networks for innovation and production.

The third is about the necessity of niche strategies. Against a backdrop in which the US and China have gigantic head starts over most rivals in nearly all areas of semiconductor technology, middle powers have had to be innovative by making breakthroughs within specific niches or applications where they can build a competitive edge. Materials and equipment from Japan, South Korean memory chips, and defense applications from Türkiye have been typical hallmarks of this strategy.

The fourth pertains to research and innovation networks. Our research output and collaboration trend analysis indicates the critical role of international scientific cooperation in the semiconductor field. The performance of countries like Japan and South Korea inside global research networks shows how middle powers can use knowledge flows to upgrade their technological capabilities. For rising new players such as Türkiye and Malaysia, the tightening of these international research ties may be important for speeding up development.

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