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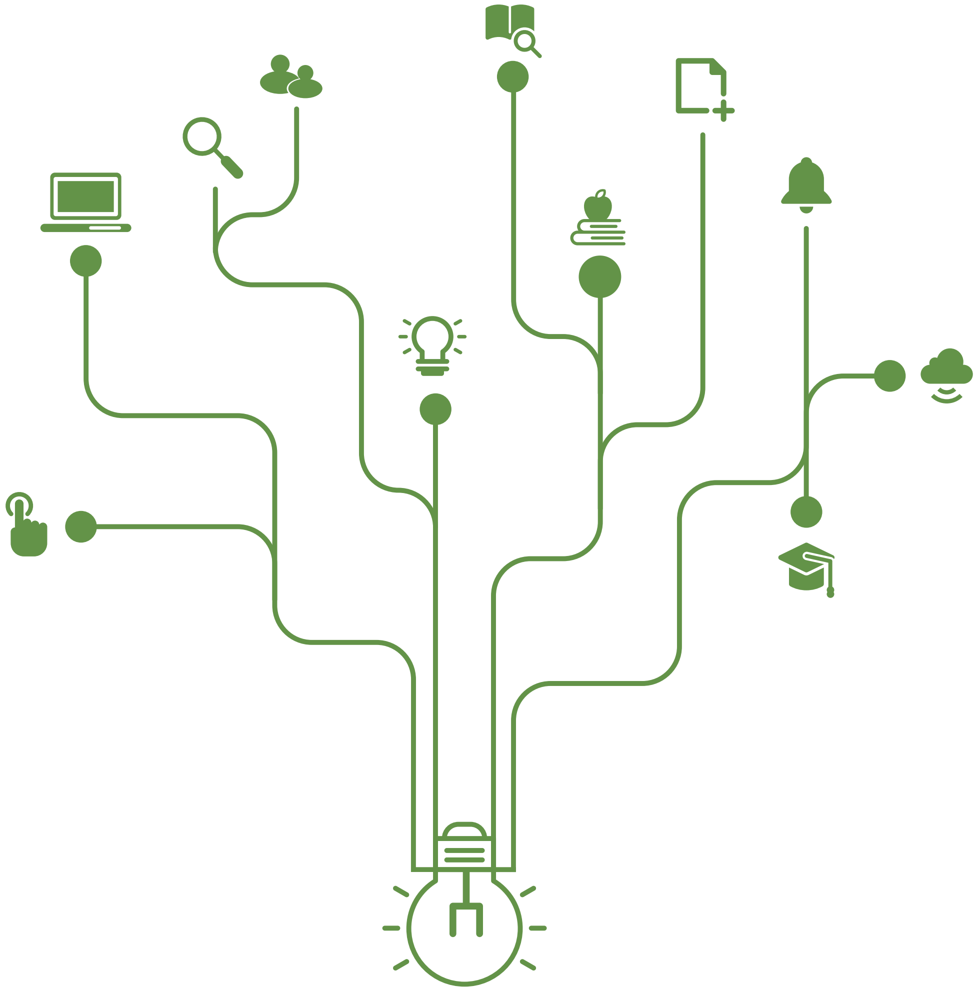

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# Technological Pathways and Market Structure: Autonomous Vehicle Innovation in the United States and South Korea[1]

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## Abstract

In this study, we identify and compare the development patterns of autonomous vehicle technologies (AVTs) in the United States and Korea using network analysis. The comparison is motivated by the distinct industrial systems of the two countries. In Korea, AVT development has primarily been driven by the RD efforts of large corporations, focusing on a limited number of technologies. In contrast, the U.S. has seen active technology transfers and mergers and acquisitions (M&As) between startups and major firms. By highlighting these differing technological trajectories, this study provides deeper insights into the interplay between market structures and technological progress.

*Keywords:* Autonomous Vehicle Technologies, Coevolution, Innovation, Market Structure

## 1. Introduction

Technologies and innovations evolve in tandem with institutions, infrastructures, and consumption patterns. For example, the widespread adoption of automobiles would not have been possible without the development of roads, driving regulations, and essential components such as gasoline and tires in the early twentieth century (Geels, 2002; Saviotti, 2023). Such coevolution is particularly evident during the early stages of emerging technologies, such as the recent rapid transitions in technological paradigms (Saviotti, 2023; Dosi, 1982). Kuhn (1962) posits that scientific progress alternates between revolutionary phases—where new paradigms incompatible

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with previous ones emerge—and periods of normal science, during which these paradigms are elaborated upon and applied to new contexts. This is followed by a convergence where stakeholders in a technology coalesce around a narrower range of technical solutions than initially possible. Over time, what began as multiple technological designs is consolidated into a dominant design through self-regulation. This process begins with radical innovations that establish new dominant designs (Utterback, 1975) or paradigms (Dosi, 1982; Dosi and Nelson, 2018), and is succeeded by numerous incremental innovations that progressively improve the technology's offerings to its users and consumers.

Based on this theoretical motivations, we study the patterns of innovation in autonomous vehicle technology (AVT), which is profoundly transforming the motor vehicle industry. AVT encompasses a range of technologies that enable vehicles to navigate to their destinations without human intervention, utilizing functions such as sensors, computer processors, and data processing systems (Rajasekhar and Jaswal, 2015). With increasing demand for efficient driving solutions to reduce vehicle accidents, energy consumption, pollution, and congestion, AVT is gaining widespread recognition within the automotive manufacturing industry Bagloee et al. (2016).

Recognizing the transformative potential of self-driving cars, both established and emerging firms are heavily investing in this technology. Tech giants like Apple, Google, and Tesla, alongside traditional automakers such as Ford and Volvo, are competing to lead this new era of innovation. This intensifying competition signals a significant transformation poised to redefine transportation systems, reshape urban landscapes, and substantially reduce road fatalities and pollution—mirroring the revolutionary impact of automobiles in the twentieth century (The Economist, September 2016).

Our research is primarily motivated by the observation that technological progress often exhibits path dependency David (1985). Previous scholarly efforts have explored the co-evolutionary dynamics between technologies, demand, institutions, and diverse market structures. This study focuses on the differing roles of US and Korean market structures in shaping innovation trajectories. Large firms with significant market power and smaller firms with limited resources often adopt distinct business strategies, leading to varying approaches to innovation. Using AVT as a case study, we examine how innovation interacts with its ecosystem and coevolves with it.

At first glance, Korea and the U.S. exhibit contrasting market structures in the development of AVT. In Korea, the Hyundai Motor Group—a major conglomerate that encompasses Hyundai Motor Company, Kia Corporation, Genesis Motor, Ioniq, and 42dot—conducts internalized RD and leads technology development in this domain. Conversely, in the U.S., AVT development is driven by a broader ecosystem involving car manufacturers, technology firms, and startups. Large corporations such as General Motors (GM), Ford Motor Company, and Tesla not only engage in in-house R&D but also acquire new AVT technologies through mergers and acquisitions (M&A) and patent transfers from startups.

Given these contrasting technology market environments, this research seeks to answer a key question: How do the AVT development trajectories differ between the U.S. and Korea? To address this, we construct and compare two types of networks: a technology network and a firm network, employing methodologies from the field of economic complexity (Hidalgo et al., 2007; Hidalgo and Hausmann, 2009; Hidalgo, 2021).

- Technology Network: We trace the evolution of AVT development trajectories and compare the differences between the two countries.
- Firm Network: We investigate the differing market environments in the U.S. and Korea through MA activities and collaborative efforts, such as R&D investments.
- Comparative Analysis: We analyze annual changes in both networks for Korea and the U.S., highlighting how the relationships between technological and market dimensions differ in these two contexts.

For the analysis, we first compile patent data from institutions, including established firms, startups, universities, and public organizations, that applied for AVT-related patents annually from 2010 to 2019, when AVT emerged as a widely recognized concept (Ko and Lee, 2021). Patent data for US and Korean firms are sourced from PATSTAT (Patent Statistical Database, Spring 2021 edition, provided by the European Patent Office). To identify transaction information in the technology market, we investigate M&A and collaborative activities between firms that hold AVT patents. For this, we utilize data from Crunchbase, a platform that offers comprehensive business information on startups, CEOs, investments, and funding. Finally, we manually verified and corrected errors in the raw data using information from more than 300 media sources.

## 2. Background Information

Regarding the technological development environment, Korea and the U.S. have different technology development histories and accumulated technological infrastructures. Korea, the latecomer, started its economy from agriculture and transitioned to a heavy chemical industry after the 1960s, while the U.S., the first mover, achieved its first industrialization in the early nineteenth century and the second industrial revolution in the late nineteenth century. The country that showed successful co-evolution in the automobile industry in the early twentieth century was the U.S.. After the mass production of cars and subsequent massive construction of the infrastructure in the 1920s, the automobile industry in the U.S. has developed its technology ecosystem for more than a hundred years.

In addition to the length of their automotive histories, the size and characteristics of domestic markets significantly influence the industry dynamics in the United States and South Korea. The stark disparities in size and population between the two countries play a pivotal role in shaping their respective automotive markets.

The United States, with its vast land area of approximately 9.8 million square kilometers—over 97 times the size of South Korea—presents unique challenges and opportunities for the automobile industry. The country's expansive geography and low population density in many regions drive a strong demand for larger vehicles such as trucks and SUVs, which are better suited for long-distance travel and diverse terrains.

In contrast, South Korea, with its compact size of around 100,000 square kilometers and a population of about 51 million, features a more urbanized landscape. This urban density fosters a preference for smaller, more fuel-efficient vehicles, which are well-suited for navigating the crowded streets of densely populated cities.

These fundamental differences in geography, population distribution, and urbanization are critical factors that shape the distinct automotive market dynamics of the two countries. Together, they highlight the interplay between market characteristics and the evolution of automotive technologies and preferences.

The industrial structures of the automotive industries in South Korea and the United States differ significantly, reflecting distinct market characteristics and technological ecosystems. While South Korea ranked fifth in global motor vehicle production in 2023, its industry is highly concentrated. Hyundai Motor Group, encompassing Hyundai, Kia, Genesis, and related subsidiaries, dominates the market, consolidating both production and technological development within a single conglomerate (Kim et al., 2022). This monopolization has led to the centralization of automotive technology, with Hyundai Motor Group serving as the primary driver of innovation and R&D efforts in South Korea.

In contrast, the U.S. automotive industry features a more diversified and competitive market structure. Major automakers such as General Motors, Ford, and Stellantis coexist alongside a host of technology firms, startups, and suppliers that contribute to the development of automotive technologies. This diversification is particularly evident in emerging fields such as autonomous vehicles and electric mobility, where companies like Tesla, Rivian, and a range of smaller startups have introduced disruptive innovations. The broader ecosystem also includes active collaboration and competition among traditional manufacturers, technology firms, and venture capitalists, further fostering technological pluralism.

This divergence in industrial structure highlights the implications for automotive technology development. South Korea's concentrated model allows for streamlined decision-making and large-scale investments within Hyundai Motor Group but risks limiting technological diversity. Meanwhile, the U.S. model leverages competition and collaboration across a broad range of actors, creating a dynamic environment where diverse technological approaches can emerge and evolve. These structural differences underscore the varying pathways by which each country advances its automotive technology and adapts to global market trends.

## 3. Data

To find the relationship between AVT market side and AVT development side, this study combines multiple data sources. First, as we focus on specific technology domain, i.e., AVT, we identify target CPC (Corporate Patent Classification) codes related to AVT based on the category suggested by Balland and Boschma (2021) [2]. We focus only on the development pattern of AVT for 10 years from 2010 to 2019, when the AVT is started to be actively developed and used (Ko and Lee, 2021). In order to construct a representative technology network that is not biased by period-specific factors, such as disturbance by Covid-19, this study utilizes accumulated patents of 10 years from all countries that filed over ten patents.

Second, since one of our goals is to overlap the heterogeneous technological development trajectories of the U.S. and Korea on the representative technology network, AVT-related patents filed by the institutions in both countries are searched in PATSTAT (Patent Statistics Database) (Spring 2021, provided by the European Patent Office). As the institutions, we include existing firms, startups [3], public institutions, and universities that have applied for at least three AVT-related patents as the unit of analysis. However, as the names of patent applicants are not recorded as unique IDs, therewith are not unified, we employ OECD HAN database [4] to match the owner of patents with different applicant names. For minor errors found in OECD HAN, ownership is searched and corrected through manual review.

Third, to examine the relationship between AVT development and AVT market activity, we investigate M&A or investment events for the final sample institutions. We use CrunchBase dataset (www.crunchbase.com) to collect M&A or investment information related to startups. CrunchBase is a startup that provides charged information on all types of companies, from startups to large conglomerates. Since the total amount of money transferred in investment or M&A

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[2] From an extensive literature review, Balland and Boschma (2021) allocate following CPC codes to autonomous driving technology; G05D1 (Control of position course altitude or altitude of land water air or space vehicles); G01S17 (Systems using the reflection or reradiation of electromagnetic waves other than radio waves); H04W4/40 (Wireless communication networks for vehicles); B60W30/14 (Cruise control); B60T2201/0 8 (Lane monitoring; Lane Keeping Systems). We consider all patents assigned to these CPC codes to be AVT-related patents

[3] We consider companies that have been in business for less than 10 years to be startups. Private companies that have operated their business for more than 10 years are included in the 'Company' category.

[4] https://www.oecd.org/sti/inno/intellectual-property-statistics-and-analysis

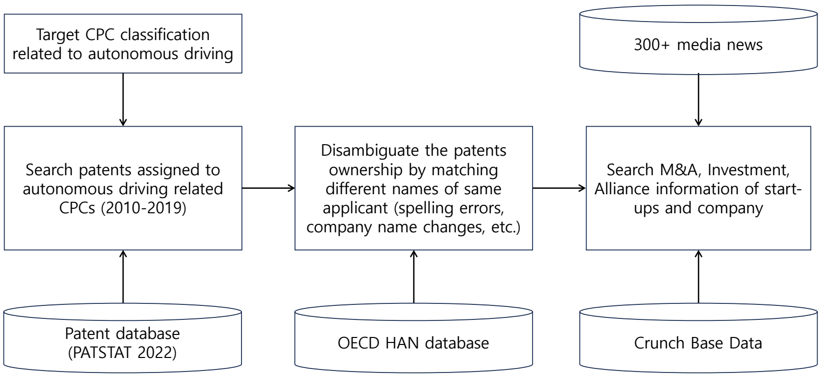

Figure 1: Data Construction Process

are not always disclosed, we only figure out whether there are activities in the AVT market such as investment or M&A or not (i.e., dummy variables for M&A or investment). As all the information on the web is collected based on CrunchBase's algorithm, we could see a significant number of errors in the raw data. Therefore, we manually correct the errors based on the information from more than 300 media sources (newspapers, Linkedin, etc.).

Figure 1 summarizes the structure of our data set. We combine multiple data sources to find the relationship between the trajectory of AVT development and collaborations in the AVT market. We gather patents from PATSTAT that focus on CPC codes assigned to AVT-related technologies. Next, we match the names of patent applicants, who are identical but in different forms, based on the OECD HAN database. Then, we examine institutions, including firms, startups, universities, and public institutions, that have applied for more than three AVT-related patents. Information on M&A or investment between institutions is collected from CrunchBase data, and errors in this dataset are corrected by multiple media sources.

We finally select institutions with more than three AVT-related technologies for ten aggregated years. Table 1 shows some differences between the two countries. The most significant difference is its composition, where startups make up the majority in the U.S., while universities and public institutions make up almost half in Korea. Next, startups in the U.S. are actively changing their status to prepare for an IPO or acquisition.

Table 1: The composition and number of institutions in the U.S. and Korea from 2010 to 2019.

| | The U.S. (Total 266) | Korea (Total 126) |
|---|---|---|
| 1. Company<br>(subsidiary or division level) | 165<br>(listed firms: 68) | 52<br>(listed firms: 33) |
| 2. Startup<br>(in business for less than 10 years) | 83<br>(5 companies went public,<br>17 companies were acquired.) | 16 |
| 3. University | 15 | 41 |
| 4. Public institutions | 3 | 17 |

## 4. Technology and Institutional Networks

Before conducting a comparative analysis of technological development trajectories and technology market activities, we first construct representative technology and institutional networks for the United States and Korea.

### 4.1. Global Technological Network

Figure 2 describes the data structure and the process of building a representative technology network, based on Hidalgo et al. (2007). Panel (A) explains how we match the AVT-related CPC codes to the patents filed in each country as developed technologies developed in that country. As shown in Panel (B), we select only AVT-related technologies with RTA for each country. The red dots in the technology-country bipartite matrix indicate the technologies with RTA developed by the countries. Over the past 10 years, 43 countries have developed more than 10 AVT-related technologies.

We first build the technology-country bipartite matrix to capture the cognitive distance between technologies. From this matrix, we can identify only those technologies for which a country has revealed technological advantage (RTA) using the following equation.

$$RTA_{i,\alpha,t} = \frac{\frac{P_{i,\alpha,t}}{\sum_{\alpha} P_{i,\alpha,t}}}{\frac{\sum_{i} P_{i,\alpha,t}}{\sum_{i}\sum_{\alpha} P_{i,\alpha,t}}} \tag{1}$$

where $P_{i,\alpha,t}$ is the number of patents assigned to the AVT, $\alpha$ applied by country $i$ at time $t$ (Balassa,

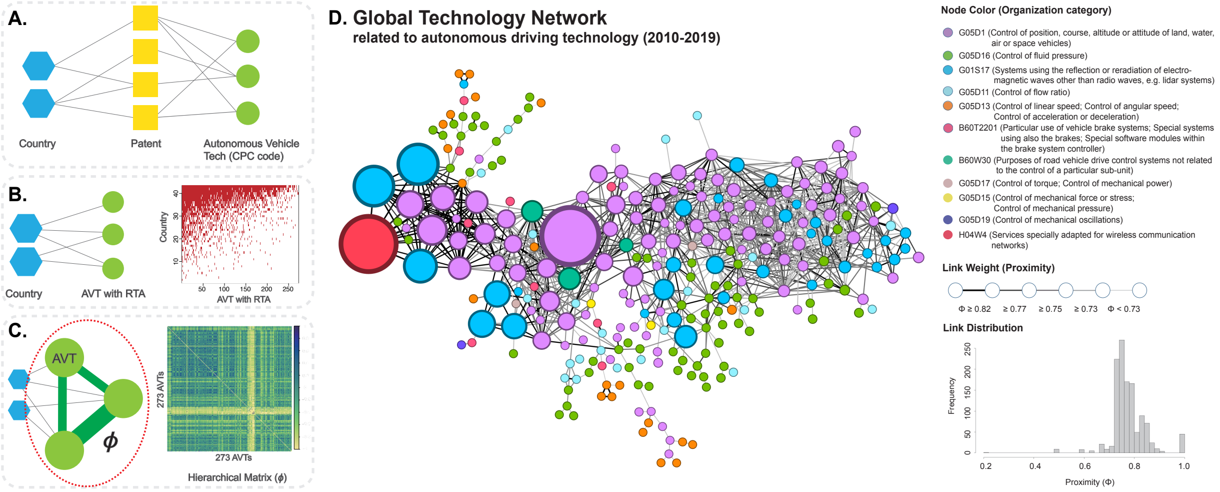

Figure 2: Building Global Technology Network. (A) We consider the AVT-related CPC codes assigned to patents filed in each country as developed technologies developed in that country. (B) Only AVT-related technologies with RTA for each country are selected. The red dots in technology-country bipartite matrix indicate the technologies with RTA developed by the countries. Over the last ten years, 43 countries have developed more than 10 AVT-related technologies. (C) We calculate the cognitive distance ($\phi$) between 273 AVT-related technologies. The proximity ($\phi$) is expressed as the thickness of links in the technology network. (D) The global AVT-related technology network. Nodes denote 273 types of 6-digit AVT-related CPC codes, and their 11 colors represent different types of 4-digit AVT-related technologies. The radius of a node means the total number of patents assigned to the node's CPC code

1965) [5]. We convert the continuous $RTA_{i,\alpha,t}$ values to a binary number, where 1 when $RTA_{i,\alpha,t}$ is larger than 1, or 0, otherwise. We only consider $RTA_{i,\alpha,t}$ greater than 1, which is the sample mean, because we only consider the significant technologies the country possesses.

Next, we calculate the cognitive distance between technologies to construct an AVT network. The minimum of the pairwise conditional probabilities is used to estimate the cognitive distance between two different AVTs. It is called proximity between technology $\alpha$ and $\beta$ ($\phi_{\alpha,\beta}$) and calculated based on the following Equation 2.

$$\phi_{\alpha,\beta} = \min\left\{\Pr\left(RTA_{\alpha} \mid RTA_{\beta}\right), \Pr\left(RTA_{\beta} \mid RTA_{\alpha}\right)\right\} \tag{2}$$

$\phi_{\alpha,\beta}$ is the probability for the country that already has an RTA at AVT $\beta$ to have an RTA at AVT $\alpha$, and vice versa. A higher $\phi_{\alpha,\beta}$ means that two AVTs $\alpha$ and $\beta$ are more likely to be found

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[5] We only consider countries that have applied more than ten cumulative patents. We do this because if a country has only one patent, then its RTA values will be overestimated, resulting in a biased network topology.

together in the same country. Because high $\phi_{\alpha,\beta}$ values indicate that both AVTs $\alpha$ and $\beta$ require similar background knowledge or share infrastructure and are therefore usually found together in the same country. In the technology network, technology $\alpha$ and $\beta$ with high $\phi_{\alpha,\beta}$ are located closer than others when using forceatlas2 algorithm in Gephi 0.10 (https://gephi.org/), as shown in Figure 2 (C).

Panel (D) illustrates the output: the global AVT-related technology network. Nodes denote 273 types of 6-digit AVT-related CPC codes, and their 11 colors represent different types of 4-digit AVT-related technologies. The radius of a node means the total number of patents assigned to the node's CPC code.

### *4.2. Institutional Networks*

Next, we construct an institutional network by measuring the cognitive distance between institutions and visualizing the relationships among them. Given that the technology-institution bipartite matrix shares an identical structure with the technology-country bipartite matrix, we apply the same equations, modifying the subscript $i$ from country to institution in Equation 1 and replacing the subscripts for technologies $\alpha$ and $\beta$ with institutions $i$ and $j$ in Equation 2. For this analysis, we focus exclusively on AVT-related technologies for which two or more patents have been filed by institutions, thereby minimizing biases caused by network topology.

$$\phi_{i,j} = \min\left\{\Pr\left(RTA_i \mid RTA_j\right), \Pr\left(RTA_j \mid RTA_i\right)\right\} \tag{3}$$

In Equation 3, a high $\phi_{i,j}$ means that institution $i$ is similar to institution $j$, indicating that both have similar technology portfolios. We build two different institutional networks, one in Korea and one in the United States.

In Figure 3, we draw the two distinct kinds of institutional networks for the U.S. and Korea: nodes as institutions and links as closeness between them. Panel (A) explains the matching of the AVT-related CPC codes to patents filed in each institution as exploited technologies developed in that institution. As in 2, Panel (B) shows that only AVT-related technologies having RTA of each institution are chosen. The red dots in the technology-institution bipartite matrix indicate

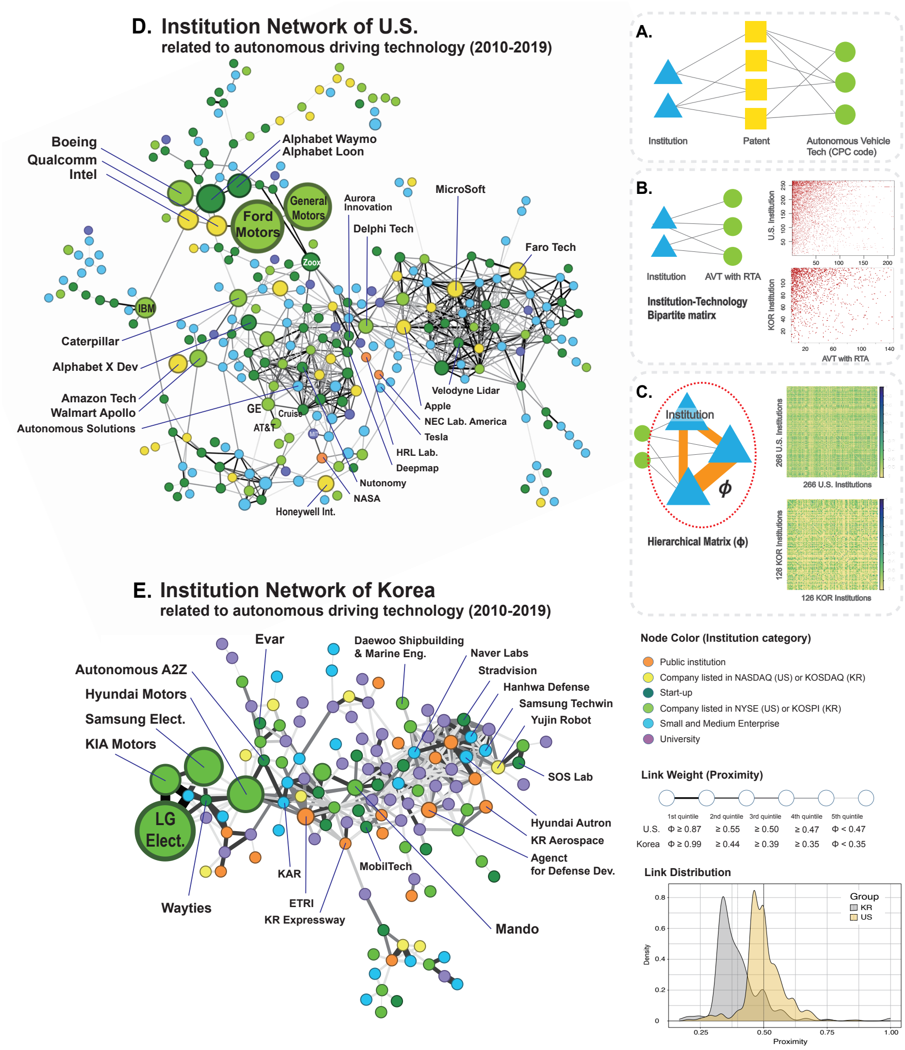


Figure 3: Data structure and the process of building an institutional network for the U.S. and Korea.

the technologies with RTA developed by the institutions in the U.S. and Korea, respectively. In Panel (C), we compute the cognitive distance ($\phi$) between the pairs of institutions. The proximity ($\phi$) is described as the thickness of links in the institutional networks.

Panel (D) and (E) compare the institutional networks of the U.S. and Korea. The institutional network of the U.S. Nodes denotes 266 institutions that have developed more than three AVT-related technologies, and the six colors represent the institutions' classifications. Compared to

Korea, US firms mainly comprise large conglomerates, small and medium enterprises (SMEs), and startups. Based on the community detection algorithm, all nodes can be roughly divided into three main clusters, the first cluster consists of traditional carmakers or automobile components manufacturing companies (General Motors, Ford, Boeing, Delphi Technologies), chip-makers (Intel, Qualcomm) and subsidiaries of large conglomerates such as Alphabet Inc. (Waymo is established for self-driving car project and Loon LLC produces high-altitude balloons for providing internet access) and Amazon (Zoox). The second cluster consists of companies like Amazon Tech, Walmart Apollo, Autonomous Solutions, GE, AT&T, Cruise, Aurora Innovation, Nutonomy, Deepmap, Alphabet X Dev, Tesla, and Caterpillar. The third cluster includes companies such as MS, Faro Tech, Velodyne Lidar, and Apple.

On the other hand, Korea's institutional network is divided into two parts, centered on large conglomerates and startups, and a part mainly consists of universities, public institutions, and a few companies. Major electronics manufacturers such as Samsung Electrics, LG Electrics, and automobile makers such as Hyundai and Kia Motors are located nearby. In addition, technologically competitive startups such as Wayties, Evar, and Autonomous A2Z are closely linked to these large corporations. Another cluster is a mix of public institutions, universities, and companies. This implies that the government plays a certain role in the development of AVT by connecting universities and companies.

## 5. Technological Development Trajectory

### *5.1. Methodology*

As new technology is a recombination of existing ideas (David and Foray, 1995), it is rare to find a new technology suddenly appearing overnight. To reduce the cost of exploiting new technologies, organizations typically expand their technological horizons incrementally by leveraging their existing knowledge, which is known as the principle of relatedness (Hidalgo et al., 2007).

To trace the development path of AVT, we propose a methodology to visualize their trajectory by overlaying the yearly changes of technologies for which RTAs have been secured by

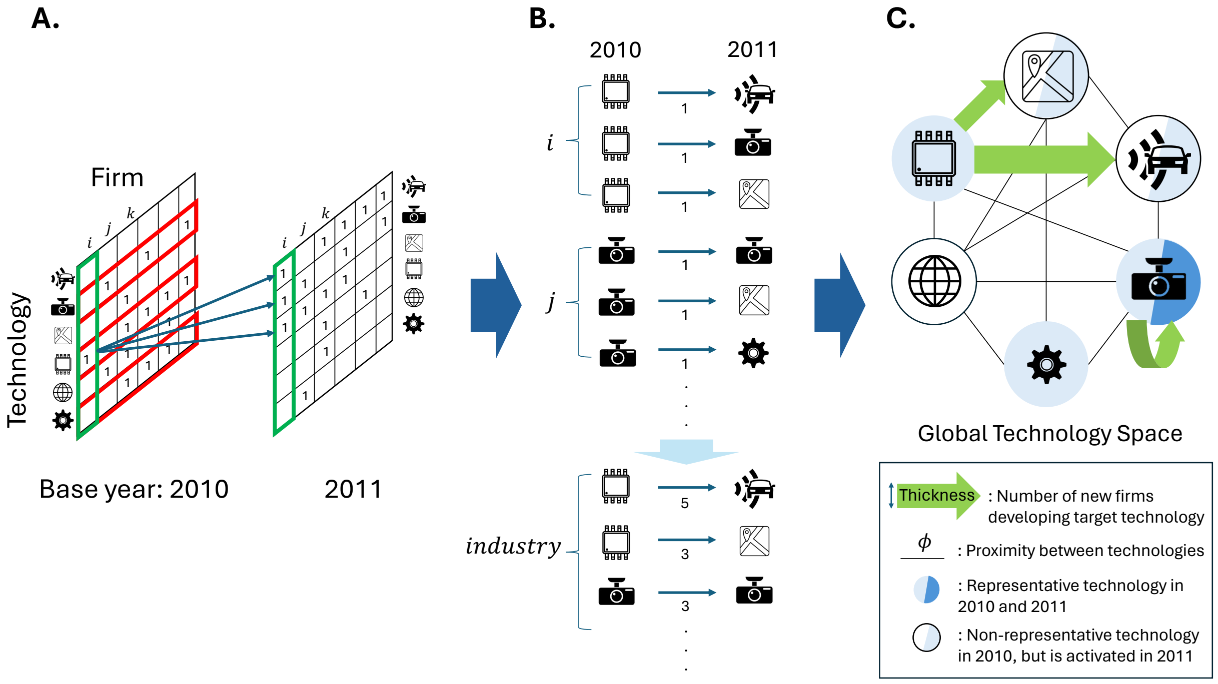


Figure 4: (A) Three representative technologies are selected: the technology with the largest number of institutions holding RTAs (ubiquity) and the largest number of patents per technology (dominance) for 2010, which is the starting year of our analysis. (B) We count how many institutions with three representative technologies will develop or maintain based on those technologies in the following year (2011). This is because the three technologies serve as background knowledge that influences the development of the next technology. When we look at the technological developments of all institutions, we can see the technological changes in the whole industry. (C) The development trajectory (from background knowledge to newly developed technologies) for the technologies that have changed the most in a year are overlapped on the technology network. The representative technologies in 2010 are marked in light blue. If it is not a representative technology in 2010 but became a representative technology in 2011, the color is darkened one tone from white. If it is a representative technology in 2010 but is also a representative technology in 2011, the color is darkened one tone more.

most institutions on the technology network (Figure 4). Starting from the assumption that previous AVT-related knowledge affects the development of the next new AVTs, we can follow the paths of AVT development. Since technologies already possessed will influence the development of new technologies for organizations (). Therefore, we start our analysis with the three representative technologies of 2010, which have secured RTAs by the largest number of institutions (ubiquity), and at the same time have the largest number of patents (dominance) as shown in Figure 4 (A). We calculate the sum of the ubiquity ranking of a technology and the dominance ranking of a technology and consider the technologies with the lowest combined ranking as the representative technologies. From these three representative technologies in 2010, we looked into what technologies the companies possess will be developed in the following year. we count the number if there is a change in comparative advantage in a firm and then aggregate the changes of all companies to identify the technological changes of the entire industry (in Figure 4 (B)). Lastly, as shown in 4 (C), based on the background technological knowledge of the previous year, the new technologies developed by most organizations during the year are displayed by overlaying them on the technology network of 2. These changes are considered to be the most popular changes based on the previous year. Since 2011, three representative technological changes have been selected each year using the same method.

There may be some technical concerns with the visualization methodology. First, since technology is developed over *n* years, all technological knowledge from year 1 to n-1 can have an impact. Therefore, we take a moving average from the first of the development year to 10 years during which the patent citations are valid (Hall et al., 2001). Next, since this study focuses only on the phenomenon of new AVT development, the result does not reflect technological changes in which the number of patents decreases or the number of companies with RTA decreases. In other words, when the number of patents or the number of companies with RTA decreases, the color of the node does not change and remains the same.

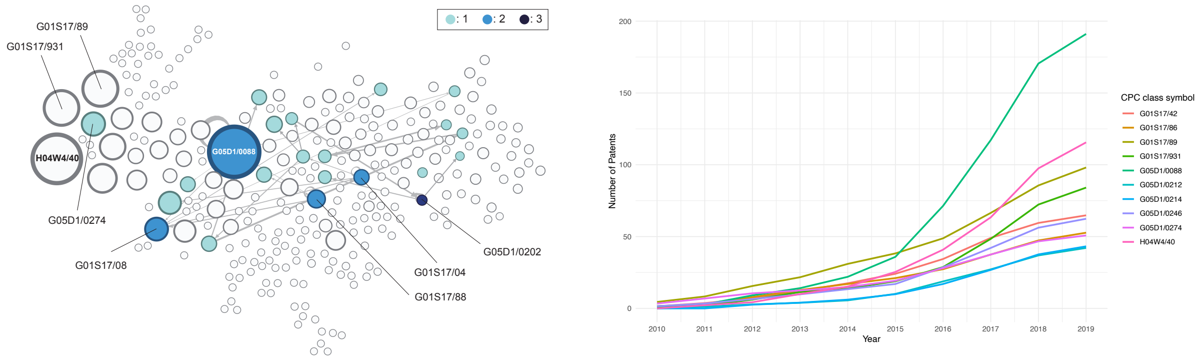
### *5.2. Comparison of Technology Development Trajectories*

In Figure 5, we analyze the position of autonomous vehicle technology in two countries, the United States and Korea, and trace its development trajectory on the technology space. In the case of the United States (Figure 5 (A)), we can see that AVT development takes place on a wide range of the global technology space, especially on the right side, unlike Korea. In addition, there is only one case where the same technology has been developed for over 3 years: G05D1/0202 (Control of position or course in two dimensions specially adapted to aircraft). This means that technological development in the United States has been carried out simultaneously across various technologies rather than concentrating on a few specific technologies.

On the other hand, in Korea (Figure 5 (C)), technological development has been mainly carried out on the left area of the global technology space. In addition, while three technologies

A.The development trajectory of autonomous driving technology in the U.S.

B. Annual number of applied patents with the top 10 CPC related to AVT in the U.S.



C. The development trajectory of autonomous driving technology in the KR

D. Annual number of applied patents with the top 10 CPC related to AVT in the KR

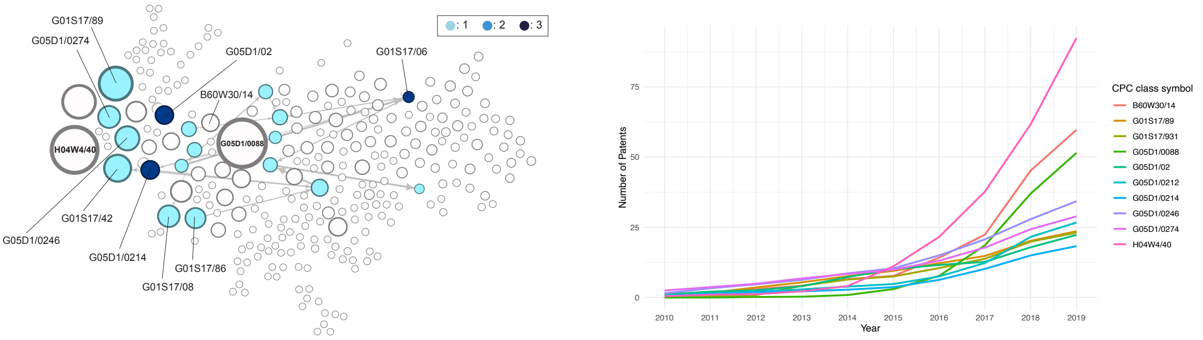


Figure 5: Comparison of autonomous driving technologies in the United States and Korea. **(A)** Development trajectory of autonomous driving-related technology in the U.S. The AVT development trajectory of the U.S. can be seen as being developed in a wider range on the global technology network than Korea. **(B)** Annual number of patent applications by top 10 CPCs of AVT in the U.S. G01S17/931 (Systems using the reflection or reradiation of electromagnetic waves other than radio waves for anti-collision purposes of land vehicles) is the patent classification with the largest proportion in the U.S. since 2016, but the node in Figure (A) is not activated because a small number of companies own almost all of the patents. **(C)** Development trajectory of autonomous driving-related technology in Korea. In the case of Korea, AVT development takes place in a narrower range (mainly on the left side of the global technology network). Unlike the U.S., Korea does not have the technology classification developed twice. On the other hand, there are three technologies that have been developed for more than three years. **(D)** Annual number of patent applications by top 10 CPCs of AVT in Korea. Similar to the U.S., the H04W4/40 (Services specially adapted for wireless communication networks for vehicles) is inactive because a few large companies hold most patents.

were mainly developed three times (G05D1/0214 - Control of position or course in two dimensions in accordance with safety or protection criteria, e.g. avoiding hazardous areas, G05D1/02 - Control of position or course in two dimensions, and G01S17/06 - Systems determining position data of a target), and there are no technologies that have been developed twice. This means Korea has focused on developing a few specialized technologies rather than developing diversified AVT-related technologies.

We can confirm that the technology classification codes G01S17/931 (Systems using the reflection or reradiation of electromagnetic waves other than radio waves for anti-collision purposes of land vehicles) and H04W4/40 (Services specially adapted for wireless communication networks for vehicles), which have the largest proportions in both the United States and Korea, are not active in the AVT development trajectory. This means that the technology has low ubiquity in each country because only a few companies hold almost all the patents. Appendix A( A1) and Appendix B( A2) describe technological changes of the two countries by year.

How are the observed technological development patterns between the two countries related to the market structure? Figure 6 shows technology market activities that have occurred across different organizational networks in the United States and Korea. The United States and Korea exhibit starkly contrasting dynamics in their domestic technology markets, particularly regarding the development and commercialization of autonomous vehicle technology (AVT). These differences are shaped by the roles of key players, the funding landscape, and the broader innovation ecosystem.

In the United States, the domestic technology market thrives on active mergers and acquisitions (MA) and robust venture capital investment. The U.S. Department of Defense (DoD), along with other government agencies, played a pivotal role in establishing the foundation for AVT innovation. The DARPA Grand Challenges (2004, 2005) and the DARPA Urban Challenge (2007) acted as transformative milestones, bringing together top researchers to build self-driving car prototypes and publicly showcasing the vast market potential of AVT. These events not only catalyzed AVT innovation but also laid the groundwork for a thriving startup ecosystem, with participants and successors later spearheading vigorous RD and creating new ventures.

In the mid to late 2010s, the U.S. witnessed several high-profile acquisitions, such as Intel-Mobileye, GM-Cruise, Uber-Otto, and Delphi-nuTonomy. These acquisitions underscored the active interplay between startups and major industry players. While AVT startups in the 2020s are experiencing more consolidation than rapid emergence, successful cases, like Aurora's IPO and Waabi's funding round, continue to attract focused and significant investment. This ecosystem demonstrates a private-sector-driven innovation model, where venture capitalists and industry players, rather than government bodies, play a dominant role in shaping the market.

In contrast, Korea's domestic technology market reflects a more centralized and government-led model. Hyundai Motor Company has been a key player in promoting innovation, hosting contests related to future car technologies since the 1990s. However, Korea's first self-driving competition, akin to the DARPA Challenges, only took place in 2010. Unlike the DARPA Challenges, which brought together interdisciplinary teams of top researchers from various laboratories, Korean competitions primarily featured teams from single laboratories. Although these participants later collaborated within conglomerates, government-funded research institutes, and startups, the funding landscape diverged significantly from that of the U.S.

In Korea, a considerable portion of funding for AVT-related institutes and startups has come from government initiatives, such as the Autonomous Driving Technology Development Innovation Project. Venture capital investment, while present, plays a less prominent role compared to the U.S. ecosystem. Even in terms of corporate investments, Hyundai Motor Group's engagement has been limited to notable instances, such as its 2018 investments in startups StradVision and MobilTech. This highlights a more cautious and concentrated approach to technology acquisition and development, in contrast to the dynamic and competitive U.S. market.

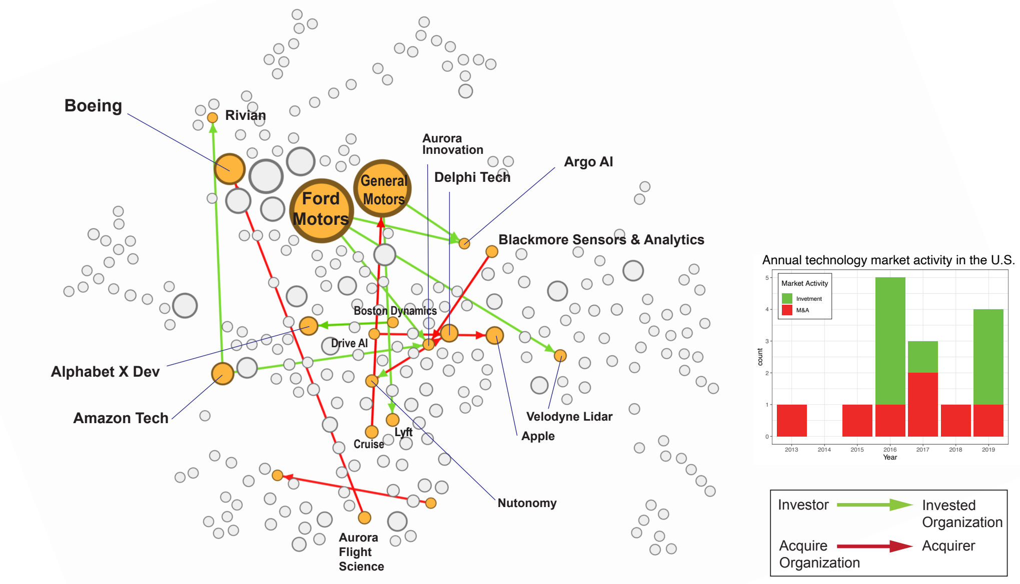
These contrasting dynamics underscore how market structures and funding sources shape the innovation trajectories of AVT in the two countries. While the U.S. benefits from a competitive, decentralized, and venture-driven environment, Korea's centralized and government-supported model fosters a different pathway for technological development and market activity.

## 6. Conclusion

This study examined the contrasting technological development trajectories and market structures of autonomous vehicle technology in the United States and South Korea. By analyzing technology networks and firm networks, we provided a detailed comparison of how innovation progressed within these two distinct environments. Our findings highlighted the critical role of market structure in shaping the pathways of technological advancement.

Our primary contributions lie in the methodological framework we employed. Using tools

A. Information on the U.S. autonomous driving technology market activity



B. Information on the KR autonomous driving technology market activity

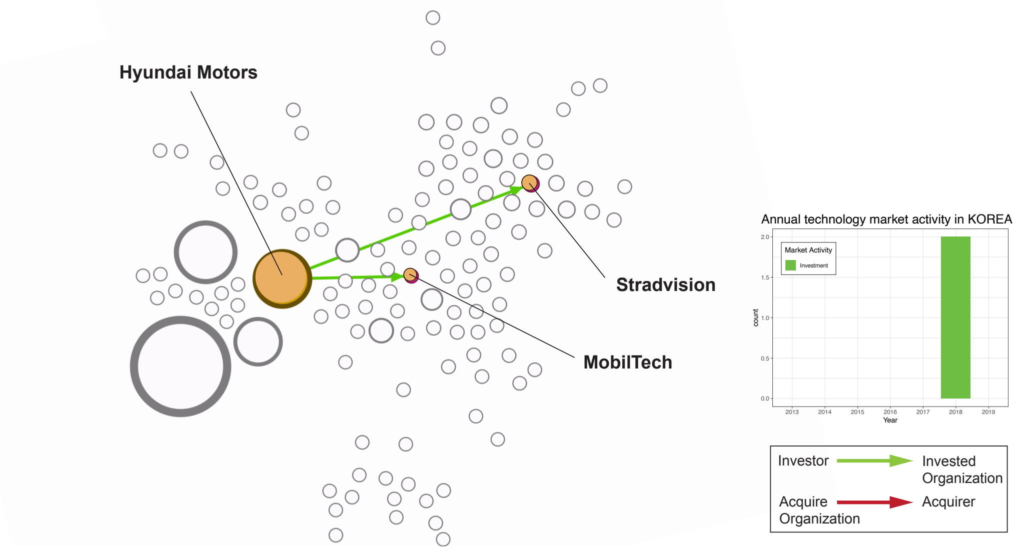


Figure 6: Technology market activity among organizations with autonomous vehicle technology in the United States (A), and Korea (B). Since M&A costs are sometimes undisclosed, we only checked whether there was either an M&A or an investment.

from economic complexity, we constructed and analyzed technology and firm networks for each country. This approach integrated patent data from institutions, startups, and public organizations with transaction data, capturing M&A and collaborative activities. We further ensured data accuracy by manually verifying over 300 media sources, offering a robust foundation for studying the coevolution of technology and market structures.

In the technology network, we observed that the U.S. fostered a decentralized and competitive ecosystem where diverse actors, including startups and large firms, drove innovation. In contrast, South Korea exhibited a centralized, government-supported approach, with conglomerates like Hyundai Motor Group playing a dominant role in advancing AVT through internalized R&D efforts.

These observed technological patterns were both shaped by and actively influenced the underlying market structures. In the U.S., a vibrant technology market, characterized by active M&A activity and venture capital investment, enabled the rapid exchange and commercialization of technologies. This competitive and decentralized structure not only supported technological diversification but also evolved alongside it, creating a dynamic feedback loop. In South Korea, limited M&A activity and significant government funding through initiatives such as the Autonomous Driving Technology Development Innovation Project created a more stable, centralized system. Here, technology development reinforced the dominant role of conglomerates, while the market structure coevolved to support this centralized model.

In conclusion, the differing AVT trajectories of the U.S. and South Korea underscored how market structures and technological innovation coevolve to shape distinct pathways of development. While the U.S. leveraged a competitive, venture-driven system, South Korea relied on a centralized model shaped by government and conglomerates. Our methodological approach contributed a rigorous framework for future comparative studies of emerging technologies, offering insights into how global market environments shape technological ecosystems.

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# Appendix A. The autonomous vehicle-related technological development trajectory of the U.S.

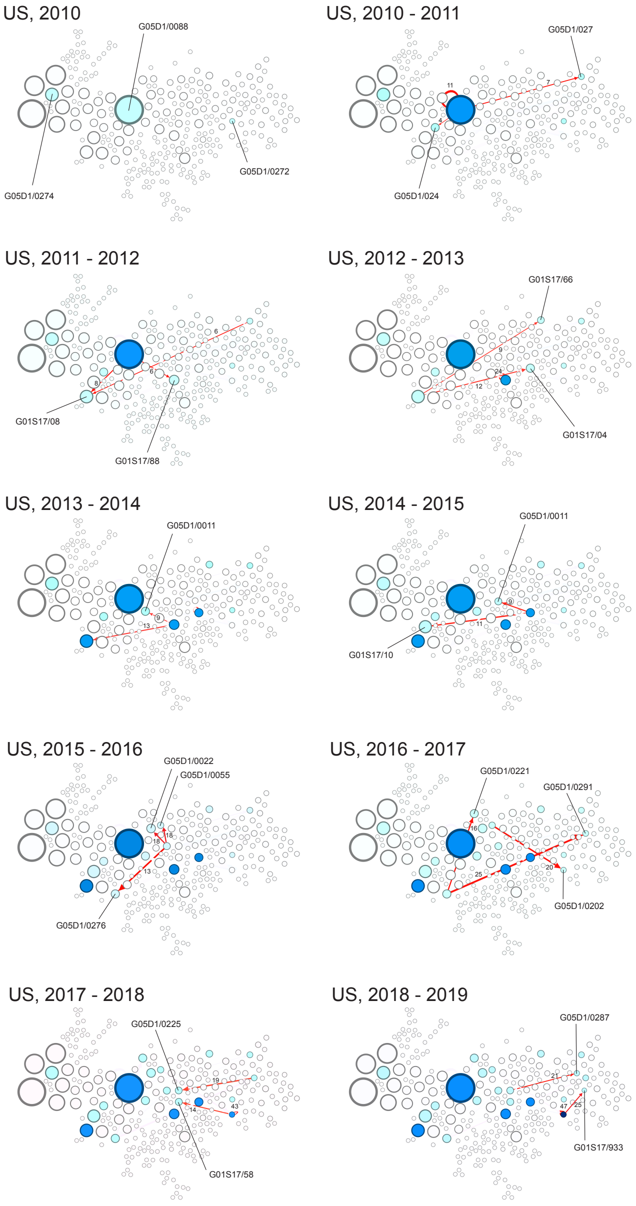
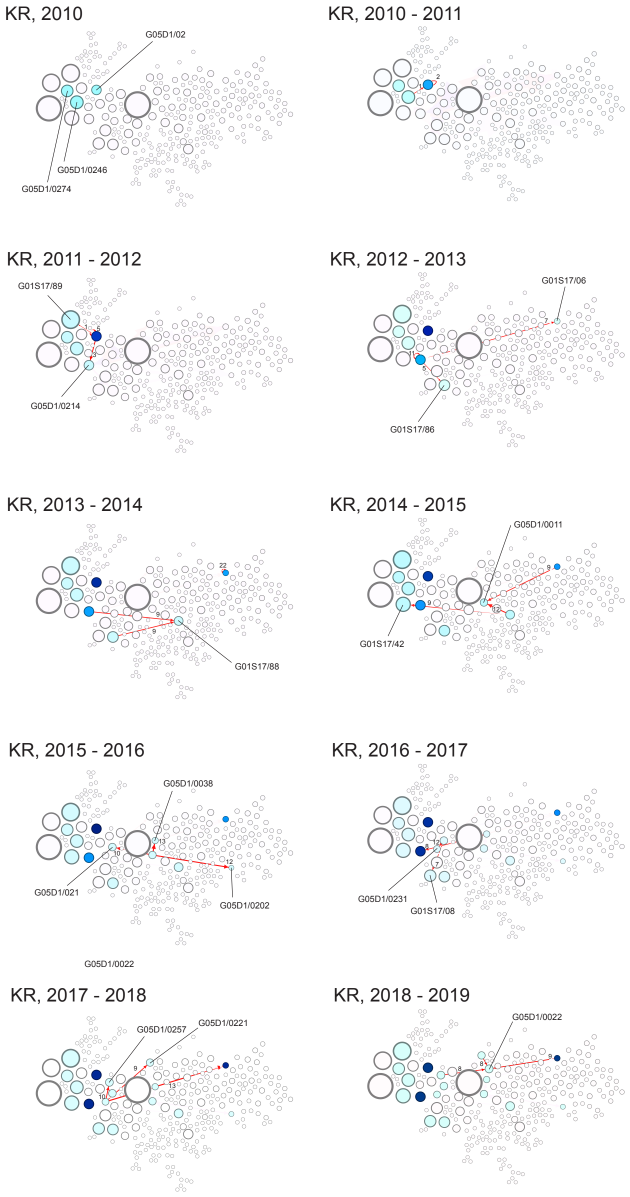


Figure A1: Annual development path of autonomous vehicle-related technology in the United States

## Appendix B. The autonomous vehicle related technological development trajectory of Korea


KR, 2010

KR, 2010 - 2011

KR, 2011 - 2012

KR, 2012 - 2013

KR, 2013 - 2014

KR, 2014 - 2015

KR, 2015 - 2016

KR, 2016 - 2017

KR, 2017 - 2018

KR, 2018 - 2019

Figure A2: Annual development path of autonomous vehicle-related technology in Korea