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Innovation Policies of South Korea

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Executive Summary

Tasking

With the goal of better understanding how different countries implement innovation policies, the Office of the Director of National Intelligence asked the Institute for Defense Analyses (IDA) to examine the industrial and innovation policies of South Korea, Russia, and Brazil. A team of IDA researchers reviewed the literature and interviewed experts to provide an overview of the political, economic, demographic, and other factors that are brought to bear on each country's industrial and innovation policies, relative to other countries.

This report documents the outcome of this examination for South Korea. It examines

- Drivers behind South Korea's innovation goals;
- Mechanisms South Korea uses to execute its innovation policies aimed at achieving those goals;
- Trends that indicate the effectiveness of the mechanisms/policies;
- Socio-cultural characteristics that could affect success or failure;
- Primary partners in South Korea's innovation activities;
- Implications of South Korea's innovation policies for the United States, particularly U.S. national security; and
- Future vision relative to how changes in innovation policies translate to threats and opportunities for U.S. national security, innovation, and economy.

South Korea's National Innovation System

The primary components of a national innovation system are a country's endowments and how government and industry leverage those endowments. A scarcity of natural resources has motivated South Korea to look at its human capital as its biggest endowment, and the country has invested heavily in education, science and technology, and a "knowledge-based" economy.

Government's Role in Innovation

Through state-led research and education and corporate research and development (R&D), South Korea has developed a robust science and technology capacity. The country is currently emphasizing R&D in the areas of green technologies, value-added services, and technology convergence—merging telecommunications and network technologies into a single device, for example. The government also ensures that, through its support of industry-oriented research centers, there is a central locus of research geared towards the development of platform and infrastructural technologies (fundamental technologies that enable subsequent creation of other products and processes).

Industry's Role in Innovation

South Korea's industry and economy is dominated by business conglomerates called *chaebol* (e.g., Samsung, Hyundai, Pohang Iron and Steel Company, and LG electronics). These companies have moved from safe technology investments and incremental innovation toward cutting-edge science-based innovation by adopting Western business practices; as the country has developed, South Korea's historical focus on manufacturing has shifted to services and investing in research and development (R&D) at the forefront of technology.

In a Booz & Company ranking (*The 2012 Global Innovation 1000: Key Findings*), Samsung is ranked fourth among the world's most innovative companies, behind Apple, Google, and 3M. In a different ranking of innovative companies ("The Most Innovative Companies 2012: The State of the Art in Leading Industries"), Hyundai gained the top spot among the automotive companies moving up 12 rankings in the past 2 years to surpass Toyota.

The South Korean private sector's strengths provide opportunities for the country to continue on its innovation trajectory. But South Korean business practices face challenges as well. While the *chaebol* culture is a source of South Korea's success, it is not a transparent culture, and many of its business practices are considered corrupt. The growth of the *chaebol* has come at the expense of small and medium sized companies, as they attract the top talent in the country, creating a dichotomous economy. The presence of the *chaebol* also creates obstacles for entrepreneurs and has depressed the prospects of a venture-backed, start-up culture. South Korean social issues also pose threats to continued success.

Summary and Conclusion

Summarized in the following tables are the strengths and weaknesses of South Korea's national innovation system and the opportunities and threats that are of potential relevance to U.S. interests.

Strengths and Weaknesses of South Korea's Innovation System

Strengths	Weaknesses
<ul style="list-style-type: none"> • Highest literacy rate in the Organisation for Economic Cooperation and Development (OECD); investments in science, technology, engineering, and mathematics education; more than 50% of faculty at top Korean universities are U.S. trained • Strong government support for science, technology, and innovation; highest research and development intensity (3.36% of gross domestic product, 70% in private sector) <ul style="list-style-type: none"> – Shift in government funding away from technology development towards basic science research and development • Strong manufacturing base; control over vertically integrated supply-chain allows for rapid incremental innovation 	<ul style="list-style-type: none"> • Ethnically homogeneous culture, language barrier for outsiders <ul style="list-style-type: none"> – Low acceptance of outsiders (non-ethnic Koreans) in corporate culture • Lack of natural resources • Education heavily biased towards rote memorization • Significant gender gap in workforce • Chaebol (conglomerate) culture results in lack of transparency, corrupt business practices • Lack of support for entrepreneurship, although attitudes are changing with return of U.S.-raised ethnic Koreans

Opportunities and Threats of South Korea's Innovation System

Opportunities	Threats
<ul style="list-style-type: none"> • Openness towards learning from outsiders <ul style="list-style-type: none"> – Largest percentage of students going overseas for university education – Large pool of foreign-trained personnel in big companies • Culture of consolidation driven by need for stability and security, but high tolerance for risk in business, even in large companies (which distinguishes South Korea from Japan) • High levels of business innovation <ul style="list-style-type: none"> – Use low-cost, high-volume production to corner the market, use profits to drive R&D for high-technology models • Strategic use of patenting and increasing involvement in global standards setting • Attitudes towards entrepreneurship are changing with return of U.S.-raised ethnic Koreans 	<ul style="list-style-type: none"> • Heavy societal cost of rapid transformation <ul style="list-style-type: none"> – High levels of stress in society, starting at high school – Marginalization of elderly, high suicide rates • Dichotomy in economy; few high-performing big firms and large, underdeveloped SME and service sectors • Economy concentrated in few sectors • Systemic threat in presence of North Korea • Underdeveloped defense technology • Lack of knowledge transfer between university research and industry

South Korea has grown tremendously over the last 30 years by following a strategic approach to science, technology, and innovation to create world-class companies. In technology innovation, South Korea's success in leapfrogging technology generations has been underscored by a pragmatic strategy of starting at the low end of the market in new product segments and continuously improving their product sophistication, using economies of scale to secure a competitive market share.

This analysis of South Korea's innovation system shows that:

- Both governance and socio-economic factors play important roles in determining how well a country is able to use its endowments to create a strong national innovation system.
- A high-quality of education, particularly in the STEM fields, is foundational for developing the human capital needed for an innovation-driven economy.
- Consistent, long-term investments in research and development are instrumental in achieving a leadership position in technology-based fields. The South Korean government supports long-term research in the basic sciences and defense technologies while the private sector is the primary funder of applied research.
- An underdeveloped and uncompetitive small and medium enterprise sector can reduce the capacity for innovation in the overall economy.
- Finally, in today's globalized economy, countries and companies are increasingly looking outward to learn about other cultures and increase their ability to be responsive to their global customers in a competitive market.

South Korea's rapid economic growth in a compressed timeframe has not been without its challenges and social pressures. There is a widening gap between prosperous, urban South Koreans and those who have been left behind in the country's sudden rise to prosperity, characterized in part by marked rise in income inequality. Traditional cultural values and a desire for security have inhibited the growth of entrepreneurship and a start-up culture, particularly among the highly educated, technically-minded youth; however, increasing involvement by US-based venture capitalists in the Korean diaspora may slowly change that.

Looking ahead, many of South Korea's investments in science, technology, and innovation are driven by national security priorities such as energy efficient and green technologies, high-energy physics, and space. Recent policies suggest the government and private sector leaders in South Korea are transitioning from technology and commercialization-driven R&D toward more ambitious, long-term, and transformational science. The government's long-term (technology agnostic) investments in basic science R&D as well as raising the standards of universities and emphasizing global collaborations will go a long way toward realizing Korea's vision for a knowledge-based economy, but only if paired with an increased tolerance for risk taking.

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1. Introduction

A. Tasking

Industrial and innovation policies are designed to give a country a competitive advantage in a particular industry or sector. Some countries have made significant leaps in industrialization and technological advancement in the last two decades by strategically combining sustained investments in research and development, infrastructure and human capital along with policy frameworks that support nascent industries through tax breaks, export support, and access to capital and markets. Others follow a less rapid and more organic path to industrial growth. In all cases, socio-economic, cultural, and political factors influence how effectively a country is able to capitalize on its natural advantages, be it supply of raw material, large population, or market size.

With a goal of better understanding how different countries implement innovation policies, the Office of the Director of National Intelligence asked the Institute for Defense Analyses (IDA) to examine the industrial and innovation policies of South Korea.

B. Approach

The study addresses the following broad questions:

- What are the emerging trends in Korea's innovation system?
- What are the challenges to advancing the innovation system?
- What are the possible transformative innovation events?

To answer these questions, a team of IDA researchers reviewed the literature and interviewed experts on South Korea to develop an overview of the political, economic, demographic, and other factors that are brought to bear on South Korea's innovation policy, relative to other countries. The themes addressed in this report are:

- Drivers: What are the factors behind South Korea's innovation goals?
- Mechanisms: How is South Korea executing its innovation policies?
- Trends: Have any of the mechanisms or policies been effective?
- Socio-cultural influence: Are there socio-cultural characteristics that might accelerate or inhibit South Korea's ability to execute its innovation goals?
- Partnerships: Who does South Korea view as key partners?

- Future vision: Looking to the future, how do changes in innovation policies translate to threats and opportunities for U.S. national security, innovation, and economy?

From discussions with experts and the literature, the team collected data along the following dimensions:

- Education policies and policies to attract talent
- Focus and level of R&D spending, with emphasis on emerging or high-risk technologies
- Quality of civil infrastructure
- Intellectual Property Regime (IPR), trade policy and regulations
- Focus on National Security

The report begins with a discussion of South Korea's innovation system following the premise that primary components of a national innovation system are a country's endowments and how government and industry leverage those endowments. A scarcity of natural resources has driven South Korea to look at its human capital as its biggest endowment, and South Korea's economic success has been described as an example of the primacy of institutions over geography. In Chapter 3 we provide a brief historical perspective of South Korea's economic and political climate and the evolution of the chaebol (family-owned business conglomerates), which dominate much of South Korea's economy today.

Chapter 4 introduces the institutions involved with science, technology and innovation governance, as well as recent S&T policy trends and their impact. Next, we discuss the role of the industry in national innovation system, which, in the case of South Korea, is substantial. Finally, we examine some factors that are important for South Korea's continuing success in innovation and the challenges that lie therein. South Korea's vision for the future is to transition to a knowledge based economy, and the strength and weaknesses of its current political, socio-economic, and business climate towards achieving these goals are discussed

2. South Korea's National Innovation System

A. Background

A national innovation system emerges from the belief that a nation's technological capabilities are its primary source of competitive performance and that these capabilities can be built through national action (Nelson 1993). A nation's innovation system is shaped by how the nation leverages its endowments—natural resources, culture, history, geography, and demographics—through policies that create a thriving market-oriented (firm-centric) economy and accelerate the transition of new technologies, processes, and services to the market (Branscomb and Auerswald 2002). The core of a nation's innovation system, then, are its endowments and how government and industry leverage these endowments—the nation's government through policy investments, incentives, and regulations and industrial firms through strategies, investments, and training.

For this report, we define innovation as the introduction of a new, or improved upon, product, process, model, or service in any field that produces a new advantage or value, and is either widely disseminated into the market, or influences the market such that economies are impacted (OECD 2005). Stone et al. (2008) describe the breadth of the term by pointing to its presence in new or improved products, processes, experiences, or business models, and this definition covers a broad spectrum of business activity. Innovation is often spoken of as an interconnected innovation system because it is not limited to only science and technology but can cross over into many fields, such as business practices, design, and services. By definition, it requires successful transition into the economy.

The concept of a *national* innovation system was proposed in the 1990s by economists such as Freeman (1995), Lundvall (1992), and Nelson (1993). These and other economists attempted to explain the relationship between a nation's investment in science and technology and its economic development. By contrast to an innovation system in general, a national innovation system is made up of primary actors whose relationships and interactions foster innovation within a nation.

B. Elements of a National Innovation System

Figure 1 shows the interconnections between the three primary components of a national innovation system—endowments, government leverage, and industry leverage—and indicates their influence on each other.

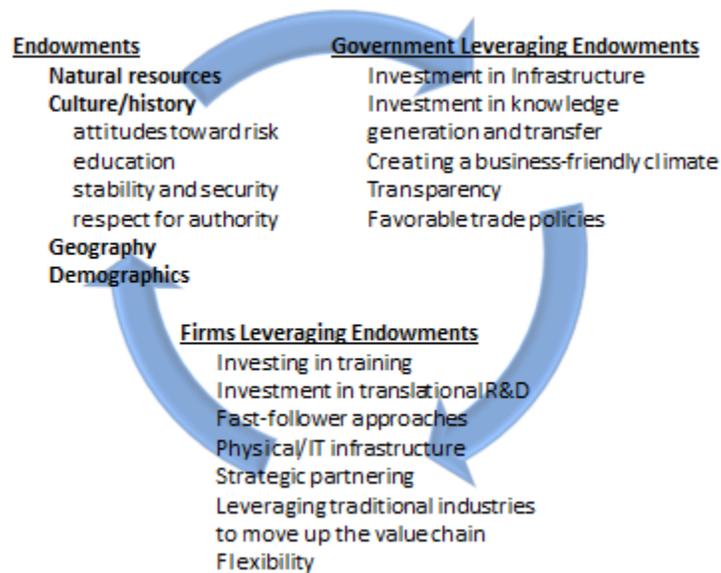


Figure 1. Core Components of a National Innovation System

A national innovation system also encompasses many innovation “pipelines,” which are strategies for advancing innovation to industrial output. Such strategies are not necessarily linear. These pipelines aim to create a healthy innovation ecosystem through functional policies that guide primary actors to foster innovation.

National governments may have a range of motives for pursuing innovation. Chief among them is economic development to increase national wealth and prosperity via the creation of new products and services and, in turn, high-paying jobs. For high-wage countries like South Korea, this may mean having more attractive products or better production processes than firms in low-wage countries. Endowments such as a nation’s size and natural resources provide comparative advantages and drive conscious decisions to develop and sustain economic strength in certain areas. Countries with abundant natural resources, for example, may benefit from revenues and foreign investment that leverage those resources. Differences in endowments change how a government structures its innovation policies.

While industry firms draw extensively on external sources like universities and government laboratories, most of the innovative effort is made by the firms themselves. Profiting from innovation requires the coordination of R&D, design, production, and marketing, which tends to proceed more effectively within an organization.

C. South Korea’s Endowments

South Korea does not have natural resources. However, natural resources are not necessarily a nation’s only endowments. Socio-economic, cultural, and political

circumstances are also important. South Korea has compensated for its lack of natural resources by achieving the highest literacy rate among Organisation for Economic Cooperation and Development (OECD) countries. The government has done this by investing heavily in education, science and technology, and a “knowledge-based” economy. The government also ensures that, through its support of industry-oriented research centers, there is a central locus of research and development in the disciplines associated with particular technologies.

D. Government Leveraging of South Korea’s Endowments

The South Korean government has developed a robust science and technology capacity following two parallel tracks:

- Creation of a state-led research and educational capacity
- Corporate research and development efforts by the country’s large conglomerates

The government’s science and technology policy is implemented in the form of Science and Technology Basic Plans every 5 years. The most recent, the *577 Initiative*, focuses on sector-specific strategies, including automobiles, shipbuilding, semiconductors, steel, machinery, textiles, and materials. South Korea is also developing in the three broad areas of green technologies, value-added services, and technology convergence, such as the convergence of telecommunications and network technologies into a single system or device (MKE 2010). South Korea has focused historically on manufacturing but has shifted the focus to services and creation of a knowledge economy as the nation has developed.

To achieve the goal of increasing R&D investments as a share of gross domestic product (GDP), the government launched a variety of financial incentives to encourage private investment in R&D, notably by encouraging private financial institutions to turn their collateral-based loans into technological value-based loans. The government also spends extensively on infrastructure; Korea is ranked thirteenth in the world in infrastructure, and leads in broadband penetration (WEF 2012). The government’s investments have been largely effective in spurring S&T-based innovation and progress. South Korean companies have achieved high levels of global competitiveness in leading-edge technologies, ranking second globally (behind the United States) in innovation in 2013 (Bloomberg Rankings 2013).

E. Industry Leveraging of South Korea’s Endowments

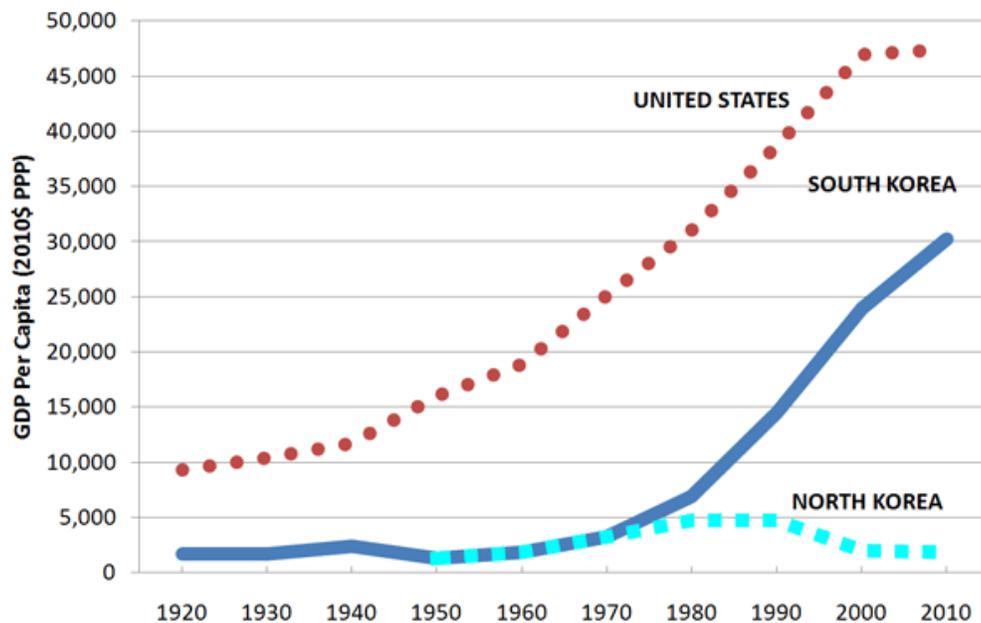
Over the past two decades, South Korea has transformed itself into a leading innovator by adopting Western business practices and making aggressive R&D investments while capitalizing on the strengths of a consolidated manufacturing supply

chain. Today, innovation in the South Korean economy is primarily driven by the private sector, which is dominated by chaebol, such as Samsung, Hyundai, Pohang Iron and Steel Company (POSCO), and LG electronics. These firms typically span a broad spectrum of related and unrelated businesses and control about 70% of South Korea's total spending on R&D (with government contributing about 25%). For example, Samsung is diversified across the food, infrastructure, shipbuilding, life insurance, surveillance, recreation, advertising, and financial industries, among others, leading many to refer to South Korea as the "Republic of Samsung."

South Korean companies have moved from safe technology investments and incremental innovation toward cutting-edge science-based innovation. Capitalizing on future possibilities in science and technology requires disruption and risk taking. Koreans prize efficiency; their desire for success leads them to be highly strategic in their approach. They emphasize planning for R&D in government and industry and using metrics to track success. The government's long-term (technology agnostic) investments in basic science R&D, raised standards for universities, and emphasis on global collaborations will secure Korea's evolution of a knowledge-based economy, but only if paired with an increasing tolerance for risk taking.

3. Historical Perspective

The Republic of Korea (South Korea), one of four “Asian Tigers,” has achieved a degree of economic growth that has been described as miraculous.¹ From a per capita GDP on par with sub-Saharan Africa in 1962, today it has surpassed the Organisation for Economic Cooperation and Development (OECD) average and is on a growth trajectory similar to that of the United States, while balancing growth with democratic governance. South Korea’s economic growth is a story of the primacy of institutions over geography. Driven by a paucity of natural resources and a deep seated need for security, South Korean leadership has consistently invested in science and technology along with human capital as a lever for economic growth. Figure 2 presents a comparison of South Korea’s per capita economic growth over time, compared to that of North Korea and the United States.



Source: <http://www.navigantresearch.com/2011/06?page=7>.

Figure 2. South Korea’s GDP per Capita Growth, 1960–2009

¹ Asian Tigers (or Asian Dragons) refers to the highly developed economies of Hong Kong, Singapore, South Korea, and Taiwan. These countries and areas were notable for maintaining exceptionally high growth rates (in excess of 7% a year) and rapid industrialization between the early 1960s and 1990s.

Today, South Korea is reaping the rewards of more than five decades of S&T-fueled economic growth, and over the past five years has emerged onto the global stage as a technology and innovation leader. This report examines the main actors of South Korea’s national innovation system—the government policies that have been instrumental in spurring innovation; the impact of these policies and strategic directions undertaken by the private sector; the role of the education system; and the interactions among these actors to facilitate innovation.

A. Primacy of Institutions over Geography

South Korea is located on a peninsula on the Eastern coast of Asia, separated from China by the Yellow Sea to the west, and from Japan by the Sea of Japan to the east. (See Figure 3.) South Korea is small with a dense, culturally homogenous population. At just under 100,000 square kilometers (39,000 square miles), it is roughly the geographic size of the state of Indiana, but with a population of 50 million, resulting in one of the highest population densities in the world.



Source: worldofmaps.net.

Figure 3. Map of South Korea by Region

South Korea’s population is 49 million with 8 out of 10 people living in urban areas. The capital, Seoul, is one of the most populous urban areas in the world. The median age is 39 years and there are 1.25 times more people under 25 than over 55, indicating an aging population. The country’s GDP has increased steadily over time (see Figure 2 and Table 1). A comparison of the Gini Index, a commonly used measure of income inequality on a scale of zero to 100, shows South Korea at 42 and the United States at 45.

Table 1. Population, Urban Population, and Age Distribution in South Korea, 2012

Population (25)	48,955,203 (July 2013 est.)
Urban population	83% of total population (2010 est.)
Major cities - population	Seoul (capital) 9.778 million Busan (Pusan) 3.439 million Incheon (Inch'on) 2.572 million Daegu (Taegu) 2.458 million Daejeon (Taejeon) 1.497 million (2009 est.)
Gross Domestic Product (GDP – PPP) ^a	\$1.622 trillion (2012); \$1.579 (2011); \$1.524 (2010)
GDP real growth rate	2.7% (2012); 3.6% (2011); 6.3% (2010)
GDP per capita (40) ^b	\$32,400 (2012); \$31,700 (2011); \$30,800 (2010)
Investment (gross fixed) (33)	27.4% of GDP
Median age	39 years
Age distribution	0–14 years: 15.1% 15–24 years: 13.6% 25–54 years: 48.3% 55–64 years: 11.2% 65 years and over: 11.9%
Labor force	25.18 million workers
Unemployment rate	3.8%
Population below poverty line	15% (2006 est.)
Gini index (51) ^c	41.9 (2011); 35.8 (2000)
Household income by percentage share	Lowest 10%: 2.7% Highest 10%: 24.2% (2007 est.)

Source: CIA (2012), unless noted otherwise.

Note: Country comparison to world in parentheses. All estimates are for 2012, unless noted otherwise.

^a Estimate in U.S. 2012 dollars, adjusted for Purchasing Power Parity (PPP).

^b WEF (2011).

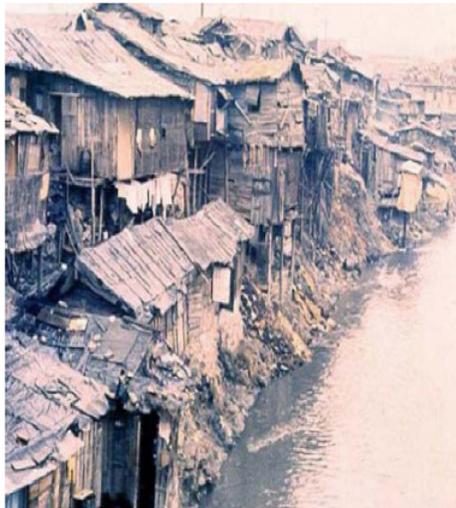
^c Gini index measures the extent to which the distribution of income or consumption expenditure among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.

B. Political History

South Korea’s economy is closely tied to its political history. Before the 20th century, the Korean peninsula was a politically isolated “hermit kingdom,” wary of foreign influence after centuries of successive invasions by neighboring countries. Japan’s invasion and annexation of Korea to its empire in 1910 increased its distrust of foreign powers. After

Japan's defeat in World War II, the homogenous communist North Korea was backed by the Soviet Union and China, and South Korea by the United States. In 1950, North Korea invaded the South, and the resulting Korean War ended in a stalemate with the peninsula divided as before. Both countries started with autocratic governments—Kim Il Sung heading the communist North and Syngman Rhee leading the South.

A student uprising in 1960 overthrew the oppressive South Korean government, but the new government was fleeting and General Park Chung-hee subsequently rose to power via military coup. Over 20 years later, South Korea held free and direct presidential elections. During the rule of Park and his similarly autocratic successor, Chun Doo-hwan, political liberties were severely restricted even as the economic foundations were laid for South Korea's meteoric rise from poverty to preeminence. In 1960, Korea's economy was on par with sub-Saharan Africa. Only a few decades later in 1994, Korea had entered the OECD. The country currently has a per capita income of \$32,100, higher than the EU average (*Economist* 2011). Views of downtown Seoul circa 1950s and in the past decade show the strides that Korea has made over the past decades, being the only country in the world to go from aid recipient to donor in such a short timeframe (Figure 4). See Figure 5 for a brief timeline of key historical events in South Korea.



Chong-gye stream, Downtown Seoul (1950s)

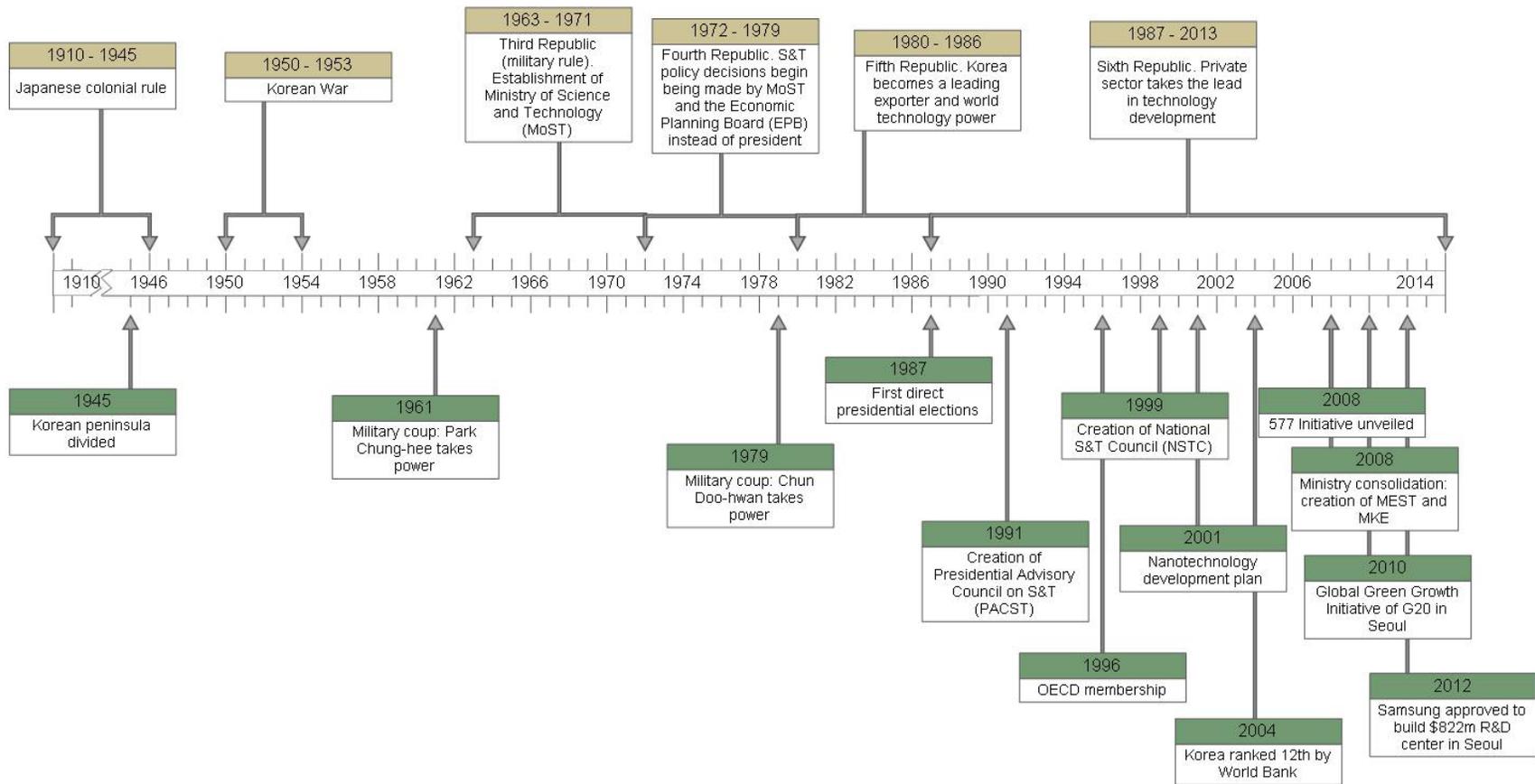


Chong-gye stream, Downtown Seoul (2000s)

Source: Chun (2010).

Figure 4. Views of Downtown Seoul, Circa 1950s and 2000s

South Korea Timeline: 1910-Present



Note: Created with Timeline Maker professional. Produced on June 28, 2013.

Figure 5. South Korea's S&T Timeline Since 1910

C. Role of the Chaebol

South Korea's economic success followed aggressive industrial development on the part of the government and the pursuit of an export-driven economy. Additionally, the government nurtured close ties with the large, family-owned industrial conglomerates known as chaebol that have dominated the Korean economy for decades. During this crucial developmental time, the Korean industry had import and FDI restrictions, direct credit, and tax relief, which allowed it to develop in a protected economic environment and become internationally competitive. The government, in turn, wielded influence through industrial policy, choosing and nurturing strategic industry sectors like shipping, refining, and semiconductors.

Exports from the huge multinational chaebol continue to drive the Korean economy, and their competitiveness drives innovation. The four largest chaebol: Samsung, Hyundai, LG, and SK² are strong in a wide range of activities from automobiles to shipping to banking to tourism to consumer electronics. Continued government assistance and economies of scale allow the chaebol to be extremely competitive. South Korea is currently the largest shipbuilder in the world, with close to 50% of the world market (Maritime Bulletin 2012); the largest electronics company (Samsung) (Bishop 2013); and the eighth largest auto maker (Hyundai).³ The southeastern industrial district of Ulsan alone contains the largest automobile factory, the largest shipyard, and the third largest oil refinery in the world. South Korea is also a major player in the manufacture of liquid crystal displays (LCDs), which now account for 5% of exports.⁴ South Korea's total exports and imports and primary trading partners are as follows:⁵

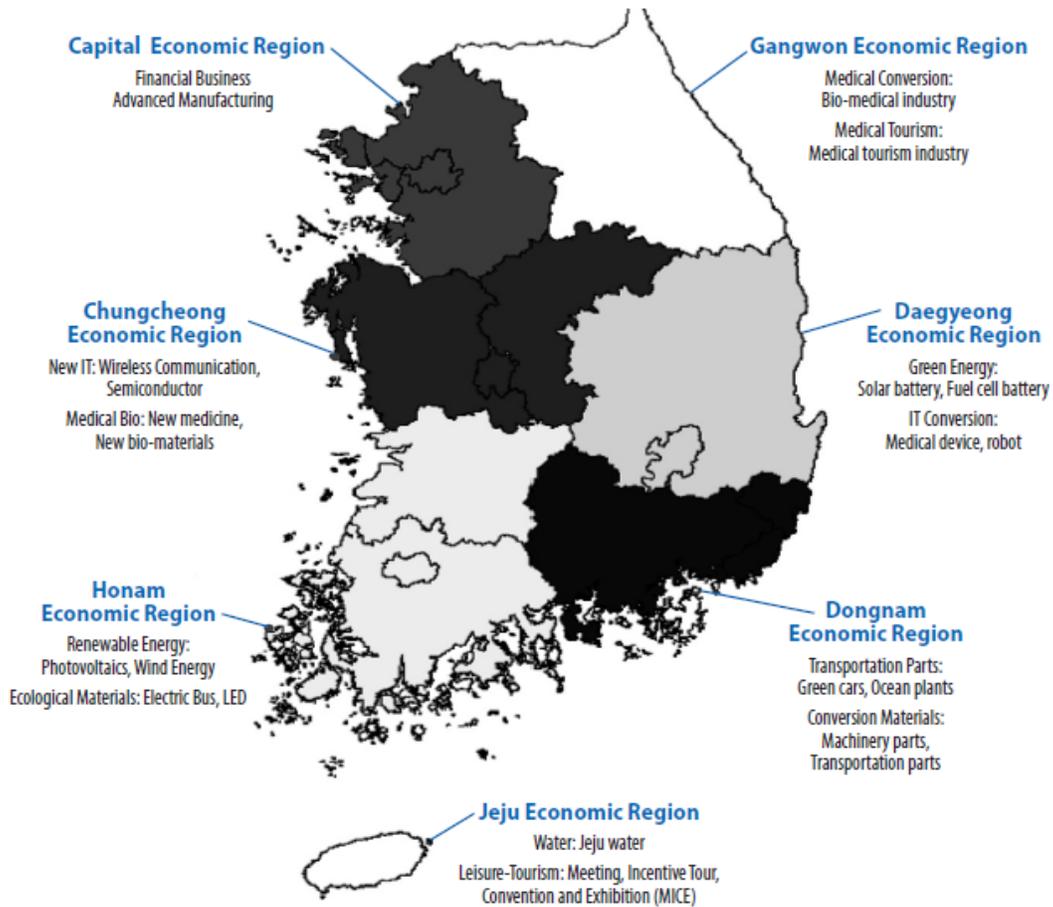
- Exports—\$548.2 billion (2012 est.)
 - China 24.7% (2011 est.), United States 10.1% (2011 est.), Japan 7.1% (2011 est.)
- Imports—\$520.5 billion (2012 est.)
 - China 16.5% (2011 est.), Japan 13% (2011 est.), United States 8.5% (2011 est.), Saudi Arabia 7.1% (2011 est.)

² SK Group is the third largest chaebol in South Korea. The SK Group is composed of 92 subsidiary and affiliate companies that share the SK brand and culture. It changed its name from Sunkyong Group to SK Group in 1997.

³ Organization of Motor Vehicle Manufacturers (OICA), "World Motor Vehicle Production," <http://oica.net/wp-content/uploads/world-ranking-2008.pdf>.

⁴ The Observatory of Economic Complexity, <http://atlas.media.mit.edu/>.

⁵ Estimates in U.S. 2012 or 2011 dollars, adjusted for Purchasing Power Parity (PPP).



Source: Ministry of Knowledge Economy, Korea.

Figure 6. Main Industries of South Korea by Region

Despite Korea's competitiveness in industry, the expectations are for the Korean economy to slow down, driven by demographics and increasing competition in key areas. Korea, like Japan, has a rapidly aging population and a rapidly shrinking labor force that will have to support the increased costs of the aging population. Additionally, the rise of China with lower wages and massive, state-owned companies threaten competition from South Korea's position of dominance in the electronics, auto, and heavy industry sectors.

4. Governance and Innovation

Much like Japan, from the beginning of its economic development path the South Korean government selectively restricted FDI in favor of heavy borrowing and obtained foreign technology through imitation and technical agreements. These policies allowed the Koreans to maintain control over the industrial base, encouraged investment in R&D from an early stage, and increased the likelihood of positive domestic spillovers.

The Ministry of Science and Technology (MoST), established during the years of military rule, was one of the first government ministries devoted to S&T in the developing world. Until the late 1980s, innovation policy was mostly conducted through MoST; subsequently the chaebol began to partner with the government in shaping the direction of South Korean S&T. See Table 2.

Table 2. South Korea's S&T Timeline Since 1963

Third Republic (1963–1972)	<ul style="list-style-type: none">• Set up a Ministry of Science and Technology (one of the first ministries in the developing world dedicated to technological development)• Established the Korean Institute of Science and Technology dedicated to applied technology• Established the Korean Advanced Institute of Science (Korea's leading technical university today)
Fourth Republic (1972–1980)	<ul style="list-style-type: none">• Policy decisions started coming from MoST (instead of the President) and the Economic Planning Board (EPB)• Private sector starts playing a role• Set up the groundwork for the Daedok Science Town (later called Daedok Science Valley)
Fifth Republic (1980–1987)	<ul style="list-style-type: none">• Leading exporter and technology power• Chaebol became partners with the state
Sixth Republic (1987–present)	<ul style="list-style-type: none">• Private sector (chaebol/conglomerates) started taking the lead in technology development

The Korean government has developed a robust science and technology capacity following two parallel tracks—the creation of a state-led research and educational capacity and corporate research and development efforts by the country’s large conglomerates. It has also taken a strong and consistent interest in partnering with industry to promote modernization and economic growth.

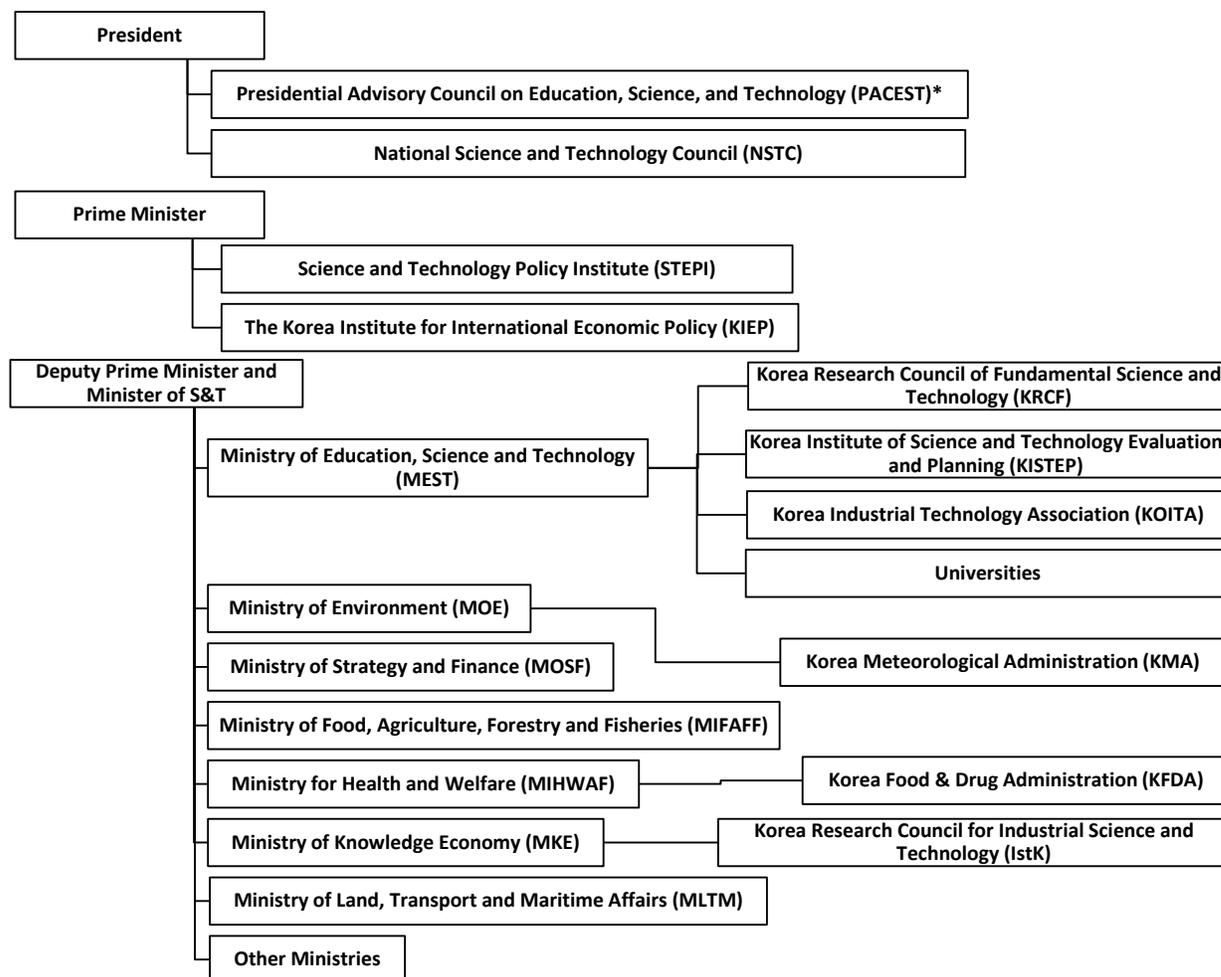
A. Current Innovation Leadership Structure

The S&T policy governance structure in South Korea in many ways resembles that of the United States. The two main advisory and coordination bodies serving the executive branch are the South Korean National Science and Technology Council (NSTC) and the Presidential Advisory Council on Science & Technology (PACST).

The two ministries most responsible for setting innovation policy in South Korea are the Ministry of Education, Science, and Technology (MEST) and the Ministry of Knowledge Economy (MKE). MEST is the most influential, as it is primarily responsible for formulating policies for S&T development and R&D investment and supporting the nation’s universities and research institutes (both government and private). MKE, on the other hand, works primarily with industry. See Appendix B for detailed descriptions of the governing bodies.

Figure 7 shows the structure of the Korean government institutions that have a role making policy related to science, technology, and innovation. Over the past decade Korean government policies have increasingly focused on fundamental science (as opposed to a historical emphasis on technology development). Gross domestic investment in R&D has grown at 10.5% annually since 2002. South Korea spends 3.5% of its GDP on R&D (NSB 2013).⁶ This is the highest among the OECD countries, totaling USD \$56 billion in 2012. The government’s share accounts for 24% of this, with industry covering the balance (NSB 2013, Appendix table 4-44).

⁶ For comparison, Brazil’s R&D intensity is 1.16 (2008), Russia’s is 1.24 (2009), India’s is 0.76 (2007), China’s is 1.70 (2009), and South Korea’s is 3.36 (2008) (NSB 2013, Appendix table 4-44).



Source: STI Policy Administration in Korea http://astp.jst.go.jp/uploads/Korea_S&Torg_201003.pdf.

Figure 7. South Korean Government Structure

B. Government Innovation Policies

A recent development in Korea's innovation policy was a newly empowered National Science and Technology Commission formed in 2011, with broad authority for the allocation of the government R&D budget (up to 70% of the total budget⁷). Of the National Science and Technology Commission's \$16 billion budget in 2012, almost half of the allocation was made to public research institutes, and about one-fourth each to universities

⁷ The funding is mainly channeled through the three main ministries, Ministry of Education, Science, and Technology; Ministry of Knowledge Economy; and Ministry of Strategy and Finance. The Ministry of Knowledge Economy sets aside close to 40% of its funds for the small and medium size company (SME) sector, which is underdeveloped.

and to industry.⁸ Technology areas selected for long-term funding in the 2012 National Science and Technology Commission budget were space and avionics, high energy physics, construction and maritime industry, renewable energy, ICT, system-on-chip semiconductors and LEDs, and machine and equipment technology (Campbell 2012).

Technology selection considers a large number of factors, including U.S. S&T policy. The National Science and Technology Commission's technology planning and investment is a consensus-based adaptation of U.S. and European Union science, technology, and innovation plans.⁹ The programmatic technology selection is based on input from evaluation studies. This approach has been criticized for putting excessive pressure on researchers, incentivizing short-term research, and therefore dampening creativity in scientific research. (Mahlich and Pascha 2012)

At the operational level, the MKE and MEST have the power to allocate about 30% of the R&D budget. The MKE's science, technology, and innovation policy is implemented in the form of Science and Technology Basic Plans every 5 years. Since the implementation of the first of four S&T Basic plans in the late 1990s, the government has emphasized investment in R&D, highlighting the role of researchers in the economy and strengthening innovation policy.

The most recent is the *577 Initiative* which focuses on seven technology areas. These are key industrial technologies, emerging industrial technologies, knowledge-based service technologies, state-led technologies, national issues related technologies, global issues-related technologies, and basic and convergent technologies. Table 3 presents 50 critical technologies and 40 candidate technologies grouped by these seven areas. Each area has one or two primary themes. For example, the first group, key industrial technologies, focuses on next-generation environmental automotive technology; shipbuilding; intelligent production systems; high-precision machining and instrumentation controls; next generation networks; mobile internet and communications; non-memory semiconductors; semiconductor equipment and processes; and display technologies. Critical technologies (column 2 of Table 3) build on existing strengths and candidate technologies (column 3 of Table 3) push into new areas.

The MKE is also focusing on developing sector-specific strategies for what they consider their primary industries. These include supporting their automotive industry, as well as shipbuilding, semiconductors, steel, general machines, high-technology textiles, parts, and materials. They are also broadly developing their green technology, advanced Information, Communications, and Technology (MKE 2012) and value-added services sectors (MKE 2011).

⁸ Discussion with National Science and Technology Commission (NSTC) staff, December 10, 2012.

⁹ Ibid.

Table 3. Critical and Candidate Technologies Targeted under South Korea's 577 Initiative

Technology Areas	Critical Technologies (50)	Candidate Technologies (40)
1 Key Industrial Technologies	(1) Environment-friendly automotive Technology (2) Next-generation Shipbuilding and Offshore-platform Technology (3) Intelligent Production System Technology (3) (4) High-Precision Micro-machining and Instrumentation Control Technology (5) Next-generation Network Technology (6) Mobile Internet and 4G Mobile Communication Technology (7) Non-memory Semiconductor Technology (8) Next-generation Semiconductor Equipment and Process Technology (9) Next-generation display Technology	(1) Intelligent Automotive Technology (2) Next-generation Production Process and Equipment Technology (3) Next-generation Memory Semiconductor Technology
2 Emerging Industrial Technologies	(10) Cancer diagnosis and treatment Technology (11) Drug Discovery and Development Technology (12) Clinical testing Technology (13) Medical apparatus development Technology (14) Stem-cell Technology (15) Proteomics and Metabolics Applied Technology (16) Technology of Identification of Drug Target and Drug Candidate (17) Brain Science Research and Brain Disease Diagnosis and Treatment Technology (18) Next-generation System Software Technology (3) (19) Next-generation high performance computing Technology (20) Next-generation Human-Computer Interaction Technology (3)	(4) Biomaterials and Process Technology (5) Conservation of Marine Resources and Utilization Technology of Marine Biotechnology (6) Regulation Technology of Cellular Function (7) Genomics Applied Technology (8) Application and Analysis Technology of Biomedical Information (9) Gene Therapy Technology (10) Oriental Medicine and Treatment Technology (11) Next-generation Computing Solution Technology (3) (12) Information Security Technology
3 Knowledge-based Service Technologies	(21) Converging Contents and Knowledge Service Technology (22) Advanced Logistics Technology	(13) Converging Technology of Communication and Broadcasting
4 State-led Technologies	(23) Satellite Development Technology (24) Next-generation Airplane Development Technology (25) Nuclear Fusion Technology (26) Next-generation Nuclear Reactor Technology (27) Next-generation Weapon Development Technology	(14) High-Rise Building Technology (15) Next-generation Railroad System Technology (16) Construction-based Technology (17) Super-long Bridge Construction Technology (18) Advanced Transportation System Technology (19) Advanced Residence and Education Environment Technology (20) Intelligent National Geographic Information System Development Technology (21) Satellite Propulsion Technology (22) Utilization Technology of Satellite Information (23) Planet Exploration and Space Monitoring System Development Technology (24) Global Navigation Satellite System Technology (25) Efficiency and Safety Enhancement Technology of Sea-Air Aviation (26) Utilization Technology of Radiation and Radioactive Isotope (27) Nuclear Fuel Cycle Technology (28) Nuclear Power Use and Safety Enhancement Technology
5 National Issues-related Technologies	(28) Immune Disease and Infectious Disease Response Technology (29) Human Safety and Risk Evaluation Technology (30) Food Safety Evaluation Technology (31) Agricultural Resources Development and Management Technology (32) IT Nano-device Technology (33) High-Efficiency Energy Management Technology	(29) Food Resource Utilization and Management Technology (30) Insect Pest and Disease Prevention and Control Technology (31) Applied Technology of Environment-Friendly Nano-materials (32) Nano-Bio Materials
6 Global Issues-related Technologies	(34) Hydrogen Production and Storage Technology (35) Next-Generation Fuel Cells & Energy Storage and Conversion Technology (36) New and Renewable Energy Technology (37) Energy and Resource Exploration & Development Technology (38) Marine Territory Management Technology (39) Marine-Environments Maintenance Technology (40) Atmospheric Environmental Improvement Technology (41) Environment Conservation and Restoration Technology (42) Water Quality Management and Water Resources Protection Technology (43) Climate Change Prediction and Adaptation Technology (44) Natural Disaster Prevention and Management Technology	(33) Next-generation Superconductivity and Power-IT Technology (34) Highly Efficient Technology for Resource Utilization (35) Environment-friendly Process Technology (36) Resource Recycling and Waste Safe Treatment Technology (37) Integrated Management and Utilization Technology of Environmental Information (38) Life Safety and Anti-terror Technology (39) Fire Safety and Future Fire Extinguishing Equipment Development Technology
7 Basic & Convergent Technologies	(45) Drug Delivery Technology (46) Biochip and Biosensor Technology (47) Intelligent Robot Technology (48) Nano-based Functional Materials Technology (49) Nano-based Convergent and Composite Materials Technology (50) Advanced city planning and construction Technology	(40) Nano Measuring and Evaluation Technology

Source: MEST (2008).

There has been concern about the lack of space and defense motivated research among Korean policymakers, highlighted by the recent provocation from North Korea. A 2009 report by the Samsung Economic Research Institute (2011) found support in the research community for focus on space exploration, launch vehicles, and satellite technology as well as basic science areas such nuclear fusion and particle physics; these are addressed in the 577 Initiative. The 577 Initiative provides incentives for corporate research investment, improving research universities, and cultivating human talent, and plans to expand investment in basic research from 25% to 50% of government R&D budget.¹⁰

The government spends extensively on research infrastructure. Korea is ranked thirteenth in the world in infrastructure, and leads in broadband penetration (Schwab 2012). In addition, an extensive network of Government Research Institutes (GRIs), both at the national and state levels, support domestic companies. During the years when technologies were largely acquired from foreign firms, GRIs were used extensively to support domestic companies in technology development and provide R&D talent, in the manner of the Fraunhofer Institutes. By the 1980s, Korean firms had significantly increased their corporate R&D spending, and GRIs were no longer considered relevant by the industry.¹¹ Today, they are seeking to re-establish their relevance by specializing in basic science areas and long-term research undertakings (OECD 2009b).

To achieve the goal of increasing R&D investments as a share of GDP, the government has launched a variety of financial incentives to encourage private investment in R&D. Many government departments have set up funds for direct financial support to small and medium enterprises (SMEs). Large and small corporations both benefit from tax deductions to not only research activities but also human development cost (including a 50% income tax reduction for foreign experts) (O'Donnell 2012).

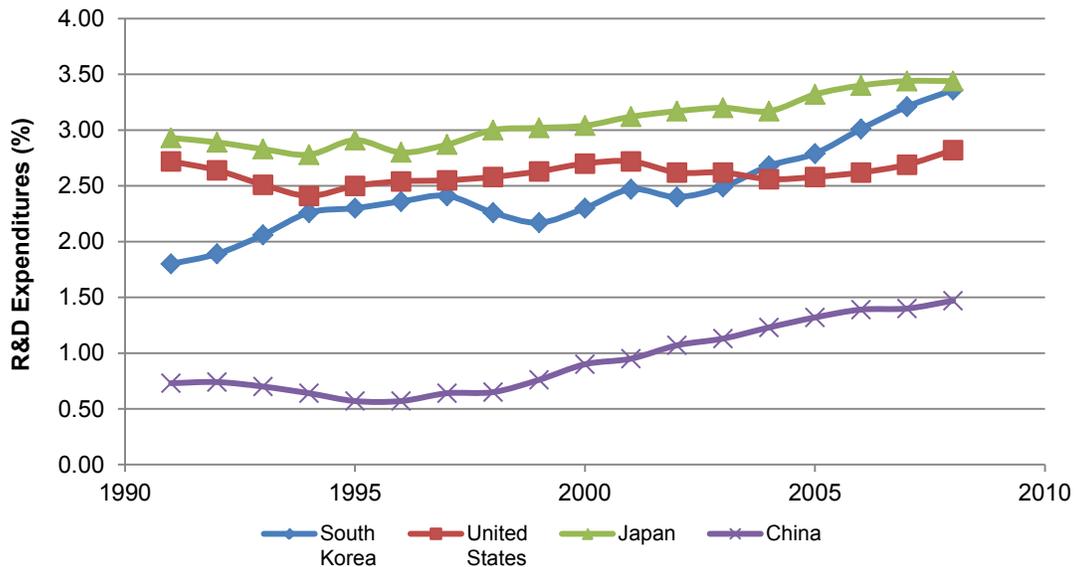
C. Impact of Innovation Policies

The government's investments have been largely effective in spurring S&T-based innovation and progress. The 5-year plan for S&T innovation in the 1990s and the basic S&T plans in the 2000s were developed with the aim of improving capacity and funding for R&D, developing an R&D workforce and increasing funding for basic science. The policies have resulted in increased R&D intensity, a rise in patents and publications, and an increase in high-technology exports, all of which have contributed to Korea's shift from a fast follower to a leadership position.

¹⁰ Other S&T plans of significance are the NSTC's "Advancement Plan of National R&D System" initiated in 2010, which seeks to nurture creative and convergence-oriented R&D, the second "5 year Basic R&D Plan" extending 2011–2015, which emphasizes the linkages between S&T and the humanities, and a "Green Growth" initiative from the MKE in 2010 which committed \$4.7 billion to fundamental research in energy efficient transportation and renewable energy.

¹¹ Discussions with experts. See Appendix A.

Figure 8 shows the trends in R&D funding as a percentage of GDP and the increase in the number of researchers. Additionally, the South Korean S&T workforce has increased from 17% to 25% over the past 5 years as a percentage of total employment, and South Korea has risen from the fourteenth to the fifth position in S&T competitiveness while ranking fifth in R&D intensity (share of GDP spent on R&D).

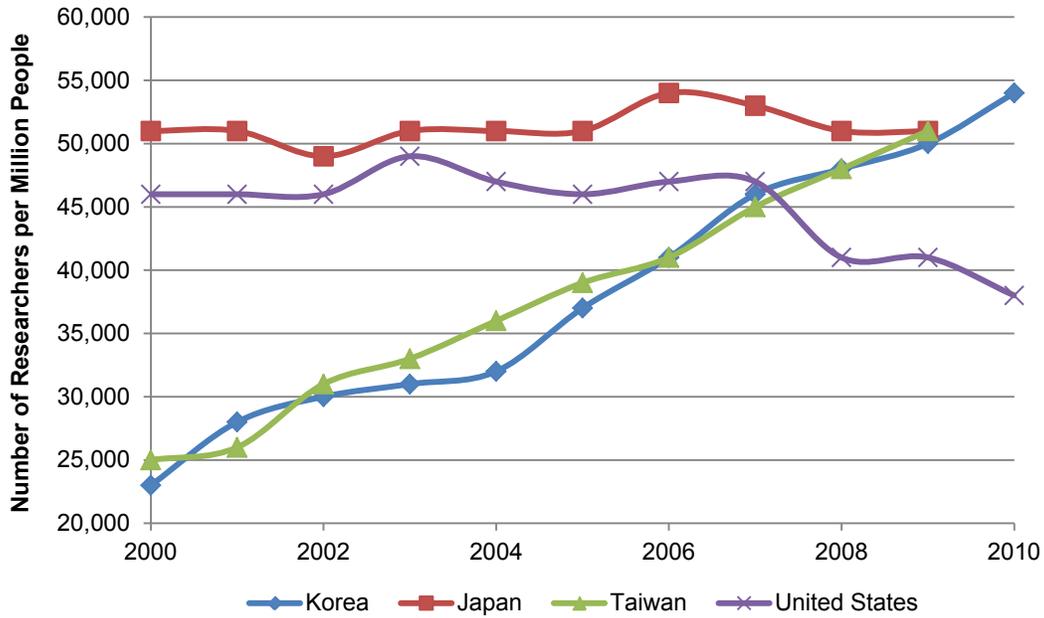


Source: Science and Engineering Indicators 2012

Note : Japan's rising ratio reflects the confluence of declining GDP and largely flat R&D spending.

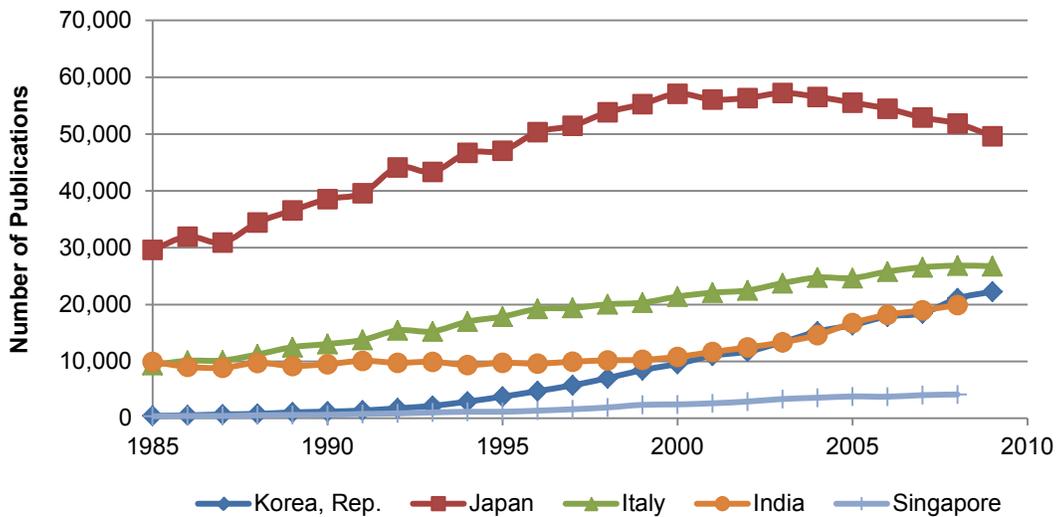
Figure 8. Gross R&D Expenditures as a Share of GDP for Selected Countries, 1991–2009

Innovation output trends show a marked increase in human capital and patenting activity, and the rate of scientific publications have also grown significantly, although Korea ranks lower in publication quality (citations) than in raw number of journal articles. Figure 9 shows that the relative number of researchers engaged in R&D in South Korea over the past decade has more than doubled from 23,000 to 54,000 researchers per million people and closing the gap with Japan and the United States. Taiwan shows a similar increase in the percentage of workforce engaged in R&D. Figure 10 shows the long-term trend in scientific publications for South Korea steadily increasing over the past 15 years, reaching parity with Italy and India.



Source: Korea Institute of Science and Technology Evaluation and Planning (KISTEP) and World Bank data.

Figure 9. Number of R&D Researchers in South Korea Compared to Selected Other Countries, 2000–2010

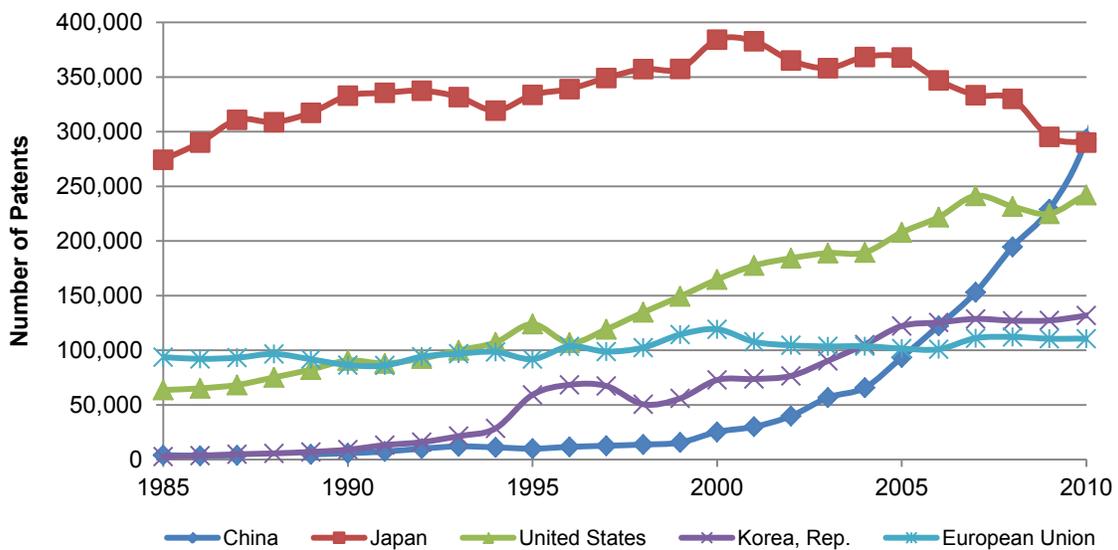


Source: World Bank data.

Figure 10. Scientific and Technical Journal Article Publication Trends for South Korea Compared to Japan and Selected Other Countries, 1985–2010

Patent activity worldwide remains highly concentrated with only five patent offices (China, Japan, the European Patent Office, the Republic of Korea and the United States of America) accounting for 77% of all patents filed and 74% of all patents granted.

Strength of intellectual property protection and domestic and foreign patent filings in South Korea have grown rapidly in the past decade (reflecting a higher level of integration of South Korea with worldwide economic activity) (WIPO 2007). Figure 11 shows a steady rise in patent applications by South Korean residents (either through the Patent Cooperation Treaty or the national patent office) starting in the mid-1990s, when innovation laws incentivizing intellectual property creation started coming into effect. The World Intellectual Property Organization (WIPO) ranks South Korea fifth, after the United States, Japan, Germany and China, in filing patent applications under the Patent Cooperation Treaty (PCT¹²), reflecting an increase in Korea companies filing abroad. South Korea's manufacturing sector leads the world growth of patenting activity (patents granted as percentage of applications submitted and applications granted worldwide today) (Bloomberg Rankings 2013) and close to 40% of the filings are in the fields of electronics and communications (KIPO 2013). Table 4 shows the top 10 South Korean applicants for PCT filings in 2012.



Source: World Bank.

Figure 11. Trends in Patent Applications (through the Patent Cooperation Treaty or a National Patent Office) by Residents of South Korea and Selected Other Countries, 1990–2010

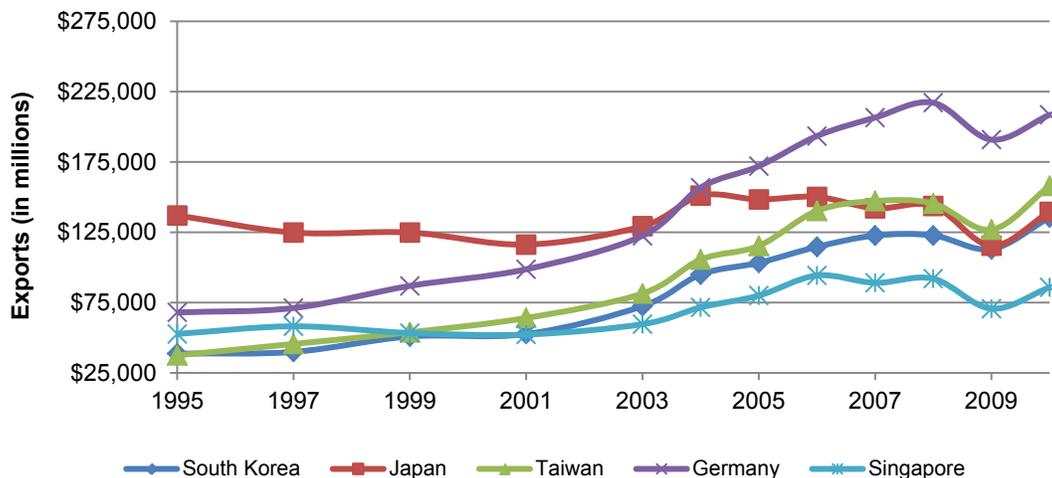
¹² Under the PCT, an inventor can file a single international patent application in one language with one patent office in order to simultaneously seek protection for an invention in up to 117 countries throughout the world.

Table 4. Leading Applicants under the Patent Cooperation Treaty (PCT) Agreement, 2012

PCT Top Applicants (Publication Year = 2012)		
Applicant	Publication	Rank
LG ELECTRONICS INC.	1,094	11
SAMSUNG ELECTRONICS CO., LTD.	683	16
LG CHEM, LTD.	352	41
LG INNOTEK CO. LTD.	227	67
ELECTRONICS & TELECOMMUNICATIONS RESEARCH INSTITUTE OF KOREA	116	157
PANTECH CO., LTD.	110	168
SEOUL NATIONAL UNIVERSITY	101	184
KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY	82	242
CHEIL INDUSTRIES INC.	77	255
KOREA RESEARCH INSTITUTE OF BIOSCIENCE AND BIOTECHNOLOGY	76	259

Source: World Intellectual Property Organization, Statistical Country Profiles.

Protection of intellectual property combined with long-standing government priorities on export orientation and competitiveness in S&T-related sectors have moved Korea (like Taiwan) to the top ranks in terms of exporting high-technology products, behind China, the United States, and Germany (Figure 12). In value added of high-technology manufacturing industries, South Korea ranks fifth in the world, behind the United States, China, Japan and Germany. However, in terms of the value added to knowledge-intensive industries, South Korea ranks eleventh, indicating that the economy is strong only in select sectors (Science and Engineering Indicators 2012). Overall, Korean companies (discussed in the next chapter) have achieved high levels of global competitiveness in leading-edge technologies, ranking second globally in innovation in 2013, behind the United States (Bloomberg Rankings 2013).



Source: Science and Engineering Indicators, 2012.

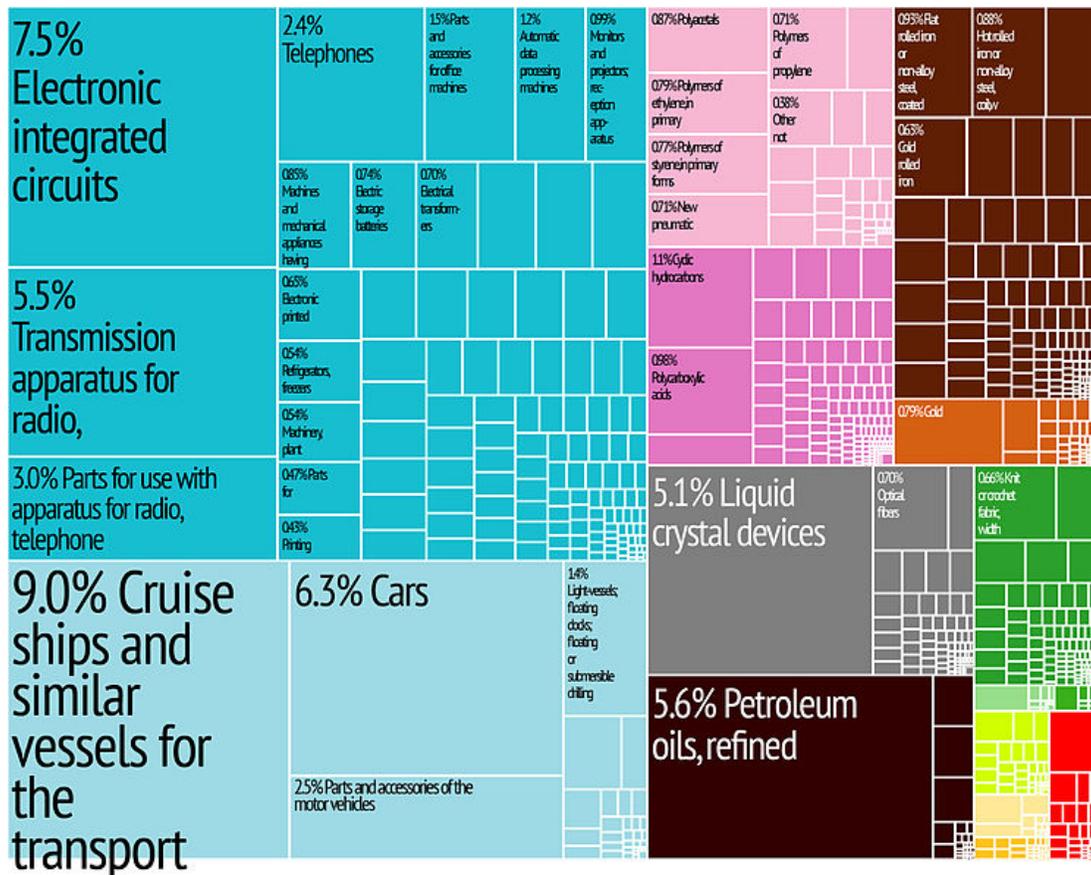
Figure 12. Trends in Exports of High-Technology Products for South Korea and Selected Other Countries, 1995–2010

5. Business and Innovation

The Korean economy is heavily reliant on manufacturing, which makes up close to 27% of the economy. When measuring manufacturing value added as a percentage of GDP South Korea ranks second after China. The industrial structure is primarily composed of chaebol, the small and medium-sized companies that primarily comprise the supply-chain, and service providers for the chaebol and other service-providing small industry.

Innovation in the Korean economy is primarily driven by the private sector, which is dominated by the top conglomerates (Samsung, Hyundai, POSCO, and LG). These chaebol typically span a broad spectrum of related and unrelated businesses. An example is Samsung, which is diversified across the food, infrastructure, shipbuilding, life insurance, surveillance, recreation, advertising and financial industries among others, leading many to refer to Korea as the “Republic of Samsung.” These four dominate Korea’s private spending on R&D. These chaebol were handpicked by the government in the 1960s to lead Korea’s industrial revolution (Chung 2011), and started out deeply rooted in the Japanese model of low-cost manufacturing with a focus on quality and process improvement. Over the past two decades, they have transformed themselves into leading innovators by adopting Western business practices and making aggressive R&D investments while capitalizing on the inherent strengths of a consolidated manufacturing supply chain. Today, Samsung is ranked fourth among the world’s most innovative companies, right behind Apple, Google and 3M (Jaruzelski, Loehr, and Holman 2012). In a different ranking of innovative companies, Hyundai is the top ranked among the auto companies (Taylor, Wagner, and Zablitz 2013), moving up 12 rankings in the past 2 years to surpass Toyota.

As Figure 13 shows, South Korea’s strengths are in electronic integrated services, shipbuilding, automobiles, and petroleum refining. Other areas are emerging as well.



Source: The Observatory of Economic Complexity, <http://atlas.media.mit.edu/>.

Figure 13. Main Industrial Sectors of South Korea

A. Industrial Innovation: Evolving from Fast Follower to First Mover

South Korea has adopted several innovation strategies that allowed its firms to overcome their initial technological disadvantages and to surpass Japan and other southeastern Asian manufacturers in the past decade.

1. Global Sourcing of Knowledge and Business Practices

Over the past two decades, Korea has systematically built up a global-savvy brain trust by strategic external sourcing and assimilation of knowledge at the university and workforce education levels. This state-promoted endeavor, reinforced by its education-focused culture, gives Korea an advantage over Japan. In the past decade, leading Korean firms such as Samsung and Hyundai have been incorporating western business practices into their “Japanese system,” disrupting the traditional organizational structure by bringing in outsiders into an insular culture and sending company executives overseas to get first-hand experience of foreign markets, resulting in knowledge sourcing on a global

scale. This has allowed them to succeed in understanding the customer in emerging markets, while also improving their marketing and design competencies to gain recognition in established markets (Khanna, Song, and Lee 2011).

In addition, there are several Korean organizations such as the Korea-U.S. Science Cooperation Center (KUSCO), a non-profit that sponsors about 140 students yearly for 18-month internships at U.S. companies. These internships immerse students in business, accounting, marketing, and public relations functions.¹³ The number of Korean students going overseas for university education has steadily increased over the past two decades, increasing 32% between 2006 and 2011 (Woo-young 2011) and is the highest with 19.99 per 10,000 people, followed by Japan (4.92), China (3.07), and India (1.19) (APEC 2008). The United States is the top destination for students, followed by China and Japan. While STEM fields account for 25% of enrollment, business management and social studies degrees (areas where Korean universities are particularly weak) attract more than 40% of Korean foreign students (Institute of International Education (IIE) 2012).

2. Private R&D Investment

Business innovation in South Korea has been accelerated by substantial R&D investments by South Korean industry over the past decade. Samsung's R&D investment has doubled over the past 3 years from \$6 billion in 2009 to \$12 billion in 2012 (with an additional \$30 billion in facilities and capital investments), going mainly to research in memory chips, LED displays, and systems-on-chip, a next generation semiconductor technology. As a comparison, leading competitors Intel Corp spent \$11 billion in 2012, and Taiwan Semiconductor Manufacturing Corporation (TSMC) expects to spend \$9 billion in 2013 (Gupta, Kim, and Levine 2013). Hyundai Motor spent \$12 billion on R&D and facilities in 2012 (compared with Toyota which spent \$9.9 billion in 2011). Of the \$12 billion, \$4.4 billion was allocated to fuel efficient cars (Beene 2012).

Patenting activity in top Korean companies has risen to fourth place behind the United States, China, and Japan (Toor 2012; IFI CLAIMS 2011). Korea follows the United States in nanotechnology patents (Shapira and Wang 2010). More significant than the increase in number of patents is the trend in types of patents. While patents were predominantly process and product patents 10 years ago, with the chaebol increasing their investments in fundamental research, the number of patents related to platform technologies is slowly increasing, an indicator of growing expertise at the forefront of new technology paradigms. For example, Samsung, a leading competitor in the smartphone industry, is also gaining ground in the battle on patenting technological platforms (such as 4G) on which future telecommunications services will be delivered. Owning the patents to the technological infrastructure on which mobile devices are based

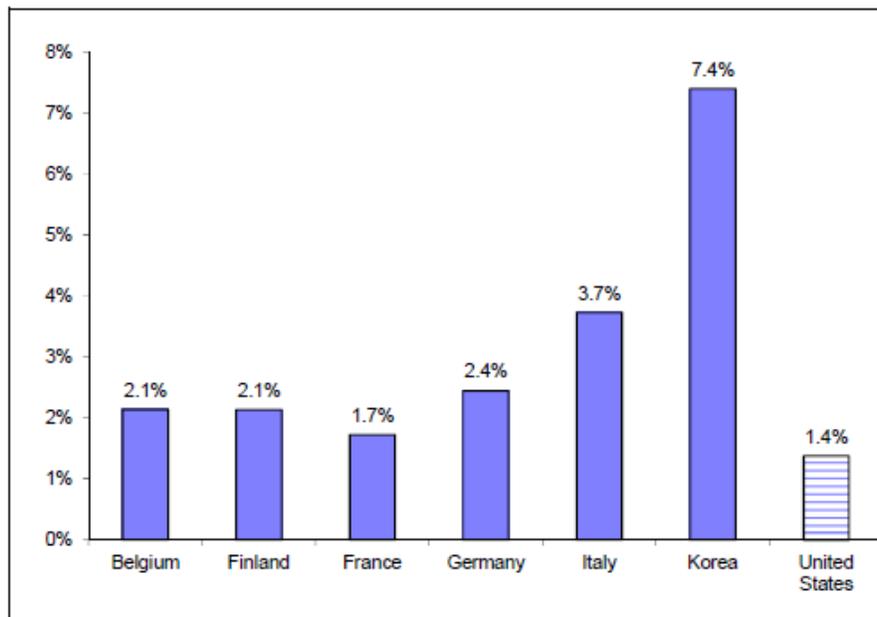
¹³ Discussions with experts. See Appendix A.

means that any company that chooses to develop a product compatible with the underlying platform is required to pay a royalty to the firm that controls the platform (Kim 2012). A similar story can be seen in the automotive sector's investments in wireless energy transfer for battery recharging, an underlying and critical technology for the hybrid and electric car industry (Zachary 2012).

3. Leadership in Manufacturing

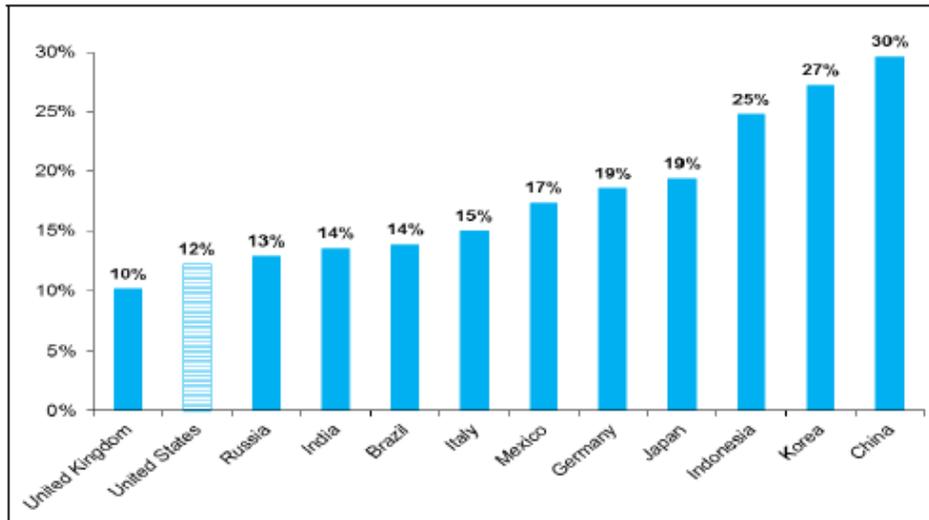
Another characteristic of the Korean economy is leadership in manufacturing capacity which it leveraged to grow an innovation-based economy. Korean firms have close control over their vertically integrated manufacturing supply chains, which allows them to be flexible and change direction more rapidly than their competitors who use globally dispersed supply chains. It is estimated that Samsung's control over the manufacturing supply-chain gives them a 6-month lead over competitors in launching new products. An inherent desire for efficiency and speed pushes Korean companies to reportedly "do things quicker than almost anyone else" (Sang-Hun 2012). This has allowed them to repeatedly move ahead of competitors, as they are able to quickly change direction and respond to changing trends in technology, in essence disrupting them if needed.

Korea has the world's highest investment in manufacturing fixed capital as a share of GDP (7.4%), with the U.S. at 1.4% (see Figure 14). Other than China, South Korea has the highest manufacturing value added as a percentage of GDP at 27% compared to the United States at 12% (see Figure 15).



Source: OECD, National Account Statistics, "Detailed National Accounts: Capital formation by activity" and "Gross Domestic Product."

Figure 14. Investment in Manufacturing Fixed Capital as a Share of GDP, 2009



Source: World Bank, computed from data available at <http://data.worldbank.org/indicator/NY.GDP.MKTP.CN> and <http://data.worldbank.org/indicator/NV.IND.MANF.CN>.

Note: Figures are rounded to nearest percentage point.

Figure 15. Manufacturing Value Added as a Percentage of GDP, 2010

4. Rapid Learning Cycles in Technology Development

Korea's innovation system is characterized by a capacity to learn, produce, and implement high quality processes to produce high quality products; its leadership in manufacturing; and its significant investments in R&D.

Korean companies demonstrate a capacity for rapid “do-learn-improve” cycles that allow them to enter the market at the low end of the technology and flood the market with a large amount of lower cost products to secure the market. Five years ago, Sony was the first company to make what is widely seen as the next-generation television. It featured the organic light-emitting diode (OLED) display, which is thinner, more vivid, and more energy-efficient. Sony was never able to mass-produce or market it because it was too expensive. Samsung and its domestic rival, LG Electronics, entered the market, building mass-production capabilities by first making smaller OLEDs for high-end smartphones, and worked their way up to securing the market on 55-inch OLED televisions (LeClair 2013).

Today, the top South Korean companies compete on high-skilled labor and high-quality products not just by incremental innovation on rival technologies (their former fast follower position), but by steadily increasing R&D investments and focus on innovation which are moving them towards a first mover position in some industries. Korea has 14 companies in the CNN 500 global rankings, compared to 7 each for Brazil

and Russia (CNN Money 2011). South Korea's biggest companies are described in Appendix C.

B. Drawbacks to South Korea's Chosen Innovation Path

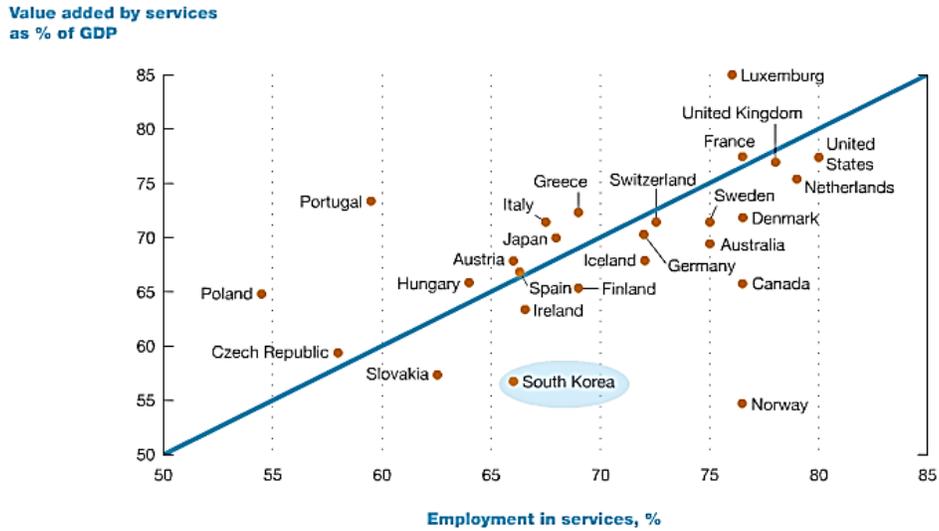
South Korea's chosen route to industrial catch-up has its drawbacks. The legacy of siphoning off capital, top talent, and other resources toward developing South Korea's industrial chaebol has come at the cost of a widening gap between big and small firms, and between manufacturing and services. It has created a sharp dichotomy in the industry, a world with "a few big fish and lots of minnows."¹⁴ Outside the chaebol, much of Korean industry is imitative and faces low profit margins and competition from China and other foreign competitors.

SMEs which supply parts and components to the chaebol are disenfranchised compared to their counterparts in Japan and Taiwan (which operate in a similar structure) in that they are locked into fairly closed production networks with very limited decision-making power, which has denied them learning opportunities with diverse firms, both foreign and domestic, to improve internal competitiveness. Recently, the government has been pushing for financial incentives and technology commercialization opportunities for small and medium-sized firms (although the human capital equation is difficult to address, as employment by chaebol is far more socially prestigious), and their effectiveness remains to be seen.

South Korea's service sector is the second smallest in the OECD area, accounting for almost 58% of its GDP (OECD 2012). Only 4 of its 30 largest enterprises are in services; small and medium-sized companies dominate the service sector, accounting for about 80% of output and 90% of employment. Productivity in services is 53% of the productivity level of the manufacturing sector, much below the OECD average of 87%; this mirrors the ratio of wages between the two sectors (OECD 2012).

Figure 16 shows the value added by services in South Korea as a percentage of GDP compared to other countries.

¹⁴ Discussions with experts. See Appendix A.



Source: Roach et al. (2010).

Figure 16. Value Added by Services in South Korea as Percentage of GDP

South Korea also faces other challenges that make it hard to build an entrepreneurial bottom up economy to complement its successful top down state-created companies that dominate the economy. The most problematic factor is policy instability followed by inefficient government bureaucracy. Challenges for small and medium-sized companies are lack of access to financing, insufficient capacity to innovate, and restrictive labor regulations. These challenges and others are ranked in Table 5.

Table 5. Most Problematic Factors for Doing Business in South Korea, 2012–2013

Factor	Percentage of Responses
Policy instability	18.3
Inefficient government bureaucracy	13.4
Access to financing	12.8
Insufficient capacity to innovate	10.3
Restrictive labor regulations	9.3
Tax regulations	6.2
Poor work ethic in national labor force	5.8
Tax rates	5.2
Inflation	5.1
Corruption	4.5
Inadequately educated workforce	3.2
Inadequate supply of infrastructure	2.8
Foreign currency regulations	1.5
Government instability/coups	1.5
Crime and theft	0.2
Poor public health	0.0

Source: From a set list of factors, respondents were asked to select the five most problematic for doing business in their country and to rank them between 1 (most problematic) (WEF 2012).

6. Factors that Impact Continued Success in Innovation and Challenges Therein

Here we examine some of the ways the South Korean government is seeking to overcome systemic challenges and ensure its path toward economic security is driven by innovation. How these factors are managed today and in the future is important for South Korea's continued success in an innovation-based economy. In some cases, the lack of adaptive strategies may jeopardize South Korea's growth and those are also discussed.

A. Education and Workforce Trends

South Korea has a strong national emphasis on education, based on long-standing Confucian values. A highly developed education system has been one of Korea's greatest assets during its rapid industrial growth over the past half century. Korea today has a literacy rate close to 98%, with 65% of the population under 35 having completed a university education, the highest in the OECD (OECD 2013).

South Korean students rank in the top 5 among 34 OECD countries in mathematics, science, and reading literacy at age 15. The culmination of secondary education in Korea is the College Scholastic Aptitude Test (CSAT), an exam that accounts for 70% of the admission criteria to higher education institutes.¹⁵ The World Economic Forum (WEF) ranks Korea first among 144 countries in university education enrollment, with 31 percent of the students enrolling in science and technology fields. Since 2005, the social sciences have had the most graduates while there has been a decline in the number of engineering graduates.

There is dissatisfaction about the quality of university education in South Korea, its lack of focus on independent thinking and inadequacy in preparing students for the workplace.¹⁶ The university system has been criticized for being comprehensive rather than specialized, and having the same broad curriculum with "many courses being mediocre at best and [that] universities do not challenge students sufficiently (OECD 2012). This stems from the original mission of the education system to provide human capital, not ideas. The government's investments over the past decade to improve the education system, as well as work with industry to create more specialized curricula have

¹⁵ Most parents send their children to expensive "cram schools" that stress rote memorization and test-taking techniques to prepare for this ultra-competitive exam (OECD 2009b).

¹⁶ Discussion with experts. See Appendix A.

resulted in improved college rankings (Byrne 2012), as Seoul National University, Korea Advanced Institute of Science and Technology (KAIST), and Pohang Science and Technology Institute (POSTECH) moved into the top 50 of the 2012 Times Higher Education world rankings (Thomson Reuters 2012). (See Table 6.) They have also moved into the top 10 places in the ranking of the 2012 “100 under 50”, i.e., the top 100 universities under 50 years old (Thomson Reuters 2012), which aims to showcase not those institutions with centuries of history, but the rising stars that show great potential. Over half of the professors at the Seoul National University received PhDs from the United States (the number rises to 90% in the business schools). This is similar for the other top universities in Korea as well.

Table 6. South Korea’s Top Five Universities

Name	World Ranking	Research Strengths	Industry Collaboration	Notes
Seoul National University, Seoul	50–100	Mechanical, chemical, and civil engineering, chemistry, materials science, physics, computer science, management	Samsung, Interpower Co., Pohang Iron and Steel Co., Hynix Semiconductor	Top 5 in Asia. Freshmen constitute top 2.5% of National University Entrance Exam. Spends as much on research as the next 3 universities combined.
Korea Advanced Institute of Science and Technology (KAIST), Daejeon	100–150	Mechanical, chemical, electrical engineering, chemistry, materials science, computer science	Samsung, Hynix Semiconductor, LG, Microsoft	Home of the National Nanofabrication Center and Korea Institute for Advanced Study
Pohang University of Science and Technology (POSTECH), Pohang	150–200	Materials Science, chemical engineering, chemistry, physics	Pohang Iron & Steel Co., Samsung, LG	Ranked #1 of young (<50 years) universities by Times Higher Ed.
Yonsei University, Seoul, Wonju, Songdo	150–200	Computer science, communications, sociology	Samsung, Severance Hospital	Top-ranked private school in Korea.
Sungkyunkwan University, Seoul, Suwon	200–250	Chemical engineering, materials science	Samsung, LG	Founded in 1398, the oldest university in Korea. Currently owned by Samsung Group

Sources: U.S. News/QS, Times Higher Ed, and Shanghai Jiao Tong University rankings for 2012 and websites of respective universities.

Despite its outward look with respect to university education, the role of the English language in South Korea has been controversial. South Korea is largely monolingual, yet competence in English is promoted and regarded as a major criterion in education, employment, and job-performance evaluation. Recently, South Koreans debated whether to adopt English as an official language of South Korea (Song 2011). However, some stated there are not enough Korean teachers who speak English fluently or confidently enough to make this plan viable (Ahn 2011).¹⁷

Korea has low participation of women in the workforce (108th out of 135 countries (WEF 2012), despite high levels of education. This is partly driven by culture and partly by unfavorable working conditions, including a wage gap of 39% (Min-young 2012), the largest in OECD countries. South Korea is facing a workforce shortage as a result of a declining birthrate (at 1.2, the lowest in the OECD) and a rapidly aging workforce. Korea is projected to have the second oldest population by 2050. If the female labor force participation rate in Korea were to converge to the current level for males for each age group by 2050, the labor force would only decline to around 25.6 million, which would be almost 19% higher than in the case of unchanged participation rates (OECD 2012).

B. Leadership in Technology and Business Innovation—Creating a Knowledge-Based Economy

Korea has combined policy-driven S&T investments with market-driven business strategies to become one of the most innovative economies today. This growth and innovation has been driven by the country’s biggest chaebol (Samsung, Hyundai, LG, and POSCO, formerly Pohang Iron and Steel Company). A combination of speed and product-specific strategy gives Korean companies a competitive edge in markets that have rapid product cycles and constantly lowering prices, such as electronics and communications. This was demonstrated in the aftermath of the IP lawsuit brought by Apple against Samsung in April 2011, accusing Samsung of “slavishly copying” the feel and look of its iPhone and iPad products (Sang-Hun 2012). By the time Apple won the court case, the Samsung product in question had already been replaced by newer versions in an attempt to stay ahead of the patent battle.

Korean firms have consistently invested in R&D and product innovation, focusing on patenting innovations not just in process and product, but also in technology infrastructures such as the 4G telecommunications standard. Patenting infrastructural technology ensures that any company that chooses to develop a product compatible with the underlying platform is required to make royalty payments to those firms who control the patents over the platform. Going forward, Korean firms are increasingly focused on gaining commercial control of platform and infrastructural technologies (such as wireless

¹⁷ Discussions with experts. See Appendix A.

energy transfer technology and communications standards) that have the potential to be transformative in the future, and their industry-based R&D enterprise has been more successful than the United States at converting scientific and engineering strengths into commercial success.

C. Room for Innovation in Small and Medium-Sized Enterprises, Especially in the Service Sector

Korea's underdeveloped small and medium-sized enterprises remain in the imitation mode rather than on the innovation frontier. This is in contrast to small and medium-sized enterprises (SMEs) in Taiwan, Singapore, and other neighboring countries where SMEs are exposed early to apprentice-like learning arrangements with large firms, both foreign and domestic. The advantages that Korean SMEs have enjoyed because of close ties to the chaebol have eroded in the face of shortening product cycles and global outsourcing by the chaebol seeking cheaper and more innovative suppliers.

The service sector has much room to grow and offers potential for innovation, reducing income inequality, and increasing productivity (Dobbs and Villinger 2010). The U.S.-Korea free trade agreement that went into effect in March 2012 can potentially enable Korea's small and medium-sized companies to expand their customer base overseas while the United States invests in the service sector (Department of State 2012).

South Korea needs additional policies to develop their SMEs. Government support for SMEs in South Korea has been ineffective thus far because of the control exerted by big businesses. A noncompetitive SME sector slows innovation while contributing to income inequality and uneven development. It is also responsible for a continuing high level of dependence on imports of foreign technologies (OECD 2009a).

D. Entrepreneurship and Start-ups

Encouraging creativity and risk-taking in business is one of South Korea's challenges. South Korean President Park Geun-hye's has called for a "creative economy" that supports the growth of an entrepreneurial economy that encourages startups and small companies. Korea's Science and Technology Policy Institute (STEPI) coordinated a symposium in May 2013 to address the challenges of doing this. However, "despite South Korea's embrace of technology and its citizens' incredible work ethic, Koreans are still predominately conservative in their opinion of entrepreneurship and risk-taking. The idea of a leaving a highly paid corporate job at one of South Korea's three conglomerates (chaebol) for a startup goes completely against the country's traditional definition of success" (Vu 2013).

The start-up ecosystem in Korea is underdeveloped relative to the high level of education and technological sophistication attained by the country. This can be partly

attributed to the fact that the chaebol dominate in every sector of the economy. They have entered new industries at the pace of one new business every 18 months over the past decade (Hirt, Smit, and Yoo 2013), creating a big obstacle to the start-up economy. Another inhibiting factor is the lack of private capital for new, high-risk ideas (particularly late stage funding for taking the product to market). New ideas or sectors that do get funded find it difficult to develop an ecosystem or a supply chain outside the reach of the chaebol, given their pervasiveness (Webb 2007).

Venture-backed companies emerged in Korea in the late 1990s, grew steadily during the Internet boom, to 11,000 companies during the lead-up to the bursting of the Internet bubble in 2001 and the closure of most companies. Start-up firms started growing again in 2004 and have been steadily increasing with an 83% surge between 2007–2011 standing at over 2,000 firms in 2011.

A new wave of start-up activity began in 2012, championed by foreign returned ethnic Koreans creating start-ups targeted at the fast growing mobile software sector where the need for start-up capital is relatively small. Widespread youth unemployment has belied the conventional wisdom of looking no further than the chaebol for employment, and young Koreans are increasingly ignoring the stigma of starting one's own business and registering as "one man creative enterprises" in fields such as gaming and social media. Today, start-ups such as SparkLabs (McKenzie 2012) and AhnLab,¹⁸ both started by U.S.-returned ethnic Koreans have renewed a spirit of entrepreneurship in Korea and it remains to be seen whether and how these kinds of innovative companies will help the economy.^{19 20}

¹⁸ About AhnLab, <http://www.ahnlab.com/company/site/eng/about/overview.jsp>.

¹⁹ SparkLabs provides 3-month programs for entrepreneurs to build global companies that expand outside of Korea. SparkLabs provides mentors to accelerate and guide each company. The focus of the startups is on companies whose focus is to change the Internet, online gaming, mobile, ecommerce and digital media sectors. They invest \$25,000 in each company, provide office space, and access to a global network of companies, programs and people. The founders are entrepreneurs who built companies in Korea and the U.S. "We have bootstrapped, funded our companies by credit cards, raised angel funding and secured venture capital. We have endured the ups and downs of entrepreneurship, gone through our share of successes and failures, and have developed a strong desire to help out the next generation of global entrepreneurs" (About SparkLabs, <http://www.sparklabs.co.kr/en/about>). The co-founders each have a U.S. and Korean education and business experience. Bernard Moon received his MPA in Telecom and New Media Policy from Columbia University and a BA in English and Psychology from the University of Wisconsin-Madison. Hanjoo Lee was born and raised in Korea and immigrated to the United States at age 13. He holds a BA in Biology from the University of Chicago. Jimmy Kim received his B.S. in Engineering from Northwestern University, and also a M.S. in Engineering from Korea Advanced Institute of Science and Technology (KAIST). He also completed the Stanford University's Graduate School of Business's Executive Management Program.

²⁰ Ahn Cheol-Soo (founder and chairman) developed a program to find and remove a computer virus and named it "Vaccine." Since then, anti-virus software has been called "Vaccine software" in Korea. Ahn Cheol-Soo promoted his new company in 1995. Ahn Lab, Inc. is one of Korea's most successful start-up stories. Starting with five employees, today the company, headquartered in Seoul, employs over 300

The South Korean government has initiated policies to assist entrepreneurs and small businesses. These policies have focused on creating “hundreds of incubators throughout the country, offered entrepreneurs free office space, thousands of dollars in grants, and guaranteed loans, but the country has yet to succeed in nurturing the kinds of disruptive companies that are prevalent in the U.S.” (Vu 2013). While a small percentage of Korean start-ups have earned more than a trillion Korean won (about USD 90M), none have broken into the international market with any success.

With the imbalance in the South Korean economy created by the dominance of a handful of large conglomerates, it is possible that a truly entrepreneurial economy will only emerge in the wake of the declining fortunes of the dominant chaebol. Attitudes toward entrepreneurship may decide how a country or company copes with such decline. For example, in Finland, Nokia’s declining fortunes in the smartphone market unleashed a flood of start-up activity in Finland as the company itself began a program to help highly skilled departing employees set up their own start-ups, offering financial help and training (Lomas 2012; Bosworth 2012).

E. Knowledge Diffusion from Universities and Research Institutes²¹

Since the late 1990s, the Korean government has supported transitioning to a knowledge-based economy, instituting ambitious goals in the form of publication and patenting targets for public research institutes. Publications have jumped by two-thirds over the past 15 years (from under 10,000 in 1996 to 61,000 in 2011 (SCImago 2013; WEF 2012). However, there is suspicion that some of this growth is due to over-publication and over-patenting, as evidenced by the marginal growth in citation rates (about 1% per year over the past 15 years) and relatively low levels of technology

professional developers. AhnLab develops industry security solutions to secure and protect information and has been growing steadily in terms of both market share and revenue, operating in more than 20 countries today (see the biography of Charles Ahn, http://www.ahnlab.co.kr/company/site/eng/pr/founder_retire.jsp). After earning a medical degree from Seoul National University in 1991, Ahn Cheol-Soo went to the University of Pennsylvania’s School of Engineering and its Wharton School of Business and earned an Executive Master’s degree in Technology Management in 1997. A much admired entrepreneur and public figure in South Korea. Dr. Ahn resigned as the CEO of AhnLab in 2005 (though he continues to remain involved as a chairman of the board of directors) and has since moved on to academia, most recently as the Dean of the School of Convergence at the Seoul National University (Ahn 2011). He was also a prominent candidate in November 2012 presidential elections in South Korea where he captured a large part of the youth vote by running on a progressive platform (Roehrig 2012).

²¹ Universities in South Korea were set up to train students in science and technology and historically have contributed only marginally to knowledge transfer to the business sector. In terms of the role of the universities in research, there remains a significant mismatch between research spending and human resource capabilities—the universities have almost 70% of all Korean doctorates but perform just 10% of Korean research (OECD 2011). In 2000, universities contributed to 0.6% of the patent applications in Korea, while industry filed 48% of patent applications (Lee and Park 2006). This was still true in 2011--industry showed large increases in patent filings while universities did not (WIPO 2012).

transfer from universities. In 2007, Korean universities earned USD 3.2 million from over 600 transfers of technologies to the marketplace. As one benchmark, this compares to more than USD 1 billion earned by U.S. universities from around 4,000 transfers to the marketplace (OECD 2012).

South's Korea publication and patenting strategy is insufficient. As a result, businesses have little expectation of economically valuable knowledge transfer from domestic universities as a result of poor system linkages, cultural differences and a misdirected incentive system that undermines the impact of academic and government researchers. Adaptive strategies are needed to overcome these challenges.

F. Societal Adaptation to Change over Time

Koreans have seen their country change significantly in a compressed amount of time (“the past and the future are very close in Korea”²²) and most prosperous urban South Koreans are only one generation removed from their rural countrymen. As a result there is much empathy for those who have been left behind in the country's sudden rise to prosperity. As South Korea has experienced a marked rise in income inequality and relative poverty over the past 15 years, widespread sympathy has grown for small and medium-sized enterprises. “Economic democratization” was a buzzword in the 2012 presidential election, capturing the notion of reducing inequality by reining in the power of the chaebol (Min-uck 2012).

Culturally, the chaebol enjoy the status of most favored employers in Korea, and parents steer their children into steady careers in the chaebol, the government, or the professions (*Economist* 2012). For Koreans, the increasing power of the chaebol has become a two-edged sword. On the one hand, Koreans are deeply competitive and admire the conglomerates for the traits they want for themselves—ambition, speed, and the ability to adapt and stay at the top (*Economist* 2012). They recognize that South Korea's continuing success relies on groups with a competitive edge against international rivals, and only the biggest chaebol have given Korea a place in the global marketplace. On the other hand, chaebol-bashing has become an established, though ineffective sport in Korea, as there is little agreement on how to tackle the issue.

The presence of the chaebol discourages risk-taking even in areas where possibilities are very close home. For example, despite having an extremely advanced mobile broadband infrastructure, which presents new, non-physical white spaces for innovation, Korea's lifestyle, gaming, and service-based software industries are behind those of countries with comparably advanced infrastructure. Advances in translational research in new areas such as biotechnology are also weak compared to similarly

²² Discussion with experts, see Appendix A.

advanced countries. The *577 Initiative* is attempting to address these issues, but as incomes rise more advances are needed in the entertainment and service industries.

7. Summary and Conclusions

A. Strengths and Weaknesses of South Korea's Innovation System

South Korea has had tremendous growth over the last 30 years by following a strategic approach to science, technology, and innovation and creation of world-class companies. In technology innovation, South Korea's success in leapfrogging technology generations has been underscored by a pragmatic strategy of starting at the low end of the market in new product segments and continuously improving their product sophistication, using economies of scale to secure a competitive market share. In this manner, they have risen to the top of international competition by evolving from a "fast follower" position into a "first mover" position, close to the technological frontiers (Leber 2012). The technological sophistication of South Korean companies can be gauged from their growing strengths in patenting infrastructural and platform technologies in sectors such as communications and renewable energy.

The private sector's success in innovation has been buoyed by government investments in education and training, achieving one of the most literate populations among OECD countries. These strengths set the stage for opportunities for continuing on its innovation trajectory. South Korea sends large numbers of students overseas to obtain university education and these students are more likely to work in the chaebol. This global sourcing of knowledge and ideas has allowed leading South Korean companies to evolve into competitive multi-nationals in a relatively short period of time. While not considered as risk-taking as U.S. firms, South Korea's firms are still more likely to take risks when compared to Japanese firms, particularly in making changes to their organizational culture and attracting foreigners into their workforce. Publications and patenting are beginning to increase, indicating more openness in innovation. Attitudes toward entrepreneurship are changing with the return of U.S.-raised ethnic Koreans who are starting new companies, often jointly with the United States.

South Korea faces challenges as well. (See Table 7.) The country is still ethnically homogenous and its language is a barrier. It has compensated for its lack of natural resources by building a knowledge-based economy, yet its education system requires a shift from rote memorization to one that encourages creativity. Overcoming the workforce gender gap would offset the decline in the labor force caused by a rapidly aging population. The chaebol culture, while the heart of South Korea's success, is also considered a weakness in that it is not transparent and many of its business practices are considered corrupt. South Korea also has many social issues to address, including high

levels of stress due to long school and work hours, and lack of infrastructure for caring for the aging population.

Table 7. Characteristics of South Korea’s Innovation System

Strengths	Weaknesses
<ul style="list-style-type: none"> • Highest literacy rate in OECD; investments in of STEM education; more than 50% of faculty at top Korean universities are U.S. trained • Strong government support for S&T and innovation; highest R&D intensity (3.36% of GDP, 70% in private sector) <ul style="list-style-type: none"> – Shift in government funding away from technology development towards basic science R&D • Strong manufacturing base; control over vertically integrated supply-chain allows for rapid incremental innovation 	<ul style="list-style-type: none"> • Ethnically homogeneous culture, language barrier for outsiders <ul style="list-style-type: none"> – Low acceptance of outsiders (non-ethnic Koreans) in corporate culture • Lack of natural resources • Education heavily biased towards rote memorization • Significant gender gap in workforce • Chaebol (conglomerate) culture results in lack of transparency, corrupt business practices • Lack of support for entrepreneurship, although attitudes are changing with return of U.S.-raised ethnic Koreans
Opportunities	Threats
<ul style="list-style-type: none"> • Openness towards learning from outsiders <ul style="list-style-type: none"> – Largest percentage of students going overseas for university education – Large pool of foreign trained personnel in big companies • Culture of consolidation driven by need for stability and security, but high tolerance for risk in business, even in large companies (distinguishes from Japan) • High levels of business innovation <ul style="list-style-type: none"> ○ Use low-cost, high-volume production to corner the market, use profits to drive R&D for high-tech models • Strategic use of patenting and increasing involvement in global standards setting • Attitudes towards entrepreneurship are changing with return of U.S.-raised ethnic Koreans 	<ul style="list-style-type: none"> • Heavy societal cost of very rapid transformation <ul style="list-style-type: none"> – High levels of stress in society, starting at high school – Marginalization of elderly, high suicide rates • Dichotomy in economy, few high-performing big firms and large, underdeveloped SME and service sectors • Economy concentrated in few sectors • Systemic threat in presence of North Korea • Underdeveloped defense technology • Lack of knowledge transfer between university research and industry

B. Vision for the Future

South Korean companies have moved from incremental innovation toward more cutting edge science-based innovation. Capitalizing on future possibilities in science and technology requires disruption and risk taking. Koreans employ a highly strategic, consensus-based approach to policymaking, with high emphasis on planning and metrics

for R&D in government and industry. This low-risk approach is seen by some as an inherent barrier to innovation (Webb 2007).

South Korea's challenges will be to develop an entrepreneurial culture in small and medium-sized companies as well as provide incentives to support R&D in both firms and startups. This may spur higher levels of codifying knowledge in the form of patents and publications, which is considered low in impact given the high level of R&D spending. The speed of the chaebol in developing new technologies may lend itself to maintaining trade secrets, but not to diffusing knowledge. In addition, South Korea funds basic research primarily through its Government Research Institutes (GRIs), not its universities. Mutual distrust and a lack of understanding between the GRIs and the universities inhibit the development of closer and mutually beneficial interactions (OECD 2012).

Foreign direct investment in South Korea is low at \$4.7 billion (Heritage Foundation 2013) (compared to \$124 billion in China), offset by the large share of GDP that South Korea devotes to R&D (Bartzokas 2009). South Korea has achieved tremendous success in growing their economy through innovation. To continue that success will require changes to support R&D at universities and the resulting creation of an entrepreneurial economy.

Looking ahead, many of South Korea's investments in science, technology, and innovation are driven by national security priorities such as energy efficient and green technologies, high energy physics, and space. Recent policies suggest the government and private sector leaders in South Korea are transitioning from technology and commercialization-driven R&D toward more ambitious, long-term, and transformational science. The government's long-term (technology agnostic) investments in basic science R&D as well as raising the standards of universities and emphasizing global collaborations will go a long way toward realizing Korea's vision for a knowledge-based economy, but only if paired with an increased tolerance for risk.

Appendix A. Experts Interviewed

Table A-1. List of Experts by Sector

Sector	Expert Name	Affiliation	Date of Discussion
Industry	Bok, Deukkyu	Research Fellow, Samsung Economic Research Institute	Nov 26, 2012
	Lee, Sungho	Research Fellow, Samsung Economic Research Institute	Nov 26, 2012
Government	Dresser, Heather	US Department of State	Oct 30, 2012
	Lee, Inil	S&T Counselor, Embassy of the Republic of Korea	Nov 15, 2012
	Muelkhe, David	South Korea Desk Officer, US Department of State	Oct 30, 2012
Nonprofit	Kim, Jong Deok	S&T Program Director, Korea-US Science Cooperation Center (KUSCO)	Sep 24, 2012
	Kim, Byoungsoo	Director, Division of Corporate Strategy and Global Cooperation, STEPI	Sep 25, 2012
	Lee, June Seung	President, Korean Institute for Science and Technology Evaluation and Planning, KISTEP	Sep 26, 2012
	Son, Byoung-Ho	Director General, Office of Future Strategy, KISTEP	Sep 26, 2012
	Oh, Dong Hoon	Director General, Office of S&T Policy and Planning, KISTEP	Sep 26, 2012
	Oh, Katy	Korea scholar, US Institute for Defense Analyses (IDA)	Oct 5, 2012
	Park, Jongwon	Research Staff, Stanford Research International (SRI)	Nov 19, 2012
	Sangki, Jeong	Director, Office of National R&D Coordination, STEPI	Sep 25, 2012

Appendix B.

South Korea's Government Structure

The current government bodies and ministries that focus on science, technology, and innovation were largely formed in 2008, when the government consolidated many ministries to reduce redundancy and rivalry among the existing players. The Ministry of Science and Technology (MoST) was assimilated into the newly formed Ministry of Education, Science, and Technology (MEST). Currently, the two ministries most responsible for setting innovation policy in South Korea are MEST and the Ministry of Knowledge Economy (MKE). MEST is the most influential, as it is primarily responsible for formulating policies for S&T development and R&D investment. MEST is also charged with supporting the nation's universities and research institutes (both government and private). MKE, on the other hand, works primarily with industry. It is charged with attracting foreign investment, keeping the energy industry competitive, advancing the design, materials, automobiles, shipbuilding, machinery, steel, petrochemicals, and textile industries, and promoting the high tech industries of semiconductors, information technology, and biotech. Though these are the two largest players, most ministries with a science, technology, and innovation mandate have appointed their own advisory committees to help formulate policy.

The S&T policy governance structure in South Korea in many ways resembles that of the United States. The two main advisory and coordination bodies serving the executive branch are the South Korean National Science and Technology Council (NSTC) and the Presidential Advisory Council on Science & Technology (PACST). The NSTC has been the highest decision-making body of the Korean government since its formation in 1999. The council consists of a mixture of government ministers and experts from the S&T community. Created as a cross-ministerial body, the NSTC's purpose is to coordinate the ministries' S&T policies and initiatives and create an overall national S&T plan. The secretariat for NSTC is provided by the MEST.

PACST, established in 1991, is a 30-member council composed of representatives of prominent industries, academia, and research institutes. Composed of five subcommittees, the PACST directly advises the President on strategic policies related to technological innovation and development of human resources. Since most of the members of PACST represent the private sector and diverse S&T communities, it is a valuable mechanism for allowing the President and deputy prime minister to listen to voices outside the government. Members of PACST are appointed by the president for a term of one year and meet on a monthly basis.

In addition to the governmental bodies responsible for forming, advising, and coordinating S&T policy, there are several government supported institutes that form the core of the strategic intelligence on S&T and innovation. They are the:

- Korea Institute of Science and Technology Evaluation and Planning (KISTEP), which is the main S&T planning agency in South Korea, and supports MEST in its objectives,
- Institute for Industrial Technology Evaluation and Planning (ITEP), which supports MKE in evaluating and managing industrial R&D programs,
- Institute for Information Technology Advancement (IITA), also under MKE, which provides strategic intelligence specifically to the information technology sector, and
- Science and Technology Policy Institute (STEPPI), which operates three research centers and supports the National Research Council for Economics, Humanities, and Social Sciences (NRCS) in conducting analyses on S&T issues and promoting innovation.

Appendix C.

South Korea's Biggest Companies

Table B-1. South Korea's 10 Biggest Companies

Company	Market Cap	Primary Sector
<p>Samsung Electronics. Samsung Electronics is the flagship subsidiary of South Korea's biggest business conglomerate—Samsung Group—which has nearly 80 affiliates, and is the world's biggest technology firm by revenue.^a It was founded in 1969 and is now the world's biggest maker of memory chips, smartphones and televisions. The family-run group has a significant impact on South Korea's economy, accounting for about one fifth of the country's GDP.</p> <p>For many years considered a copier and not an innovator, Samsung has climbed to third place in the list of the world's most innovative companies behind Apple and Google^b and is the only non-American company in the list of the ten most valuable brands in the world.^c While best known for their mobile phone products, Samsung Electronics produces a wide breadth of electronic products, covering their consumer's homes from the kitchen to the living room.</p>	<p>Market cap: \$165.2 billion (compare to Apple at \$400 billion)</p>	<p>Mobile phone products</p>
<p>Hyundai Motor. Hyundai Motor is the world's fifth-biggest carmaker, based on annual vehicle sales, and the top automaker in South Korea. Founded in 1967, it launched the first Korean passenger car—the Hyundai Pony—in 1976. By expanding its presence in key markets like China, the carmaker sold 4.06 million vehicles in 2011. Last year, Hyundai moved ahead of Toyota and Ford in the BCG list of the world's most innovative companies, leading the automotive companies at the #10 spot on the list.^d The company has steadily expanded their market share overseas, particularly in the U.S., with an emphasis on quality and after-sales services.</p>	<p>Market cap: \$49.8 billion (Compare to Toyota at \$206.5 billion)</p>	<p>Automobiles</p>
<p>POSCO. POSCO was founded in 1968 as a joint venture between the South Korean government and tools manufacturer TaeguTec. POSCO Energy is Korea's largest private power generator; it produces more than 39 million tons of steel a year, making it the world's third largest steelmaker behind Britain's ArcelorMittal and Japan's Nippon Steel. It has a joint venture with U.S. Steel called USS-POSCO in California and expects to break ground on a \$12-billion steel mill project in India's eastern Orissa state this year. The company has plans to invest in renewable energy research and development, and has already built the world's largest fuel generation cell (with a capacity of 50MW) which is now in operation.^e</p>	<p>Market cap: \$32.6 billion</p>	<p>Steel</p>

Company	Market Cap	Primary Sector
<p>Kia Motors. Kia Motors is South Korea's second-largest automaker and a subsidiary of the Hyundai Motor Group since the original company declared bankruptcy during the Asian financial crisis and was acquired by Hyundai. Since then, the automaker has expanded globally with manufacturing plants in the U.S., Europe and China. Tapping in to the world's largest auto market, Kia's China sales jumped over 30% in 2011. The company is planning to open its third factory in China this year to increase annual capacity by 200,000 units to 730,000 units by 2014. In 2012, Kia motors signed an agreement with oil refiner SK Innovation, a Korean company, to develop batteries for future electric cars and cooperate on the marketing strategy for expanding the electric vehicle industry base in South Korea,^f and bring the company to a leadership position in EV development.</p>	<p>Market cap: \$29.2 billion</p>	<p>Automobiles</p>
<p>Hyundai Mobis. Seoul-based Hyundai Mobis, a subsidiary of the Hyundai Motor Group, is the country's leading maker of auto parts. Founded in 1977 as Hyundai Precision Industry to produce containers, the company turned its focus to autos and launched the Galloper brand of vehicles in the 1990s. Primarily supplying auto parts to South Korean carmakers Hyundai and Kia, Hyundai Mobis has been reducing its dependence on domestic customers by increasing its overseas business with companies like BMW, Volkswagon, Subaru, Mitsubishi and most recently a \$1.07 billion deal to supply parts to General Motors and Chrysler.</p>	<p>Market cap: \$26.1 billion</p>	<p>Auto Parts</p>
<p>LG Chem, LG Chem is South Korea's largest chemical maker, and one of the leading suppliers of car batteries. The company was founded in 1947 as Lucky Chemical Industrial and merged with LG Petrochemical in 2007. It operates in two segments—petrochemicals and electronic materials, such as rechargeable batteries for mobile phones, laptops and electric vehicles. LG Chem's customers include GM, to which it supplies batteries for the automaker's plug-in hybrid, electric vehicle Volt.</p>	<p>Market cap: \$20 billion</p>	<p>Petrochemicals and electronic materials</p>
<p>Hyundai Heavy Industries. Hyundai Heavy Industries Co. is the world's largest shipbuilding company. The firm which started in 1947 as a construction business split from the Hyundai Group in 2002. Today, it has subsidiaries in engineering, heavy machinery, construction and green energy. Operating out of the world's largest shipyard at Ulsan, the company (whose ships include the Deepwater series) is able to compete with overproduction from China on the basis of superior fuel efficiency,⁹ for which shipping lines are willing to pay higher prices. The company has announced a number of big deals recently, including a \$1.2 billion ship order from Greece and three orders worth a total \$600 million to build oil and gas rigs.</p>	<p>Market cap: \$19.8 billion</p>	<p>Shipbuilding</p>

Company	Market Cap	Primary Sector
<p>Samsung Life Insurance. Samsung Life Insurance is biggest life insurer in South Korea with about 26% of local market share. Founded in 1957, the insurer's growth accelerated after it was incorporated under Samsung Group in 1963. Its initial public offering in 2010, which raised \$4.4 billion, catapulted the firm to the status of one of South Korea's most valuable companies. The insurer's top shareholder is Lee Kun-hee, South Korea's richest man and former CEO of parent firm Samsung Group. The company is at the heart of a web of Samsung Group cross-shareholdings that have come into question as Lee defends three lawsuits from relatives on his holdings in the conglomerate. In a move to expand into emerging markets, there were reports in May that Samsung Life was planning a partnership with Dubai sovereign fund to sell life insurance in the Middle East and north Africa.</p>	Market cap: \$18.8 billion	Life Insurance
<p>Shinhan Financial Group. Shinhan Financial Group, South Korea's largest banking services firm, is the only financial company to make the top-ten list. The group was founded in 2001 as a holding company for 11 subsidiaries that include Shinhan Bank (originally named Hanseong Bank)—which is best known as the first bank in Korea—and Jeju Bank. The group also has interests in asset management and life insurance. Last year, the firm experienced a major shakeup with the appointment of new chairman Hang Dong-woo, after a public embezzlement scandal dented its image and led to the resignations of three top leaders.</p>	Market cap: \$18.2 billion	Banking
<p>SK Hynix, SK Hynix, formerly known as Hynix Semiconductor, is the world's second largest memory chipmaker, producing DRAM and Flash memory chips. The company was founded in 1983 and changed its name to SK Hynix after SK Telecom paid \$2.98 billion in February for a 21-percent stake in the firm. Since 2011, Hynix has collaborated with Hewlett Packard and Toshiba in the development of next generation memory technologies.</p>	Market cap: \$16.4 billion	DRAM and flash memory chips

Source: CNBC.com (2011).

- ^a Samsung surpassed Apple in revenue this year, with second quarter earnings at \$50 billion compared to Apple's \$43.6 billion and Intel's \$12.8 billion.
- ^b In a ranking published by the Boston Consulting Group at <http://www.forbes.com/sites/haydnshaughnessy/2013/01/16/samsung-shines-in-the-worlds-most-innovative-company-rankings/>.
- ^c From <http://www.businessinsider.com/most-valuable-brands-in-the-world-2012-10?op=1>.
- ^d In a ranking published by the Boston Consulting Group at <http://www.forbes.com/sites/haydnshaughnessy/2013/01/16/samsung-shines-in-the-worlds-most-innovative-company-rankings/>.
- ^e From <http://www.worldsteel.org/steel-by-topic/sustainable-steel/company-case-studies/fuel-cell-posco.html>.
- ^f From <http://energy.korea.com/archives/31355>.
- ^g From <http://www.bloomberg.com/news/2013-07-07/hyundai-heavy-to-lift-prices-on-demand-as-china-shipyards-falter.html>.

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Abbreviations

APEC	Asian-Pacific Economic Cooperation
CIA	Central Intelligence Agency
EPB	Economic Planning Board
GDP	gross domestic product
GRI	Government Research Institute
IDA	Institute for Defense Analyses
IITA	Institute for Information Technology Advancement
IITEP	Institute for Industrial Technology Evaluation and Planning
KAIST	Korea Advanced Institute of Science and Technology
KISTEP	Korea Institute of Science and Technology Evaluation and Planning
KUSCO	Korea-U.S. Science Cooperation Center
LCD	liquid crystal display
MEST	Ministry of Education, Science, and Technology
MKE	Ministry of Knowledge Economy
MoST	Ministry of Science and Technology
NSB	National Science Board
NRCS	National Research Council for Economics, Humanities, and Social Sciences
NSTC	National Science and Technology Council
OECD	Organisation for Economic Cooperation and Development
OLED	organic light-emitting diode
PACST	Presidential Advisory Council on Science and Technology
POSCO	Pohang Iron and Steel Company
POSTECH	Pohang Science and Technology Institute
PPP	Purchasing Power Parity
R&D	research and development
S&T	science and technology
SME	small and medium-sized enterprise
STEM	science, technology, engineering, and mathematics
STEPI	Science and Technology Policy Institute
TSMC	Taiwan Semiconductor Manufacturing Corporation
WEF	World Economic Forum

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