No. 2025-31 BANK OF KOREA

BOK Issue Note

November 03, 2025

Understanding the Drivers of STEM Talent Outflows and Their Policy Implications

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① **Science and engineering (STEM) talent plays a central role in driving future growth in areas such as digital transformation, artificial intelligence, and advanced manufacturing, forming a strategic foundation for national competitiveness.** Their technological capabilities are essential assets that support both the economy and national security, and they cannot be easily replaced simply through the recruitment of foreign workers or increased capital investment. In Korea, however, a growing share of top-performing high school students are choosing medical studies, reflecting a strong shift toward the medical profession, while those who do pursue science and engineering often look abroad for better research environments and career opportunities, contributing to a rising trend of talent outflows.

② **The overseas outflow of STEM talent represents a structural risk that may weaken Korea's technological innovation capacity and long-term growth potential, as it entails the loss of human capital accumulated over many years.** This challenge therefore warrants timely and careful policy attention. In this context, **this study**, in cooperation with the Korea Institute of Science and Technology Information, **conducted a survey of approximately 2,700 STEM personnel in Korea and abroad. Based on the survey results, it provides an empirical assessment of the current status and determinants of overseas outflows among Korean STEM talent, and outlines potential policy responses.** Unlike previous surveys that focused solely on domestic STEM workers, this study includes both domestic and overseas respondents and examines a wide range of financial and non-financial factors. This broader approach offers a valuable foundation for micro-level analysis of the drivers behind overseas career decisions and the emerging tendencies toward talent outflow.

③ Korean STEM professionals have continued to move overseas, with particularly strong flows to the United States. **The number of Korean STEM doctorate holders working in the U.S. almost doubled between 2010 and 2021, increasing from about 9,000 to 18,000. LinkedIn data also indicates that net overseas outflows have accelerated since 2015, driven primarily by talent in biotechnology and ICT.** Notably, graduates from Korea's five leading science and engineering universities account for 47.5% of the net overseas outflow on average over the period 2004–2024, underscoring the concentration of outflows among highly trained individuals.

④ The survey results show that **42.9% of domestic STEM professionals are considering moving abroad within the next three years, with the share rising to 70% among those in their 20s and 30s.** As expected, **financial factors—including wage levels and expected earnings—were cited most frequently.** At the same time, **non-financial considerations, such as the research ecosystem, professional networks, and assurance of career opportunities, also accounted for**

a substantial share. This suggests that broader constraints in working conditions—particularly the quality of the research environment and career sustainability—significantly influence professionals' motivation to seek opportunities abroad.

⑤ The empirical analysis using a logit model shows that **when satisfaction with earnings increases from "fair" to "satisfactory"** (a one-point increase on a 1–5 scale)**, the probability of moving overseas declines by 4.0 percentage points.** Similarly, higher satisfaction with employment stability and promotion opportunities reduces the probability of an overseas move by 5.4 and 3.6 percentage points, respectively. These results indicate **that improvements in working conditions—particularly job security and career development—can be just as effective as financial compensation in mitigating talent outflows.**

⑥ **A more detailed analysis of non-financial factors by individual characteristics reveals clear heterogeneity.** When examined by degree level, master's degree holders showed a lower intention to move overseas when promotion opportunities and the research environment improved, whereas doctoral degree holders placed greater importance on employment stability and their children's educational environment. When broken down by academic major, individuals in emerging industries such as biotechnology and IT were strongly influenced by the research environment and their children's educational environment, while employment stability emerged as the principal factor for those in fields outside emerging industries.

⑦ Drawing on the analysis, this paper proposes three key policy directions: 1) reforming the financial compensation system to secure top STEM talent, 2) enhancing the effectiveness of R&D investment, and 3) expanding the innovation ecosystem by strengthening the foundation for technology startups and promoting openness in strategic technologies.

1) **In order for Korean businesses to attract top talent, 1-1) a transition to a more flexible wage and compensation system**—one that reflects performance and market value—**is essential.** This is not an issue confined to the science and engineering sector; rather, it is a strategic direction required to strengthen Korea's overall talent competitiveness and build a sustainable foundation for long-term growth. According to the survey, the current salary system for domestic STEM workers remains largely uniform and seniority-based, underscoring the need to shift toward a structure in which compensation is adjusted more flexibly according to career stage, performance, and market value. 1-2) **Such changes cannot be achieved through corporate efforts alone, making strong policy support from the government indispensable for the accumulation of human capital.** Experts suggest that bold policy measures—such as enhancing the effectiveness of tax credits for enterprise investment in human resources and expanding income-tax exemptions for core talent—would meaningfully improve the recruitment and development of highly skilled professionals.

2) **To improve the effectiveness of R&D investment, it is essential not only to expand its scale but also to transition to a "brain circulation" R&D structure.** In particular, young professionals with master's degrees—who serve as the backbone of the R&D workforce—exhibit a strong intention to move overseas due to limited career development opportunities in Korea. Supporting their stable career progression within the domestic system requires 2-1) **strengthening R&D capabilities through more predictable career-track reforms, promoting active exchanges with overseas research institutions and researchers, and improving access to cutting-edge research infrastructure.** Furthermore, to enable experienced professionals with accumulated expertise to return to and contribute to the domestic

research ecosystem, **institutional support is needed to ensure flexible organizational arrangements and incentive systems—such as dual appointments and the extension of retirement age—that can more effectively accommodate talent with overseas experience** (2-2).

3) Technology startups provide a key pathway for STEM talent to achieve economic returns and professional fulfillment comparable to those in high-income professions. To enable more STEM professionals to pursue such ventures, the government should strengthen its role as an early-stage, risk-absorbing investor and catalyst for innovation. 3-1**) This includes expanding second-chance opportunities for entrepreneurs who have experienced unavoidable failures and reinforcing exit mechanisms**—such as M&As and IPOs—to facilitate investment recovery. The government should also play a stronger role as an early adopter in advanced industries to support technological validation and early market formation. 3-2) **In strategic and dual-use technology domains long dominated by the government for national security reasons**—such as aerospace and defense—**establishing clearer commercialization pathways and allowing broader market participation**, while maintaining strict institutional safeguards and technology-protection systems, **can promote private-sector innovation and generate spillover effects** without compromising their value as core national security assets. Israel's experience illustrates how well-designed openness can advance both security and innovation.

■ Disclaimer: The views expressed herein are those of the authors, and do not necessarily reflect the official views of the Bank of Korea. When reporting or citing this paper, the authors' names should be always explicitly stated.

■ We gratefully acknowledge the valuable comments provided by Jaeho Lee (Senior Economist, Bank of Korea), Minsik Kim (General Manager), Jiho Lee (Director General), Professor Changhwan Shin (Korea University), and Professor Sangyun Song (Kyungpook National University).

Bank of Korea

I. Motivation

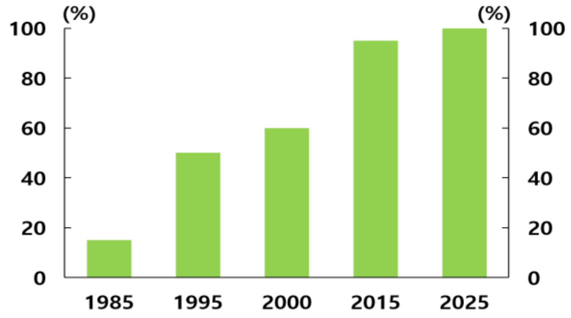
1. Science and engineering (STEM) talent constitutes a core driver of technological innovation and productivity growth, forming a fundamental pillar of long-term national competitiveness. Their expertise generates substantial spillover effects—particularly as advances in digital technologies such as AI increasingly diffuse across sectors—strengthening the strategic importance of securing and developing STEM human capital. Recognizing this, major economies such as the United States and China actively attract global STEM talent through large-scale initiatives such as the Thousand Talents Program and the Ten Thousand Talents Program in an effort to maintain technological leadership and secure future growth engines.

2. In Korea, however, a large share of top-performing high school students in the natural sciences are choosing medical studies (Figure 1), reflecting a strong shift toward the medical profession. Among those who do enter science and engineering fields, many seek better research environments and career opportunities abroad, contributing to a growing tendency for STEM talent to move overseas for work. This outflow of STEM professionals is not merely the outcome of individual career choices; it poses a structural risk that may weaken Korea's science and technology capabilities by draining human capital accumulated over many years. Notably, Korea's level of brain drain relative to its population is higher than that of other major countries (Figure 2), underscoring the need to evaluate whether the domestic environment sufficiently supports continuous capability development and career growth.

3. Against this backdrop, this study conducted a survey of STEM master's and doctoral graduates—both in Korea and abroad—to identify the key determinants of overseas outflows and to empirically assess their patterns and drivers. Drawing on these findings, the study proposes policy measures aimed at mitigating the outflow of STEM talent and strengthening their contribution to Korea's technological capabilities and productivity.

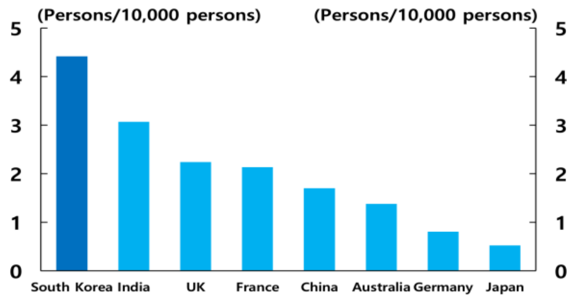
High-achieving Korean students are increasingly concentrated in the medical field.	Korea has the highest rate of talent outflow to the United States among major countries.

Figure 1. Medical college admission rates[1)] among top-performing students



Note: 1) Share of medicine-, dentistry-, Korean medicine-, and Pharmacy- related majors within the top 20 which is ranked by mock university enroll exam
Sources: Jongro Academy, Visang Education.

Figure 2. Number of U.S. EB-1 or EB-2 visa holders [1)] among total university graduates



Note: 1) Average from 2014 to 2023.
Sources: U.S. Department of State, OECD.

II. Importance of STEM Talent and Trends in Overseas Outflows

4. The critical role of the STEM workforce in driving economic growth has been well established in the literature. While early neoclassical growth models treated technological progress as an exogenous factor, Romer (1990) and Jones (1995) developed endogenous growth models that explicitly incorporate research manpower—such as scientists and engineers—as direct inputs in the production of new knowledge. Their work demonstrated that an increase in STEM professionals accelerates the creation of new ideas, thereby enhancing the growth of total factor productivity. Subsequent discussions went further to explore how the STEM workforce, particularly in emerging industries such as artificial intelligence, simultaneously strengthens the three fundamental pillars of economic growth: labor, capital, and technological innovation. Skilled professionals in science, technology, engineering, and related fields (STEM) directly enhance output through their specialized expertise (Goldin & Katz, 1998; Autor et al., 1998). They improve capital productivity by complementing physical capital, amplifying the effectiveness of capital goods (Krusell et al., 2000; Acemoglu & Autor, 2011; Ohanian et al., 2020). Furthermore, these professionals drive innovation and knowledge accumulation through research and development activities, fostering technological progress and economic growth (Corrado et al., 2005, 2009; Brynjolfsson & McAfee, 2014). These findings imply that the STEM workforce is a core factor of production that determines an economy's growth potential. Research shows that, in the United States, occupations related to science and technology exhibit productivity levels[1] that are more than twice those of other professions. Between 2012 and 2021, the growth of engineering majors and increase in investment in research and development accounted for approximately 25% of the

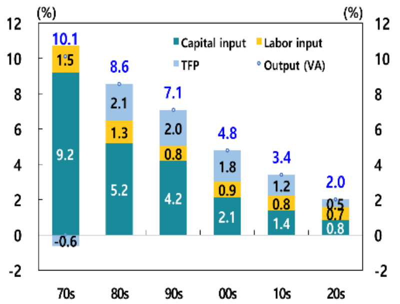
[1] Studies by the U.S. Department of Commerce (Langdon et al., 2011) and the Brookings Institution (Rothwell, 2013) found that STEM professionals—engaged in high-value-added activities such as technology, automation, and data analysis—achieve productivity 1.5 to 2 times greater than workers in other occupations, generating significant spillover effects across industries.

rise in per-capita GDP among U.S. workers.[2]

5. The STEM workforce has also played a crucial role in Korea's economic growth.[3] In the early stages of industrialization, Korea's growth relied heavily on simple material inputs. Over time, however, the economy evolved into a structure where technological innovation and productivity improvements became the key drivers of growth (Figure 3). Under the heavy industry promotion policy implemented in the 1970s, the Korean economy transitioned to a technology-intensive industrial structure accompanied by rapid productivity improvements. This productivity growth was largely driven by the accumulation of R&D capacity, supported by the cultivation of a skilled science and engineering workforce and R&D professionals. Over the longer term, the growth rate of R&D manpower slightly led the growth rate of total factor productivity (TFP), though both indicators moved closely in tandem (Figure 4). Using data between 1970 and 2024, a vector autoregression (VAR) model was estimated, and an impulse response analysis was conducted.[4] The analysis found that the expansion of R&D manpower had a positive and persistent effect on productivity over the long term (Figure 5).

Korea's growth structure has gradually shifted toward one led by TFP.

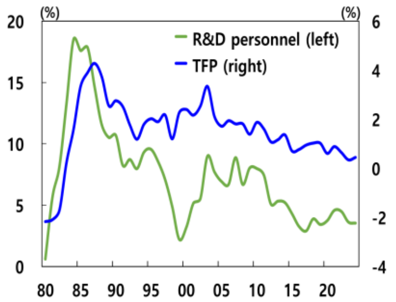
Figure 3. Growth rate decomposition[1)]



Note: 1) Period average.
Sources: estimated by Research Department using National Accounts and Economically Active Population Survey data.

Increasing R&D personnel is a key driver of productivity improvement.

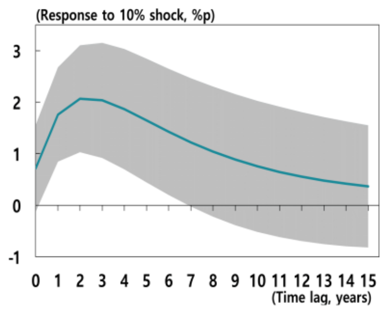
Figure 4. Trends of R&D personnel and TFP growth rate



Sources: National Accounts, Economically Active Population Survey, Korean Educational Statistics Service.

Increase in R&D professionals significantly boosts productivity.

Figure 5. Impact of R&D personnel increase on TFP[1)2)]



Notes: 1) VAR model estimation.
2) The shaded area indicates a 95% confidence interval.
Source: estimated by Research Department.

6. The number of science and engineering personnel in Korea has steadily increased over the past decades; however, structural constraints have emerged that limit the ability of outstanding STEM talent to fully develop and demonstrate their capabilities. Driven by the increase in science and engineering majors and implementation of policy measures[5] such as the

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[2] Trivitt et al. (2024) conducted a panel analysis of 50 U.S. states and Washington D.C. using American Community Survey data, revealing that per-capita worker productivity increased from USD 111,575 to USD 141,907 from 2012 to 2021, with roughly 25% of this growth attributed to improved outcomes in engineering education.

[3] For detailed information on the accumulation and evolving role of the science and engineering workforce across Korea's industrial development phases, please refer to Box 1.

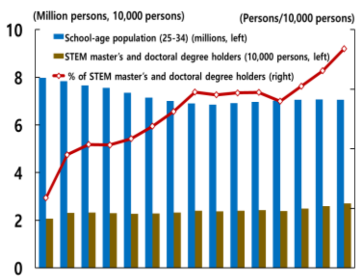
[4] In the VAR analysis, the Cholesky ordering was set according to the hypothesized causal sequence—STEM student cultivation leads to the expansion of research professionals, which in turn drives increased R&D investment, ultimately resulting in improved productivity. For details on VAR analysis, refer to Box 2.

[5] Such policy efforts include the second phase of the Brain Korea 21 (BK21) program (2006-2012) and the National Science and

expansion of graduate school enrollment, the number of professionals with master's and doctoral degrees has continued to grow, even as the population aged 25 to 34 has declined (Figure 6). As a result, by 2022, Korea's R&D workforce reached approximately 170 per 10,000 people—the highest level among major countries (Figure 7). However, despite this quantitative expansion, structural limitations remain that prevent outstanding STEM talent from fully realizing their potential. An increasing number of top natural science students are choosing to enter medical colleges—a trend likened to a "herd effect"—while the performance of technology startups in Korea continues to lag behind those in major countries such as the United States and China.[6] In addition, a mismatch between the supply of graduates by academic major and the demand for skilled workers from industry has hindered the efficient allocation of human resources (Figure 8).

Quantitative expansion of STEM personnel.	Number of R&D personnel as a share of total population exceeds that of major countries.	Significant mismatch between supply of STEM graduates and industrial demand.

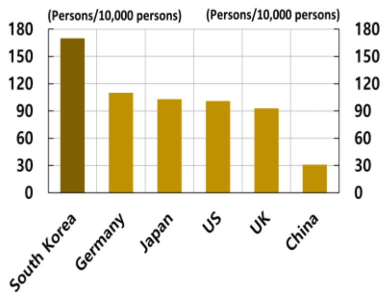
Figure 6. Number and proportion of STEM master's and doctoral degree holders[1)]



Note: 1) STEM master's and doctoral degree holders as a share of school-age population (25-34).

Sources: Statistics Korea, Korea Educational Development Institute.

Figure 7. Share[1)] of R&D personnel relative to population in major countries[2)]

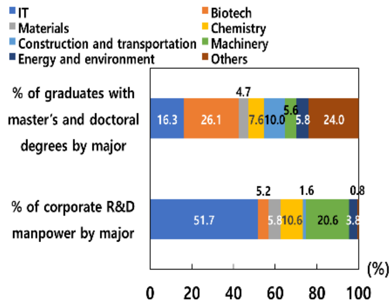


Notes: 1) As of 2022 for Korea, Germany, and Japan; 2021 for the United States; and 2020 for the UK.

2) Based on working age population (15-64).

Source: OECD.

Figure 8. Sectoral mismatch of STEM master's and doctoral degree holders[1)]



Note: 1) As of 2016

Source: Ministry of Science and ICT.

7. In particular, the overseas outflow of STEM professionals—primarily to the United States—continues to increase. According to the National Science Foundation, approximately 65 to 70% of Koreans who obtain doctoral degrees in the United States seek research or employment opportunities locally. As a result, the number of Korean STEM professionals working in the United States has been steadily rising (Figure 9). Analysis of LinkedIn member profile data indicates that, with the exception of the pandemic period, there has been a persistent net outflow of domestic STEM personnel, and the scale of this exodus has surged in recent years (Figure 10). Since 2015, the net overseas outflow of STEM professionals has been particularly pronounced in the biotechnology and ICT sectors.[7] Moreover, graduates from leading domestic science and

Technology Human Resources Development Basic Plan (2008-2012).

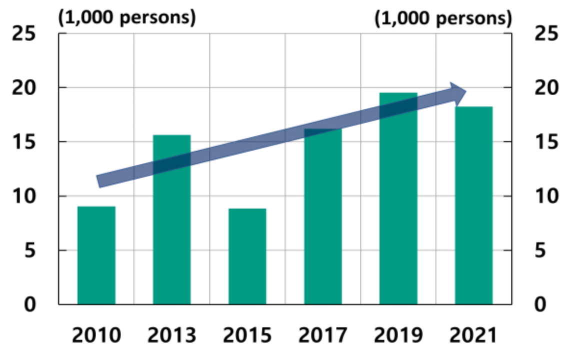
[6] Based on the Hurun Report's "Global Unicorn Index 2025," Korea accounts for only 1.2% of science and technology-based unicorn startups globally—a figure that falls far short of the United States (49.8%) and China (22.5%).

[7] The Stanford Institute for Human-Centered AI (HAI) reported that Korea's net outflow score for AI professionals in 2024 was -0.36 (net outflow), ranking 35th out of 38 OECD countries. In 2020, during the pandemic, Korea posted a score of 0.23 (net

engineering universities—Seoul National University, KAIST, POSTECH, Yonsei University, and Korea University—accounted for 47.5% of the total net overseas outflow between 2004 and 2024, on average. This trend indicates that the overseas outflow of top-tier talent may erode the foundation of the nation's science and technology capacity.

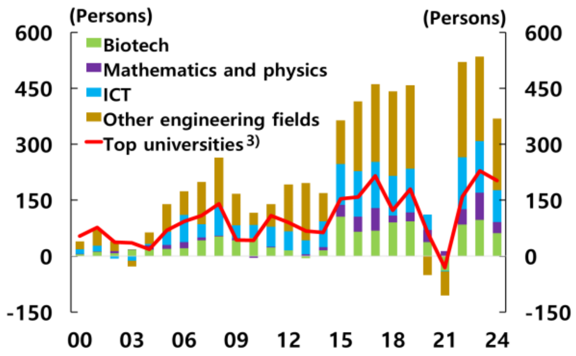
The number of Korean STEM doctorate holders active in the United States is rising.	**Nearly half of Korea's net STEM outflow are graduates of five major STEM universities.**

Figure 9. Korean STEM doctorate holders active in the United States



Sources: NSCG, BLS, authors' calculations.

Figure 10. Net outflow[1)] of Korean STEM workforce[2)]



Notes: 1) Annual net outflow (workplace change): outflows (from Korea to overseas) minus inflows (from overseas to Korea)

2) Based on individuals whose surname is korean and career history indicate at least one work experience in Korea.

3) Among individuals who obtained any degree from SNU, KAIST, POSTECH, Yonsei university, or Korea university, those holding a master's or doctoral degree

Sources: LinkedIn, Research Department.

8. Given these circumstances, this paper analyzes the factors influencing professionals' decision to move overseas, drawing on survey results from science and engineering master's and doctoral degree holders residing in Korea and abroad. Using a micro-level analysis that accounts for individual respondent characteristics, we examine the determinants of the intention to move overseas and derive relevant policy implications.

inflow). However, since 2023, the net outflow of AI talent has intensified.

III. Determinants of Overseas Outflows of STEM Talent[8]

9. The overseas outflow of STEM professionals is shaped by multiple factors—including compensation levels, the research environment, and career pathways—rather than any single cause. However, there is insufficient research that systematically analyzes these causes using robust data. Existing international comparison indices, such as the OECD Talent Attractiveness Index and IMD World Talent Ranking, provide useful data but remain index-based assessments. As a result, they are limited in their ability to yield concrete policy implications for Korea.

10. To address this issue, in collaboration with the Korea Institute of Science and Technology Information (KISTI), this study surveyed the perceptions of income level, research environment, residential conditions, career pathways, and policy systems among 2,700 STEM master's and doctoral degree holders residing in Korea and abroad (1,916 in Korea and 778 overseas).[9] Through this approach, this paper seeks to identify factors influencing the intention of STEM professionals to move overseas and empirically derive necessary institutional improvements. The survey employed identical questionnaire frameworks for both domestic and overseas residents, enabling direct comparison of STEM professionals using the same criteria. Moreover, in addition to financial factors, this study assessed a set of non-financial dimensions—such as employment stability, the research environment, residential conditions, and global networks—as multidimensional indicators of satisfaction to examine the micro-level factors shaping decisions to move overseas for work. Notably, this paper provides foundational data that is highly applicable for policy-making purposes.

① Survey responses of STEM professionals in Korea and abroad

11. About 42.9% of STEM professionals residing in Korea indicated that they are considering moving overseas for work within the next three years, while 5.9% reported that they already have concrete plans or are currently participating in interviews (Figure 11). Notably, among the younger workforce in their 20s and 30s, a substantial 70% expressed a desire to move overseas. By field of work, more than 40% of professionals in biotechnology, pharmaceuticals, medical devices, IT, software, communications, and shipbuilding, plant, and energy sectors—areas regarded as technological strengths for Korea—reported that they are considering moving overseas for work within the next three years, with 7.1% already having established concrete plans (Figure 11). **Those most actively considering moving overseas for work are primarily in their 30s and 40s, and are typically R&D professionals or university faculty members, as well as employees of small and medium-sized enterprises, including startups.**

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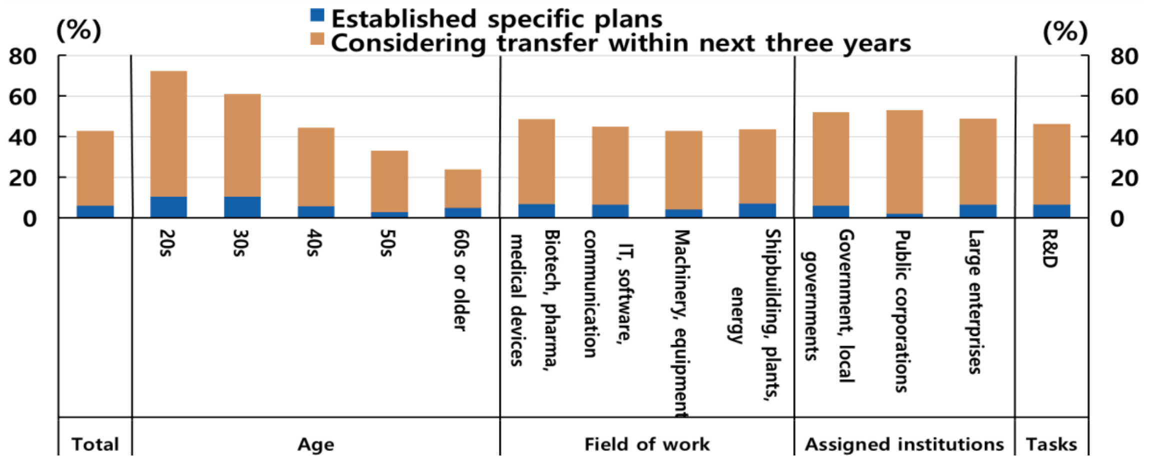
[8] This chapter's analysis is based on the results of a survey of STEM master's and doctoral degree holders, both within Korea and abroad. While there are certain limitations regarding respondent characteristics and sample composition, this study nonetheless provides empirical insights into the perceptions and behaviors of the STEM workforce and is expected to offer useful evidence for shaping policy directions.

[9] For details on investigations, refer to Box 3.

Younger personnel exhibit a stronger intention to move overseas for work, with R&D professionals in IT, software, communications, biotechnology, pharmaceuticals, and medical devices showing particularly high propensities to pursue employment abroad.

Figure 11. Share of STEM professionals considering an overseas move



12. Financial considerations emerged as the most frequently cited reason for considering an overseas move, with 66.7% of STEM professionals identifying it as their primary motivation (see Figure 12). Over half of domestic STEM professionals reported feeling "dissatisfied" or "very dissatisfied" with their annual salary levels, whereas fewer than 20% of overseas STEM professionals expressed similar dissatisfaction. By sector, dissatisfaction was highest among professionals in biotechnology, pharmaceuticals, and medical devices, followed by those in electric and electronic devices and semiconductors, IT, software and communications, and then automobiles and mobility (Figure 13). In particular, although the electric and electronic device, semiconductor, and automobile and mobility sectors offer relatively high average annual salaries, master's and doctoral degree holders in these fields are likely to feel that their compensation does not adequately reflect corporate performance. Examining average annual salary by years of experience, domestic STEM professionals in Korea see a gradual increase in pay as their years of service grow. In contrast, overseas STEM personnel experience a sharp rise in salary during the early stages of their careers, after which salary growth becomes largely unrelated to tenure. (Figure 14). This disparity in compensation structures, particularly the sharp salary increase in the early stages of overseas careers, is a key factor driving young professionals to favor employment abroad.

Financial factors are the most important reasons for considering working overseas.	There is a big gap in satisfaction with annual pay between domestic and overseas STEM personnel.	Annual pay of overseas STEM personnel is not related to number of years worked after a certain period.

Figure 12. Reasons for considering an overseas move

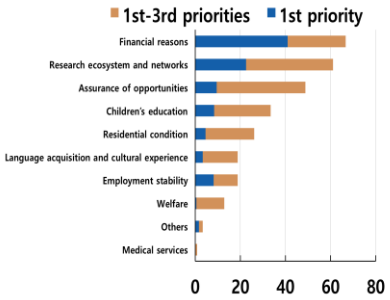
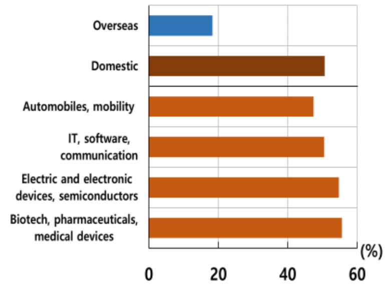
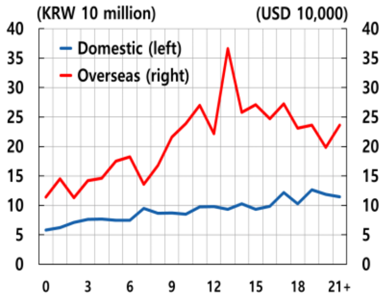


Figure 13. Percentage of STEM professionals dissatisfied[1] with current annual pay



Note: 1) Shares of responses of "very dissatisfied" or "dissatisfied."

Figure 14. Average annual pay for domestic and overseas workforce by number of years worked[1]

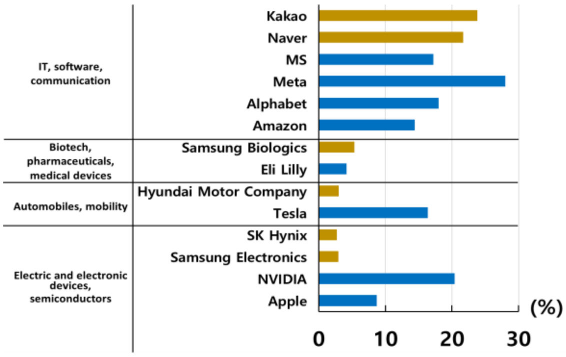


Note: 1) Number of years worked is calculated as 2025 minus the year the final degree was earned.

13. The financial factors underlying compensation differences can be traced to variations in industrial structure and overall corporate profitability. As shown in Figure 15, the ratio of personnel expenses to sales among leading domestic firms in the IT, software, communications, and biotechnology sectors is comparable to that of their U.S. counterparts. Accordingly, the gap in pay levels between domestic and overseas firms largely reflects differences in their respective levels of corporate earnings, rather than disparities in personnel cost structure. In contrast, within Korea's core manufacturing sectors—including the electrical and electronic device, semiconductor, automobile, and mobility industries—the ratio of personnel expenses to sales is relatively low. This reflects the structural characteristics of these industries, where a significant portion of total costs is allocated to intermediate inputs such as equipment, components, and depreciation, rather than to labor costs. In comparison, leading U.S. technology firms—such as Apple and Tesla—outsource much of their manufacturing operations or concentrate on high value-added activities, including design, software development, and platform services. This focus enables these companies to reinvest their substantial profits into research and development (R&D) and provide competitive compensation packages for top talent, as illustrated in Figure 16. As a result of these structural differences and the superior financial performance of major global corporations, it is, to a certain extent, inevitable that some portion of the domestic workforce will seek higher compensation opportunities abroad.

The wage gap between domestic and global firms is largely attributable to differences in corporate performance and industrial structure.

Figure 15. Share of personnel expenses in sales for Korean and U.S. companies[1)2)]

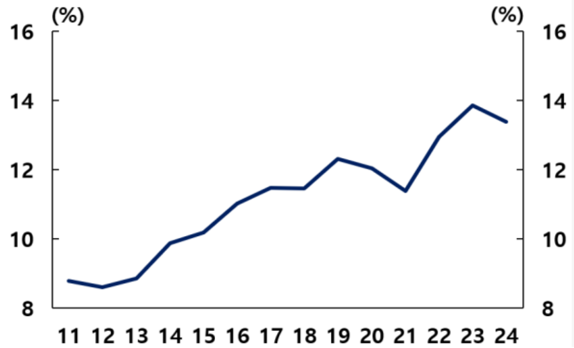


Notes: 1) Average values are calculated for the period from 2020 to 2024.
2) Personnel expenses for U.S. firms are estimated using publicly disclosed data.

Sources: company disclosures, Research Department.

U.S. firms are increasing the proportion of R&D in their operations.

Figure 16. Share of R&D expenses[1)] in sales for U.S. companies



Note: 1) R&D expenses include personnel costs for R&D employees, materials and equipment-related costs (including depreciation), and external contract costs. Of these, personnel expenses typically account for approximately 50 to 70% of total R&D expenditure.

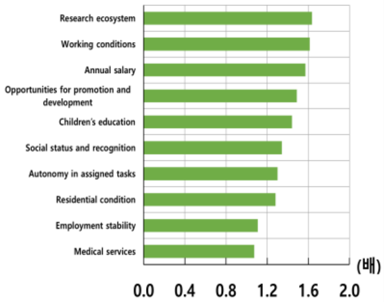
Source: company disclosures.

14. Rather than viewing the overseas movement of STEM talent as driven solely by financial factors, it is important to adopt a broader perspective. Indeed, the survey results show that the primary reasons for seeking employment overseas extend well beyond monetary considerations. Significant proportions of respondents cited the "research ecosystem and networks" (61.1%) as well as "assurance of opportunities" (48.8%) as major factors, as shown in Figure 12. Additionally, there are significant disparities between domestic and overseas STEM professionals in their satisfaction with their current workplace,[10] particularly regarding "research ecosystem and networks" and "working conditions," as illustrated in Figure 17. Furthermore, 81% of respondents indicated that the overseas outflow of STEM personnel is a "serious" issue, and they prioritized "improving the research environment" (39.4%) as the most urgent task for advancing science and technology, ahead of "bold financial compensation" (28.8%), as shown in Figures 18 and 19. These findings suggest that the issue extends beyond salary alone, with the quality of the research environment and limitations on career development opportunities serving as critical factors driving personnel mobility.

[10] To compare satisfaction levels, a five-point scale was used, assigning scores from "very dissatisfied (0)" to "very satisfied (100)." The satisfaction index for each item was calculated by applying item-specific response counts as weights.

There is a notable gap in satisfaction levels between domestic and overseas firms with respect to the research ecosystem and workplace conditions.

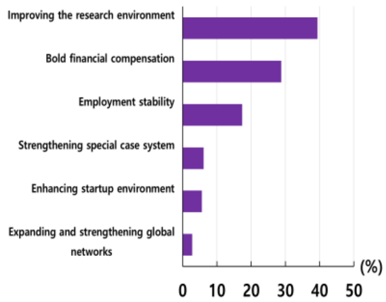
Figure 17. Comparison of domestic and overseas satisfaction levels by item[1)]



Note: 1) Satisfaction levels are presented as ratios of the overseas satisfaction index to the domestic satisfaction index for each item.

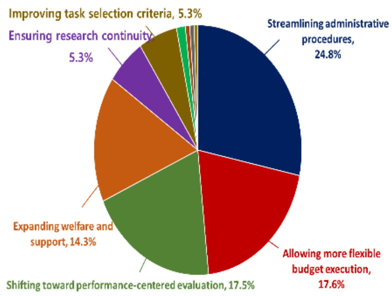
Enhancing the research environment is the most urgent priority for advancing Korea's science and technology sector.

Figure 18. Most urgent policy direction for Korea's science and technology development



There is strong demand for streamlining administrative procedures and ensuring greater flexibility in budget execution.

Figure 19. Areas of current support policies most in need of improvement[1)]



Note: 1) Percentages indicate the top 10 items categorized from responses to VOC survey questions.

15. As discussed, the decision to relocate overseas is influenced by a combination of financial and non-financial factors, and therefore cannot be adequately explained by either group of factors alone. In particular, given the domestic institutional framework and labor market environment, non-financial factors—such as research networks and opportunities for career advancement—are likely to play a role just as important as financial considerations.[11] **Accordingly, in the following chapter, we employ survey response data to estimate a logit model that controls for individual characteristics—including academic degree, age, gender, and family composition—in order to quantitatively assess the respective impacts of financial and non-financial factors on the decision to move overseas.**

② Analysis of determinants of overseas exodus of STEM workforce

16. In this chapter, we examine the determinants of STEM professionals' intention to move overseas by estimating a logistic regression model using cross-sectional survey data.[12] The logit model specified for this study is as follows.

[11] According to the survey results, 70% of respondents in their 20s and 30s expressed a desire to work overseas. However, these age groups receive lower wages both abroad and in Korea compared to older age groups, and the difference between domestic and overseas wages for them is minimal. Notably, overall workplace satisfaction among individuals in their 20s and 30s was the lowest in Korea but the highest for the same-age cohorts overseas. This suggests that higher overseas wages are not the primary motivation for migration among younger professionals.

[12] Logistic regression analysis is a statistical method used when the dependent variable is binary. It estimates the probability of a particular event occurring as a function of multiple explanatory variables. Unlike standard linear regression, logistic regression employs a logit transformation to ensure that predicted probabilities fall between 0 and 1, thus allowing for the measurement of the effect of each explanatory variable on the likelihood of the event occurring. For further details on the model specifications and analytical methods used in this chapter, refer to Box 4.

$$logit\,(Pr(Y_i = 1 \mid X_i)) = ln(\frac{Pr(Y_i = 1 \mid X_i)}{1 - Pr(Y_i = 1 \mid X_i)})$$
$$= \beta_0 + \beta_1 \times income + \sum_{j=2}^{n}(\beta_j \times X_{ji}) + \sum_{k=n+1}^{m}(\beta_k \times X_{ki})$$

In this equation, "income" represents income satisfaction at the current workplace; X_j indicates satisfaction with non-financial factors at the current workplace—including research environment, opportunities for promotion, conditions for children's education, and employment stability; and X_k denotes the individual characteristics of respondents, such as income level, age, overseas academic experience, type of degree (master's/doctorate), gender, marital status, number of children, career stage, and academic major (classified as new-growth[13] or non-new-growth sectors).

17. **Results from the model estimation—with various control variables included—show that satisfaction with earnings, which would be expected to reduce the intention to move overseas for work, is indeed negatively associated with such intentions.** The analysis also revealed that, although there are some differences in statistical significance, **higher satisfaction with non-financial conditions at current workplaces**—such as career path opportunities (promotion), employment stability, research environment, and children's education—**is generally associated with a lower intention to move overseas** (Table 1). This suggests that financial compensation alone may not be sufficient to discourage STEM professionals from moving overseas—improvements in non-financial factors, such as the working environment, should be pursued concurrently. Furthermore, the analysis shows that older individuals display a substantially lower intention to move overseas, underscoring young STEM professionals as a key target group for policies aimed at mitigating brain drain.

Table 1. Model estimation results

Variable	Estimated coefficient	Standard error	z-statistic	P-value
Satisfaction with current workplace				
- Income	-0.192***	0.056	-3.440	0.001
- Research environment	-0.053	0.054	-0.980	0.325
- Promotion opportunities	-0.170***	0.059	-2.910	0.004
- Conditions for children's education	-0.049	0.060	-0.810	0.416
- Employment stability	-0.258***	0.049	-5.300	0.000
Individual characteristics				
- Income level	-0.001	0.001	-0.830	0.406
- Overseas degree	0.295*	0.155	1.910	0.056
- Gender (Woman=1)	-0.265*	0.144	-2.000	0.045
- Marriage (Married=1)	-0.066	0.176	-0.230	0.817

[13] Of the 21 major categories, those accounting for at least 5% of the total sample are classified as new growth majors. These include biology/chemistry/environment, mathematics/physics/astronomy/geography, mechanical/metal engineering, electrical/electronic engineering, materials science and engineering, and computer/communications.

- Number of children	-0.012	0.070	-0.440	0.662
- Type of degree (Doctor=1)	0.067	0.128	1.100	0.272
- Career after degree (year)	-0.010	0.007	-2.280	0.023
- Major (Growth sector=1)	-0.077	0.102	-0.850	0.397
Dummy variable of age groups (Reference: 20s)				
- 30s	-0.545	0.466	-1.170	0.242
- 40s	-1.123**	0.477	-2.350	0.019
- 50s	-1.482***	0.494	-3.000	0.003
- 60s or older	-1.949***	0.517	-3.770	0.000
Constant	3.241***	0.502	6.460	0.000

Note: 1) *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

18. While the estimated coefficients (β_i) from the logit model indicate the direction and relative magnitude of the effect of each explanatory variable on the probability of intending to move overseas, they do not directly provide the magnitude of the actual change in probability.[14] Therefore, to quantify how the likelihood of moving overseas changes, on average, in response to a one-unit change in each explanatory variable X_i, we compute the average marginal effects (AMEs) for the full sample.[15] **The results show that a one-point increase in income satisfaction (on a five-point scale) is associated with a 4.0-percentage-point reduction in the intention to move overseas.** Moreover**, a one-unit improvement in satisfaction with promotion opportunities or employment stability resulted in a reduction of 4 to 5 percentage points in the intention to migrate overseas** (Figure 20).[16] Overseas degree holders demonstrated an intention to migrate abroad 6 percentage points higher than that of domestic degree holders. In terms of gender and age, women and older individuals exhibited a lower tendency to seek employment overseas. In particular, individuals in their 40s or older exhibited at least a 24-percentage-point lower intention to migrate overseas compared to those in their 20s (Figure 21).

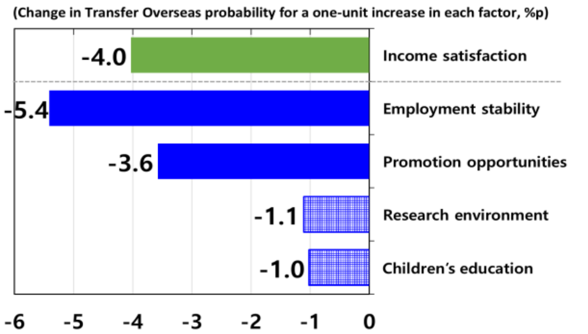
[14] A coefficient represents the change in the log-odds ($\ln\left(\frac{p}{1-p}\right)$) of the intention to move overseas associated with a one-unit increase in a specific explanatory variable. A positive coefficient indicates an increased intention to move overseas, while a negative coefficient reflects a decreased intention. A larger absolute value signifies a greater impact of the explanatory variable on the outcome. However, coefficients do not directly reveal the magnitude of change in probability. For policy implications, it is necessary to interpret the results using the average marginal effect (AME).

[15] When calculating the average marginal effect, statistical significance was not heavily emphasized. Rather than conducting significance testing for individual variables, we prioritized intuitive comparisons of relative importance by factor and overall trends to better inform policy making, consistent with the purpose of this report.

[16] The significance of employment stability became more pronounced following the structural changes brought about by the 1997 foreign currency crisis. Lee Eungyeong (2006) noted that, during the crisis, many corporate-affiliated research institutes implemented layoffs to comply with the IMF-led restructuring requirements, which undermined the sense of job security among science and engineering majors. Science and engineering professionals, including researchers, experienced restructuring in both public research institutions and industrial research centers. As a result, the perception of job stability within science and engineering fields was greatly undermined, leading many to avoid pursuing careers in these areas.

Improving promotion path and employment stability is important.

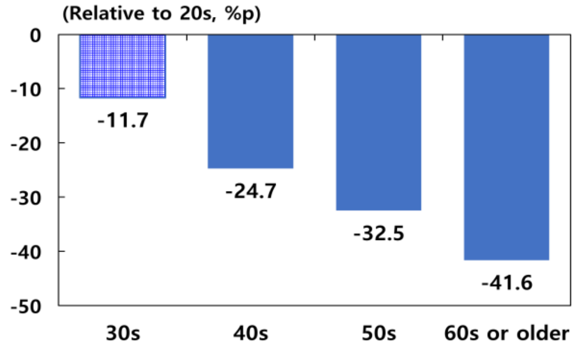
Figure 20. Average marginal effect of workplace satisfaction factors on the intention to move overseas



Note: 1) Striped bars indicate estimates that are not statistically significant at the 10% level.

The age of STEM personnel is negatively related to their intention to work overseas.

Figure 21. Average marginal effect of age group on the intention to move overseas (relative to those in their 20s)

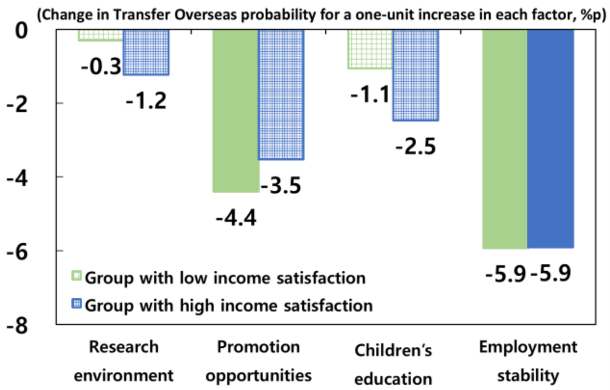


Note: 1) Striped bars indicate estimates that are not statistically significant at the 10% level.

19. Meanwhile, differences in the impact of non-financial factors were observed according to the level of income satisfaction (Figure 22). Among groups with low income satisfaction,[17] promotion opportunities and employment stability were clearly factors that reduced the intention to work abroad. This suggests that for individuals with lower economic satisfaction, factors closely tied to future income can have a relatively significant impact. Meanwhile, among groups with high income satisfaction, factors closely related to overall quality of life and working conditions—such as children's education, the research environment, and employment stability—emerged as important considerations shaping their decision to move overseas.[18]

For the group with low income satisfaction, employment stability and promotion opportunities related to future income are key factors.

Figure 22. Average marginal effect on the intention to move overseas, by income-satisfaction group



Note: 1) Striped bars indicate estimates that are not statistically significant at the 10% level.

[17] Regarding income satisfaction, individuals who selected "very dissatisfied" or "dissatisfied" were classified as the group with low income satisfaction.

[18] Average marginal effects by age group were compared according to income satisfaction level. Among individuals with low income satisfaction, older people exhibited a significantly lower intention to migrate overseas. On the other hand, the group with high income satisfaction also exhibited differences by age; however, due to larger standard errors, statistically significant differences between age groups were not observed.

20. Comparing the factors that influence intentions to move overseas for work across different groups of STEM professionals reveals notable differences (Figure 23). By academic degree, promotion opportunities (-4.3%) and the research environment (-3.0%) are particularly strong factors reducing overseas employment intentions among those with a master's degree. For doctoral degree holders, employment stability (-6.0%) is the factors that most effectively lower the likelihood of an overseas move, followed by children's education (-2.5%). This indicates that, **for master's degree holders, opportunities for advancement and research infrastructure within an organization are key factors in retaining talent, while for doctoral degree holders, a stable career base and conditions related to family and education are considered more important.**

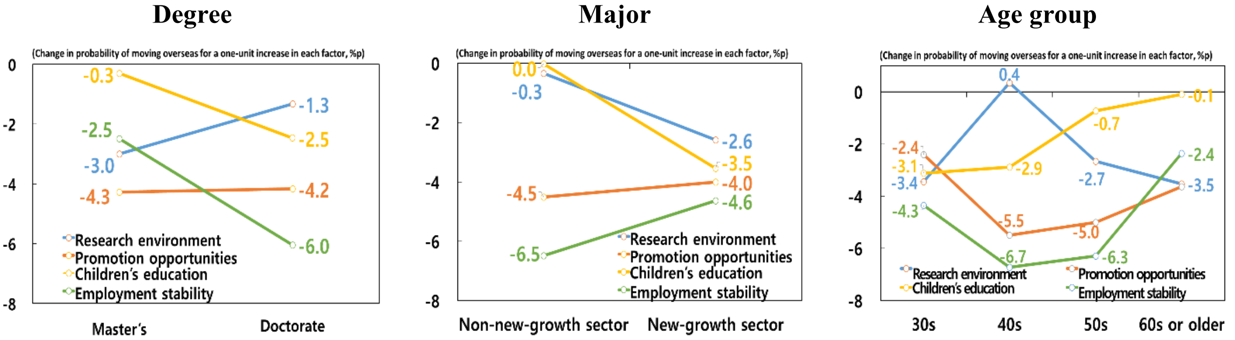
21. Differences also appear across academic majors. Individuals in emerging fields tend to place greater weight on the research environment (-2.6%) and their children's educational environment (-3.5%), while those in non-emerging fields regard employment stability (-6.5%) as the most important factor reducing their likelihood of moving overseas. This is evident because those in new-growth majors are mostly in their 30s and 40s, typically have school-age children, and experience a significant gap compared to overseas research ecosystems. That is, **for new-growth majors, research environment and family and education factors are more important, while for non-new-growth majors, employment stability is a more critical factor.**

22. Analysis by age group shows that the key factors influencing the decision to move overseas differ across generations.[19] For those in their 30s, employment stability (-4.3%) was identified as the factors that most effectively lower the likelihood of an overseas move. Individuals in their 40s and 50s prioritized both promotion opportunities (-5.5% to -5.0%) and employment stability (-6.7% to -6.3%) as key factors, while the influence of children's education (-2.9% to -0.7%) was weaker compared to those in their 30s. For those in their 60s or older, the inhibitory effect of most non-financial factors—such as employment stability, promotion opportunities, and children's education—was weaker compared to other age groups, while research environment (-3.5%) remained important. This indicates that, as individuals approach retirement and contemplate career transitions, they consider institutional flexibility that ensures research sustainability to be critical.

[19] This analysis cannot distinguish between age effects and generation effects due to limitations in the cross-sectional study design. However, the findings provide empirical evidence regarding which factors each age group is currently sensitive to. Further research using panel data to separate cohort effects is recommended.

The marginal effects of non-financial factors on the intention to move overseas differ substantially by degree, major, and age group.

Figure 23. Differences in how non-financial factor improvements influence the intention to move overseas (by individual characteristics[1])



Note: 1) Negative values indicate a reduction in the probability of intending to move overseas when the corresponding non-financial factor improves by one level. Larger absolute values reflect greater effectiveness in lowering this probability.

IV. Policy Implications

23. Science and engineering professionals are the key drivers of future growth industries—such as digital transformation, artificial intelligence (AI), and advanced manufacturing—and form a crucial foundation for national competitiveness. Their technological capabilities are vital assets that underpin the nation's economy and security and cannot be readily replaced by foreign talent or capital alone. Although the use of foreign manpower to address demographic changes and labor shortages has steadily increased, which may help alleviate overall labor shortages to some extent, it cannot substitute for core technological competencies. Therefore, maintaining and strengthening a stable technological base should be achieved through the strategic cultivation and effective utilization of the domestic STEM workforce.

24. However, domestic satisfaction with the work environment and treatment of STEM personnel remains relatively low, and the ecosystem and investment base for technology startups—where STEM professionals are expected to receive high economic compensation—remain underdeveloped.[20] Consequently, many high-achieving students with strong scientific aptitude tend to avoid science and engineering majors—often concentrating instead on medical schools—or, even after majoring in STEM fields, are more likely to move overseas due to the limitations of the domestic research and employment environment. In particular, since the foreign currency crisis, the preference for medical colleges has intensified—not due to an increase in the absolute attractiveness of the medical field, but because of accumulating limitations in STEM, including career path uncertainty, inadequate compensation structures, and diminishing social status.[21]

[20] According to a 2021 report by the Korea Institute of Human Resources Development in Science and Technology (KIRD), the most favored career paths among STEM graduate school graduates were large Korean enterprises (30.8%), public research institutes, and university faculty positions, while only 14% chose startups.

[21] While STEM professionals must undergo extended education and conduct rigorous research to earn a doctoral degree, their career

25. Due to the high global demand for STEM professionals, a wide range of job opportunities abroad offer superior compensation, research environments, and career prospects compared to Korea, thereby increasing the likelihood of Korean STEM professionals moving overseas. While this is a rational choice for individuals, it represents a loss of advanced human resources for the nation and may undermine the country's science and technology competitiveness and growth potential. In Korea, non-financial factors—such as the quality of the research environment and uncertainty surrounding career paths—along with financial compensation, play an important role in shaping STEM professionals' decisions to move overseas for work.

26. Given this reality, policy should focus on cultivating an environment in Korea where outstanding talent can achieve growth and success as well as developing pathways for the return of overseas expertise. This would ensure that talent movement is not simply a "brain drain," but rather "brain circulation." In particular, going beyond simply securing manpower, the institutional foundation should be strengthened to enable the knowledge and experience accumulated by talent to be converted and disseminated as national innovative capability. To support this direction institutionally, key tasks include:
❶ Innovating the financial compensation system to attract outstanding talent,
❷ Expanding and enhancing the effectiveness of R&D investment, and
❸ Strengthening the foundation for technology startups and fostering an innovation ecosystem through the use of strategic technologies.

① Innovating the financial compensation system (incentive structure) to attract outstanding talent

①-1. Establishing flexible wage and compensation systems based on performance and market value

In order for Korean companies to attract and retain top talent, it is essential to provide competitive financial compensation and make strategic investments in human capital. To achieve this, performance-based, flexible salary and compensation systems need to be established gradually. This issue is not limited to specific sectors such as science and engineering or particular industries; it is also important for the efficient allocation of human resources across the economy and enhancement of overall productivity. As revealed by the survey results (Figure 14), the domestic salary system for the science and engineering workforce remains largely dominated by a seniority-based structure focused on years of service. In contrast, for those working overseas, a salary system based on market value and performance is in place. As a result, salaries increase rapidly during the early and middle phases of a career and then stabilize, forming a reverse U-shaped salary curve.[22] This suggests that a compensation structure that is flexibly adjusted based on performance and

paths are largely limited to sectors such as research institutes, industry, and academia, with their compensation levels and social recognition being lower than those of professions such as medicine. Yu Jaejun, dean of the College of Natural Sciences at Seoul National University, stated, "It is regrettable that, in Korean society, the process of investing many years to become a specialist is perceived as an 'uncertain career path.'"

[22] The reverse U-shaped salary structure observed among overseas STEM professionals appears to result from a compensation system based on performance, productivity, and individual contribution. In such systems, high compensation is offered in the early career stage to attract outstanding talent, with the salary peaking during the mid-career phase based on performance and then stabilizing or declining as productivity and contribution diminish in the later stages.

market value is more effective for attracting talent.

Hence, Korean companies should transition from a uniform salary structure to a flexible compensation system, where talents who demonstrate outstanding performance receive appropriate promotions and financial rewards. This requires more than simply increasing compensation; it calls for a structural transition in the design of compensation systems to ensure that talent receive sufficient rewards and growth opportunities at critical stages of their careers. This transformation can help reduce the outflow of top talent and strengthen incentives for core professionals to remain in the domestic workforce.

❶-2. Strengthening tax incentives and institutional support systems for investment in human capital

In ensuring that performance-based salary and compensation systems are widely adopted and operate effectively, relying solely on the voluntary efforts of enterprises is insufficient. Government institutional support, such as that provided through the tax system, should be implemented concurrently. Currently, the government actively supports tangible capital investment, primarily through integrated investment tax deductions, but the range and size of tax incentives for human capital remain limited.[23]

Hence, for enterprises to actively recruit and systematically cultivate outstanding personnel, the government needs to develop a comprehensive and effective incentive system. For example, experts[24] suggest that bold policy measures—such as more effective tax deductions for enterprises investing in human resources and broader income tax exemptions for core talent—would effectively drive the recruitment and development of professionals.

❷ Expanding and enhancing the effectiveness of R&D investment

To improve R&D investment performance, it is crucial to not only select areas with high expected impact but also focus on appropriate investment size, allowing for the design of detailed policy structures that efficiently allocate limited resources. This study establishes and prioritizes two policy directions based on findings from surveys, empirical analyses, and expert interviews.

❷-1. Expanding qualitative R&D investment in core and working-level research personnel

Although Korea's R&D investment ranks among the world's highest in quantitative terms, it remains vulnerable in areas such as research environment, talent development, and

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[23] The primary tax incentive for investment in human capital in Korea is the tax deduction for research and human capital under Article 10 of the Act on Restriction on Special Cases Concerning Taxation. However, the current system is not considered a sufficient incentive to promote long-term manpower cultivation strategies. While high deductions are provided for facility investment (tangible capital) across a wide range of business types and assets, support for human capital is relatively limited, as it tends to be perceived not as "investment" but as "personnel expenses." In addition, the system is primarily geared toward the manufacturing industry and large enterprises, while support for the service industry and small and medium-sized enterprises is limited. Since deduction criteria are focused on expenditures rather than outcomes, the system is considered inadequate for generating substantial improvements in human resource development, such as enhanced productivity or increased skills.

[24] For expert opinions regarding ways to support the STEM workforce, refer to Box 5.

cultivation. The survey found that core research professionals in their 30s and 40s, as well as working-level researchers with master's degrees, showed the strongest intention to move overseas. These groups prioritized an excellent research environment and stable career development opportunities over a high annual salary. Therefore, it is important to foster career pathways and research conditions that support the long-term growth of young researchers. In particular, to prevent researchers without doctoral degrees from being subject to unstable, short-term employment structures, it is essential to establish predictable career tracks and foster a research ecosystem that enables comfortable professional growth in Korea. To achieve this, R&D programs should be expanded and strengthened through collaboration among public research institutions, universities, and private research organizations, as well as through greater exchanges[25] with overseas research institutes and scholars, thereby broadening career development opportunities. Moreover, key research infrastructure—including equipment, data, and research space—should be upgraded, and access to these resources should be expanded to improve the continuity and quality of research activities in cutting-edge fields.

②-2. Transition to a talent-circulation R&D ecosystem that accumulates and reinvests experience as an asset

For Korea's R&D ecosystem to grow, it is important to not only mitigate brain drain, but also facilitate the return of overseas experience and research capabilities so they can be accumulated as domestic assets. In particular, despite overseas mid-career professionals[26] being valuable assets with extensive research experience and global networks, they often face challenges when attempting to return to domestic research institutions and companies due to organizations' rigid personnel management practices and internal restrictions, such as the difficulty of integrating their roles with existing personnel. Furthermore, many highly skilled domestic researchers choose to move overseas as they approach retirement, as their ability to secure research funding and support personnel gradually diminishes.[27] Given these points, organizational structures and incentive systems[28] should be designed to flexibly accommodate personnel returning from abroad. By selectively extending the retirement age[29] for researchers with performance above a certain threshold, the R&D ecosystem can be

[25] Korea is implementing various international research cooperation programs, including efforts to attract outstanding overseas researchers (Brain Pool/Brain Pool+), personnel exchanges with overseas research institutions (Brain Link), participation in the European joint research framework (Horizon Europe), and establishment of permanent research hubs with overseas institutions (Global R&D Center). However, to ensure that these systems lead to qualitative improvement of the research ecosystem and sustainable career development for researchers, it is necessary to strengthen their operational efficiency and connections to career development programs, expand projects with proven performance, and continuously explore new models of cooperation.

[26] The survey found that the intention to return home among overseas personnel remains between 45% and 50% for those in their 30s to 50s, while it rises again to around 65% for those in their 60s, showing a U-shaped distribution.

[27] According to interviews with specialists, STEM faculty members and researchers often face restrictions in securing essential research personnel and operating budgets as they approach retirement age.

[28] For example, the government could provide research funding and space to institutions that accept returning personnel and award additional scores and incentives in institutional evaluations. Compensation systems that recognize overseas experience may also be considered.

[29] Discussions on extending the retirement age should go beyond simply lengthening the employment period, aiming to structurally alleviate disruptions within the research ecosystem and help prevent brain drain. In fact, POSTECH was the first institution in Korea to introduce an "early retirement age extension determination system," allowing researchers to know by age 50 whether their retirement age will be extended. This reduces uncertainty in research funding and personnel management, enabling them to pursue long-term research plans. Meanwhile, Bae Kyunghoon, Deputy Prime Minister and Minister of Science and ICT, stated in a media interview that the ministry will introduce a "Great Scholar Support System" to enable senior STEM professionals with outstanding achievements to continue their research (Chosun Ilbo, October 22, 2025).

strengthened to encourage the return and accumulation of outstanding talent.

❸ Strengthening the foundation for technology startups and fostering an innovation ecosystem through the use of strategic technologies in industries such as aerospace and defense[30]

❸-1. Establishing a virtuous cycle to mitigate risks faced by technology startups

Technology startups provide a critical pathway for STEM talent to achieve economic rewards and social recognition comparable to high-income professions such as medicine by leveraging their professionalism and research achievements. However, in Korea, high initial investment costs and uncertainty are structural factors that restrict the success of startups. To address these limitations, the government should help establish a system that enables risk-sharing for technology startups between the public and private sectors. That is, the government should act as a proactive investor and catalyst, absorbing early-stage risks and supporting a virtuous-cycle ecosystem in which private sector innovation capacity is transformed into diverse types of startups.

To achieve this, the government should strengthen re-entrepreneurship support systems that assist entrepreneurs who failed despite their sincere efforts,[31] ensuring that such experiences can be accumulated as valuable assets.[32] Additionally, by enhancing exit mechanisms such as M&As and IPOs, pathways for realizing investment returns should be promoted.[33] The government should also consider using policy funds to enhance the leverage effect that drives private investment and strengthen its role as an initial user in advanced industry sectors.[34] In particular, fostering research institute ventures that commercialize the research results of universities and public research institutions, as well as in-house ventures based on internal

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30 This suggestion is not directly derived from this study's survey analysis results, but considering the specialist interviews and related discussions and others, it is deemed to be an important task for the sake of utilizing the capacity of the STEM workforce and strengthening the innovation ecosystem.

31 "Entrepreneurs who failed despite their sincere efforts" refers to those whose businesses did not succeed due to market conditions or management challenges, rather than willful or gross misconduct. The average number of startup attempts per entrepreneur is about 2.7 to 2.8 in Silicon Valley and China. Rather than focusing solely on initial success, re-entrepreneurship and pivoting generally increase the probability of success. In contrast, the average number of startup attempts per entrepreneur in Korea is only 1.3, illustrating that Korea's startup ecosystem provides relatively weak support for repeated entrepreneurial efforts.

32 In the United States, through public investment programs such as the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, the government shares the initial risks of technology startups. In China, the government is strengthening the leverage effect of policy funds by tolerating losses of state-owned venture capital within a certain scope. This effort was formalized in 2024 with the "Policies and Measures to Promote the High-Quality Development of Venture Capital (2024-2026)," which aims to support high-quality growth in the venture capital sector. Recently, Korea has eased risks and expanded opportunities for re-entrepreneurship through the "New Government Startup and Venture Policy Vision" (2025) and the "Support for Prepared Re-Startups" initiative led by the Ministry of SMEs and Startups.

33 According to interviews with specialists, promoting M&A and IPO activities—particularly for large enterprises acquiring technology ventures—requires system improvements to broaden the applicability and effectiveness of existing policy tools, such as tax benefits, relaxed regulations on corporate venture capital (CVC), and technology special-case listing schemes.

34 As in the United States' Small Business Innovation Research (SBIR) program, participation of the government as an initial customer of cutting-edge industry startups is considered an effective policy instrument in sectors with high market entry barriers. In particular, industries such as semiconductors, biotechnology, AI, and quantum computing face challenges in forming initial markets. Thus, the government can support technology validation, secure early sales, and facilitate reference-building simultaneously by purchasing products and services from these startups. In Korea, the National IT Industry Promotion Agency (NIPA)'s AI semiconductor application validation support project has provided substantial assistance to domestic startups. This demonstrates that government support for generating initial demand can stimulate increased investment from the private sector.

innovation within enterprises, is expected to reduce uncertainty in the initial phase of startups and accelerate technology commercialization by leveraging existing organizational structures and infrastructure.

Additionally, in the late 1990s, when the venture and KOSDAQ market bubbles collapsed, Korea experienced a significant decline in the durability and resilience of its venture ecosystem. This was largely due to structural vulnerabilities such as unfair technology transaction practices between large enterprises and SME ventures and the lack of systems to properly facilitate technology transfers and resolve disputes. These cases indicate that, for startup ecosystems to achieve steady growth, it is necessary to bolster institutional foundations through such means as establishing fair technology transaction practices, strengthening technology protection, increasing the supply of short-term funds, and promoting deregulation.

③-2. Using strategic technology to harmonize security and innovation

Opening strategic technologies such as those in the aerospace and defense industries and creating pathways for their commercialization can be another important policy objective for the government in promoting private sector innovation. These frontier technologies have traditionally been managed exclusively by the government for security reasons, which has limited their transfer to the private sector and constrained opportunities for commercialization. However, as long as institutional safeguards and technological protection systems for these strategic technologies remain systematically in place, and if private sector startups and STEM professionals are allowed to participate in R&D on a step-by-step basis, innovative application technologies can be successfully commercialized.

For example, Israel has gradually opened its defense technologies to the private sector, enhancing market access.[35] Similarly, the Defense Advanced Research Projects Agency (DARPA) under the U.S. Department of Defense has institutionalized the commercialization of high-risk, foundational technologies by cooperating with the private sector from the initial development stage.[36] These overseas cases suggest that Korea should also consider gradually allowing private sector access to strategic technologies over the long term, under strict security and technology control systems, rather than the government exclusively holding such technologies. This approach can serve as a meaningful policy direction for both broadening innovation spillover and protecting strategic technologies as state security assets.

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[35] Israel's Innovation Authority operates the MEIMAD Dual Military, Defense, and Commercial R&D Program to support the private sector's use and commercialization of defense and security technologies. This provides a model for expanding private sector access to defense technology and institutionally ensuring a market entry path for private sector participants.

[36] DARPA (Defense Advanced Research Projects Agency), established in 1958 under the U.S. Department of Defense, leads high-risk, innovative technology planning and development, and facilitates the transfer and commercialization of these technologies by the private sector. DARPA collaborates with industry partners during the early planning and development stages and establishes systematic channels for technology transfer to and commercialization by other government programs and the private sector. Leading examples include its work on the internet (ARPANET), GPS, and autonomous driving technologies.

Box 1 Accumulation of STEM Workforce and Changes in Their Roles Across the Stages of Korea's Industrial Development (1/3)

Korea has achieved rapid economic growth over the past half-century through industrialization, beginning with light industries, followed by the cultivation of the heavy and chemical industries, and advancing to the development of high-tech sectors led by IT manufacturing. For every inflection point inKorea's industrial development, the STEM workforce has served as a core driver—their expanding scale and enhanced quality have propelled changes in the country's economic structure.

1. Age of light industries (1960s): Foundation for industrialization and cultivation of STEM workforce development, with limited R&D

In the early 1960s, Korea had a vulnerable industrial base, with the manufacturing sector accounting for just over 10% of nominal GDP. The main industries were light manufacturing, including textiles, clothing, and footwear, as well as agricultural and fishery product processing. In 1962, exports amounted to approximately USD 50 million, representing only 2% of GDP. The country's science and technology infrastructure was also limited, with the Agency for Defense Development (ADD) and Korea Atomic Energy Research Institute (KAERI) serving as the only two public research institutes.

The government incorporated the development of its science and technology workforce into its national economic strategy by launching the Five-Year Technology Promotion Plan in 1962, alongside the Five-Year Economic Development Plan. Subsequently, in 1967, the government inaugurated the Ministry of Science and Technology (now the Ministry of Science and ICT). In 1966, it founded the Korea Institute of Science and Technology (KIST), the nation's first government-sponsored comprehensive science and technology institute, thereby laying the groundwork for both R&D and administration. The number of STEM graduates increased steadily from the late 1960s, helping improve the quality of and productivity in light industry products. This, in turn, supported export competitiveness and drove rapid economic growth, averaging around 8%. During this period, however, the role of the STEM workforce was largely confined to introducing and imitating foreign technology and applying it on production sites, with independent R&D activities remaining limited.

2. Age of heavy and chemical industries (1970s-1980s): Expansion of investment in heavy and chemical industries, rapid increase in technology and research personnel, and promotion of R&D in the private sector

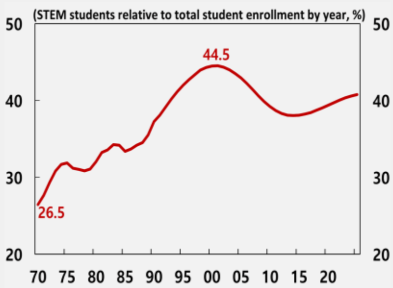
In the 1970s, the government adopted the promotion of the heavy and chemical industries as a national strategy to cultivate capital- and technology-intensive sectors. Beginning with the Heavy-Chemical Industry Drive (HCI) in 1973, massive investments were directed into six major industries—steel, shipbuilding, non-metals, machinery, electronic devices, and petrochemicals. By 1980, the heavy and chemical industries accounted for over 40% of value added in the manufacturing sector.

During this period, the demand for engineers and field technicians surged, prompting the government to strengthen vocational training by expanding technical high schools and colleges. To further support the private sector, the government established the Korea Industrial Technology Association in 1979 and, under the Specific Research Institutes Support Act, created government-sponsored research institutes specializing in steel, electronic devices, chemicals, and machinery. These institutes provided technical advisory services and fundamental developmental expertise to industries. KIST (now KAIST), established in 1971, cultivated advanced scientists and engineers, supplying them to government-supported and corporate research institutes. These professionals became key contributors to the accumulation of industrial technology in Korea.

R&D investment increased rapidly during this period. Private R&D investment, which was relatively weak until the mid-1970s, began to grow significantly in the 1980s, following the government's introduction of a national research and development project in 1982 and implementation of incentives such as tax deductions. R&D expenditure, which stood at KRW 200 billion in 1980, soared more than tenfold to KRW 3.2 trillion by 1990. R&D's share of GDP surged from 0.5% to 1.6% during this time. By the mid-1990s, Korea's R&D spending had surpassed the OECD average (2.11% in 1996). As private sector-led R&D became more prominent, corporate R&D's share of total national R&D expenditure rose sharply to over 80%. The government increased its investment in education to prevent personnel shortages from hindering R&D. As a result, more than 30% of university students were admitted to science and engineering majors. Additionally, as individuals who studied overseas began to return home in the 1980s, the combination of domestically trained professionals and returning talent[37] significantly increased the R&D workforce—from around 10,000 in 1975 to 70,000 in 1990.

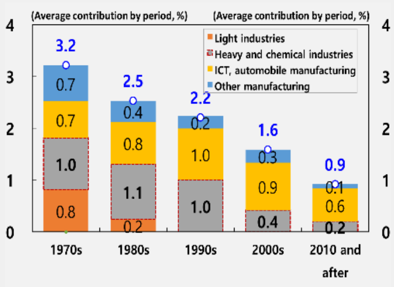
This accumulation of R&D personnel translated into industrial outcomes. The annual growth rate recorded 10.1% in the 1970s and 8.6% in the 1980s, and the manufacturing sector's share of GDP rose from the mid-10% range in the 1960s to 27% by 1989. After the mid-1980s, heavy and chemical industry products—such as automobiles, ships, and electronic devices—became major export drivers, propelling Korea into the ranks of the world's top 10 trading nations. This industrial growth was underpinned by contributions made by the science and engineering workforce the country had accumulated. In the late 1980s, Korean companies moved beyond mere imitation in certain sectors and began to develop their own technologies, launching world-leading products such as memory chips and color television sets. While limitations in creative research persisted and the technological gap with advanced countries remained, the human capital cultivated under the national policy of "technology-driven nation-building"[38] provided a foundation for Korea's transition to the telecommunications and advanced technology industries.

Figure A1. Trend of STEM enrollment



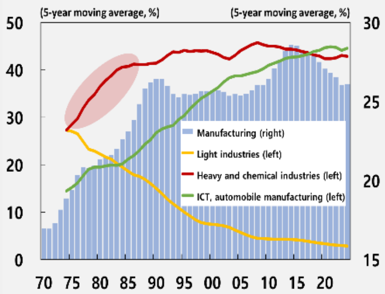
Source: Korean Educational Statistics Service (KESS).

Figure A2. Industry contributions to economic growth



Source: National Accounts.

Figure A3. Shares of industries within manufacturing[1)2)]



Notes: 1) All sector shares are presented relative to nominal GDP.
2) Share of each sector as a percentage of total manufacturing value added.

Source: National Accounts.

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[37] According to Song Hajung (1991), a reverse brain drain of STEM researchers who earned doctoral degrees in the United States was observed in the 1980s. This phenomenon resulted from Korea's remarkable economic development and subsequent expansion of economic opportunities, the government's easing of policies on studying abroad and efforts to encourage the return of overseas graduates, and vocational and cultural factors influencing research professionals.

[38] The technology-driven nation-building policy aimed to overcome the limitations of Korea's reliance on foreign technologies that became evident during the development of the heavy and chemical industries—such as steel, petrochemicals, machinery, shipbuilding, automobiles, and electronic devices. This approach also stemmed from the stark realization, amid external shocks like the oil crisis of the late 1970s, that securing indigenous technology was critical for the nation's survival and growth. With this awareness, the government established KAIST, increased the number of government-sponsored research institutes, enacted the Specific Research Institutes Support Act, and introduced national research and development projects—measures that accelerated the accumulation of technology capacity at the national level.

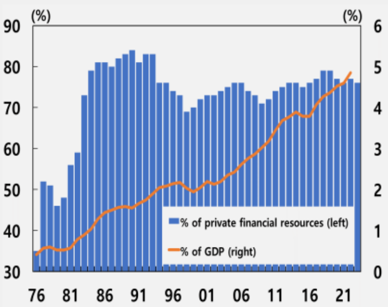
3. Age of IT manufacturing (1980s-present): Characterized by the emergence of cutting-edge technologies, expansion of advanced researchers, and promotion of new technology startups

In the 1990s, the rapid development of information and communications technology, together with globalization and the accelerated growth of the electronic device and semiconductor sectors, marked the arrival of the IT manufacturing era. Advanced ICT manufacturing—including semiconductors, computers, communications equipment, and digital home appliances—emerged as Korea's main export sector. The STEM workforce, which previously focused on adopting foreign technologies, has now taken on a leading role in creating new knowledge and driving industry innovation.

The export structure has also advanced from labor-intensive to capital- and technology-intensive industries. Since the mid-1990s, exports of electronic devices and information and communications equipment have surpassed, or reached levels similar to, those of heavy and chemical industry products. The government implemented manpower cultivation programs as part of its policy to strengthen the country's science and technology capacity, including the establishment of the Gwangju Institute of Science and Technology (GIST), improvement of the Daedeok Research Complex, and expansion of R&D investment and the BK21 program. During the foreign currency crisis in 1997, R&D manpower and investment fell by 10% and 7%, respectively. However, in the early 2000s, the government strategically expanded investment to support recovery, leading to a resurgence of private sector research personnel. As a result, by the 2010s, R&D investment accounted for over 3% of GDP, and the number of R&D personnel per 1,000 people doubled from 5 in 1990 to 10 in 2010. From the mid-2000s, Korea joined the world's top 10 countries in terms of R&D investment as a share of GDP, with its ranking steadily rising to—and maintaining—the No. 2 position globally, after Israel, in the 2010s. Currently, private enterprises account for 70 to 80% of total R&D, playing a dominant role in industry-academia-research institute collaboration.

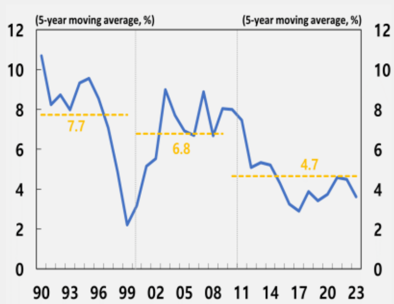
The areas of activity of the STEM workforce have become significantly diversified. Whereas most personnel previously focused on imitating and applying foreign technologies on production sites, an increasing proportion now work as R&D personnel and entrepreneurs. During the venture boom in the late 1990s, numerous STEM professionals founded IT companies or joined cutting-edge startups. Since the 2000s, there has been a significant increase in patent acquisitions and publications in international journals, particularly in electronics and communications. This indicates that social demand for the STEM workforce has shifted from functioning as a simple labor force to serving as creators of high value added through knowledge.

Figure A4. R&D investment trend



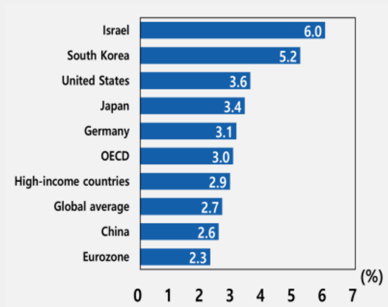
Sources: Research and Development Activity Survey, Ministry of Science and ICT.

Figure A5. R&D personnel growth trend



Sources: Research and Development Activity Survey, Ministry of Science and ICT.

Figure A6. R&D expenditure's share of nominal GDP



Source: WDI.

Box 2 Estimation of Total Factor Productivity Spillover Effects from STEM Workforce-Related Shocks Using a VAR Model

This analysis uses a VAR model to examine the dynamic effects of STEM workforce factors on total factor productivity (TFP). This approach is valuable because it can identify both short- and long-term structural spillover effects of changes in the STEM workforce and R&D activity on productivity. The variables used include STEM enrollment (l_stem_enroll), R&D workforce size (l_rd_personnel), real R&D investment (l_rd_invest_real), and total factor productivity (l_tfp). All variables are log-transformed-level variables.

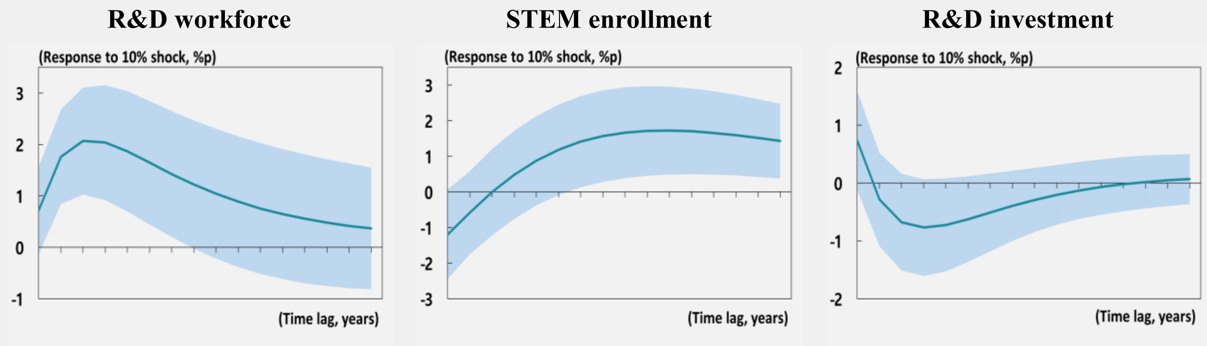
$$X_t = A_1 X_{t-1} + A_2 X_{t-2} + \cdots + A_p X_{t-p} + u_t \,,$$

Here, X_t = [l_stem_enroll, l_rd_personnel, l_rd_invest_real, l_tfp].

To identify impulse response functions (IRFs), we apply the Cholesky recursive structure (orthogonalized IRF). The variables are in the order of: STEM enrollment → R&D workforce → R&D investment → TFP. This is based on the economic logic that the expansion of the STEM workforce initially leads to increased R&D input and performance, with TFP responding subsequently. This sequence assumes that STEM workforce variables influence R&D activities simultaneously, while, conversely, TFP does not immediately affect STEM workforce variables.

The analysis results confirm that the effect of increased STEM student enrollment is uncertain in the short term, but gradually accumulates after two to three years. They also show that the effect of R&D investment size generates a short-term positive impact at an early stage and then undergoes temporary consolidation due to adjustment and learning costs, weakens over the long term, and ultimately converges to a neutral level. This indirectly indicates that productivity enhancement is more strongly influenced by the composition of investment items—such as intangible assets, software, organizational capacity, and data infrastructure—than by the size of R&D investment itself. In summary, increased productivity in the Korean economy has been realized not through the increased quantitative input of physical capital, but primarily through the accumulation of human capital. In the short term, securing and retaining outstanding researchers led directly to productivity improvement, which has been further enhanced over the long term by the development and accumulation of robust education, research, and industry pipelines.

Figure A7. Effects of each variable's shock on TFP[1)]



Note: 1) The shaded area indicates a confidence interval of 95%.
Sources: estimates of the Research Department based on National Accounts, Economically Active Population Survey, Korean Educational Statistics Service.

Box 3 Overview of Survey

- **Survey purpose:** This survey aims to identify the status of the treatment and research environment of STEM talent and provide basic data for effective talent utilization strategies and policy-making to enhance growth potential.

- **Survey targets:** Researchers holding master's and doctoral degrees in STEM fields who are engaged in domestic and overseas educational institutions (universities), research institutes, or companies.*

  * The online (mobile) survey was conducted from June 27, 2025 to July 25, 2025.

- **Respondent characteristics:** Of the 2,694 respondents, 1,916 were researchers residing in Korea (71.1%) and 778 were researchers residing overseas (28.9%).

  - Final degrees obtained were distributed as follows: domestic doctorates (56.2%), domestic master's degrees (21.2%), overseas doctorates (18.4%), and overseas master's degrees (4.2%). Among those with overseas degrees, the majority graduated from institutions in the United States (75.5%), followed by Japan (11.5%) and Europe (6.1%).

  - Respondents' ages were as follows: 40s (33.6%), 30s (29.8%), 50s (24.3%), 60 or older (8.6%), and 20s (3.6%). The average career duration is estimated to be about 12 years, given that the average year of obtaining a final degree was 2013.

  - Majors included biology, chemistry, and environment (19.2%); machinery and metals (10.5%); computers and telecommunications (9.9%); and electric and electronic devices (8.5%) (Figure A8). Areas of engagement were biotechnology, pharmacy, and medical devices (32.7%); IT, software, and telecommunications (15.3%); and electric and electronic devices and semiconductors (11.9%)* (Figure A9).

    * Regarding the match between majors and areas of engagement, 67.4% responded "closely matched," 29.3% "partially matched," and 3.3% "not matched."

  - Affiliated organizations included universities and colleges (42.2%), followed by SMEs and startups (21.1%), public research institutes (16.2%), and large enterprises (8.9%). Tasks performed were primarily R&D (56.6%), followed by professorships (28.8%), technology engineering (10.0%), and others (4.6%) (Figure A10).

Figure A8. Composition of respondents' majors

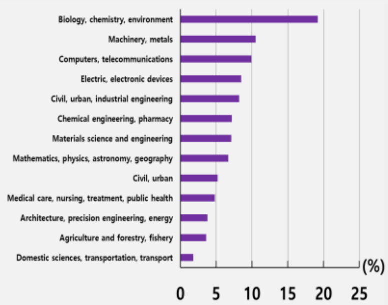


Figure A9. Composition of respondents' areas of engagement

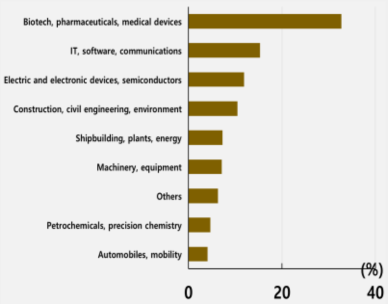
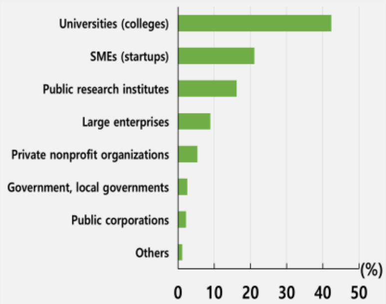


Figure A10. Composition of respondents' organizations



Box 4 Analytical Method for Identifying the Determinants of STEM Professionals' Intention to Move Overseas

- **Analysis purpose:** We used a **logistic** regression (logit) model to quantitatively examine the factors influencing the domestic STEM workforce's intention to move overseas. The logit model is suitable when the dependent variable is binary (0 or 1), as it explains the probability of a specific event—namely, the presence of an intention to move overseas.

- **Model structure:** The logit model specified for this study is as follows:

$$logit\,(Pr\,(Y_i = 1\;/\,X_i\,)) = ln\left(\frac{Pr(Y_i = 1/X_i\,)}{1-Pr(Y_i = 1/X_i\,)}\right)$$

$$= \beta_0 + \beta_1 \times income + \sum_{j=2}^{n}(\beta_j \times X_{ji}) + \sum_{k=n+1}^{m}(\beta_k \times X_{ki})$$

  - In the equation above, *income* represents income satisfaction at the current workplace; X_j indicates satisfaction with non-financial factors at the current workplace—including research environment, opportunities for promotion, conditions for children's education, and employment stability; X_k denotes individual characteristics of respondents, such as income level, age, overseas academic experience, type of degree (master's/doctorate), gender, marital status, number of children, career stage, and academic major (classified as new-growth or non-new-growth sectors).

- **Interpretation of results**

  - The coefficient of the logit model (β_i) indicates both the direction and relative magnitude of each explanatory variable's impact on the probability of intention to move overseas.

  - **Average marginal effect (AME):** AME indicates how much, on average, the probability of having an intention to move overseas changes when an explanatory variable, X_i, increases by one unit (or changes from 0 to 1 for a dummy variable).

$$AME_k = \frac{1}{N}\sum_{i=1}^{N}[\,f(X_i\hat{\beta}) \times \hat{\beta}_k]$$

    Here, $f(\bullet)$ is the probability density function of the logit model, and $\hat{\beta}_k$ is the estimated coefficient of the explanatory variable k.

  - **Willingness to pay (WTP):** To convert the effect of non-financial factors into financial terms, WTP is calculated using the coefficient estimates. WTP reflects the value of a specific non-financial factor when expressed as an equivalent wage increase, making it useful for policy prioritization.

$$WTP = \frac{\hat{\beta}_k}{\hat{\beta}_{income}}$$

Box 5 Expert Interviews on Supporting the STEM Workforce

- Interviews (including media coverage) with highly knowledgeable scholars—university professors in science and engineering—revealed that many advocate for the government to provide direct, bold support to top-level talent while simultaneously developing institutional frameworks to encourage the private sector to offer incentives for outstanding STEM professionals.

① Grant outstanding STEM talent **the authority to participate in science and technology policy formulation** and **ensure autonomy throughout all research activities**—including researcher recruitment and research funding management—in addition to providing a high level of financial compensation.

* Academician system in China: An academician is a talent with the highest authority in China's science and technology sector. Academicians are recruited by the Chinese Academy of Sciences (CAS) and Chinese Academy of Engineering (CAE) through recommendations from academia and industry and given priority in receiving financial compensation and research funding. They exercise influence in national science and technology policy advisory, research institutes' personnel management and operations, and possess significant social authority and prestige.

② Provide outstanding talent with **opportunities* to continue their research after retirement.**

* If top professionals move overseas post-retirement, it can lead to significant losses in accumulated research achievements and global networks. To address this, Seoul National University and POSTECH have extended the retirement age from 65 to 70—a policy that should be expanded across related sectors.

③ When attracting global talent, **consider providing substantial tax benefits—such as waiving income tax for a certain period regardless of nationality**—and **strengthening residential conditions for families**, including streamlined visa issuance, support for children's education, and improvement of the residential environment.

④ The government should establish an institutional framework that enables private enterprises to offer substantial compensation to talented individuals and foster a startup-friendly environment. This will help **young, outstanding students realize that pursuing science and engineering majors can lead to both high income and "superstar" status.**

* For example, tax benefits such as investment tax deductions could be provided to companies that hire top talent.

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