1 Overall assessment and recommendations

This chapter presents the overall assessment and recommendations of the review. The recommendations are categorised according to the three pillars of cross-cutting, business innovation and research system and linkages recommendations. The assessment is structured following the chronological order of the review, with an initial overview of the Korean innovation system, its evolution and challenges for the future, followed by a comprehensive analysis of business sector R&D and innovation, the production, circulation and diffusion of knowledge as well as governance for a new era of innovation in Korea.

1.1. Recommendations

This section introduces the overall assessment and recommendations (OAR) of the *OECD Reviews of Innovation Policy: Korea 2023*. The second section presents an overview of Korea's innovation system, guiding the reader through its evolution to the opportunities and challenges it may face in the future. The following sections capture these characteristics in greater detail by innovation actors, starting from the third section on business innovation; the fourth section on the production, circulation and diffusion of innovation; and the fifth section on Korea's science, technology and innovation (STI) governance structure. The final section provides an overview and summary of Korea's innovation system's strengths, weaknesses, opportunities and threats (SWOT).

This review's OAR show that Korea is on its way to becoming an innovation leader and needs to continue to build on its current strengths, such as its leadership position in manufacturing industries, a highly educated workforce and excellent information and communications technology (ICT) infrastructure. Korea's research and development (R&D) spending as a share of gross domestic product (GDP) is among the highest in the world at 4.9% of GDP in 2021. The recommendations presented here suggest rebalancing spending towards areas that require attention, such as fostering a mission-oriented approach and disruptive innovation. Korea needs to address several imbalances and faces a number of innovation-related challenges for sustainability in the years ahead, including climate and ageing. The OAR introduces recommendations that respond to these challenges by:

- creating a shared vision for Korean society (Recommendation 1)
- directing STI systems to enable transitions and address societal challenges (Recommendation 2)
- improving the efficiency of R&D policy implementation and evaluation (Recommendation 3)
- fostering internationalisation of STI (Recommendation 4)
- strengthening the role of the service industry (Recommendation 6)
- strengthening the diffusion of innovative technologies (Recommendation 7)
- further developing linkages between universities and businesses (Recommendation 11).

The 11 recommendations are grouped into 3 pillars. While all recommendations are important, they are listed roughly in the order of importance, starting from the overall vision, the need to redirect the STI system towards societal challenges and the need for efficient policy implementation:

1. **The first pillar deals with cross-cutting recommendations,** including developing a shared national vision of Korea's future economic and societal development (Recommendation 1), built upon a solid foresight exercise and a broad-based consultation with all stakeholders within the innovation system. Such an exercise should demonstrate the importance of adopting additional measures to help direct STI systems towards accelerating key transitions (e.g. net-zero) and addressing societal challenges (Recommendation 2). Such strategies need to be underpinned by efficient R&D policy implementation and evaluation (Recommendation 3). Further efforts in internationalising STI will help stimulate knowledge exchanges and international opportunities (Recommendation 4). The transition will necessitate strengthening skills and behaviours in order to gain international leadership in innovation (Recommendation 5).
2. **The second pillar deals with business innovation.** The high value-added service sectors need to be further strengthened, as they can help accelerate the transition towards the knowledge economy (Recommendation 6). The uptake of new technologies by small and medium-sized enterprises (SMEs) and the global connectivity of start-ups need to be supported (Recommendation 7). Finally, rebalancing the policy mix for business innovation can help generate economic and social benefits from support to R&D and innovation (Recommendation 8).
3. **The third pillar deals more specifically with the research sector.** Universities (Recommendation 9) and government research institutes (GRIs) (Recommendation 10) will need

a set of measures to enhance knowledge production, and additional measures are needed to drive linkages between these actors and businesses (Recommendation 11).

1.1.1. Pillar 1: Cross-cutting recommendations

Recommendation 1: Create a shared national vision and long-term plan for Korea's development

Overview

Korea has experienced rapid development over the past 60 years. It has successfully caught up with some of the world's most developed nations and has created prosperity and well-being in its society.

However, these transitions have also created a number of imbalances, as have been pointed out throughout this assessment, between the older and younger generations; between the Seoul capital area as one of the world's largest and most prosperous metropoles and rural areas; between globally competitive conglomerates and much less competitive SMEs; between a world-leading manufacturing sector and a below-average service sector; between a thriving domestic start-up scene and limited internationalisation of these start-ups, to name just a few.

Korea also faces acute challenges in meeting carbon emission goals in a strongly energy-dependent economy and one of the most acute demographic challenges globally.

Above all, Korea has been striving to switch from a successful catch-up economy to a world leader for over a decade. It has reached that status in a few sectors, such as ICT manufacturing. However, overall, Korea remains a fast follower rather than a leader in key technology sectors, such as artificial intelligence (AI) or biotechnology, for example.

In order to address all these issues holistically and in the context of a longer time frame, Korea needs to enact a paradigm shift by creating stronger links between sectoral strategies. Ideally, a cross-cutting and holistic vision would accelerate society's development towards an inclusive, knowledge-based economy where STI would play a key role.

In the absence of a whole-of-government national development vision covering all areas of policy, Korea should create explicit links and co-ordination mechanisms between existing sectoral strategies:

- The Ministry of Science and ICT (MSIT) has adopted a Science and Technology Future Strategy for 2045. This remains a sectoral strategy for science and technology (S&T), which does not address innovation and is not connected to an overall economic development vision.
- An initiative was launched by the Ministry of Economy and Finance (MOEF) in June 2021 for a mid- to long-term economic and social policy roadmap. Similarly, there are no indications that this plan takes into account the role of S&T.

Detailed recommendations

- **Recommendation 1.1. Carry out a foresight exercise to create a vision linking the Science and Technology Future Strategy for 2045 and the long-term strategy of the Ministry of Economy and Finance.** A top-level expert group would be set up to include a diverse group of highly prestigious domestic and foreign experts from business, academia and other key actors, including from social sciences. It would be tasked with drawing up alternative scenarios of Korea in 2045, with respect to the structure of the economy (evolution of the balance of manufacturing vs high value-added services); inclusiveness with respect to regional development (Seoul capital area vs regions); including socially disadvantaged groups; addressing societal challenges; opening up to international co-operation; and achieving a world-leading status. Elements of both existing

strategies should be considered with equal weighting, with a view to unifying the vision, particularly around the green and digital transitions, to realise synergies and focus future policy action across government towards achieving these overarching goals.

- **Recommendation 1.2. Organise a broad societal consultation on linking the Science and Technology Future Strategy for 2045 and the long-term strategy of the Ministry of Economy and Finance.** Following the publication of the results of the foresight exercise with its different scenarios, consultations could be organised at all levels, including for citizens who should be able to contribute ideas and views on the various scenarios, their desirability in terms of outcomes, the impact of various policy options and their robustness relative to the various scenarios, identifying policy choices that have the greatest likelihood of positive outcomes, as well as the pitfalls that need to be avoided.
- **Recommendation 1.3. Set up a whole-of-government steering committee to develop a shared vision for Korea's development and the role of STI in contributing to it,** built upon the key findings from the foresight and consultation exercise. In such a process, all areas of policy, such as digital policy, social policy, education, environmental and health policies, should be discussed as they interact with STI. These issues fall outside the traditional STI policy portfolios but invariably affect the effectiveness of policy makers' interventions. The shared vision should then be presented to a broad group of stakeholders for further consultation and buy-in. It is important that all stakeholder groups feel full ownership of this vision.
- **Recommendation 1.4. Draft an actionable and budgeted action plan for linking the Science and Technology Future Strategy for 2045 and the long-term strategy of the Ministry of Economy and Finance initiative, with clear responsibilities and monitoring mechanisms.** Clear intermediate objectives should be set at five-year intervals to reach the desired scenario in 2045. A more detailed action plan should be developed for the first five-year period, with assigned responsibilities, key performance indicators and a monitoring process.

Recommendation 2: Direct STI systems to enable transitions and address societal challenges

Overview

Korea's S&T enterprise has been a critical component in its economic development and its ability to avoid the middle-income trap many other countries face today. These impressive S&T resources will be equally critical in enabling Korea to handle a number of increasingly urgent societal challenges, such as an ageing population, growing polarisation (between generations, regions and income groups) and climate change. However, science and technology do not automatically or inevitably provide solutions to such problems. In fact, they can contribute to exacerbating them. A range of actions should be considered to ensure that knowledge and innovation can contribute effectively to ensuring Korea's future economic, social and environmental sustainability.

Detailed recommendations

- **Recommendation 2.1. Ensure the long-term continuity of STI orientations across different governments.** Different countries have found different ways to achieve this. One option would be to make the S&T Basic Plan a ten-year rolling plan. In order to allow the longer-term perspective needed to address ambitious and complex societal challenges while providing room for adaptation (aligned with the political cycle), the Basic Plan could become a ten-year plan revised every five years. A binding five-year investment plan with earmarked financial resources would be attached to the first five years. This would allow both: 1) continuity to address issues like climate change or ageing that cannot be tackled in a five-year government term; and 2) flexibility to accommodate

new priorities or approaches by the newly elected president within the longer-term framework (e.g. very few new challenge areas or sub-areas could be added/suppressed). Another option would be to create a dedicated, national, long-term, future-oriented programme for addressing major challenges, which could be governed under a specific long-term financial arrangement with regular evaluation milestones, such as the French Future Investment Programme (PIA) or the Dutch Top Sectors Policy.

- **Recommendation 2.2**. **Establish a whole-of-government approach to and policy co-ordination on certain key policy priorities.** In particular, in order to achieve net-zero targets:
  - Rapidly ramp up investment in innovation for renewable energy sources, such as solar and wind energy, to reduce carbon emissions. This should include strengthening the demand for renewable energy sources (e.g. through public procurement, supportive regulation and legislation, demonstrators and test sites) and, more generally, strengthening the broad diffusion and uptake of renewable energy technologies and solutions across industries and sectors.
  - Complement government support for investment in low-carbon technologies by further improving innovation-enhancing market mechanisms, such as a carbon pricing system, which sets prices sufficiently high to effectively incentivise producers and consumers to reduce carbon emissions.
  - Strengthen public communication and education about the severity of global warming while emphasising the opportunities that low-carbon technologies represent for Korean firms and the economy more generally.
- **Recommendation 2.3**. **Mobilise untapped resources for tackling societal challenges.**
  - Mobilise and provide support for students, researchers, cities, citizens, municipalities and companies (including start-ups) to contribute to addressing specific societal challenges, e.g. through competitions and prizes, pledges, innovation funding, proof-of-concept funding, experimentation, etc.
  - Create experimentation spaces to test new solutions (innovation labs, including regarding public sector innovation), assess the current higher education and research institute system, structure and organisation according to its ability to contribute to strategic technological and societal innovation and transformation priorities and objectives.
  - Strengthen climate literacy in primary and secondary schools.
- **Recommendation 2.4. Support initiatives that connect and catalyse basic research from different disciplines around a specific societal challenge.** The Convergence Research and Convergence Accelerator programmes launched by the US National Science Foundation can serve as inspiration. They seek to address societal challenges and "accelerate solutions toward societal impact" by building on basic research and "integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyse scientific discovery and innovation" around a specific societal problem.
- **Recommendation 2.5. Focus the role of the Innovation Office on strategic policy making in order to ensure holistic co-ordination and contribute to enhancing synergies and co-operation between programmes.** Korea's unique annual comprehensive and systematic review of all R&D programmes reduces duplications across the whole government structure and contributes to ensuring a broad consistency with the S&T Basic Plan. However, this systematic review at the central level is a resource-intensive task that tends to focus the attention and resources on programme management and compliance rather than on strategic issues. The government should consider the costs and benefits of this review process and delegate to ministries and agencies relevant tasks that could be performed at lower levels without hindering cross-government co-ordination. While centralising certain tasks is important, this recommendation applies the subsidiarity principle, where lower governance levels fill in the details of decisions made

at higher levels. This would allow the Science, Technology and Innovation Office (hereafter, the "STI Office") and the President's Advisory Council on Science and Technology (PACST) committees to focus on strategic policy making, budgeting and monitoring, as well as on national missions (see Recommendation 2.8).

- **Recommendation 2.6. Implement high-level national missions targeting large and ambitious societal challenges.**
  - A small number of pilot national missions (two to three) should be designed collectively and endorsed by PACST, chaired by the President of Korea. These missions should be included in the Basic Plan and revised or continued every five years after a thorough evaluation. The multi-year funding of each mission should be programmed in the above-mentioned five-year investment plan attached to the Basic Plan. The missions address key societal challenges facing Korean society through integrated intervention across the government structure and throughout the innovation cycle (from upstream research down to deployment). The missions are systemic in that they combine a wide range of activities (research, infrastructure, skill formation, etc.) on different types of potential technological and non-technological solutions, using a package of policy interventions (subsidies, regulatory reforms, procurements, etc.).
  - The implementation and monitoring of missions should support dedicated cross-ministerial co-ordination groups tailored to co-ordinate each mission. Furthermore, within the STI Office, dedicated operational teams should integrate the policy co-ordination, budgeting and performance evaluation for each mission. PACST could review and validate the mission strategic roadmaps and evaluation every five years and on an annual basis the monitoring reports of each mission. As part of their plan submitted to the government, the GRIs should specify their potential contribution to national missions. This initiative could also act as a "governance laboratory" for the challenge-based transformative governance framework proposed in Box 1.1.

Box 1.1. Towards a challenge-based transformative governance framework in Korea

The OECD proposes that in the coming years, Korea turns gradually towards a new "virtual architecture" for the governance of STI systems. The proposal is to structure strategic orientation and policy making along some broad challenges involving several ministerial portfolios and set up spaces for continuous cross-ministerial co-ordination around these challenges across the policy cycle. The main objective of this new type of STI governance is to set up mechanisms to allow for complex and long-term "transformative" policy issues to be collectively understood and led across the whole policy cycle, from strategic orientation to policy making and co-ordination and, finally, evaluation set to provide feedback into strategies and policies.

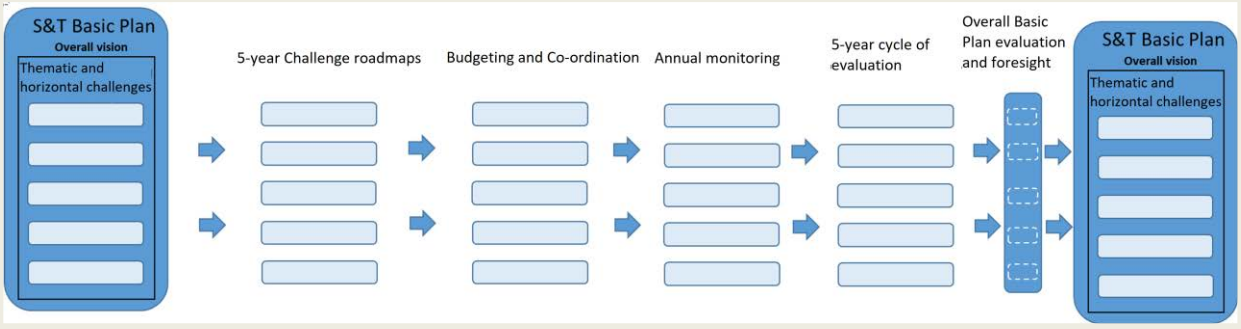
Some of these challenges would be thematic, i.e. addressing economic and societal challenges, while others would relate to the challenge of strengthening the system as a whole (e.g. improving basic science, upgrading business innovation, etc.).

These thematic challenges, set every five years in the Basic Plan, would extend far beyond R&D and aim at mobilising society as a whole and guiding research and innovation (R&I) activities (in a broad sense, i.e. including social innovation) to solve these challenges. Each challenge would have a dedicated "nested" structure of governance composed of bodies with high-level representatives of each ministry, overseeing more operational sub-committees with mid-level policy makers in charge of the relevant programmes and initiatives in different areas relevant to the challenge.

These challenges would also structure the entire policy cycle, from strategic orientation to evaluation. The process could start with the selection of the challenges as part of the Basic Plan development process.

PACST would endorse these challenges. With support from the STI Office, cross-ministerial challenge groups would develop five-year challenge roadmaps for each challenge, with associated budgets. The groups would also review activities and produce annual monitoring reports for each challenge (Figure 1.1).

Figure 1.1. The challenge-based transformative governance framework



Source: OECD based on stakeholder discussions.

- The entire STI governance structure is impact-oriented and structured around challenges with clear objectives.
- STI activities have better visibility and accountability due to the challenge-based structure (e.g. implementing challenge-based budgeting).
- There is systematic co-ordination throughout the five-year and annual policy cycles based on continuous interactions.
- The pooling of resources and strengthening of cross-ministerial co-operation supports realising the challenges' objectives.

Note: The missions proposed in Recommendation 2.6 represent a way to experiment with such a challenge-based structure, which involves the integration of policy co-ordination, budgeting and performance evaluation functions and continuous cross-government monitoring of actions and progress.

Recommendation 3: Improve the efficiency of R&D policy implementation and evaluation

Overview

Effective R&D policy evaluation is needed to flexibly adjust and achieve desired objectives. This means going beyond simple monitoring indicators and assessing the impact of policies.[1]

Detailed recommendations

- **Recommendation 3.1. Revise the methodology used in the pre-feasibility test[2] to make it better suited to the characteristics of R&D programmes**. Although the methodology of the pre-feasibility test has been adapted and a two-step process implemented, further improvements can be made to make it more suitable for risky and exploratory R&D programmes. This creates a scenario where certain crucial strategic directions hinge on the outcome of this technical process, resulting in inefficient strategies to bypass the test. Valuable insights could be gleaned from the *ex ante* evaluation of the European Commission's Research and Innovation programmes.
- **Recommendation 3.2. Inter-ministerial programmes should be implemented using joined-up approaches where different agencies work together to manage the programmes, and the**

ministries are represented in dedicated governance structures. In many cases, Korea's large inter-ministerial projects result in allocating different projects to the respective agencies of the different ministries, in contrast with agency co-operative schemes found in other countries (e.g. Pilot-E in Norway). While in some cases, a single agency is tasked with funding projects for different ministries, it remains rare and administrative silos tend to be replicated within large-scale programmes.

- **Recommendation 3.3. Set up a research and innovation assessment framework focused on impact and learning**. This framework could build on and expand the experience of the Research Excellence Framework (REF) in the United Kingdom. Such a framework would make it possible to identify good practices – and challenge areas –within the Korean STI system. It would have wider coverage than the UK REF because it would be applied to higher education institutions and GRIs (with different modalities to be adapted for these organisations). Furthermore, it would include research as well as innovation activities. Under this framework, both institutions would be required to submit "R&I impact case studies" that demonstrate the impact of their R&I activities on wider society (including national missions). These case studies would also include an auto-assessment of the bottlenecks and difficulties encountered that hindered impact delivery. The set of case studies would be analysed, and the results of the analysis would be discussed at the government level to feed into policy decisions regarding strategic (re-)orientation and needed structural reforms.

Recommendation 4: Foster the internationalisation of science, technology and innovation

Overview

The Korean innovation system needs to be better integrated into the international STI ecosystem to be stimulated by the flow of ideas and exploit international opportunities. This applies to international co-operation on a bilateral and multilateral basis, as well as the integration of foreign brainpower in the Korean ecosystem.

Detailed recommendations

- **Recommendation 4.1. Enhance scientific excellence and international co-operation through regional S&T funds.** Current discussions about Korea's association with Horizon Europe are on the right track and will open up possibilities to collaborate and compete with the best European minds. In addition, Korea could consider establishing a regional fund for innovation similar to Horizon Europe in East Asia and Southeast Asia. A research excellence fund, such as the European Research Council, should also be considered in the region. Such a fund recognises excellent research and can be a strong incentive for developing world-class scientific projects.
- **Recommendation 4.2. Envisage the development of large regional scientific infrastructures with neighbouring countries.** In the past, it has been shown that geopolitical tensions can be overcome in science. Such was the case of the European Laboratory for Particle Physics (CERN), established in the aftermath of World War II, which brought together scientists from formerly belligerent European nations to work together on peaceful nuclear research. The ultimate result was one of the world's leading scientific infrastructures, which has also benefited from significant economies of scale and allowed European countries to compete in the domain with much larger countries, such as the United States. This model was replicated at Synchrotron Light for Experimental Science and Applications in the Middle East (SESAME), which brings together scientists from Bahrain, Cyprus,[3] Egypt, Islamic Republic of Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and most recently in the Southeast Europe region in the South East European International Institute for Sustainable Technologies (SEEIIST), which brings together scientists from Albania, Bulgaria, Greece and all seven units from former Yugoslavia, some of which have no diplomatic relations. A similar infrastructure in partnership with East Asian and

Southeast Asian neighbours may benefit Korea, particularly in disciplines where Korea lacks the critical mass to compete globally.

- **Recommendation 4.3. Facilitate international mobility of researchers, innovators and entrepreneurs in the public and private sectors.** In view of the demographic trend and a reduction in the supply of skilled labour domestically, Korea could do more to harness skilled immigration. Action is needed to adapt cultural attitudes towards foreigners to encourage the acceptance and integration of foreigners into Korea's traditionally homogeneous society. Regulations should ensure equivalent hiring and promotion opportunities. Voluntary classes and counselling services for foreigners that would help them integrate into Korean society could also be useful.

  A further increase in the share of English-language curricula in Korean universities would help attract more international students and help Korean students be more open to international co-workers and scientific and business partnerships.

  Researchers could also benefit from foreign talent for collaboration and mobility schemes to (temporarily) move abroad, which could spur creative thinking and knowledge transfer. Programmes enabling and fostering this kind of exchange should be at a larger scale. Consider supporting international post-doc positions, i.e. funding positions for foreign post-docs to spend time in Korea.

- **Recommendation 4.4. Increase internationalisation in recruitment, evaluation and funding allocation.** Use the opportunity presented by the increased acceptance of online meetings to involve more foreign peers in the assessment of research funding applications (e.g. at the National Research Council for Economics, Humanities and Social Sciences [NRC]), recruitment processes (at universities) and evaluations of funding programmes, institutions, research and education.

- **Recommendation 4.5. Create incentives for researchers to participate in international collaboration.** Today, there is an incentive to apply for national research grants under the project-based system, and international collaboration is seen as presenting additional transaction costs without the benefit of additional recognition. This situation leads to a low number of international co-publications compared to other OECD countries. Including international collaboration projects and co-publications as a recruitment, evaluation and career progression criterion would incentivise enhanced collaboration. Specific grants for international co-operation projects could be provided, along with assistance to overcome administrative hurdles that may arise on such projects.

- **Recommendation 4.6. Foster internationalisation of industrial R&D.** R&D activities of foreign-owned firms can generate considerable knowledge spillovers and economic benefits for host countries (see, for example, (Veugelers and Cassiman, 2005[1]); (Dunning and Lundan, 2008[2])). Similarly, overseas R&D activities of multinational firms can help them adapt products and services to new markets and enter global value chains (GVCs). It can also help multinationals tap into new talents and technologies, complementing a company's business strategy. Firms engage in international R&D networks if a number of conditions are fulfilled. Besides governmental and macroeconomic stability, these include international mobility of researchers, inward and outward foreign direct investment (FDI) flows and intellectual property (IP) protection. Korea is below the OECD average for these three indicators. With regard to IP protection, firms are, for instance, often reluctant to share intellectual property as IP protection is perceived to be low, leading them to favour secrecy over sharing intellectual property with foreign firms and personnel.

Recommendation 5: Enhance skills and attitudes in order to gain a leadership position in innovation

Overview

Korea's education system produces a high number of tertiary-educated individuals with above-average representation in science, technology, engineering and mathematics (STEM) disciplines. It provides an excellent basis for technical and theoretical skills and knowledge. Nevertheless, Korea needs to achieve a step change to gain a leadership position in innovation: it needs to boost creativity, entrepreneurial learning and risk acceptance. Korea also needs to better attract and leverage the influx of foreign talent.

Detailed recommendations

- **Recommendation 5.1. Actively encourage and celebrate risk taking.** Launch high-profile initiatives to promote ambitious and bold actions, targeting new generations of potential entrepreneurs. Risk taking needs to be actively encouraged and celebrated with initiatives to emphasise the importance of taking risks and accepting potential failure as a natural complement to success. Korea should further develop communication campaigns celebrating entrepreneurs and risk takers as well as prizes for entrepreneurs.
- **Recommendation 5.2. Expand the use of innovation challenge prizes.** Innovation challenge prizes can stimulate positive public perceptions toward innovation, mobilise talent and capital and strengthen problem-solving practices involving various stakeholders. Korea could benefit from innovation challenge prizes by showcasing creative problem-solving innovation best practices to promote risk taking, especially among youth.
- **Recommendation 5.3. Align human resource policies to encourage risk-taking behaviour.** Examine incentive structures in higher education and public research organisations to analyse the potential adverse impact of risk taking on individuals' careers. Incentivise risk taking and ensure that negative outcomes resulting from professionally correct behaviour do not bear punishment, i.e. if negative outcomes arise due to external factors, this is not imputed to the professional in charge.
- **Recommendation 5.4. Increase the emphasis on entrepreneurial education** in the curriculum for younger generations and adults looking for a career change. Exchanges and study trips to other developed countries can be beneficial. For example, the 2013 initiative of sending venture capitalists to Silicon Valley allowed them to become familiar with risk-taking practices and investing successfully in early-stage companies.
- **Recommendation 5.5. Facilitate entrepreneurial leaves of absence from universities and government research institutes.** This would enable an academic to start a business, e.g. by taking unpaid leave from their institution, and have a guaranteed return to employment in case of failure. Korea should also consider modernising career progression and pay policies currently based on seniority and ensure that staff using an entrepreneurial leave of absence are not penalised.

  In order to encourage the development of more young and highly-talented entrepreneurs, particular emphasis should be placed on mentoring. Stimulating the secondment of undergraduate and graduate students to innovation-oriented companies could be beneficial not only to shaping entrepreneurial mindsets and enriching experiences in industry but also for SMEs that face a talent shortage in terms of adopting advanced technologies.
- **Recommendation 5.6. Strengthen critical-thinking skills and creativity** in primary and secondary education by allowing more diversity in types of schools and curricula. Introduce more diverse subjects and increase the emphasis on critical-thinking skills and creativity in university entrance examinations.

- **Recommendation 5.7. Strengthen programmes for the formation of practically relevant AI skills in the higher education system.** Provide easily accessible digital technology training programmes for SME managers and employees to increase their awareness of the potential of digital technologies and enhance their digital skills.
- **Recommendation 5.8. Evaluate university-level entrepreneurial education programmes** based on their content quality instead of relying on quantitative metrics only. Provide financial incentives to incubators and accelerators for hiring experienced staff to facilitate the provision of high-quality coaching and mentoring services by experts such as former entrepreneurs and venture capitalists.

1.1.2. Pillar 2: Recommendations concerning business innovation

Recommendation 6: Strengthen the role of the service sector in the knowledge-based economy

Overview

While continuously supporting strengths in the manufacturing sector, Korea needs to prepare for an increased role of services, particularly high value-added services, such as licensing of intellectual property, ICT services, media, financial services and other business services that can also have strong export prospects.

Detailed recommendations

- **Recommendation 6.1. Develop a dedicated service innovation strategy and action plan.** Such a strategy should be built based on a prospective study evaluating the opportunity to develop high-value-added services, such as intellectual property licensing, ICT services, media, financial services and other business services for innovation, growth and competitiveness. It should be developed in a broad consultation, considering Korea's strengths and prioritising knowledge-intensive service sectors with considerable growth potential.

  Improved co-ordination is necessary between ministries and funding agencies to foster R&D in humanities and social sciences, along with science and technology R&D in STEM disciplines. To better support service R&D, it is important to increase its budget and programmes and establish a separate evaluation system tailored to its unique characteristics, including technology transfer, different from the evaluation system used for manufacturing R&D.

  An action plan should describe specific instruments, timelines, responsible institutions and monitoring mechanisms. Examples of measures could include financial incentives for service innovation (such as grants targeted at innovation in services), specific policies to enhance critical skills for service industries, as well as actions to raise awareness about service jobs as potentially attractive relative to manufacturing.
- **Recommendation 6.2. Address remaining regulatory restrictions on trade in services,** such as foreign equity limits, requirements for foreign service providers to establish a local presence and register, and limitations on their mobility and duration of stay. This could considerably increase the "servicification" of the economy and increase trade in services. This would strengthen not only the competitiveness of the services sector but also the manufacturing industries that rely on service inputs. The Korean government has successfully implemented the regulatory sandbox as an interim policy measure to ease regulations on critical service industries, particularly finance, and to adopt disruptive technologies, especially in the ICT sector. Korea should continue its efforts in this regard. Furthermore, if the regulatory sandbox can facilitate the creation of innovative business

models in heavily regulated sectors, the Korean government should take further steps to eliminate outdated regulatory restrictions in the service sector more broadly.

Recommendation 7: Strengthen the diffusion of innovative technologies to SMEs and support the global connectivity of start-ups

Overview

While Korea has an excellent digital infrastructure, the diffusion of digital technologies to SMEs has been slow. SMEs' absorptive capacity and the pace of their digital transformation can be enhanced through initiatives to strengthen their technology readiness and leverage existing skills more effectively. Furthermore, while start-up entrepreneurship is vibrant in Korea, it can be strengthened further through measures to enhance entrepreneurs' digital proficiency and improve the global connectivity of the start-up ecosystem.

Detailed recommendations

- **Recommendation 7.1. Boost diffusion of digital technologies** by reducing stringent product market regulations, particularly on e-commerce platforms, barriers in service and network sectors and barriers to trade and investment.
- **Recommendation 7.2. Enhance the quality and quantity of labour force skills in SMEs to accelerate the digital transformation.** Low ICT adoption by SMEs is contributing to the large gap in productivity with large conglomerates. To increase the uptake of ICT, the quality of labour force skills could be improved through specialised digital skills training and lifelong learning programmes. In addition, the untapped labour force of women and retired able workers could be incentivised to work in start-ups and SMEs through flexible work arrangements and fiscal incentives, thereby increasing Korea's potential labour supply.
- **Recommendation 7.3. Strengthen SMEs' access to digital and other emerging technologies** by building on recent measures taken during the coronavirus (COVID-19) pandemic to digitalise public services and by supporting the provision of advisory services for helping SMEs tailor digital tools and technology watch services.
- **Recommendation 7.4. Reduce the administrative burden in the provision of government support for start-ups.** This is particularly important in the case of business innovation support at the seed and scale-up stages, which are critical to the success of start-ups. Policies such as the National R&D Innovation Act, which consolidated the existing 264 R&D regulations for each department into a single rule, are indicative of progress already made in this area.
- **Recommendation 7.5. Strengthen the global connectivity of the start-up ecosystem** by conducting more international events that help Korean start-ups connect with relevant foreign experts and by supporting start-ups in developing globally competitive business models and entering foreign markets. To strengthen the global connectivity of Korean start-ups, advice programmes for developing overseas markets could also be valuable, particularly for high-tech start-ups that should cater to an international market.
- **Recommendation 7.6. Remove barriers for firms to invest in data and complementary intangible assets, including software and databases.** Evidence shows that SME productivity growth suffers from barriers to the use of intangible assets as collateral in asset-based financing, which can impede initial investment in these types of assets. Reviewing accounting practices and improving the measurement of key intangible assets is also important.
- **Recommendation 7.7. Implement government support programmes for the adoption of digital technologies by SMEs in a flexible manner aligned with companies' needs.** While the diffusion of digital technologies to SMEs can be enhanced through governmental support

programmes, such programmes are most effective when support for the introduction of digital tools is tailored to individual company needs. An example includes the Korea AI Manufacturing Platform, a "smart factory" initiative where the government makes parallel efforts to establish a database of manufacturing data while private sector providers establish "smart factory" services to manufacturing firms. A holistic approach could provide for broadening the scope of services included to encompass not only manufacturing process optimisation but also energy efficiency, carbon footprint, waste optimisation and other relevant issues. It could also help expand the concept to service sectors, which could benefit from similar improvements.

- **Recommendation 7.8. Promote and disseminate good practices for SME collaboration with large companies, other SMEs and GRIs.** Government support for collaboration should be comprehensive and enable SMEs to create diverse collaborative models, such as: 1) with large companies, to strengthen and expand the value chain; 2) with other SMEs, to share knowledge and experiences within the industrial complex; and 3) with GRIs, to improve R&D capacity.
- **Recommendation 7.9. Increase access to finance for start-ups and strengthen the exit model for a sustainable start-up ecosystem.** Korea has significantly improved financial support for start-ups recently. On top of the current various supporting programmes, equity crowdfunding, which is not among the largest in the current set of programmes, could become a significant vehicle for improving financial access. International good practices show equity financing also has merit in terms of entrepreneurship promotion and research commercialisation.

  Weak exit mechanisms, in terms of mergers and acquisitions (M&As) and initial public offerings (IPOs), have been recognised as a chronic problem in Korean start-up ecosystems. Recent policy changes that permit large companies to own corporate venture capital (CVC) for M&As of prominent start-ups are a step in the right direction, but further IPO and CVC deregulation could enhance start-up finance.

Recommendation 8: Streamline and assess the impact of public support on R&D and innovation

Overview

While Korea's business R&D and innovation are strong, they can be further enhanced by addressing various imbalances and strengthening the role of SMEs, foreign multinational enterprises (MNEs), and creative industries in business innovation.

Detailed recommendations

- **Recommendation 8.1. Reduce regulatory barriers to business entry and exit,** such as excessively stringent bankruptcy laws and barriers to entry in certain sectors, such as accounting, legal, telecoms, broadcasting, and air and rail transport.
- **Recommendation 8.2. Strengthen the global integration of Korean business innovation** by cutting red tape and making it easier for foreign MNEs to do business in Korea. Encourage collaboration on innovation between Korean and foreign firms to enhance MNE investment in research labs in Korea.
- **Recommendation 8.3. Maintain support policies for R&D and innovation by SMEs, including start-ups, while simplifying innovation support.** Decrease complexity by consolidating support into fewer and broader programmes and decrease the administrative burden for applications and reporting of outcomes. Market needs could be the most important criterion to streamline and monitor government support programmes since the accommodation of market signals is likely to enhance the relevance and quality of programmes. The Tech Incubator Program for Startups (TIPS), a widely recognised and successful start-up support scheme, validates the efficacy of a

market-based approach in Korea's business context. This type of market need-based programme evaluation could also be applied to new government support programmes in the form of demand assessment. Korea should also provide appropriate incentives for all innovation activities (including service innovation).

- **Recommendation 8.4. Upgrade the evaluation of publicly supported business R&D and innovation activities** by including qualitative outcomes and quantitative indicators. Encourage radical innovation alongside incremental innovation by providing support for explorative, long-term projects and not tying subsidies to short-term and quantitative outcomes only.
- **Recommendation 8.5. Provide public support for collaborative innovation activities,** such as through the widespread introduction of innovation vouchers that are easy to obtain and use. Encourage technology collaboration between large and small firms (e.g. through collaborative platforms and R&D tax credits) to facilitate technology diffusion to SMEs.
- **Recommendation 8.6. Strengthen support for green innovation,** including green hydrogen and carbon capture, usage, and storage through technology demonstration and deployment programmes, as well as public investment in clean technology infrastructure and networks (e.g. clean power grid extensions and battery storage facilities, electric vehicle (EV) charging stations).
- **Recommendation 8.7. Broaden government support policies for creative industries,** from the provision of financial incentives and export promotion to cultural and global exchanges among creative industries. Encourage Korean entertainment and gaming companies to engage in more responsible and sustainable employment and training practices.
- **Recommendation 8.8. Assess the impact of the current R&D tax credit arrangements** and consider adapting to achieve the best value for money, notably by incentivising academia-business collaboration and collaboration between large and small firms. R&D tax credit arrangements in a number of countries offer significant additional incentives for collaborative research and generate benefits beyond the tax credit received when R&D is undertaken in-house. Furthermore, based on re-examining the design of the R&D tax credit, Korea should focus on strengthening disruptive innovation in firms (often in the service sector). Evidence from OECD countries shows that R&D tax credits primarily favour incumbent firms rather than start-ups. Carry-over provisions or cash refunds, which could benefit start-ups, should be considered to strengthen the effectiveness of R&D tax credit incentives.

1.1.3. Pillar 3: Recommendations concerning the research system and linkages

Recommendation 9: Strengthen universities' ability to conduct relevant and excellent research to serve the needs of Korean society

Overview

The Korean higher education system faces a number of rather daunting challenges, some of which are endemic and some exogenous. The government needs to find more effective ways to encourage and incentivise universities to become stronger institutions (independent, strategic, resilient, relevant and impactful) to handle these challenges for the benefit of both universities and society. This requires rethinking the role of government to become more effective in "nudging" (incentivising) such change.

Detailed recommendations

- **Recommendation 9.1. Strengthen the autonomy of universities and their ability and incentives to become more resilient, relevant and impactful, both nationally and internationally.** This could include:

- Promoting excellence and strategic development through long-term funding (similar to Finland's Flagship Program) instead of the current system of rather small-scale project funding. Part of the funding could be based on long-term strategies and mid-term performance contracts, impact evaluations and programmes that encourage strategic profiling of universities (with regard to research, education and general mission – in particular, addressing societal challenges).
- Strengthening the autonomy of universities, coupled with providing long-term funding, carrying out internal governance reforms and improving strategic management capacity to allow universities (along with public research institutes [PRIs]) to play a key role in implementing national priorities and missions.
- Reviewing current incentive structures at universities and their impact on research excellence, industry-academic co-operation and internationalisation, and adjusting those incentives to better match desired objectives such as net-zero and the digital transition.
- Moving from rather onerous funding allocation and project supervision towards more effective "nudging" (incentivising) of universities to become more strategic, differentiate themselves more, support more breakthrough research, and change recruitment systems. Currently, funding is frequently allocated formally in competition, where universities and researchers dedicate considerable time to filling out applications. However, almost everyone ends up getting funding, and there is little meaningful follow-up, a shift in behaviour or dialogue.
- Allocating funding to teams and encouraging collaboration among faculty across departments and institutions, including multidisciplinary research, for example, to address global challenges and national missions.

- **Recommendation 9.2. Upgrade evaluation and assessment.** Initiate discussions among universities, research funders and policy makers on how to shift research evaluation away from an emphasis on quantitative metrics (number of papers and patents) towards more qualitative assessments. The San Francisco Declaration on Research Assessment (which has not been signed by any institution in Korea) could serve as an inspiration. Incentivise actors to develop and try different approaches (at the university level, research funders, etc.). Produce regular quantitative and qualitative assessments of Korean research quality and long-term impact, taking into consideration international positioning (similar to the Academy of Finland's or the National Science Foundation's reports). The research and innovation assessment framework proposed in Recommendation 3.3 is a way to do this. However, this upgrade should be applied and mainstreamed throughout the research system for project, programme and institutional evaluation.
- **Recommendation 9.3. Enable and encourage research programme funders to promote more high-risk (and potentially more transformative) research and innovation at GRIs and universities.** This can be done by:
  - Adopting a portfolio management approach to R&I funding (i.e. an approach where not all projects are expected to be successful), as is the case in national missions.
  - Enriching and diversifying the research funding landscape by incentivising companies or wealthy individuals to use earnings or wealth to fund academic research (e.g. tax incentives, such as in Denmark or Sweden).

Recommendation 10: Continue strengthening government research institutes to meet the needs of government and industry in the post-catch-up period

Overview

Like PRI systems elsewhere, despite the frequent reorganisations and reforms of recent decades, the Korean PRI system still bears the marks of Korea's fragmented governance culture and its history of

focusing on catch-up. Therefore, there is a need to reinforce the government's efforts in recent years to adapt GRIs better to national industrial and societal needs and to explore the potential for providing more holistic support to policy and smaller firms.

The GRIs organised under the National Research Council of Science & Technology (NST), which focus on science and technology and have been decisive in modern Korea's industrial and economic development, went through a "role and responsibilities" process in 2019, redefining their scope and tasks as Korea moves from industrial catch-up to advanced country status. One implication of this change is that the activities of the GRIs need to be more closely aligned with the evolving needs of industry and society, and the government can no longer dictate the specific tasks GRIs should undertake. Like universities, the GRIs need to be components in a national "knowledge infrastructure" supportive of the needs of the major Korean multinationals, other large Korean firms, and broader society in response to societal challenges. A stronger flow of knowledge from GRIs and universities will support the development of new companies and industries. At the same time, smaller and less capable firms inside and outside the supply chains of the major companies need to improve their technological capabilities to remain competitive.

Detailed recommendations

- **Recommendation 10.1. Building on the Role and Responsibility exercise in which government research institutes revisited their missions, the financing model of the GRIs could be tailored to their missions.** International best practices could be referred to and further developed according to the Korean context, such as research and technology organisation (RTO) models for some GRIs and national research institutes for others. This involves reinforcing GRI autonomy by rebalancing the funding currently dominated by project-based funding with term time horizons of up to three to five years, which are insufficient for developing lines of basic research.
  - On the one hand, there should be an increase in long-term institutional funding under the control of the GRIs themselves. This will allow the GRIs to establish and maintain market-relevant capabilities on which to build their other functions. Specific projects desired by the government can be satisfied via separate contracts.
  - On the other hand, encourage GRIs to achieve a greater proportion of income via contracts with the private sector and (where appropriate) with public authorities that respond directly to client needs and do not require government agency approval. In some cases, such as when supporting companies with limited absorptive capacity, it may be appropriate to support this activity using grants to cover part of the cost.
  - While GRIs should be permitted, and potentially even urged, to compete for project-based funding, particularly for collaborative research ventures with companies, universities and other GRIs, it is important to dissuade competition with the private sector for such funding, as it can result in crowding out the private sector.
  - Allow variation in the financial models of GRIs, based on their specific missions. GRIs needing to conduct large amounts of more fundamental research should receive a larger proportion of institutional funding than those whose other activities are less dependent on research.
- **Recommendation 10.2. Evaluate the performance of the GRIs in relation to their missions.** This entails:
  - Making the GRIs responsible for internal monitoring at the project and programme level, subject to the routine activities of the national audit.
  - Focusing the evaluation of GRIs on their impact on society while requiring break-even financial performance. Generate evidence about other kinds of outputs, but crucially also outcomes and – to the extent possible – societal impacts.
- **Recommendation 10.3. Increase co-production of knowledge between GRIs and universities to strengthen GRIs' more fundamental research capabilities, signal universities**

about the need for use-oriented fundamental and applied research, and increase the quality and relevance of graduate and undergraduate education. This can involve creating joint posts between universities and GRIs, adjunct positions for senior GRI researchers in universities, and allowing GRIs to host PhD students ad hoc and outside the graduate schools in universities. These joint initiatives could be supported by dedicated university liaisons in the tasks of top research management in the GRIs. The objective of strengthening the relationships between GRIs and universities could also be reflected in the formal missions of universities' top senior managers (e.g. "Innovation Vice President").

Recommendation 11: Further develop linkages between universities, government research institutes and business

Overview

To overcome the barriers between academia and industry, co-creation instruments should be designed to facilitate matchmaking and offer financial incentives that bridge the two communities. Unfortunately, these communities do not naturally mix, representing a "social failure" due to their radically different values, time horizons, lifestyles and social circles.

Detailed recommendations

- **Recommendation 11.1. Create incentives and governance arrangements in universities and government research institutes,** including ensuring collaboration with industry, is an official mission of universities and GRIs, at the same level as research (and teaching for universities). Set objectives for GRIs and universities alike concerning private co-financing and collaborative projects in general. Korea should also adapt the monitoring metrics by decreasing the importance of patent count and including: 1) commercialisation and royalty revenue; 2) co-publications; and 3) co-patenting.
- **Recommendation 11.2. Expand "seed" innovation vouchers** with low face value and accessible to SMEs with minimal administrative procedures to initiate a large number of co-operations between academia and industry.
- **Recommendation 11.3. Expand and systemise public-private innovation partnerships,** such as matching grant programmes within the project-based system, whereby government funds match the funds provided by industry for a specific R&D project. Such programmes are widespread in other OECD countries and allow enterprises to reduce the costs and risks associated with R&D and innovation. On the other hand, they can be more efficient than direct grants since the readiness of the industrial partner to pay half the cost warrants their legitimacy and market potential. Comparable and successful models, including the US manufacturing extension programme, should be further studied and referenced.
- **Recommendation 11.4. Further invest in high-visibility infrastructure for science parks and excellence centres, with good networking institutions and public-private governance to foster the development of true collaborative research.** For example, public-private co-operative excellence centres on AI could be further developed to cover different AI applications, including Electronics and Telecommunications Research Institute (ETRI), Naver, Kakao and other public and private actors, to create a Korean AI powerhouse. Similarly, on the Smart Factory initiative, public-private partnerships such as the Korea AI Manufacturing Platform (KAMP) could be further developed with public and private entities, including start-ups, to develop the concept beyond process optimisation and include energy optimisation, environmental optimisation (including carbon footprint) and ultimately expand the concept to service industries.

- **Recommendation 11.5. Organise "triple helix" (academia, industry, government) and "quadruple helix" (include civil society) events** around social innovation (resolving societal challenges). Such events could include specific competitions with grants as prizes for the best proposals.
- **Recommendation 11.6. Further develop technology extension services** that directly support local firms, bringing about pragmatic improvements in their operations and practices with commercially proven technologies. Technology extension services fall between basic business development services, such as business planning and basic marketing, and high-end R&D (such as technology transfer offices and centres of scientific excellence). Such services should provide technology development, transfer and services, proactively addressing SME needs rather than waiting for them to ask (or trying to "push" patents developed at the provider's own initiative). Such services can be provided by technology centres or by extending the task of some universities (as has been done in the US university system).
- **Recommendation 11.7. Develop (temporary) mobility schemes between the public and private sector,** facilitating leave of absence of public research faculty to do a secondment in industry and for researchers from industry to spend time in GRIs and universities. Further develop industrial Master of Science (MSc) and PhD programmes of a dual nature, combining academic studies with practical experiences in research facilities.
- **Recommendation 11.8. Foster the presence and effective functioning of proof-of-concept programmes.** Proof-of-concept programmes could be crucial in bridging the gap between academia's early-stage research and businesses' later-stage development by upgrading technology that is not yet market-ready and facilitating potential business model development.

1.2. Introduction

Korea has achieved remarkable economic growth, stemming from its continued investment in science, technology and innovation. Building on past success, the government recognises the importance of research and innovation, and STI has long been understood as a pillar of the country's economic development. The country leads in private and public R&D investment, the former being particularly high compared to global and OECD standards. It also benefits from a large skills base with an exceptionally large share of the population with tertiary education. On the digital front, Korea represents an exemplary case in terms of building a sound infrastructure, investing in cutting-edge technologies and setting up institutional frameworks for their development.

However, Korea is at a critical juncture where it may need to reconsider the role of STI in its future growth model. The challenges Korea is facing can be captured in two aspects. On the one hand, strong investment records in STI have come at a price, leaving many gaps in the economy and society. The discrepancies are particularly acute in terms of productivity, where the benefits of fast economic development are concentrated in certain sectors of the economy. Investment in applied research fields and industrial competitiveness have helped create companies of global renown but, at the same time, have hindered Korea from exploiting the full potential of its rich experiences and assets. Against this backdrop, on the other hand, Korea is facing a number of societal challenges both internally and externally. The new challenges call for new solutions, and depending on the country's preparedness and openness to novel approaches, such trends can be perceived as either opportunities or threats. Korean society is rapidly ageing, the economy depends economically and socially on carbon-intensive manufacturing industries, and despite the country's leadership, the digital transition may accelerate the already present divide in both the economy and society.

1.3. Overview of the Korean innovation system, its evolution and challenges for the future

1.3.1. Korea is on the path to becoming a global leader in science, technology and innovation

Starting in the 1960s and over the following three decades, Korea successfully transformed from a low-income to a high-income economy. Korea's catch-up process evolved from an inward-looking and import substitution industrialisation strategy into an outward-looking export growth strategy. STI played a central role, with GRIs facilitating the transfer of key technologies to Korea and their very quick adoption by industry, particularly the large conglomerates. In addition, during the 1990s-2000s, Korea undertook domestic reforms to liberalise its economy, which led to a gradual rise in the country's participation in GVCs, with the GVC participation index increasing from around 40% in 1995 to 56% in 2010 (OECD, 2021[3]),[4] and lowered barriers to FDI (the FDI regulatory index declined from 0.532 in 1997 to 0.143 in 2010) (OECD, 2020[4]). GDP grew by an average of 7.9% per year during the 1960-2000 period, and between 2011 and 2021, compound annual growth stood at 2.38%, thus still narrowing the income gap with advanced economies.

Korea is a digital economy leader supported by a sound digital infrastructure, propelled by the government's strong commitment to investment in new technologies and a vibrant and innovative private sector. Since the 2000s, Korea has been far ahead of other OECD countries in terms of fixed broadband penetration and currently has the highest percentage of fibre in total fixed broadband connections (OECD, 2022[5]), which is key to mobile network systems and rising data traffic driven by the digital transformation (OECD, 2020[6]). It was also one of the first movers in 5G technologies, with 5G subscriptions reaching 19.4 million (26.8% of total mobile subscriptions) by October 2021. Already in 2019, Korea issued a national 5G strategy, "5G+", to integrate advanced devices and services across upstream and downstream industries into the 5G infrastructure (MSIT, 2019[7]). In parallel, the government formulated the 2019 Five-Year Development Programme for Quantum Computing Technology and the 2020 Strategy for Artificial Intelligence. Major Korean ICT firms are also aggressively pursuing cutting-edge technologies. In 2022, Samsung announced it would invest USD 356 billion in semiconductors, biopharmaceuticals and telecommunications over the next five years to lead in new next-generation telecommunications and robotics industries. Moreover, in 2019, Korea ranked fourth among OECD countries in transforming its government into a user-driven and fully digital platform that helps ensure a more comprehensive approach to the digital transformation of the public sector. It is also increasingly using data-driven regulation as a complement to traditional regulatory tools, which, by improving transparency and reducing information asymmetries, can steer the market in the right direction (OECD, 2020[8]).

Korea contained the spread of the COVID-19 virus effectively from the early outset of the pandemic. Damage to its economy from the crisis was relatively limited, owing to the government's swift and effective measures to protect households and businesses. Real GDP increased by 2.6% in 2022 with continued strong export growth, rising investment and continued policy support (OECD, 2021[9]; 2023[10]). STI policies were driving Korea's efforts to navigate the health crisis. Both targeted sectoral and horizontal measures supporting digital cross-border sales, the automation of administrative processes and the establishment of digital one-stop-shops significantly accelerated SMEs' incorporation of digital tools, thereby increasing their ability to address business complications arising from COVID-19 early (Bianchini and Kwon, 2021[11]). Additional measures included the implementation of the self-quarantine safety protection app from the outset of the pandemic to better monitor symptoms and quarantine compliance, as well as applications to overcome the shortage of masks by providing information on real-time mask stocks (OECD, 2022[12]) by Korean information service firms Naver and Kakao.

Korea has the second-highest R&D intensity among OECD countries, driven by high business enterprise expenditure on R&D (BERD). Korea's gross domestic expenditure on R&D (GERD)

represented 4.6% of GDP in 2020,[5] second only to Israel among OECD countries. The annual growth rate of R&D has been steady at 7% for the period 2011-19, growing faster in business enterprises (8%) than in government (4%) and higher education institutions (4%). The vast majority is attributed to exceptionally high BERD, which was also the second-highest after Israel among OECD countries (3.7% of GDP in 2020). Large firms spend 62.5% of the total, while the rest is shared among SMEs (25.4%)[6] and venture firms (12.1%) (Statistics Korea, 2022[13]). The composition of BERD by firm size and industry has remained largely unchanged for a decade. Expenditure for publicly funded research is also among the highest in OECD countries, as Korea ranks fourth in terms of government budget allocations for R&D (GBARD) after the United States, Germany and Japan. In terms of sector performance, public research is concentrated in GRIs more than in universities, with the highest level of government expenditure on R&D (GOVERD) among OECD countries (0.46% of GDP). Higher education expenditure on R&D (HERD) is slightly below the OECD average (0.38% vs 0.41%) (Statistics Korea, 2022[13]).

Korea's large investments in R&D and innovation in terms of human and financial resources appear to have only partially paid off in terms of increased innovation outputs. R&D outputs in quantitative measures, such as the number of patent applications and publications, are globally leading and steadily increasing: between 2006 and 2020, scientific publications per million inhabitants increased from 895 to 1 741 (OECD average 1 214). However, the productivity of scientific production remains low. For instance, the percentage of publications in the global 10% top-cited journals is around 8%, placing Korea in the bottom third of OECD countries (OECD, 2022[14]). Furthermore, the number of firms with self-reported innovations is relatively low, with about 40% (United States: 63%; Germany: 61%; Switzerland: 72%) (OECD, 2022[15]).

A highly skilled human resource base offers strong potential for future growth if utilised effectively. Korea's share of the younger adult (25-34 years old) population with tertiary education stands at 70% and is the highest among OECD countries and partner economies (OECD, 2022[16]). Among those, STEM graduates represent 31%, above the OECD average of 27% (OECD, 2021[17]). In the most recent OECD Programme for the International Assessment of Adult Competencies (*PIAAC*) survey (OECD, 2019[18]), Korea scores significantly above average in literacy and numeracy, though average in problem solving in technology-rich environments (OECD, 2019[18]). However, the International Institute for Management Development (IMD)'s university education ranking based on an employer survey shows low employer satisfaction with Korean graduates, placing Korea at rank 48 out of 63 in 2020 (IMD, 2021[19]).

1.3.2. Striking a balance: Achieving economic growth and development for all in Korea

Korea has a wide productivity gap between the service and manufacturing sectors and between firms of different sizes. This is, for instance, reflected by the low value added per employee in services, which is only 60% of that in the manufacturing sector, a gap wider than in most OECD countries (OECD, 2022[20]).[7] Labour productivity in the ICT industries is the highest relative to total productivity among OECD countries at 280%. However, the disparities between ratios of ICT manufacturing and ICT services productivity to total productivity are the widest in the OECD, with 4.9 and 2, respectively (Germany: 1.7 and 1.5; United States: 2.3 and 2.2), showing that in view of Korea's strengths in ICT, productivity in ICT services has more potential to grow (OECD, 2022[20]). In addition, despite the relatively high diffusion of digital technologies in Korea (in particular world-leading fixed broadband and 5G subscriptions), Korean firms, notably SMEs, still lag in the adoption of crucial technologies, not least because workers in SMEs tend to be older and less skilled in digital technologies, in spite of both horizontal and sectoral policies supporting the rapid uptake of digital technologies prompted by the COVID-19 pandemic (Bianchini and Kwon, 2021[11]). In an effort to support service industries, the government announced the Service R&D Promotion Strategy in 2020 and pledged to invest KRW 7 trillion (Korean won) for five years starting in 2021.

Significant regional disparities exist in Korea, particularly between the capital region (Seoul, Gyeonggi and Incheon) and the rest of the country. For instance, 64.5% of R&D organisations (universities, PRIs and firms) are centred in the capital region, and 69.8% of national R&D investment occurs in the capital region, while the rest is spread across the 15 metropolitan cities and provinces, each with less than 3% of the total (KOSIS, 2022[21]). Efforts to promote regional innovation include four additional special R&D zones ("innopolises") to foster the development of new technologies and their commercialisation. In 2019, 12 "innotowns" were additionally created to sharpen the focus on technology transfer from universities and GRIs to regional firms. The government seeks to transform the landscape and unleash the potential of regions by including the Regional Balance New Deal as one of the pillars of the Korean New Deal 2.0.

Korea's population is markedly polarised by age group, posing threats to economic viability. While the Korean STI system benefits from a highly educated younger population, the rising old-age dependence ratio is expected to be the second-highest in 2050 (OECD, 2022[22]).[8] Korea also showed the highest poverty rate after taxes and transfers for those between 66 and 75 years of age among OECD countries, straining the overall economy as fewer young people will have to bear the costs for an ever larger share of the old-age population (OECD, 2021[23]). Furthermore, the concentration of high-skilled young employees in cities risks exacerbating the already increasing inequality across age groups, largely due to the dichotomy between conglomerates and SMEs, leaving less skilled and, in particular, the old-age population in rural areas behind. Korea has the largest difference in tertiary educational attainment between the group of 25-34 year-olds (70%) and the 55-64 year-olds (25%) in the OECD (OECD, 2021[17]). The threat of increasing gaps in access to talent between large companies and SMEs crucially risks reducing the latter's innovation capabilities.

Gender equality has improved, but there is still much room for improvement. The female labour force participation rate increased from 49% in 1990 to 59% in 2020.[9] However, it is still below the OECD average of 65% (Switzerland: 80%; Sweden: 80.3%; Germany: 75.8%; Japan: 72.5%). Most of this increase has occurred in the services sector, which is less productive. Furthermore, only 24% of STEM entrants are women (Germany: 40.6%; United Kingdom: 32%) (OECD, 2022[24]). As part of Korea's most recent Basic Plan, of which four have been published since 2004 with five-year cycles, the dimension of "gender innovation" was included. This set a standard for a gender-responsive approach to innovation, aiming to improve female participation rates in science and engineering.

1.3.3. Several of Korea's strengths risk widening industry gaps even further

Korea exhibits a high productivity gap between large firms and SMEs, particularly micro-firms. More than 83% of Korean workers are employed by SMEs, the second-highest share in the OECD. The contrast is even larger when considering micro-enterprises with fewer than ten employees, which employ many more than the OECD average and contribute much less to the aggregate value added (OECD, 2019[25]). Furthermore, the high business concentration in leading companies is demonstrated by the fact that the four largest chaebols (Samsung, Hyundai Motor, SK and LG) accounted for 48.5% of sales among the top 71 business groups in Korea in 2020 (Pulse, 2021[26]). SMEs dominate the service sector, but their higher value-added activities are concentrated in manufacturing rather than services, and overall labour productivity levels of SMEs are only around 26% (OECD, 2022[27]) of that of large firms. Reasons behind their lagging performance include operational deficiencies due to low adoption of new technologies; a digital skills gap among old-age workers; and a dual labour market whereby large firms attract talent through better working conditions. Recent training initiatives launched by the Korean government have emphasised the importance of lifelong learning, including continuous upskilling of employees to ensure their preparedness for new technologies.

A traditionally strong manufacturing sector has allowed Korea to become an industrial powerhouse. The contribution of manufacturing to national income amounted to 27.1% in 2020, the

second-highest share among OECD countries,[10] and has underpinned Korea's export-driven growth model. Korea continues to benefit from its world-leading competitive position in manufacturing. A strong manufacturing base may increase resilience towards external shocks and allow for the expansion of related services industries, which are often dependent on the strength of the former (Pisano and Shih, 2012[28]). In particular, the accelerated development of new technologies will create new competitive advantages for manufacturing companies that are able to integrate these technologies and develop innovative new service-based business models. This process, sometimes called the "servicification" of manufacturing, can help companies create new revenue streams, improve customer satisfaction and differentiate themselves from their competitors.

Compared with other advanced economies, Korea exports relatively few services; of those, a large part belongs to lower value-added sectors. Korea's 35% share of domestic value-added services exports in 2018 was significantly lower than the OECD average of 52% (Germany: 47%; Singapore: 71%; Switzerland: 56%) (OECD, 2021[3]). In addition, about 65% of Swiss exports in services are high value-added, notably royalties and license fees, financial services, miscellaneous business services and IT services. Singapore shows a comparable composition, whereas Korean services exports comprise markedly lower value-added segments, such as travel, transport and construction services (almost 60%) (OEC, 2022[29]). In contrast to the OECD average of 40.7%, Korea's employment in knowledge-intensive services stood at 28% of total employment (Singapore: 54.3%; Switzerland: 52.9%) (World Bank, 2022[30]). Adopting such a cross-country perspective suggests that a stronger orientation towards higher value-added services may offer Korea vast opportunities for growth while simultaneously strengthening related manufacturing industries.

Korea's service sectors would benefit from increased business expenditure for R&D for services innovation. With BERD in services only amounting to 10% of total BERD in Korea, compared to the United Kingdom (59%), the United States (37%) and Germany (14%) (OECD, 2022[14]), Korea could benefit from untapped potential by extending its focus to service industries. The manufacturing sector accounts for 87.5% of BERD in Korea (comparable to the People's Republic of China [hereafter, "China"] at 88.4% and Germany at 85.4%), of which 91.2% is in high and medium-high R&D intensive industries (Germany: 92%; China: 60.6%). On the other hand, only 10.6% is dedicated to services and 4.8% to information and communication services (France: 13.7%; United Kingdom: 15.5%; United States: 25%; Israel: 43.7%) (OECD, 2022[14]). The rise of the digital economy is driving the trend of "servicification", in which manufacturers increasingly offer services alongside their products. This trend offers the potential for significant innovation in services.

1.3.4. Korea has benefitted strongly from global integration but has yet to fully exploit its potential

Korea's embeddedness in GVCs has enabled and facilitated rapid economic advancement through its export-led growth model. The foreign value added (FVA) share of gross exports represents the country's integration in GVCs. In Korea, the FVA increased until the mid-1980s, followed by a downward trend until the 1990s, rebounding again around 1996 when Korea joined the OECD. The 1980s and 1990s were when Korea's technology import strategy started to materialise as its firms successfully shifted from light to heavy and chemical industries (HCI).[11] Korea escaped the middle-income trap by increasing its share of local value added in its high-value-added exports and constructing its own industrial base through technological catch-up, which allowed it to move up GVCs (Lee, Szapiro and Mao, 2017[31]). Korea still maintains a relatively high level of FVA at 32% in 2018, which is 11th among OECD countries, next to Estonia (35.3%) and the Netherlands (33%), and higher than comparator countries of similar size – France (24.3%), Italy (23.1%) and the United Kingdom (17.8%). Countries' sectoral specialisation shapes the extent of their backward and forward participation; a high level of FVA is typical of countries that specialise in advanced manufacturing, as they rely on imported inputs for exports. An interesting observation is that Korea's backward participation has decreased since 2015, which may indicate that it has moved to

innovative activities that require a higher level of R&D intensity and increasing IP receipts as a share of GDP (World Bank, 2020[32]).

Several factors have revealed Korea's vulnerability to disruptions in global supply chains in high-technology sectors, pushing Korea to consider technology sovereignty as a policy priority. Currently, Korea faces a combination of global trends. This includes changing prices of intermediate inputs; the reshoring of certain production facilities by some countries; a reshaping of the regional context where China has increased its presence as a supply hub for global trade; and rising trade tensions with Japan. Geopolitical tensions between the United States and China could potentially impact Korea's position in high-technology sectors, considering its close ties with both countries. As a traditional ally of the United States, Korea is considered a country with which the United States can co-operate, e.g. in the semiconductor sector and others, such as large-capacity batteries and pharmaceuticals, while pursuing its efforts to increase the resilience of the global supply chain (The White House, 2021[33]). At the same time, China remains an important economic partner that accounted for 43.2% of semiconductor exports and 31.2% of imports in 2020, with the latter being mostly intra-firm trade with local fabrication plants of large companies, such as Samsung Electronics and SK Hynix (KIET, 2021[34]). In order to manage the immediate risks and seek long-term opportunities, relevant ministries jointly designated 12 "critical and emerging technologies"[12] that have strategic value for Korea. These technology areas will benefit from comprehensive government support, including increased R&D investment, tax benefits and technology protection measures.

Korea can alleviate the challenges by deepening the level of its regional integration. Notwithstanding that technology sovereignty has become more critical for Korea over the years, it should be balanced with efforts to diversify its trade partners and commodities, considering the relatively smaller size of the economy. While being deeply embedded in GVCs, Korea can offset the risks related to reliance on imports of intermediate goods by consolidating its regional integration, e.g. strengthening economic ties with the Association of Southeast Asian Nations (ASEAN) region. Since the Korea-ASEAN Free Trade Agreement came into force in 2007, trade in both directions expanded quickly, and in 2019, ASEAN was the second-largest partner for Korea in terms of trade volume (15.6% of total imports and exports). On the firm level, the growth potential of the region was well perceived by Korean firms, as evidenced by the partial shift to offshoring of large companies (such as Samsung and LG) to Viet Nam. The number of companies settling in Viet Nam or having created branches is bigger (3 234) than in China (2 233) (KITA, 2021[35]). However, Korea is facing growing competition, particularly with China and Japan, due to the similarity in merchandise trade structures of exports (IIT, 2019[36]). In order to compensate for this and to ensure the stability of trade relations with the region, engaging in deeper regional trade agreements could be considered an option. Regional trade blocs provide common disciplines that help address credibility issues and internalise cross-border policy spillovers (Ruta, 2017[37]). The effect tends to be stronger in sectors that are more deeply integrated in GVCs, which is the case for many high-tech sectors in Korea.

FDI, in particular towards knowledge-intensive sectors, is not yet leveraged to its full extent. Following its accession to the OECD in 1996, Korea has liberalised FDI, as witnessed by the fall in the OECD FDI Regulatory Restrictiveness Index from 0.532 in 1997 to 0.135 in 2020. This compares to the OECD average decrease from 0.127 to 0.063 in the same period (OECD, 2020[4]). Despite such significant improvement, Korea was still the sixth-most restrictive OECD country in 2020, remaining above the OECD average. Overall FDI inflows have stagnated at around 0.6-0.8% of GDP in recent years, about one-third of the OECD average (OECD, 2022[14]). While hardly any trade and investment restrictions apply to the manufacturing sector, some service industries, such as communications, pose conditions, including foreign equity limits of 50% (OECD, 2022[38]). Besides factors such as equity restrictions or limitations with regard to the mobility of key foreign personnel, evidence suggests that informal institutions also impact FDI decisions. Notably, strong social capital, meaning trust-based networks of individuals and local firms in which foreign entities can be integrated, positively drives inward investments (Mondolo, 2019[39]). In this regard, Korea has the potential to benefit from deepening business networks and global integration.

Korea is not fully leveraging its traditionally open policy towards talent immigration. The government has set up a comprehensive migration framework for foreign tertiary graduates. As a result, foreign students registered in Korean tertiary programmes increased by 91% during 2010-19, with the majority originating from East Asian countries. Even so, only 2% of university students are foreign nationals (KESS, 2022[40]). Similarly, immigration via professional routes, such as work-visit programmes for ethnic Korean foreign nationals, has seen an influx of Chinese migrants, who make up about half of the 3.7% of foreign residents among the economically active population. In 2003, Korea launched one of the largest temporary employment permit systems in the OECD, both in absolute numbers and relative to the labour force. It targeted SME personnel needs in particular, as SMEs are affected by shortages of employees with practical skills. In view of a drastically ageing population, these shortages for SMEs are likely to intensify. Korea has restructured its migratory framework to attract highly skilled workers by adopting various policy measures, including a points-based system allowing skilled migrants to settle based on the fulfilment of professional criteria and an accelerated path to permanent residency. Nonetheless, few international students and workers remain in the country long-term due to stringent working conditions and hierarchies; gender disparities; a highly competitive job market for tertiary graduates; difficulties in enrolling their children in the education system; and closed social networks (Shin and Choi, 2015[41]; InterNations, 2021[42]).[13] In addition, some regulatory complexities remain, such as around 170 sub-categories for study, employment and family permits (OECD, 2019[43]). Integrating skilled immigrants into the local labour force could spark new ideas, facilitate knowledge diffusion and foster the creation of new businesses, as they tend to have a higher propensity for risk taking.

1.3.5. Societal and structural challenges and Korea's preparedness for transitions enabled by science, technology and innovation

Korea has demonstrated a clear commitment to tackling societal challenges, which benefits from broad-based public support, e.g. combating climate change. According to the Green Future Index,[14] Korea is ranked 10th among the top 20 countries making the greatest progress toward building a low-carbon future, next to Germany and Sweden (MIT Technology Review, 2022[44]). Among the five pillars, Korea leads in three dimensions: "energy transition" (eighth); "green society" (first); and "clean innovation" (eighth).[15] The recent OECD survey on climate literacy shows that Korea is on par with the United States and European countries (Dechezleprêtre et al., 2022[45]; OECD, 2022[46]). The overwhelming majority of 94% out of 1 500 respondents answered that climate change is an important problem, and as in many OECD countries, climate policies received considerable popular support.

In terms of the green transition, Korea needs to overcome its reliance on carbon-intensive manufacturing sectors. The CO_2 intensity of GDP[16] in Korea dropped from 0.52 kg in 2000 to 0.28 kg in 2018 but remains above the OECD average (0.20 kg) and higher than its comparator countries (France: 0.10 kg; Germany: 0.15 kg; Japan: 0.21 kg; United States: 0.24 kg) except for China (0.47 kg). Korea also displays one of the highest energy intensities and ranks 92nd out of 143 countries as measured by the International Energy Agency (IEA) in terms of energy consumption per GDP (IEA, 2021[47]). The high performance of carbon-intensive manufacturing sectors, such as petrochemical, iron and steel, largely explains this. Korea's coal-fired power plants were the largest, both in absolute volume and by share in energy generation (which accounted for 86.9% of greenhouse gas [GHG] emissions in 2018) (Ministry of Environment Greenhouse Gas Inventory and Research Center, 2020[48]; IEA, 2021[47]). Fossil fuels accounted for 73% of power generation in 2018, of which coal was 44%.

Various policies have been put in place to support the green transition, but overarching concerns about economic growth and exports, employment, and geopolitics still take precedence over climate change. Since the 2010 Framework Act on Low Carbon, Green Growth created the legal framework for setting mid- to long-term emission reduction targets, the country has adopted the Korea Emissions Trading Scheme (K-ETS) and the GHG and energy target management system. More recently, in 2020, the Korean government committed to becoming carbon neutral by 2050 and reducing emissions

by 40% in 2030 compared to 2018. Currently, 96.5% of emissions are covered by effective carbon rate, which puts Korea first among the Group of 20 (G20) countries, followed by Canada (88.2%) and Germany (88.1%) (OECD, 2021[49]). The government also defined a list of critical technologies that needed to be developed to realise carbon neutrality as R&D investment areas. However, as mentioned above, policy makers' focus on investing in technology,[17] where Korea is already performing better than any other economy, needs to be balanced with acknowledging and handling industry resistance to transformative change (e.g. in phasing out fossil fuels). A need remains to formulate more specific action plans towards reducing GHG emissions over the next decades (Lee and Woo, 2020). As a start, Korea recently introduced policy measures, such as the Support Measures for Fair Job Transition, in response to industrial structure change in order to increase social responsiveness to the green transition.

Within the private sector, there is an increasing emphasis on corporate social responsibility and environmental sustainability, although it remains unclear to what extent Korean companies have altered their behaviour towards more sustainable practices. Many companies work towards receiving high corporate environmental, social and governance scores, which are widely calculated and published. As per K-ETS, since the start of its first phase in 2015, the three highest-emission industries in the manufacturing sector[18] saw a significant increase in carbon productivity after participating in the scheme (Jung et al., 2021[50]). Also, as of 2021, 13 Korean companies, including large conglomerates such as SK Hynix and LG Energy Solution, have joined the Renewable Energy 100 (RE100) campaign, a voluntary initiative that brings together over 300 companies worldwide committed to 100% renewable energy to power their operations.[19] In particular, Korean conglomerates have assumed leading roles in specific green technologies, such as the manufacturing of batteries for electric cars. However, the rapid introduction of carbon reduction targets is widely perceived as a threat to companies' competitiveness and jobs. Thus far, the Korean track record on mitigating global warming is not positive, as carbon emissions per unit of GDP are high and have increased until 2018. Unless emissions are reduced soon, Korean exports may face carbon import taxes in other countries.

Korea faces declining growth prospects due to rapid ageing, adversely affecting its labour supply. With skilled labour among the most critical factors determining a country's success in innovation, having a sufficiently large and tech-savvy labour force is vital to reducing skills mismatch. Korea's projected economic trajectory shows particularly high vulnerability to this trend, most notably when considering the very long term. As such, the annual GDP growth rate is projected to reach the lowest level among OECD countries in 2030-60, at 0.8%. By 2050, more than one-third of the population will be over 65, while over half of the labour force will be above 50. More specifically, the 10.8% growth rate in the number of seniors between 2000 and 2018 was already the second-highest among OECD countries, far exceeding the 4.1% OECD average (OECD, 2021[51]). This is partly due to the widespread seniority-based approach in human resource management practices, where senior employees are pushed to leave their jobs around the age of 50 (mandatory early retirement or "honorary retirement") to settle in low-productivity service sectors with their severance payments (OECD, 2018[52]). These trends underscore the importance of previously mentioned imperatives, such as lifelong learning, as the old-age workforce will become increasingly important for Korea's economy by size. In parallel, this increases the need for skilled employees who are knowledgeable in contemporary technologies. In the meantime, the shrinkage of the talent pool is at this stage unlikely to be significantly compensated by an influx of skilled migrants, considering its slow evolution.

Korea's restrictive product market regulations may also hinder progress in digitalisation in terms of pursuing cutting-edge innovation and diffusing existing technologies. Korean product market regulations are among the most restrictive among OECD countries, imposing barriers to trade, competition and business operations. In 2018, it remained among the most restrictive OECD countries in terms of state involvement in business operations, including in price controls, command and control regulation, as well as trade and investment regulations, such as tariff barriers and restrictions in the service sector (OECD, 2022[53]). These restrictions limit market competition and thus may impede investments in innovative digital

technologies needed to remain competitive. They also hurt productivity growth with specifically adverse effects for SMEs.

The digital transformation, despite its benefits, has the potential to accelerate digital and other divides. For all OECD countries and beyond, the rising demand for ICT skills poses the threat of widening the gaps in income and productivity between age groups, large companies and SMEs, to a larger extent in Korea, as well as the geographical divide between more and less innovative regions, unless addressed by appropriate policies. Despite the continuous policy attention given to its traditionally strong ICT sector and emerging technologies, Korea is at particular risk for all of these factors since it is expected to have the highest population dependency ratio in the world by 2060, which may be exacerbated by aggravating generational educational gaps (OECD, 2018[52]). Therefore, the digital transformation may also further widen the productivity gap between SMEs that face a shortage of skills, and thus, absorptive capacities for technology diffusion, and large firms that benefit from top talent. This may, in turn, further increase the concentration of innovative activities in urban areas. Furthermore, as data becomes increasingly important for innovation, those firms with superior access will benefit disproportionately, potentially increasing market concentration within and across sectors.

Conversely, digital technologies could help reduce such divides if effectively disseminated throughout society. They often require less fixed ICT investments (e.g. cloud computing alleviates the need for large storage capabilities) and increase productivity. The digital transformation also offers better access to public services across demographics and geographies and facilitates teleworking, which may lead to workers settling in rural areas for a better lifestyle; such trends should be encouraged. Moreover, the digital transformation has the potential to spur the development of new industries, such as data centres and smart factories, which are often located on large manufacturing sites outside of major cities and can contribute to reducing regional disparities.

1.4. Business sector R&D and innovation in Korea

Korea's developmental catch-up strategy has helped the country build a dynamic business sector that acts as an engine for the growth of the knowledge-intensive economy. Despite this impressive achievement, there remain widespread discrepancies in innovation and productivity among firms, notably between a small number of extremely successful conglomerates and under-performing SMEs and within industries between world-leading manufacturing and a lagging service sector. Furthermore, as outlined earlier, Korea faces several headwinds that require immediate action sustained over the next decade or two. These include global technology competition; demographic and labour market challenges; income and social inequality; and climate change, all of which will affect the ability of Korea's business sector to remain a source of growth and competitiveness in the future.

1.4.1. General diagnosis of Korea's business sector R&D and innovation performance

Korea's business R&D investment is very strong. At first glance, Korea's business R&D and innovation performance is strong in quantitative terms. Korean firms' R&D expenditures have more than doubled in the last decade, from USD 39 billion in 2010 to USD 82.3 billion in 2019. Business R&D intensity amounted to 3.73% of GDP in 2019, the second-highest among OECD countries. However, a closer examination reveals some fragilities in Korea's business R&D structure. Not only is business R&D heavily concentrated within industrial conglomerates ("chaebols"), ten of which accounted for 47% of business R&D in 2019, but the growth in business R&D has been led by only four of these chaebols, suggesting that business R&D spending in non-leading chaebols is weaker (Chung and Ratnovski, 2016[54]; Shin, 2017[55]). The concentration of R&D expenditures can be both a strength and a weakness. It is a strength because large chaebols rely less on external finance for R&D investment. However, it may also be a weakness, potentially exposing Korea to the "Finnish scenario", where the failure of a major technology group (Nokia) to

anticipate market and technology changes led to a drop in R&D spending and associated knowledge spillovers throughout the economy.

Korea is among the world leaders in patenting, especially ICT patents. Korea has established itself alongside innovation leaders such as Germany, Japan and the United States as a major player in technological innovation. The number of Korean patents filed under the Patent Cooperation Treaty (PCT) increased from 8 731 in 2009 to 15 523 in 2017, while its share of PCT patents in the ICT and biotechnology industries grew from 9.6% and 4.2% of the OECD total in 2009 to 11.9% and 7.5% in 2017, respectively (OECD, 2021[56]). At the same time, patenting in the new growth sectors, including green technologies such as hydrogen, battery storage or carbon capture storage technologies, has been increasing, and Korea is catching up with some key competitors. For example, concerning hydrogen technology development, Korea (0.90) is approaching the level of Germany (1.19), Japan (1.17), Austria (1.05) and Denmark (0.98) in terms of global patent applications per million population in 2018.[20] However, technological progress in green tech is more complex than technological innovation in the ICT sector for several reasons. For one, private investment in green technologies is subject to many market and policy failures, such as the inability to price in negative externalities from CO_2 emissions, for example, through carbon pricing. While Korea has the most advanced carbon emissions trading scheme in Asia, carbon prices have decreased to an average of EUR 10.34 per tonne of CO_2, down by EUR 3.96 since 2018 (in real 2021 euro) (OECD, 2021[49]). Another reason is that clean energy innovation, especially at its frontier, relies on strong input from basic science and builds on a strong relationship between business and public research, an area where Korea needs further improvement.

From a qualitative perspective, Korean firms' innovation performance is significantly less strong. The OECD 2019 release of *Innovation Indicators*, which provides a country-level aggregate picture of innovation performance, placed Korea at 25th out of 36 OECD countries and partner economies (OECD, 2020[57]). More specifically, between 2017 and 2019, 23.8% of Korean manufacturing companies introduced a new product, and 28.3% developed a new business process, whereas, for the EU27, the respective shares were 25% and 30.3%. Firms mostly rely on formal R&D, internal sources of information and in-house activities when innovating. Most innovation is incremental, with 85.9% of firms focusing on improving goods and services compared to 39.8% that seek to introduce new products and services. Furthermore, Korean manufacturing firms' self-assessed degree of innovativeness is low, with a reported score of 3.0 on a scale of 1 to 7 (STEPI, 2020[58]).

Meanwhile, the internationalisation of business R&D is comparatively low. R&D spending is dominated by domestic companies, with only 3.9% of all R&D in manufacturing industries due to foreign companies in 2018. R&D by foreign companies is increasing, albeit from a very low base of 60 foreign entities engaged in R&D activities in 1999 to 375 in 2014 (Hemmert, 2020[59]). In addition, business R&D mostly consists of firms' in-house activities. The relative share of external R&D is only 6% of all R&D expenditures in 2019, compared to 23.7% in Germany in 2017 and 17.2% in Japan in 2020 in the manufacturing sector (KISTEP, 2021[60]).

Korean firms recognise the need to innovate, but most face significant barriers. The high cost of innovation and a lack of internal finance and access to information are the most frequent innovation barriers for Korean firms (STEPI, 2021[61]). While large firms tend to innovate frequently and successfully by leveraging their strong in-house R&D resources and capabilities, there appears to be a lack of technology diffusion to SMEs due to the inability to attract the best and brightest, who are hired into the conglomerates.

1.4.2. Imbalance in R&D performance between large firms and SMEs

While the high share of R&D performed by large firms is not unique to Korea, the concentration is much higher than in other developed countries. Some 47% of corporate R&D is undertaken by Korea's top-ten largest companies. Further, the R&D expenditure of the top 30 sales companies has risen, whereas the R&D expenditure of companies with sales rank from 31st to 70th has decreased year on year (KISTEP,

2021). Furthermore, OECD analysis of start-ups indicates that young businesses in Korea significantly contribute to net job creation but have a low survival rate and low average employment growth after entry (OECD, 2020[62]). In addition, access to finance, bankruptcy regulations and contract enforcement have been found to play a very important role in explaining cross-country differences in young firms' employment growth, e.g. (Calvino, Criscuolo and Menon, 2016[63]). These characteristics hint at the possible existence of barriers to scaling up.

SMEs are the primary focus of governmental support for business R&D, but the fragmentation of support programmes could be reduced. Korea ranks among the OECD countries with the highest level of total government support to business R&D as a percentage of GDP, at 0.29% in 2019. In 2019, SMEs accounted for 77% of R&D tax relief recipients, while the share of R&D tax support accounted for by SMEs amounted to around 54% (OECD, 2021[64]). At the same time, the generosity of tax incentives for large firms has been steadily reduced over time and is relatively low among OECD countries. Furthermore, while tax credits for large firms are capped at 2% of R&D spending, there is no ceiling for the R&D tax credits for SMEs, so the implied R&D tax subsidy rate for profit-making SMEs was 26% in 2021. Although there is no apparent negative effect on business R&D at the aggregate level, it is still necessary to conduct a more comprehensive evaluation of how this has affected the R&D investment of large firms. Meanwhile, direct support for SMEs is rather fragmented across many field-specific programmes run by government agencies. The online portal for SME support policies created by the government lists over 400 separate programmes related to technology support. While a minor part of the subsidies needs to be paid back for non-successful projects, performance evaluation standards are lenient. The highly specific scope of many support programmes could lead to inefficient use of public resources, causing possible overlaps between different programmes and, at the same time, hindering individual programme recipients from utilising the best resources.

1.4.3. A wide productivity gap between ICT and non-ICT industries

Korea's ICT industry has achieved remarkable growth and maintained robust potential for further innovation. Its competitiveness is outstanding on the global stage, and the industry has been a main driver for economic growth in Korea. Korea ranked top in ICT value added (10.4%), ICT employment rate (4.6%) and the ICT patent ratio (62.8%) in OECD countries (OECD, 2017[65]). Meanwhile, from 2010 to 2018, the share of domestic value added in knowledge-intensive industries has substantially increased; however, it was not created equally across business sectors. In particular, value added in ICT has increased by 75%, outpacing other manufacturing industries (29.2%).

The productivity gap between ICT and other industries is significant. The Korean economy's success formula, export-led growth in key manufacturing industries and targeted support to a small set of information technology (IT) sectors drove growing productivity gaps in Korea. While the productivity of Korean ICT manufacturing stands at 294% of economy-wide productivity, compared to 163% for the OECD average, the productivity of other sectors remains at half that of ICT manufacturing (OECD, 2020[62]).

1.4.4. Large discrepancies between manufacturing and service industries

Service firms perform little R&D compared to manufacturing. The share of non-manufacturing R&D among business R&D in Korea was only 10.6% in 2019 (KISTEP, 2021[60]), compared with an average of 29.2% across the United States, Japan, Germany, the United Kingdom and France in 2016 (OECD, 2021[56]). Furthermore, the R&D intensity (the ratio between R&D expenditures and sales) is much higher among Korean manufacturing firms than service firms. It was 4.49% in the manufacturing sector and 2.21% in the service sector in 2019 (KISTEP, 2021[60]) (KISTEP and Ministry of Science and ICT, 2019[66]).

There is a wide productivity gap between the manufacturing and service industries. Productivity in the service sector is 43% of that in manufacturing (OECD, 2020[62]). The productivity gap mirrors wage

disparities, leading to a lack of talent in service industries. Furthermore, another significant disparity between manufacturing and services can be found in GVC integration. While Korea ranked 7th among manufacturing hubs in GVCs, it ranked only 21st among services (OECD, 2021[3]).

In addition, there is scope to increase value added in both services and manufacturing. With the development of ICT technologies, services are increasingly embedded in manufacturing products, and Korea has the potential to increase the "servicification" of the manufacturing sector (OECD, 2021[67]). Korea is strong across manufacturing sectors, from more basic production industries like steel to advanced electronics, and high value-added services (including exports) typically originate from a strong manufacturing base. For example, there are many services attached to a Samsung cell phone or a Hyundai vehicle, but few domestic services are embedded in manufacturing. In fact, the contribution of domestic services to manufacturing exports is one of the lowest among OECD countries at 15%, while the OECD average is 28% (OECD, 2021[3]).

1.4.5. Korea is building a vibrant start-up ecosystem

Korea has a vibrant start-up ecosystem supported by active government support policies. Enterprise birth rates, measured as the share of new enterprises over existing ones, are high in Korea, at 15.1% compared to 11.4% in France and 6.9% in Germany (OECD, 2022[27]). Furthermore, the number of technology start-ups, particularly in ICT and biotechnology, is increasing. Support policies for start-ups, amounting to nearly USD 1.2 billion in 2020**,** include direct measures, such as investment and R&D support, and indirect measures, such as support of entrepreneurship education, mentoring and consulting, workspace supply, and networking events. In particular, the government has played a dominant role in start-up finance throughout the last decade. However, although governmental seed funding is widely available, some start-ups do not use it due to a perceived high burden of paperwork. Recently, government and private funding of start-ups have been bundled through matching investment programmes (TIPS). In this programme, the selection of start-ups to be supported is outsourced to private accelerators.

Despite the rise in start-up finance, which amounted to approximately USD 31 billion in 2021, it remains insufficient to support the ecosystem. Failing to find domestic funding, some Korean start-ups turn to international sources when scaling up to reach the "unicorn" range. Furthermore, exit models for start-ups have been weak. Due to regulatory hurdles and limited interest by major technology companies in acquiring start-ups, there were few IPOs (114) and M&As (43) in 2019 (STEPI, 2021[61]). Only 23% of venture capital (VC) investment in Korea is recouped through IPOs and a mere 2% through M&As. In contrast, M&As account for 37% of total VC returns in both the United States and Europe. When combined with IPOs, they represent 94% and 54% of VC returns in the United States and the European Union, respectively (Asan Nanum Foundation, 2021[68]). While the situation is improving on both counts, engaging in serial start-up entrepreneurship remains challenging.

Mobilising entrepreneurs, encouraging a positive attitude towards risk taking and increasing diversity are essential. In 2019, Korea ranked 88 out of 141 countries for "Attitudes towards entrepreneurial risk" in the World Economic Forum's Global Competitiveness Report (World Economic Forum, 2020[69]). Furthermore, confidence in one's own skills and abilities to start a business is low (33rd), while starting a new business is perceived as difficult. Korean entrepreneurship remains below its potential due to a perception of insufficient opportunities. As reported by the Global Entrepreneurship Monitor 2021/22, Korea is 17th out of 19 countries in the high-income group in terms of perceived opportunities to start a business (Global Entrepreneurship Monitor, 2022[70]). Partially due to a lack of international exposure, most start-ups focus on developing business models, products and services for the domestic market. The ratio of newly founded firms expanding beyond Korea stood at only 2.2% in 2019 (STEPI, 2021[61]), and even fewer succeeded internationally. It is worth noting that, based on the OECD Product Market Regulation indicator, which measures the administrative burden on start-ups, Korea improved from 1.87 in 2013 to 1.09 in 2018. This is better than the OECD average but still far behind the top-five best-

performing countries (0.49) (OECD, 2022[53]). According to the same source, Korea faces some of the highest barriers to domestic and foreign entry among OECD countries, particularly in service and network sectors, as well as trade and investment. These barriers may contribute to the perceived lack of opportunity for entrepreneurs. Improvements in promoting entrepreneurship could, therefore, be made. In addition, in order to diversify venues for growth, the biotechnology industry is a promising field to tap into.

Korea still depends on the ICT industry more than any other OECD country, but new technology-based industries, such as biotechnology, are emerging. ICT still has a dominant presence in the Korean economy, and some figures suggest that over the course of overcoming the havoc wreaked by COVID-19, dependence on ICT is increasing further. According to the Hyundai Economy Research Institute (HERI), the ratio of ICT value added to GDP is expected to increase from 10.8% in 2020 to 11.3% in 2021 (HERI, 2022[71]). Meanwhile, thanks to continuous government support since the early 1980s, when the Biotechnology Promotion Act was enacted and provided the legal framework governing support policies, the expansion of the Korean biotech industry has been impressive; many Korean firms are now leading globally in this area.

Public R&D investment in biotechnology has paved the way for the creation of a solid ecosystem. Government R&D investment in biotechnology increased significantly from USD 1.2 billion in 2007 to USD 3.4 billion in 2016, and from 15.7% of total government R&D spending in 2016 to 19.2% in 2020 (MSIT, 2017[72]; 2021[73]). Biotech firms have high R&D intensity, and biotech product development takes much longer with much less prospect of success than other manufacturing products. Strong and continuous government investment could encourage entrepreneurs to create and expand biotechnology-related businesses (Giesecke, 2000[74]). The number of biotech start-ups created in Korea rose from 140 in 2010 to 440 in 2016. The Korean biotech industry has become competitive globally, and Korea is now ranked second regarding the production capacity of biomedicine (MOTIE, 2021[75]). Total exports from Korean biotech firms also more than doubled, from USD 1.8 billion in 2016 to USD 4.4 billion in 2018. Furthermore, the workforce in the biotech industry has continued to grow; in 2020, it marked a 10% increase from 2019 (KBIO, 2020[76]).

1.4.6. Knowledge-based service industries offer the potential for value-added growth

Despite various policy measures by the Korean government to promote service industries, the results have fallen short, notwithstanding successes in some sectors. Previous work by the OECD has identified regulatory burdens, lack of competition, restrictions on foreign entry and other barriers to inward investment and competition from abroad as principal reasons for the weakness of the Korean service sector (OECD, 2014[77]). The Korean government has introduced numerous measures to boost service sector competitiveness over the past two decades. For example, to level the playing field between manufacturing and services, in 2016, the tax incentive for the service industry was shifted from a positive-list to a negative-list approach so that all service activities not listed in the law are, by default, eligible for tax credits. In 2019, Korea also introduced a regulatory sandbox in ICT convergence and financial innovation. Through the regulatory sandbox, firms can test their services and business models without being subject to all existing legal requirements. Meanwhile, the government has prioritised its policy to promote a few high-value-added service industries, including healthcare, education and software.

The software industry is growing with government support. Korea has actively promoted the software industry with a comprehensive policy mix based on the Software Promotion Law enacted in 1987. This law requires the MSIT to formulate a mid-term (three-year) plan to promote the software industry. The law also includes provisions for software-related R&D support, the development of human resources, policy loans and tax incentives, as well as standards and certifications. It also provides a legal basis for software pricing and contract terms with respect to public procurement. Recent policy measures to promote the software industry as a high-value-added service industry has concentrated on lifting regulation of public procurement and developing human resources. Until recently, large firms were not allowed to participate

in public procurement of software to protect local small software firms. Starting in 2015, public procurement has gradually opened to specific large firms, such as in those emerging technologies. In order to provide software talent, the government has expanded the number of "software-centred colleges" to 44 as of 2022. Meanwhile, Korean software firms are actively expanding to overseas markets; exports doubled from USD 5.1 billion in 2012 to USD 10.6 billion in 2017 (IITP, 2019[78]).

1.4.7. Digital transformation presents a major opportunity but requires continuous policy attention

Korea has strong foundations for the digital transformation, yet there is room for improvement. It has the highest share of fibre connections in total broadband subscriptions (80.4%), as well as a high share of value added and employment in the ICT sector (OECD, 2020[62]). Moreover, Korea has a generally strong proliferation of digital tools in business-related and administrative systems in society, a high adoption rate of digital technologies among consumers, and the highest density of industrial robots globally, with 855 per 10 000 workers, which is about three times the OECD average (World Economic Forum, 2020[69]).

The Korean government has provided continuous policy support for the nationwide adoption of digital technologies. In the 2000s, the National Informatics Master Plan (2008-12) established "creating soft power", i.e. creating intangible assets, such as knowledge, technology and culture and "(building) innovative infrastructure for digital convergence" as two important pillars for Korea's transformation into an information society. In 2017, the Presidential Committee on the 4th Industrial Revolution (PCFIR) was established as a policy co-ordination body that develops comprehensive policy direction, strategy and action plans for ministries. More recently, in response to the COVID-19 pandemic, a wide range of immediate policy measures were rolled out to enhance the adoption of digital technologies by SMEs, notably the digital service voucher by the Ministry of SMEs and Start-ups (MSS), which subsides SME uptake of digital services with conditional grants to facilitate digital trade and strengthen cyber security (Bianchini and Kwon, 2021[11]). In the Digital New Deal, a major component of the Korean New Deal for the post-COVID-19 era announced in 2020, a total investment of USD 37.2 billion was budgeted until 2025, the majority of which is targeted at data networks and AI.

However, the pace of diffusion of digital technologies among Korean firms so far has been slow, particularly among SMEs. The digital divide is wide between large firms and SMEs, as in other OECD countries, but the gap tends to be wider in Korea compared to the OECD average (OECD, 2020[62]). For instance, as of 2018, the difference between large and small firms purchasing cloud computing services was around 31.1% (OECD average: 28.8%), and the difference in having performed big data analysis was 30.7% (OECD average: 22.5%). Korean firms are far behind OECD countries, with only 3% of small and 10.8% of large enterprises performing big data analysis (BDA) (United Kingdom: 13.3% for small and 35.4% for large firms; Germany: 12.9% and 33.9%, respectively).

As data-driven innovation is increasingly important within the digital transformation, Korean businesses have vast potential to benefit from user-related and firm-related data. Recent evidence shows that BDA significantly improves firms' innovation capacities in products, processes and organisation, with the highest impacts on productivity if combined with other ICTs, such as cloud computing (Gierten et al., 2021[79]). However, in Korea, the gap between large firms and SMEs in adopting sophisticated digital technologies, notably BDA, remains wide (Pak, 2021[80]). Moreover, Korean SMEs often lack awareness of the potential increase in productivity by digital systems and equipment as well as big data. The shortage of specialists who can help them with the introduction of digital technologies is a major problem. Korea shows the second-largest variation in training participation across firm sizes in the OECD (30% of micro-firms compared to 70% in large firms) (OECD, 2020[62]). However, Korea has undertaken numerous initiatives, e.g. network programmes connecting digitally advanced firms with SMEs,

open data initiatives, including the "Data and AI-driven Economy Promotion Plan" (2019), as well as lifelong learning and vocational training programmes.

1.4.8. Recent support for the green transition could provide the momentum for major change

The green transition is a major challenge for the Korean business sector. In combatting climate change, Korea is under-performing, even with its swift introduction of the emission trading scheme (K-ETS) in 2015. GHG emissions per capita are among the highest in OECD countries and rose until 2018 (OECD, 2021[49]). Furthermore, Korea has the lowest ratio of renewables in its primary energy supply among all OECD countries. Korean companies exporting energy-intensive products may encounter significant decarbonisation challenges unless they decrease their carbon emissions soon, particularly in the face of potential carbon border taxes. This is especially true for the manufacturing and energy sectors, which contributed 37% and 36% of Korea's carbon emissions, respectively, in 2017 (Ministry of Environment Greenhouse Gas Inventory and Research Center, 2020[48]). Meanwhile, there is widespread awareness of global warming in Korea. In 2021, Korea's Ministry of Culture, Sports and Tourism conducted a survey, and of the 1 600 respondents, 96.3% responded that they perceived climate change as a severe problem. However, it remains to be seen whether the growing awareness of the climate crisis has been sufficiently translated into robust public support for the government's ambitious carbon neutrality target. Particularly, the rapid introduction of carbon reduction targets has been more or less perceived as a threat to companies' competitiveness and to employment in the manufacturing sector.

The green transition also presents opportunities for Korean businesses. Korea's climate strategy encompasses several broad objectives, including achieving carbon neutrality by 2050 and reducing GHG emissions 40% below 2018 levels by 2030. Climate change is not only a threat to energy-intensive legacy technologies but also presents opportunities to introduce innovative technologies that help reduce GHG emissions and meet the growing demand for low-carbon products and services. The recently announced Green New Deal sets ambitious goals for expanding the supply of electric and hydrogen vehicles. The provision of 1.13 million EVs, including passenger cars, buses, and freight vehicles, will be supported along with the installation of 45 000 chargers. The provision of 200 000 hydrogen vehicles, including passenger cars, buses and freight vehicles, will be supported along with the installation of 450 charging facilities. Some Korean companies have technological competencies and competitiveness, notably regarding solar panels and electric car batteries and reinforce their technology competency across different emerging green technologies. An "eco-ship" with high fuel efficiency and low pollutant emissions and a hydrogen-fuelled car have now become the world's number one products with a global market share of 65% and 55.2%, respectively.

1.4.9. Geopolitical tensions bear risks for Korean technology competitiveness

Uncertainty in global trade may harm Korean businesses in the longer term. A prolonged United States-China trade dispute could have a series of ramifications on Korean business and industry. In the short run, some Korean companies would benefit from US sanctions on Chinese high-tech goods. For example, Samsung's 5G network market share increased significantly after the start of the trade dispute, from 3.2% in 2017 to 23.3% in 2019 (KIEP, 2020[81]). However, eventually, this benefit is likely to fade as China's capabilities in advanced technologies strengthen despite pressures from the United States. In fact, China is not only closing the gap in advanced technology but advancing to the frontier, particularly in areas where Korea still has a comparative advantage, such as in semiconductors, batteries and displays. Furthermore, if the conflict between the United States and China intensifies, Korea will face increasing pressure from both sides. It will leave fewer policy choices for Korea, whose top two export markets are the United States and China.

Maintaining and enhancing technology competency in industry is essential. The United States-China trade dispute has implications for business entrepreneurs and policy makers in Korea. First, the importance of securing and maintaining technology competence for key and emerging industries cannot be overstated. For example, even after Japan sided with the United States, China took no retaliatory measures against Japan. China's imports from Japan even increased from USD 322 billion in 2017 to USD 344 billion in 2020 (KOTRA, 2020[82]). This is due to the robust competitiveness of Japanese products that cannot be easily replaced. Secondly, STI policy should be perceived and designed within a broader context, incorporating issues like supply chains, commerce, and national security. COVID-19 also exposed the disruption of global value chains. Third, diversification of international co-operation in STI and trade is important. In 2019, Korean firms' technology exports to the United States and China amounted to USD 2.59 billion and USD 2.55 billion, respectively and in total, technology exports to the two countries accounted for 37.4% of all technology exports (KOITA, 2022[83]). Korea is tightly integrated with the United States and China throughout the business innovation cycle. In order to reinforce its responsive capacities to external shocks, Korean businesses need to diversify their trade partners. At the same time, STI policy makers should broaden their perspective beyond these leading countries in order to build more diverse strategic international partnerships.

1.5. Production, circulation, and diffusion of knowledge for a new era of innovation in Korea

Compared to many other developed countries, Korean knowledge production – regarding resources, actors and outputs – has increased dramatically over a rather short period. As the knowledge production system has expanded, the roles of some of its key actors have also begun to change. GRIs, originally created to serve the needs of various strategic industries for technological development, now have to rethink their role, as several Korean firms have become technology leaders with advanced and substantial research capacities of their own. Universities have evolved from a purely teaching role to developing significant research activities, particularly with the emergence of the "IST"[21] universities. This implies that GRIs, higher education institutions (HEIs) and the government need to rethink their roles and identify pathways for ensuring that the Korean system for production, linkages and diffusion of knowledge is fit for purpose.

1.5.1. Defining features of Korean society that affect research and innovation policy

There is room for improvement in social capital, notably institutional trust, in order to advance towards innovation leadership and tackle transformation and societal challenges. Korea displays a high general awareness of government strategies, particularly R&I strategies. Nevertheless, trust in government institutions is low (also sometimes referred to as "institutional trust"), as confirmed by a recent OECD study (OECD/KDI, 2018[84]). The same source also confirms that "policy development and formulation in Korea may face low levels of transparency, lack of consistency, institutional competition between political parties and lack of internal collaboration." Such an overall lack of trust and weak social capital[22] partially explains the accountability and micro-management that characterise government S&T funding. There are also few independent academies and think tanks that stimulate, contribute to and curate public discourse and debate on the role of science and technology in Korea's development and societal and economic objectives.

Some past elements of Korea's S&T policy are now counter-productive to its current goal of innovation leadership and addressing societal challenges. These include detailed *ex ante* specifications and expectations for S&T projects, including technological objectives, goals or outcomes. Further, in the post-catch-up phase, where GRIs struggle to prove their value and find a clear purpose, there is a tendency towards mission drift, overlap and fragmentation as they attempt to position themselves

in areas considered topical means to secure government funding. As explained in Chapter 4, The orchestration of this system could be made more effective, and the incentives should be enhanced for GRIs to collaborate among themselves or with academia or industry around clear strategic objectives.

1.5.2. Korea's higher education system is comprehensive, but its research performance could improve

HERD spending is below the OECD average and relies mostly on project-based funding. HERD represented 0.43% of GDP in Korea in 2020 (OECD, 2022[14]), a level comparable to Japan, the United Kingdom and the United States but below that of France and Germany.

Even though many universities perform research, few are true research universities. Among Korea's 430 HEIs, 85% perform R&D. HEIs employ 58% of PhD-level researchers in Korea. Most research done at universities is basic research, and most basic research in Korea is done at universities. Basic research was financed to the level of KRW 2 trillion (USD 1.7 billion) in 2020, with 75% from the MSIT and 25% from the Ministry of Education (MOE). This represents almost double the amount of 2017.

A few Korean universities benefit disproportionately from highly path-dependent advantages in terms of reputation, prestige, talent attraction and funding. There are different groups of universities: 1) institutes of technology under the purview of MSIT;[23] 2) national and public universities, which include flagship universities under the purview of MOE; 3) private universities. The five universities under the purview of MSIT and a handful of leading national universities, most notably Seoul National University, represent the top tier. A large gap separates them from the second-tier national and regional universities. This path dependency, combined with a rather limited exposure to international competition, stifles institutional dynamism and renewal, which seems to manifest itself in Korean universities' average rankings and research performance in terms of international comparison.

Korea has relatively few top-ranked institutions. Compared to countries such as Germany and Sweden, Korea has, in relation to population size, markedly fewer institutions among the top 200 universities in various university rankings, particularly the Shanghai and the Centre for Science and Technology Studies (CWTS) Leiden rankings, which assign more weight to research awards, publications in high-impact journals and citations. The Leiden ranking shows, for example, that only three universities[24] achieved 10% or more papers among the top 10% cited, while the others have 3-7% of publications among the top 10% cited.

1.5.3. The current funding structure for higher education institutions in Korea may limit growth

The dominance of project-based financing makes for limited autonomy and short-term focus. Some block funding for research has been introduced for universities under MSIT and recently also at national and public universities. However, a large part of funds still depends on project-based funding. Since priorities for this funding change with each election (five-year horizon), developing long-term research agendas and building large research teams is difficult.

Administrative processes create disincentives. The Korean government has made significant efforts to simplify administrative procedures and enhance research management autonomy, notably though the National Research and Development Innovation Act. Moreover, starting in 2022, the Integrated R&D Information System was put in place to comprehensively manage the information on research fund spending, investigators and research projects, with simplified and standardised templates. Nevertheless, it was noted during interviews with Korean stakeholders that researchers spend considerable time applying for and reporting to the government on research projects. There is still room to improve the degree of freedom for researchers to reorient research during the course of a project by encouraging researchers and project managers to utilise the new act. Similarly, investigators have to specify in advance which

research equipment (valued above KRW 30 million) they intend to purchase. Meanwhile, it is encouraging that the National R&D Innovation Act, which took effect in June 2022, now enables investigators to adjust their purchases to changing circumstances or new needs. It remains to be seen if additional measures will be needed in the future. The government has made several efforts to increase the flexibility of research funding, the freedom of researchers and the institutional autonomy of universities. MOE and the Korean Council for University Education formed a task force in 2019 to tackle the issue of regulations on university operations to increase their autonomy. The National Research Foundation (NRF) has also implemented changes to make its funding more user-friendly and reduce the micro-management of research projects. However, changes in administrative culture – from a strong focus on short-term accountability, micro-management and nearsighted quantitative indicators of success to institutional autonomy, research freedom and long-term impact and breakthrough research – take time to develop (both in government and academia). They also require policy consistency and predictability. This is particularly the case in Korea, which does not have a longstanding tradition of strong and independent research universities. In this regard, the government should continue to strive to reduce the administrative burden for researchers regarding research funding and seek to increase researchers' freedom to change their research focus during the course of government-funded projects.

Research funding rules and reporting obligations for HEIs could be more flexible. While funding is relatively easily accessible and success rates for projects are quite high, researchers perceive difficulties in justifying deviation from the initial scope of research, as is often needed, particularly in basic research. The National R&D Innovation Act intends to ease funding rules for changes in research programmes and expenditures, which is a welcome change. However, the implementation of the law should be supported by adequate means, and it is too early to see the full effect of the law yet. As explained in Chapter 4, monitoring and performance measurement is focused on short-term, quantitative metrics (such as publications in leading journals and patents) rather than assessing and promoting ground-breaking research and long-term impact.

A specific incentive structure in at least one university provides for excellent performance. Ulsan National Institute of Science and Technology (UNIST) is one of the most successful universities on many metrics. For one, it has more than 13% of its publications among the top 10% cited[25] ones – the best result in Korea. In addition, they have 10-20% of their revenues from industry collaboration. This is the result of a specific, different incentive structure, whereby academics are incentivised to collaborate with industry (this directly impacts their salary), and the publications counted for their evaluation and promotion must be in the "top-cited" category. In addition, there is an incentive for international collaboration since invited talks at international events are required to obtain tenure at UNIST.

A rapidly ageing population is putting significant financial strain on many HEIs. Due to low fertility rates, the number of students is declining, marking a 13% decrease in enrolled students in 2020 compared to 2010. This, in turn, reduces tuition income and thus increases financial pressures on HEIs, in particular, less well-established ones. In 2015, the government implemented the Evaluation for University Consolidation Policy, where universities were assessed according to five grades. Institutions with lower grades reduced admission capacity and received limited financial support.

1.5.4. Korean universities can maximise their potential by collaborating internationally

International co-publications account for a smaller share of total publications than in a number of OECD countries and China. Furthermore, international co-publications, as a share of total publications, have increased more slowly than in countries such as Japan, Switzerland, the United Kingdom and the United States. Thus, there seems to be a difference between large Korean multinationals with a strong global market and innovation presence and research institutes and universities, which seem less international than their counterparts in many other OECD countries.

1.5.5. The role of public research institutes in Korea needs to be continuously redefined to match the changing needs of the economy and society

This sub-section discusses non-university research institutes that receive institutional (or "core" or "basic") funding from the state. It should be noted that outside of what would usually be considered as PRIs, MSIT manages five universities – the Korea Advanced Institute of Science and Technology (KAIST), the Gwangju Institute of Science and Technology (GIST), the Daegu Gyeongbuk Institute of Science and Technology (DGIST), UNIST and the University of Science and Technology (UST) – that are institutes of technology in the same sense as the Massachusetts Institute of Technology (MIT), namely research universities specialising in science and technology. They are formally regarded as GRIs but should rightly be regarded as universities since they account for a significant contribution to education and teaching. They do not form part of the analysis in this section.

PRIs seem to be misunderstood internationally for at least four reasons. First, PRIs tend to be discussed as a single category because the state owns them, while there are different PRI categories that have very different functions. These include government labs, scientific research institutes, RTOs and "technology centres" (see Chapter 4). Second, the role of some PRIs changes through the course of development, so if one compares countries at different stages of development, then similar-looking organisations turn out to be doing very different things. Third, different countries make different decisions about the division of labour between the university and institute sectors, so context is important in understanding PRIs. Fourth, there are (still) no coherent or internationally consistent statistics about PRIs.

1.5.6. The structure of the Korean public research institute system has been questioned but remains largely unchanged

Korea's PRI sector is a large part of the R&I system, accounting for 45.8% of Korean state spending on R&D in 2017 (KISTEP, 2018). The role of government labs has declined over time as their function was mostly split into two parts. Some of their more hard science and technological activities were moved into the GRIs under the NST, while the policy support functions have been moved into the NRC. Today, there are three groups:

- A group of 25 GRIs work in STEM disciplines with diverse roles and responsibilities, depending on their research strength and orientations. Some GRIs mainly support industry, while others attempt to tackle socio-economic strategic missions. It remains to be assessed whether the individual roles and responsibilities of the GRIs will be conducive to the overall national strategy for the innovation system.
- Technology centres promote industrial and business development within their own sector. Fourteen specialised production technology research institutes (SPTRIs) are governed by the Ministry of Trade, Industry and Energy (MOTIE) and provide testing, evaluation and process technology support, technology transfer services, notably from overseas sources, technological support, R&D projects and vocational training to SMEs in specific sectors, including electronics, automotive and photonics.
- A group of 26 government labs focus on policy research rather than on "hard" science and technology. These are today under the control of the Prime Minister's Office and organised under the NRC, which reports to the Ministries of Economics and Finance, Labour, Environment and Education and through those ministries to the Prime Minister's Office.

The original mission defined a broad scope for GRIs, ranging from basic through applied research and technology transfer to the industry. The first GRI – the Korea Institute of Science and Technology (KIST) – was set up based on the model of the Battelle Memorial Institute in the United States as an industrial technology centre to support industrialisation. It had a great deal of latitude to set its own strategy and experienced little micro-management from the government. Many of the other GRIs spanned off from

it and were instrumental in acquiring, localising and transferring technologies in support of the highly successful catch-up industrial development in Korea. Over time, industry acquired strong capabilities in the higher technology readiness levels (TRLs),[26] and at the turn of the century, the mission drifted towards a stronger focus on basic and applied science rather than direct co-operation with industry.

In 1996, however, Korea's rapid industrial development and the growing technological capabilities of its large firms meant that the GRIs' role began to be questioned.[27] The role of the GRIs needed to change to adapt to Korea's stronger position and, particularly, to industry's higher technological capabilities. Accordingly, the government introduced a "project-based system" (PBS) of external, project-based funding, which was designed to promote competition between GRIs and led to the greater autonomy of principal investigators. This action slowed the growth of GRI institutional funding and introduced the incentive of competing for PBS funds. While principal investigators may now have greater autonomy in managing project progress and employing participating researchers, this has reduced their degree of autonomy under the Battelle model and, correspondingly, their ability to devise autonomous strategies. Namely, responding to PBS calls for proposals constrains researchers to topics defined in the calls rather than providing funding for developing long-term lines of research they deem important. While PBS was intended to align the work of the GRIs with higher-level R&I policies laid down at the government level, it also fragmented their work.

While some orientations for the GRIs from the *OECD Reviews of Innovation Policy: Korea 2009* were taken into account, many of them remain valid today. The 2009 review mentioned: 1) supporting technological development in SMEs; 2) moving away from industrially oriented R&D and towards public and welfare research; 3) concentrating on platform technologies; 4) leading Korea's shift towards more fundamental research; and 5) working in areas of interdisciplinary and fusion research. Some of these were taken into account; in particular, the government has made concerted efforts to raise the importance of fundamental research over the years, which is mostly backed by dedicated funding. The Institute of Basic Science (IBS) was founded in 2011 as a network of research centres modelled after Germany's Max Planck Society and Japan's RIKEN. The budget for basic research increased from KRW 1.2 trillion in 2020 to KRW 1.4 trillion in 2021 for individual researchers and to KRW 313 billion for research teams. In the recent Role and Responsibility reform, MSIT invited the GRIs to consult widely and consider how to revise their strategies in line with current needs. Several new themes suggested by the ministry are more societally oriented than before and are more technologically based.

However, several factors appear to have made it difficult for the GRIs to change course and enhance their orientation to industrial markets. The introduction of the PBS fragmented their work and tied them to policy priorities set at a higher level rather than increasing their market orientation. This trend is being gradually reversed. In 2021, institutional funding represented 41.5% of total funding, higher than before the introduction of PBS, according to MSIT data.[28] The role of GRIs in the national innovation system has become somewhat ambiguous. With the rising importance of universities, they have become less relevant to the big firms that have developed high levels of technological capability and look internationally for technology acquisition to complement their in-house R&D. The former GRI model of acquiring or developing new technologies and then transferring them to industry is now focusing on middle-level SMEs, which can make use of technology transferred in this way, but which lack the reach and resources themselves to acquire technology internationally.[29] For instance, KIST receives only 9% of its financing from private sector sources and has no ambition to increase it. It reset its official research direction to "creative and challenge-driven research". GRIs typically receive less than 10% of their funding from industry, in contrast to Europe, where it ranges from 30% to 70%, highlighting a weak connection between GRIs and industry, especially large conglomerates. Overall, their level of state funding – including institutional block funding plus PBS funding – remained very high, insulating them from the kind of market pressures RTOs experience in other countries.

GRI directors are formally appointed by the NST Council. They are elected by 17 NST board members, including 5 government officials. They are replaced after three or six years, depending on the evaluation

of institutional performance. Paradoxically, this kind of instability at the leadership level, with constantly changing strategies and plans, risks promoting stability or path dependency within organisations, which become resilient to the desires of transient leaders. A lack of effective autonomy over spending, hiring, strategy, careers and equipment purchase, among others, has promoted path dependency. Although PBS was introduced to promote competition among PRIs, it would be useful to introduce a holistic government strategy for reforming the PRIs to adapt their roles to current needs. Recently, the individual GRIs revised their own roles and responsibilities, but the concern remains whether their individual roles will be conducive to and aligned with the national strategy for innovation. The recent provision by NST of "convergence funding" intended to promote co-operation between GRIs and between research areas to address complex socio-economic issues involves small sums of money. Since 2014, the evaluation of GRIs under NST is customised for each institution, which sets its own qualitative and quantitative objectives. However, it is not yet clear whether this has helped address the societal mission of the GRIs – which was historically to support industrial development, evolving towards addressing societal challenges. It is also unclear whether the incentives are aligned and whether the co-production of capacity and technology needed to help companies develop is encouraged. In 2019, the government specified within its National R&D Performance Evaluation Implementation Plan that for performance evaluation of research institutes, a minimum of 60% of criteria should be qualitative, marking a shift away from the previously strong focus on quantitative measures, such as scientific publications and papers.

The Korean PRI system, more broadly, is relatively fragmented. This holds true, particularly when compared with other countries, where institutes have tended to become more polytechnic and, therefore, better able to work with a range of customers in different branches, technologies and markets. To address this issue, the MSIT made changes to the governance of the NST and adjusted the function of individual GRIs to avoid duplicating functions across organisations. For example, GRIs commonly support SME development, but research fields and targets are differentiated based on each GRI's roles and responsibilities.

Evidence from other countries suggests a growing need for interplay between university and institute research for two reasons. First, as the level of development rises, so industry (and other user sectors) needs increasing access to more fundamental developments in knowledge. Second, more generally, the amount of scientific knowledge necessary to keep pace with advancing technology is increasing. However, there is little evidence of the Korean institute and university sectors co-operating more closely via collaborative research, joint appointments and joint PhD supervision, as seen elsewhere, for example, among the Fraunhofer institutes in Germany or the RISE institutes in Sweden.

1.5.7. Investment in research infrastructures is good, but more awareness is needed

The Korean government has invested significant resources in national large research infrastructures, with positive effects. The government set up two roadmaps to strengthen Korea's lead position in science and technology and its creative economy. Large research infrastructures contribute significantly to domestic and international co-operation, attracting foreign talent and promoting knowledge exchange. Korean participation in international research infrastructures such as CERN and the European Molecular Biology Laboratory (EMBL) further underscores the government's awareness of such activities' positive effects.

Investments have caught up with other leading innovation countries but still lag other innovation leaders. Korea has earmarked around 0.27% of GDP as part of its two National Large Research Facilities Roadmaps, which is a combined investment on par with the United States (0.28%) but below that of Japan (0.48%), the European Union (0.37%) and China (0.33%).

Although policy makers are highly aware of the potential and benefits of research infrastructures, this awareness needs to be promoted at the institutional level. While the various adopted roadmaps and initiatives and their increased funding reflect strong progress and awareness of the need for research

infrastructures, on the practical level, the co-utilisation of equipment, for instance, remains rather low. University professors are often not aware and/or are not incentivised to make their research equipment available to other scientists. This may be due to factors such as a potential lack of awareness, low recognition, absence of plans for shared use of equipment or accounting issues.

1.5.8. Knowledge flows between higher education, GRIs and business have room for improvement

GRIs were set up in the 1960s as RTOs with the primary goal of transferring technology to the Korean private sector. This initiative was largely successful, and today, Korea's large companies are autonomous with huge R&D budgets (Samsung spent around KRW 21.2 trillion in 2021, comparable to the entire government of KRW 27.4 trillion). However, today, the positioning of GRIs varies, with some working closely with industry while others (such as ETRI) compete against it. In general, private co-financing of GRIs is quite low (around 10%), and GRIs are not striving to increase it.

Knowledge flows from universities and GRIs to industry, traditionally limited in Korea, have increased since the turn of the millennium. Diverse policy measures are being used to facilitate the commercialisation of public research results. For example, the Innovative Product Public Procurement Pre-validation system helped the market launch of R&D outcomes that were having difficulty in commercialising; the Public Technology Commercialisation Fund increased investments in the commercialisation of basic research outcomes; and the Public Research Result Use Promotion R&D Project supported the technological advancement needed for linking outstanding public research results and market demands. Between 2011 and 2019, technology transfer cases more than doubled, from 5 193 to 11 676, with a relatively even split between GRIs and HEIs.It is important to note, however, that formal technology transfer based on patents and licensing is normally only a small part of the wider pattern of knowledge exchange among institutes, universities, industry and civil society.

Enhanced by governmental subsidies, collaborative research projects between universities and firms are also increasing, but there is potential to increase the quality and scope of knowledge transfer through research collaborations. Practices and performance indicators in the GRI sector continue to focus on technology transfer via the sale or licensing of intellectual property rather than the co-production of innovation. Industry appointments by researchers at national universities are not allowed. Research university faculty and GRI research staff are incentivised to focus on publication in academic journals instead of engaging in industry collaborations, for which they receive limited institutional support and recognition. Large conglomerates sometimes collaborate with leading research universities in Korea but tend to prefer to collaborate with leading universities in western countries when developing fundamental technologies. Many university-industry research collaborations are conducted between non-research universities and SMEs and tend to be short-term and small-scale.

Inter-organisational knowledge co-creation and knowledge flows have increased between leading research universities, GRIs and private sector companies in recent years. This development appears to have been driven by the enhanced research capabilities of leading universities and the lower cost for companies when using subsidised on-campus collaborative research facilities. There are also now some major research consortia that include university, GRI and private sector company partners. However, these positive changes appear to be mostly concentrated in specific departments of universities and GRIs with relatively abundant resources and strong research capabilities. Most university faculty and GRI researchers are still not interested in engaging with industry.

Academia-industry collaboration today is below potential. The number of co-publications between industry and academia has been decreasing over the last decade,[30] and private sector co-financing remains confidential, with only a few projects co-financed by the conglomerates at the top universities, such as Seoul National University, KAIST and UNIST, and projects financed by the Samsung Foundation, which pledged USD 1.5 billion for research.

Multiple barriers to collaboration persist, and they vary across different actors. From the research side, the main hurdles are: 1) high pressure on academics for publications, which precludes them from working on more pragmatic industry-relevant projects that are less likely to produce sufficient publications; 2) easy availability of project-based funding, which reduces incentives to develop more demanding projects with industry; and 3) researchers' personal objectives that do not take into account industry collaboration. From the large business side, there are also significant barriers, including a perception of academics as being too slow and disconnected from business needs and as having a preference for keeping most research in-house, made possible through sufficient internal resources (somewhat at odds with international practices that favour more collaboration with academia). Finally, these firms share the feeling that basic research is better addressed by academia outside Korea, to which the conglomerates have easy access through their global networks (even though Samsung does have a significant number of co-publications with Korean academia).

Collaboration between GRIs and industry is burdened by legacy. Since the 2000s, the practices and performance indicators in the GRI sector have continued to focus on technology transfer via the sale or licensing of intellectual property rather than the co-production of innovation. Having noted the limitations of such linear models of knowledge diffusion promotion, in 2014, the NST started the Joint Technology Licensing Office (TLO) Promotion programme (KRW 15.9 billion for 2014-19) that aimed to shift the focus to the "demand-pull" approach and to better monitor the use of transferred technologies by companies.[31] In parallel, technology-holding companies, such as ETRI Holdings[32] in 2010 and Korea Science and Technology Holdings (KST) in 2013,[33] were established to promote the transfer of technologies. Nevertheless, challenges remain since industry collaboration is generally far from the focus of their mission (defined by their roles and responsibilities), which is largely determined by the heads of organisations. Government support is largely considered insufficient. Also, GRI research staff is incentivised to focus on publication in academic journals instead of engaging in industry collaborations, for which they receive limited institutional support and recognition.

Research universities are a relatively recent concept in Korea, and only a few have the capability to meet the knowledge demands of world-leading companies, compete with top international academic institutions and generate a substantial number of start-ups/spin-offs. These include mostly the universities under MSIT mentioned above and a few national universities, such as Seoul National University. Faculty do not have sufficient incentives to create spin-offs, and entrepreneurship occurs mainly among students and sometimes as a retirement option.

Regional universities provide R&D support to SMEs, but such co-operation could be better structured. Co-operation occurs on demand from an SME when it formulates a need. The university responds and performs the research only if the SME gets project-based government financing. A more proactive approach is that of manufacturing extension services, which is embodied through the SPTRIs to a certain degree.

Infrastructure for linkages and co-creation could be further developed. Korea has 5 innopolises and 12 innotowns that aim to promote technology commercialisation in PRIs based on regional needs. It also has 19 science and technoparks focused on fostering local industries and Creative Economy Innovation Centres (CCEI) on start-ups. Concurrently, in many OECD countries, comprehensive infrastructure is being systematically developed to provide office and laboratory space, along with services such as dust-free labs, supercomputing platforms, and consulting in areas such as strategy, marketing, intellectual property, legal, and human resources, to foster the creation of "deep tech" start-ups. Examples of such infrastructure include the EPFL (École Polytechnique Fédérale de Lausanne) Innovation Park in Switzerland, as well as competence or excellence centres for public-private co-operation on projects and programmes. Even though Korean innopolises have been successful in grouping research institutes, research activities and innovative companies, the development of linkages has been less successful than, for example, in the San Diego biotechnology cluster, due to insufficient networking activities (Kim and An, 2012[65]). The original innopolises were considered too big (more than 40 organisations) to generate

significant synergies, and this is why much smaller innotowns were created in 2019, designed to be "small but robust R&D zones", run by the regional government and focusing on stakeholders from universities, GRIs and businesses with high innovation potential in a limited zone to prevent excessive geographical spread.

Policy instruments in favour of linkages rely on the classical technology transfer paradigm rather than co-creation. All universities and GRIs have technology-licensing offices, but the licensing revenue generated is relatively limited, which is unsurprising in a "technology push" mode. Korea has developed innovation vouchers of relatively high unit value, but matching grants between academia and industry are not very common. Many OECD countries opt for a large number of low-value vouchers, which act as "spreading pollen", creating incentives for a large number of seed collaborations to take place and overcome the barrier of starting collaboration between SMEs and academia. On the other hand, there are already a number of events designed to bring together the communities and raise awareness about each other's needs, the biggest being the University-Industry Collaboration (UIC) expo held jointly by MSIT, MOTIE and MOE. At universities, the spread of the "third mission", where collaboration with industry becomes an official mission at the same level as teaching and research, seems limited.

1.6. STI governance for a new era of innovation in Korea

Since the 1960s, the Korean government has played a key role in setting favourable framework conditions and, more importantly, steering and sequencing the development of Korea from an agrarian to a dynamic industrial economy. Following the development of the STI system via numerous reforms, the development of the Korean STI structure is currently led by three imperatives:

- streamline and better integrate the expanding governance system to reduce well-acknowledged problems of co-ordination (overlaps between ministries' R&D programmes, conflicting priorities, difficulty allocating a vastly increasing R&D budget, etc.)
- reframe policies, organisations and programmes away from catch-up and towards supporting Korea's new position as an innovation leader in some sectors
- implement directional and holistic policies to tackle the societal challenges faced by all advanced and developing countries.

These three imperatives have important implications for the way Korea sets strategic orientation to the system, ensures the necessary co-ordination to align actors' plans and resources, and co-operates across the government.

1.6.1. A comprehensive STI governance system

The STI governance system was initiated by the Framework Act on Science and Technology in 2001 and continuously refined over the past decades. Since 2001, the act has been amended several times and implemented through a proliferation of new or reformed funding bodies, laws, regulations and programmes. A major step in streamlining the STI system was enacting the National R&D Innovation Act of 2021 to rein in and simplify its governance. There have also been attempts to merge or reorganise certain institutions to improve co-ordination and/or streamline the structure.

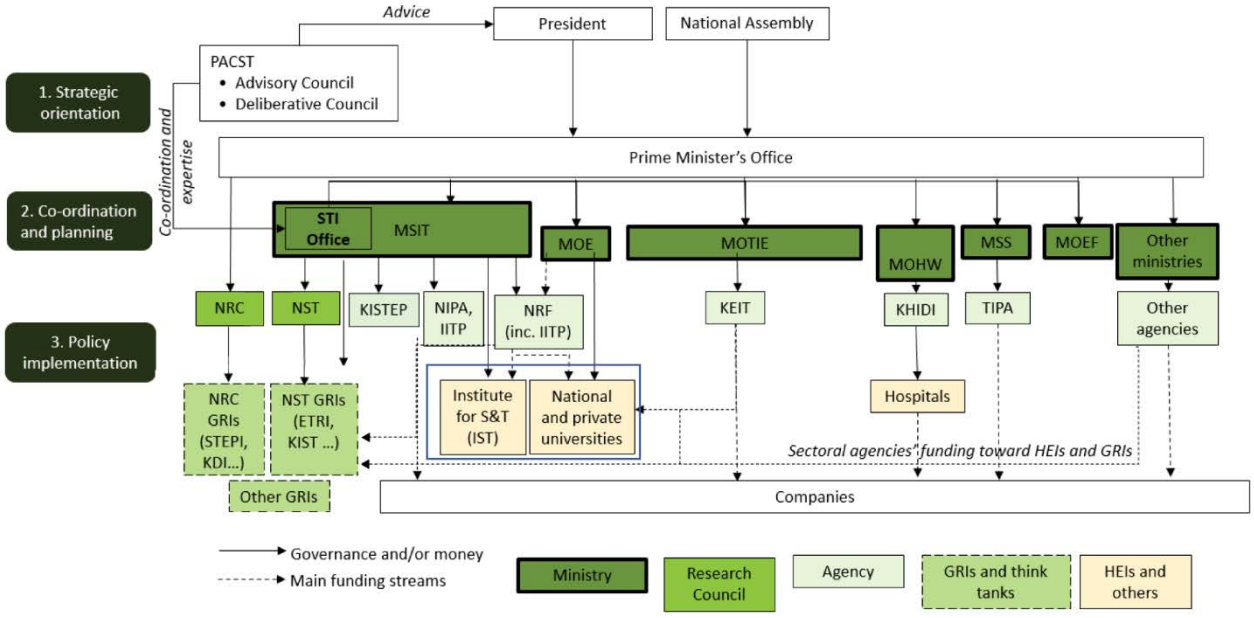
Efforts to adjust to new priorities on a five-year cycle provide the flexibility to adapt STI policy to changing government priorities but can result in a significant discontinuity in the R&I governance and funding system. Achieving consistency between the political agenda and R&I policy is not always possible. However, many successful systems manage to establish at least a high-level consensus across the political spectrum about the priorities of R&I policy and the need for a set of organisations that is stable or evolves relatively slowly. Shifting priorities makes it challenging to establish the necessary trust in government orientations to promote ambitious R&D investment, particularly in addressing societal

challenges that require greater reliance on public funding and longer-term commitments to develop the necessary expertise and infrastructure.

Like several other countries, Korea has demonstrated a significant level of responsiveness when confronted with crises, such as the COVID-19 pandemic or the Japan-Korea trade dispute in 2019, in order to mobilise STI communities. Specific action plans, strategies and committees were formed to ensure an effective and co-ordinated response.

1. **Korea has a well-established three-tier governance structure typical of advanced countries.** The Korean STI system has three main levels of governance, composed of dedicated institutions with clear legal mandates to perform the essential functions necessary to steer, co-ordinate and implement STI policies (Figure 1.2).
2. **Strategic orientation:** the level of the executive and legislative branches of government and the advice provided to them.
3. **Co-ordination and planning:** the level of the individual ministries or "administrations".
4. **Policy implementation:** the level of funding agencies (also known as intermediary or management agencies) which implement and evaluate policy on behalf of the ministries.

Figure 1.2. Korea's STI governance structure



Note: Full names of institutions here in descending order: Presidential Advisory Council on Science and Technology (PACST), Ministry of Science and ICT (MSIT), Ministry of Education (MOE), Ministry of Trade, Industry and Energy (MOTIE), Ministry of Health and Welfare (MOHW), Ministry of SMEs and Start-ups (MSS), Ministry of Oceans and Fisheries (MOF), National Research Council for Economics, Humanities and Social Sciences (NRC), National Research Council for Science and Technology (NST), National IT Industry and Promotion Agency (NIPA), Institute of Information and Communications Technology Planning and Evaluation (IITP), Korea Association for ICT Promotion (KAIT), National Research Foundation (NRF), Korea Evaluation Institute of Industrial Technology (KEIT), Korea Health Industry Development Institute (KHIDI), Korea Technology and Information Promotion Agency for SMEs (TIPA), Korea Institute of S&T Evaluation and Planning (KISTEP), Korea Institute for Industrial Economics and Trade (KIET), Korea Institute of Marine Science Technology Promotion (KIMST).
Source: OECD based on desk research and stakeholder interviews.

1.6.2. The role of the S&T Basic Plans in a fragmented STI landscape

In the Korean system, the high-level orientations are set in the programme outlined by the newly elected President and used as the basis for developing the five-year Science and Technology Basic

Plan (hereafter, the “Basic Plan”). This overarching document, reflected in and complemented by area-specific strategies and plans, has driven and provided legitimacy for some important changes in the past. This is evidenced in the turn to a post-catch-up STI system with a strong increase in basic research funding, related reforms, and proactive measures taken to support the emergence of new industries (e.g. the biotechnology sector).

The Basic Plans are structured along broad strategic directions increasingly focused on solving societal issues, in line with the overall vision to build a more human-centric STI system. These wide orientations are complemented by more concrete programmes with clearly assigned responsible ministries. The 5th Basic Plan announced in 2022, covers 2023-27 in response to national societal challenges, such as technological hegemony, supply chain issues, climate change, the digital transition and low birth rates. As for previous Basic Plans, each broad strategic thrust includes more precise implementation programmes, action initiatives and a list of 12 critical technology areas and 50 core technologies that will receive specific support. The 5th Basic Plan also indicates targets for some important indicators, such as the share of top-1% cited papers (set at 4.8% for 2022-26, up from 3.53% in 2015-19).

The Basic Plan is developed through an elaborate multi-stakeholder process that aims to cut across sectoral, disciplinary and bureaucratic silos. During the development, each strategic thrust is governed by dedicated committees and sub-committees gathering experts and stakeholders, including decision makers from different parts of the government. Furthermore, the Basic Plan's development includes analysing and considering over 90 medium- to long-term strategies from different ministries.

The Basic Plan development process follows different stages of foresight and technology forecasting, consultation and concertation with a broad range of communities. The cycles of S&T foresight and Basic Plans are aligned, and a formal procedure, starting two years before the launch of the Basic Plan, connects the two processes. The Korea Institute of S&T Evaluation and Planning (KISTEP) plays a key role in supporting the government in terms of technology assessment, foresight and S&T planning. Although the foresight exercises increasingly take into account societal aspects, the exercise remains centred on technology forecasting and culminates in a set of technological guidelines. More generally, various research institutions (in particular KISTEP and the Science and Technology Policy Institute [STEPI]) provide strategic intelligence on science, research and innovation through foresight, planning and evaluation work. GRIs under the NRC (e.g. Korea Development Institute [KDI], Korea Environment Institute [KEI] and STEPI) are instrumental in providing various types of analytical support for STI strategy development, policy making and evaluation in their respective areas. Several have kept close links with the sectoral ministries they were created to support in the 1980s or 1990s.

Taking into account the orientations set in the Basic Plan, several ministries also develop their mid-term strategies and plans, often with support from sectoral or cross-sectoral advisory committees. While the Basic Plan is meant to be the strategic document with the highest-level authority in the area of science and technology, important strategies include those set by MOTIE to guide business innovation (e.g. the Industry Technology Promotion Plan and the Industry Convergence Basic Plan). Other plans provide strategic guidelines for R&D in energy, transport and agriculture, among others. Some plans (such as the one from the Ministry of Land, Infrastructure and Transport [MOLIT]) have a ten-year horizon and are revised every five years. Other plans, such as the Agricultural, Food, Science and Technology Comprehensive Development Plan of the Ministry of Agriculture Food and Rural Affairs, have a five-year timespan.

The Framework Act on Science and Technology includes a formal and comprehensive process for monitoring the implementation of the Basic Plan on both a mid-term (five years) and an annual basis. Each ministry submits a mid-term action plan to the STI Office within MSIT that provides an overview of the new and ongoing programmes and activities to be implemented in the coming five years. The MSIT is tasked with reviewing these mid-term plans, notably to check whether they align with the Basic Plan and do not overlap with other ministries’ plans. Each year, the sectoral ministries and agencies also report to

the STI Office about actions undertaken in the different strategic thrusts of the Basic Plan and the main outcomes of these actions. The STI Office integrates these reports in an annual Basic Plan implementation plan submitted for review to the Deliberative Council of the PACST, the highest STI advisory and co-ordination body in Korea, chaired by the President of Korea.

At the end of the review process, the MSIT delivers a list of recommendations that may require the ministries to amend their plans and/or should be taken into account in their annual action plans. However, this monitoring does not seem to result in significant changes, and its influence on ministries' policies remains unclear, in practice, beyond MSIT programmes. Despite the different centralised processes for ensuring the alignment of the Basic Plan and sectoral plans, ministries keep a high level of strategic autonomy, which has usually led to new processes for additional supervision and monitoring.

Against this backdrop, there seems to be little space for strategic and systemic discussion among ministries between a strategic orientation process every five years that is too generic and a budgeting process that focuses each year on a multitude of specific programmes.

The first five-year R&D Investment Strategy delivered by the STI Office in 2023 is an important new step to better bridge the S&T Basic Plan and the sectoral ministries' mid-term plans. The objective of this document is to be the "missing link" between mid-term overall strategic orientations and annual sectoral planning. It is too early to assess the added value of this new process.

PACST's Advisory Council is the highest-level body that validates the different processes at key milestones. They also host relevant policy discussions among experts to advise the President, which can prove useful on specific policy issues. However, it is not playing a more systematic role in generating mid- to long-term policy. PACST's Deliberative Council plays a comprehensive role at different stages of the policy cycle, from aligning strategies and sectoral five-year plans to reviewing action plans and monitoring reports and yearly programme proposals. The STI Office supports these councils, leads the development of the Basic Plan, and reviews the ministerial plans, which is discussed in the setting of the Ministerial Conference as well.

Based on the directions set in the Basic Plan and the mid- to long-term investment strategy, more detailed holistic strategic orientations are provided at the programming level during the annual planning and budgeting process. This tends to result in the strategic orientation being overrun by short-term administrative imperatives, information overload, low-level budget competition and inter-ministerial turf battles.

1.6.3. Sophisticated mechanisms for cross-ministerial co-ordination of STI budgets are prevalent, but processes could be more efficient

A sophisticated process is in place to set the overall R&D budget, allocate it among the different ministries according to their plans for activities during the year, and co-ordinate these plans to increase strategic consistency and avoid unnecessary overlaps. The plans and programmes from about 26 ministries and departments (900 programmes in 2020) are submitted to the STI Office, which reviews them with support from the Deliberative Council, 8 sub-committees of about 15 scientific and technological experts from the public and private sectors, in specific areas (energy, ICT and convergence technologies, etc.). These experts assess the technical soundness and feasibility of the different R&D programmes submitted by the ministries. The assessments are supplemented by the STI Office's analysis of the consistency of the different programmes between themselves and with the priorities of the Basic Plan.

In addition to co-ordinating within the annual budgetary process, the ministers from the eight ministries with the highest spending regularly convene in the Ministerial Conference of Science and Technology to exchange information and discuss their plans and programmes. These meetings,

held about once a month, allow for more lively and frank discussions about challenges and new initiatives than in more formal committee settings.

Despite this elaborate, systematic and centralised process for co-ordinating STI plans and programmes, insufficient inter-ministerial co-ordination remains one of the key issues hindering the effectiveness and efficiency of STI policy. A survey carried out by STEPI regarding the relevance of the diagnosis and level of implementation of the recommendations of the 2009 and 2014 *OECD Reviews of Innovation Policy* for Korea shows a high level of consensus on the need to improve policy co-ordination across ministerial and agency silos. It is one of the recommendations that has been the least implemented. It comes second in terms of importance for Korea's present and future (of all 2009 and 2014 review recommendations). The many stakeholders consulted during the review exercise, within the government and in performing organisations, fully support the results of this survey.

The annual budgeting process provides a unique mechanism for a holistic review of the budget requests of 26 ministries, but it is labour-intensive and results in only minor adjustments to programmes. This process mobilises significant human resources within ministries, at the STI Office, among experts of the Deliberative Council and at the MOEF. Furthermore, there are rarely significant changes to the content of programmes, the merger of programmes or the reshuffling of projects among programmes. The process intervenes mainly on budget requests. According to the STI Office, the process resulted in significant efficiency gains, representing about 9.3% of the overall 2023 R&D budget, as it avoided important overlaps. Another significant added value of this process is that the sectoral ministries interact with STI-specific organisations (the STI Office and the Deliberative Council) with expertise in this policy field, while in most other countries, the finance authorities keep their main budgetary prerogatives. The need for specific research and innovation expertise was one of the main reasons for the delegation of the budget formation function to the STI Office and Deliberative Council in the first place.

The annual budgetary review of ministries' proposals operates at a granular level of R&D programmes, which insufficiently feeds into higher-level, more systemic, strategic discussions. The reasons for implementing such a process are deeply entrenched in Korean bureaucracy on various levels. Overall, the MSIT can only intervene within the budgetary limits set for each ministry by MOEF, therefore, through the adjustment of programmes and projects. The "meso" level of policies and groups of programmes, essential to linking the large strategic orientations and the activities implemented in projects and other types of initiatives, seems to be overlooked in Korea. Against this backdrop, larger strategic entities are often used as an "umbrella" for smaller-scale programmes.

Another key potential issue is the sustainability of this process of centralised annual review of programmes. While in 2003, this process involved the review of 234 R&D programmes submitted by 19 ministries and agencies, with 142 civilian experts joining the review process, 949, 1 198 and 1 254 programmes were reviewed, respectively, in 2020, 2021 and 2022. This increase in the number of programmes to be reviewed might, in the future, consume an unsustainable amount of resources and/or lead to a procedural mechanism with less value. It is essential to preserve resources for actions of the STI Office at a more systemic and strategic level, in close interaction with sectoral ministries. The already mentioned new five-year R&D Investment Plan aims to strengthen the strategic aspect of budgeting. Reviewing whether this new mechanism has had the intended effect will be important.

Overall, policy making seems overly focused on the process of allocating resources and managing ministries' budgetary competition, whereby arising problems and emerging priorities are addressed by reallocating and reshuffling funding rather than developing a coherent and holistic R&I policy.

1.6.4. Cross-agency co-operation in R&D programme implementation is limited, although reforms have been made

STI policies are mainly implemented in the form of multi-annual R&D programmes by several management agencies, with elaborate programme management procedures throughout the whole project cycle. The National R&D Innovation Act of 2020 includes new provisions for regular reviews of agencies by their respective "principal". As in all advanced countries, these agencies are tasked with defining the precise programmes with their line ministries. They have well-established processes for performing a variety of tasks (development of roadmaps, calls for proposals, consultation with various experts and stakeholders, monitoring and evaluation). Within agencies, Programme Directors are important actors responsible for consultation with stakeholders and managing the portfolio of projects in their respective areas.

Agencies are funded quasi-exclusively by their line ministries, which steer and evaluate them. Co-operation between agencies remains infrequent and often limited to a division of work in large inter-ministerial programmes. Large programmes are one of the main mechanisms for collaboration among ministries and agencies across policy silos. However, these programmes often take the form of umbrellas to host the numerous small projects of different ministries managed by their own implementation agencies. They therefore often replicate the vertically segmented structure between policy fields, with exclusive relationships between ministries and their respective agencies in each silo. Therefore, the added value of these programmes lies in the *ex ante* division of tasks among the participating ministries, which avoids unnecessary overlaps and some integrated monitoring of the programmes. While this undoubtedly raises the efficiency of these large-scale programmes, it falls short of more co-operative practices and joint actions where integrated teams belonging to different agencies collaborate to select, manage and evaluate projects.

1.6.5. The monitoring and evaluation of programmes and projects has significantly changed, but it is too early to assess the effects of the reforms

The pre-feasibility test that conditions the launch of large programmes can, in principle, prove beneficial to avoid misuse of considerable budgets. The criteria for reviewing these large programmes have been modified to be better suited for different profiles of R&D projects. The mechanism seems to have several objectives, including the imperatives to reduce budgetary expenses, increase programme effectiveness and better align them with overall priorities.

The difficulty in passing the feasibility test may create opportunity costs and lead to avoidance strategies. Several ministries reduce the size of their projects or split them into several programmes in order to not exceed the KRW 50 billion threshold. This can result in increased transaction and management costs and possibly in reduced effectiveness of sub-scale programmes. It also worsens the issue of the fragmentation of the STI landscape in smaller programmes and projects without sufficient attention to wider systemic issues or needs. The MSIT has recognised this issue and plans to raise the threshold to KRW 100 billion. This process should be reviewed in one year to assess the result of this change and, more generally, its overall added value and unintended effects.

The monitoring and evaluation of programmes and projects is framed by a system of laws, guidelines and procedures that has evolved significantly since the adoption of the performance-based system in 1996 and the performance management system in 2003. Many reforms have been enacted, but the system's limitations persisted. Monitoring and evaluation continued to focus unduly on the project level and to treat *ex post* evaluation more as a test of project execution than as a tool for understanding goal achievement and learning lessons at the programme and policy levels. In particular, monitoring and evaluation both focus on short-term inputs and outputs (publications, patents, licensing income, etc.).

The 2005 Research Performance Evaluation Act was significantly revised in 2021 to alleviate some key issues. Importantly, the autonomy and responsibility of sectoral ministries for programme and project evaluation were strengthened. For the sake of transparency, ministries were also asked to develop an evaluation strategy plan and to evaluate this evaluation strategy plan. Another change, in continuation of previous reforms, consisted of promoting research quality and using evaluation criteria rather than indicators focused on the quantity of outputs. Finally, the STI Office performs a new "impact-chasing" evaluation five years after the end of selected projects to assess a broader range of impacts, including societal ones. It is too early to assess the effect of this recent reform.

1.6.6. Overarching strategic framework for Korea's sustainable transition

In line with the President's commitment to combatting climate change, the government proposed in October 2020 to achieve carbon neutrality by 2050. This recent commitment remains to be confirmed in years to come, as difficult trade-offs, with potentially significant economic and social consequences, will have to be made. The challenge is considerable as Korea starts from a high level of emissions.

The government launched comprehensive policy plans and programmes to turn these commitments into action. The Committee on Carbon Neutrality is a specific body established in May 2021 to serve as the "control tower" of all carbon neutrality policies in the country (the Net Zero Policy Framework) and as a platform for citizen consultation and engagement. The Korean New Deal, announced in July 2020 and revised since then, consists of three main pillars: the Digital New Deal, the Green New Deal and the Stronger Safety Net, along with measures to support regional development. In 2021, upon reassessing the recent changes in domestic and external environments and their impact on Korean society, the government rebranded the initiative as Korean New Deal 2.0. Some of the policy areas were redefined and expanded, and, for instance, "building a policy framework for carbon neutrality" was newly introduced under the green transition initiatives.

While these new initiatives, their high-level governance and considerable budgets are significant steps, it is unclear whether they represent a qualitative shift from traditional strategy and modes of intervention. The governance structure needs to be clarified and streamlined as there is a profusion of committees active in the areas of carbon neutrality, notably those established to co-ordinate the Net Zero Policy Framework and the Green New Deal. It is also unclear whether this programme represents more than a new source of funding. It is essentially an umbrella for ten large programmes with rather short-term objectives implemented by different ministries. Furthermore, the Green New Deal seems to be focused on achieving economic recovery through new activities in the green area.

Korea has demonstrated a strong interest in technology-focused, mission-oriented innovation policies in the past three to four years, actively engaging in the work of the OECD on this policy approach and experimenting with three schemes: the Innovation and Challenge Projects by MSIT; the Alchemist by MOTIE; and the Future Challenge Technology Development Programme by the Ministry of Defence.

These initiatives are too recent to be assessed. However, these belong to the type of "DARPA-like" challenge-led schemes. These tend to be focused on research and technology outcomes, and their success will depend on their ability to be coupled with public procurement instruments or some other dependable source of demand, as is the case in the United States and Nordic countries (e.g. Norway's Pilot-E scheme). These initiatives can be effective in accelerating technical changes in some targeted areas but fall short of supporting more systemic innovation that links technological, behavioural, regulatory, social and market innovation. The characteristics of the Korean programmes are consistent with their main objective, which is to strengthen national competitiveness. The mobilisation of this policy approach to support the green transition will require a different type of design and governance. Some recent announcements propose to follow this route but have not yet been enacted.

1.7. SWOT analysis of Korea's innovation system

Table 1.1. SWOT analysis of Korea's innovation system

Strengths	Weaknesses
Framework conditions for innovation • Korea's STI policy is strongly committed to and agile in adopting international best practices. • Entrepreneurs benefit from macroeconomic stability, high-quality infrastructure and ease in starting a business. • Progress has been made in trade and investment openness, and few restrictions remain in the manufacturing sector. Industrial dynamics and business innovation • Korea has a highly competitive industrial and manufacturing base, notably in (high-end) electronics, automotive, communications, shipbuilding and petrochemicals. • Leading conglomerates are well integrated into domestic and global value chains and are strongly export-oriented with growing global market share. • Korea has excellent ICT infrastructure, high adoption rates of some digital technologies among consumers and large firms, and the highest robot density in industry. • Korea has world-leading levels and growth of business innovation research spending. • Strong governmental support for SMEs and early-stage entrepreneurship results in a rapidly growing start-up scene. Research institutes and higher education • Korea has a strong higher education system with the highest ratio of tertiary graduates worldwide, many of whom are in STEM disciplines. • Korea boasts high and growing expenditure for research in government research institutes and higher education institutions. Governance and initiatives to tackle societal challenges • Korea's strong foresight system systematically informs the whole of government and sectoral strategies and plans. • Korea has a comprehensive, five-year, overarching strategic framework to guide STI activities, informed by foresight and comprehensive consultations. • Korea has a central STI co-ordination unit ("control tower") with a powerful mandate to co-ordinate STI-related plans and activities of about 26 ministries who intervene in this area.	Framework conditions for innovation • Korea has had longstanding difficulty transitioning from being a "fast follower" into a leader in science, technology and innovation. • Koreans show risk aversion when launching new initiatives (including initiating high-risk research). • Cultural openness towards foreigners, which could bring new stimuli and creative ideas, is not very pronounced in Korea. Industrial dynamics and business innovation • There is limited contribution of knowledge-intensive services to the economy as services are concentrated in lower value-added sectors. • There are restrictions on foreign investment in services, including communications. • There are large gaps in society and duality in labour markets, particularly regarding SME/chaebol, rural/urban and old/young divides. • Many SMEs have a low absorptive capacity for new technologies due to difficulty raising digital and technical skill levels and attracting talent, leading to a wide productivity gap with large firms. • Low business R&D expenditure in the service sector leads to slow development of high-value-added services and exports of such services, including royalties and license fees, financial services, miscellaneous business services and IT services. Research institutes and higher education • Strong reliance on the government-funded project-based system fosters short-term focus, fragmentation and a lack of market orientation in research. • There is a low share of high-impact and high-visibility research. • Korea has a modest performance on international higher education rankings. Governance and initiatives to tackle societal challenges • Resource-intensive and rather mechanistic co-ordination leads to inflexibility, slow action, and the production and sharing of excessive amounts of centralised information. • There is insufficient co-operation and reduction of ministerial silos within large inter-ministerial programmes and initiatives (including the Green New Deal).
Opportunities	**Threats**
Industrial dynamics and business innovation • Korea's large and innovative firms are well-positioned to shape and lead the international innovation frontier in upcoming technological transitions as part of the 4th industrial revolution. • Despite being relatively restricted in trade and investment, particularly regarding services, Korea has shown strong progress since its accession to the OECD. Further reducing remaining barriers may result in job creation, knowledge transfer and, therefore, enhanced innovation and productivity growth. • The recent uptake in venture capital funding has contributed to a rapidly growing start-up scene that may well give rise to the next	***Industrial dynamics and business innovation*** • Korea's strong embeddedness in global value chains creates a high reliance on geopolitical and global economic stability. Due to its relatively low market size, it is particularly affected by rising trade tensions and protectionism tendencies, for instance, as a consequence of United States-China disputes in recent years. • Korea is missing future major opportunities due to its knowledge-intensive service sector lagging that of other major innovative economies.

Korean innovation leaders, particularly in knowledge-intensive services industries, which are critical for the digital transformation.

- Cultural attitudes regarding risk taking and openness to foreigners, as well as creativity, are changing with the younger generation, who are more exposed to international ideas and practices, as well as the onset of more practical and innovative education curricula.
- Korea can leverage its lead status in Asia and globally to set standards and lay out strong infrastructures, particularly as China increasingly seeks to serve its large domestic market.

Research institutes and higher education

- Recently, the government has initiated several efforts to increase flexible funding for research and encourage universities' autonomy.
- Knowledge flows and technology transfer from universities and public research institutes to industry have increased in recent years. Leveraging linkages between research institutions and industry can foster interdisciplinary strategic partnerships and boost co-creation and, thus, disruptive innovation.
- Korea can promote technical skills development by expanding on past initiatives, such as vocational training and lifelong learning for the old-age workforce, addressing SMEs in particular.
- Korea can strengthen the ability and incentives for universities to do more high-impact research (excellence, breakthrough, relevance).
- Korea can foster interdisciplinary research by merging public research institutes according to disciplines, which would improve co-ordination and reduce fragmentation and inefficiencies.
- Korea can use research institutes as policy tools to tackle societal challenges in large and ambitious initiatives, leveraging knowledge, skills, technological infrastructure and industrial networks.

Governance and initiatives to tackle societal challenges

- Korea can leverage its leading position in certain green technologies, including batteries for electric cars, to meet the increasing global demand for green innovation.
- Korea has ambitious government strategies and initiatives (e.g. Net Zero Policy, Green New Deal) to raise awareness of researchers, civil servants, industry and civil society on the societal challenges imperative and alleviate fears of disruption to jobs and the economy.
- Korea is increasing its attention on mission-oriented innovation policies to address key national societal challenges in a better-oriented and co-ordinated way to structure collective action across silos.

- SMEs' high and persistent productivity gap with large companies despite considerable resources being provided to SMEs risks Korea's industrial base falling behind, particularly in ICT technology adoption.
- Failing to open up to foreign cultures could damage prospects for deeper global integration, including global scale-up of Korean start-ups and unicorns, better integration in the global science system and achieving global societal goals.

Research institutes and higher education

- The ongoing contraction in the higher education sector (due to a drop in the number of students) risks exacerbating social and regional inequality.
- A rising level of development and an increasing amount of fundamental scientific knowledge required to keep up with technological advancement creates a need for intensified industry and academia collaboration. The prevailing fragmentation of the public research institute system is not conducive to strengthened co-operation and co-creation.

Governance and initiatives to tackle societal challenges

- Widening societal gaps need to be addressed with proactive policies to ensure inclusive growth, e.g. population ageing will reduce Korea's labour force, which requires adequate and up-to-date skills for its STI system.
- Lack of actions in pursuing necessary change to address climate change, such as phasing out fossil fuels, due to concerns with regard to demographic and economic disruptions has led to a slow start in society for the green transition.
- The unabated barriers to collective action across sectoral, disciplinary and policy silos hinder Korea's ability to respond with the necessary scope and scale to rising societal challenges.

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Notes

1. As noted above, an additional future recommendation of overall STI governance will further reinforce this capability.

2. The pre-feasibility test is a review process that conditions the launch of large programmes.

3. Note by the Republic of Türkiye:

   The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".

   Note by all the European Union Member States of the OECD and the European Union:

   The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

4. Calculated as the sum of the forward participation (domestic value added in foreign exports as a share of gross exports) and backward participation (foreign value-added share of gross exports) in GVCs.

5. Number will be updated when new MSTI statistics become available in April 2023.

6. This includes the share of “middle-market firms” and SMEs.

7. Compared to the United Kingdom (81%) and Germany (75%) in 2018. OECD calculations based on OECD Structural Analysis Database (STAN).

8. Korea is expected to have the sharpest increase in the ratio between 2021 and 2050. The old-age to working-age demographic ratio is defined as the number of individuals aged 65 and over per 100 people of working age defined as those aged 20-64.

9. Having slightly decreased from 2019, mostly due to COVID-19 disruptions in the economy, and notably the services sector, which largely employs women.

10. It is worth noting that Ireland is ahead of Korea, but this is due to a specific context of mostly US-based multinationals relocating manufacturing operations to better access the EU market.

11. Six target HCI sectors: 1) iron and steel; 2) non-ferrous metal; 3) machinery; 4) shipbuilding; 5) electrical appliances and electronics; 6) petrochemicals.

12. Artificial intelligence, 5G and 6G, quantum technology, space and aeronautics, rechargeable battery, cybersecurity, advanced biology, advanced robotics and manufacturing, semiconductors and display, and hydrogen.

13. In the 2021 InterNations Expat Insider ranking, Korea ranks 47th out of 59 destination countries surveyed globally, with expats appreciating the quality of life, in particular healthcare, safety and transportation, but reporting they have difficulties settling down, experience difficulty making local friends, struggle with learning the language and more generally do not feel at home. The HSBC Expat Explorer study shows similar results, pointing out barriers particularly linked to career progression, social relations and raising children in Korea.

14. The Green Future Index presents the comparative ranking of 76 nations and territories on their ability to develop a sustainable, low-carbon future. It measures the degree to which their economies are pivoting toward clean energy, industry, agriculture, and society through investment in renewables, innovation and green policy.

15. The other two pillars are “carbon emission” (Korea 42nd) and “climate policy” (23rd).

16. CO_2 intensity of GDP is calculated as kilograms of production-based CO_2 emissions per real GDP (kg/USD). Included are CO_2 emissions from the combustion of coal, oil, natural gas and other fuels.

17. In 2021, the government published the Roadmap for CCU Technology Innovation, which focuses on technologies for the conversion and utilisation of CO_2 that are needed and urgent for technology development. It aims to commercialise at least 14 CCU products by 2030 and includes 59 technologies that would require strategic investment to that end.

18. Basic metals, chemicals and chemical products, other non-metallic mineral products.

19. The initiative is led by the Climate Group (in partnership with CDP), which is a non-profit organisation working with businesses and national governments to address climate change. For more information, see https://www.there100.org/.

20. OECD calculation based on the OECD Patent Database (OECD, 2022[85]) and World Bank Population data (World Bank, 2022[86]).

21. Institutes of Science and Technology – a group of leading universities in S&T fields.

22. According to Woolcock (1998), social capital, a broad term encompassing the norms and networks facilitating collective action for mutual benefit, including, but not limited to, trust. It is one of the key drivers of economic development, alongside with physical and human capital (labour) (Woolcock, 1998[88]).

23. These include KAIST, GIST, DGIST and UNIST.

24. UNIST, KAIST and Pohang University of Science and Technology (POSTECH).

25. The percentage in top 10% is the top 10% most cited documents in a given subject category, year and publication type divided by the total number of documents in a given set of documents; 10% among the top 10% cited would mean performance at the same level as the world average.

26. Technology readiness levels (TRLs) is a scale measuring the maturity of technologies originally developed at the National Aeronautics and Space Administration (NASA) during the 1970s. It ranges from TRL=1, which denotes basic principles research, through intermediary steps denoting technology concept formulation, experimental proof of concept, assessment of feasibility, validation of integrated prototype in laboratory, testing the prototype in a user environment, pre-production and testing, low scale pilot production, manufacturing fully tested, validated and qualified, up to TRL=9, which denotes a fully operational and competitive product. See, for example, EARTO (2014[87]).

27. The discussion seems to have been complicated by the fact that while the GRIs were mostly RTOs, they also did some big science and performed some of the technical functions carried out in government labs.

28. The institutional (block) funding of GRIs is generally about 40%. This is similar to the European average, though there are considerable variations: KIST has 53.2%, KICT 33.6%, KITECH 30.9%, while ETRI has 14.5%, due mostly to the fact that it has grown considerably due to the success in securing competitive project funding.

29. The mission drift is evident from the spending breakdown: while experimental development accounted for 43.7% in 2006, it dropped to 26.7% in 2020; applied research progressed from 35.8% in 2006 to 40.9% in 2020; and basic research from 20.5% in 2006 to 34.9% in 2020. This is further differentiated across the GRIs, as some of them (KIST, KFE, KASI, KRIBB, KRISS, KIGAM) allocate more than 50%, and up to 80% of their funding to basic research, while others (KICT, KRRI, KFRI, WIKIM) allocate more than 50% on experimental development and can thus be considered as RTOs.

30. Academic-industry co-publications, as a share of total publications, declined between 2009 and 2019 from around 5.9% to 4.5%. In Germany, they rose from 5.8% to 6.7% in the same period.

31. The initiative is supported by a dedicated secretariat under NST. See http://tlomarketing.com/.

32. For more information, see https://www.etriholdings.com/.

33. Seventeen GRIs, including KIST and KRISS, are the shareholders. For more information, see http://kstholdings.co.kr/kor/main/.