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Policy Exchange Activity 3

Science, Technology and Innovation (STI) Priorities

Supporting the development of Vietnam’s Science Technology and Innovation (STI) Strategy 2021-30

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Important disclaimer

Contents

1 EXECUTIVE SUMMARY

This report has been prepared as an output of the Policy Exchange Activity 3 (PE3) project - 'Supporting the development of Vietnam's Science Technology and Innovation Strategy 2021-30'. This project is a component of the Aus4Innovation program funded by the Australian Department of Foreign Affairs and Trade (DFAT), with co-contributions from DFAT's Innovation Exchange (IxC), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

The PE3 project is being undertaken as a partnership between the Vietnamese Ministry of Science and Technology (MoST) and CSIRO. The component of the project, addressed in this report, assesses the relevance for Vietnam of international experience with setting priorities for Science, Technology and Innovation (STI). A complementary component assesses the relevance for Vietnam of international experience with STI indicators.

The report is organised in the three parts:

- Part A discusses the frameworks for overall STI policy. The first section reviews the role, within overall economic development policies, of strategies for STI. It draws in particular on the experience of the successful East Asian economies. The second section reviews general frameworks for innovation management and policy. Over the past 30 years there has been a transformation in understanding of innovation processes and of the role of innovation in the economy. The major elements this transformation and it's implications for policy are discussed. This section concludes with an outline of recent developments in innovation policy. The final section of Part A, draws out one particular thread of the discussion in the first two sections - the role of learning in priority setting systems and in STI policy generally.
- Part B summarises the key points from cases studies of how nine selected countries approach STI priority setting: Australia, Chile, China, Europe (selected countries) Korea, Japan, Malaysia, Singapore, and Taiwan. The summary includes an assessment of the key challenges in STI priority setting and also identifies some of the key implications for Vietnam of the diverse international contexts, approaches and experience. The detailed country case studies are in Appendix 1.
- Part C discusses the policy context for STI priority setting in Vietnam. Innovation policy frameworks provide one of the foundation components for priority setting; Vietnam's development priorities and strategies provides another. The first section of this part discusses some of the pragmatic principles for selecting priorities from long lists of candidates. The following sections review the draft of Vietnam's Socio-Economic Development Strategy (SEDS): 2021-2030, drawing out the indirect and direct implications for STI priorities. The SEDS has clearly been informed by analyses of the performance of Vietnam's innovation system.
- Appendix 1 sets out the detailed country case studies.

1.1 Innovation Policy Foundations for Priority Setting

Priority setting for STI has two key objectives:

- Steering activities in the STI system toward achieving social, economic and environmental goals. This relies on identifying those investments (of financial, human and organisational resources) in science, technology, innovation, and related activities, that are likely to have the greatest impacts in relation to those goals.

- Facilitating the coordination of different actors and activities involved in the innovation system in order to improve overall efficacy and efficiency.

Identifying which investments in which elements of STI will have the greatest impacts over time requires an understanding of the relationships between S,T and I. It also requires an understanding of the strengths and weaknesses of a nation's innovation system.

This is particularly important for Vietnam as the S&T Development Strategy of 2011-2020 focused on developing S&T capacities but was not closely aligned with the Socio-Economic Development Strategy. It is considered that science and technology did not enable transformative change by raising labor productivity, and effectively applying science and technology and organizational and production management innovation. The lack of focus on raising the managerial, technological and innovation capabilities of firms limited the impacts of investments in indigenous S&T capability.

Since the 1990s, innovation policy in most countries has been increasingly influenced by the innovation systems perspective. This perspective emphasises the central significance of processes of knowledge acquisition and generation, and the roles that interaction among actors and institutions have in stimulating and shaping those processes. From this perspective it is firms that are the central actors in an innovation system.

From the innovation systems perspective it is the accumulation of capability (ie learning) throughout an economy that raises productivity and innovation levels. Rather than focus on a few high -tech or high-R&D sectors and firms, it emphasises the role of the diffusion of knowledge and hence of the absorptive capacities of all firms and organisations.

As innovation systems are complex, any policy intervention involves a level of uncertainty regarding the diagnoses of the source of problems, the identification of opportunities, and the likely impacts of policies to address problems and pursue opportunities. Consequently, policy is unavoidably experimental. All participants in innovation systems are continuously learning how to be effective and how to interact with other participants.

In the many countries that have moved from low levels of productivity and innovation capability to 'catch up to the global frontier', government STI policy has played a key role. However, the policies that have been critical in each country and the roles of the private sector, state-owned firms, foreign-owned firms, universities and publicly -funded research organisations have varied widely – each country has developed a unique path, shaped by both the national context and by the prevailing global technological and economic context. The experience of these countries points to the importance of:

- strengthening the capabilities of firms and ensuring that the economic environment provides incentives for firms to invest and innovate
- recognising the role of uncertainty in planning
- developing mechanisms for coherence and coordination in strategies
- developing strategies at the sectoral level
- building momentum through positive feedbacks
- developing roadmaps to impact so that investments in knowledge and capability are linked to objectives
- addressing major shifts in technological regimes
- empowering opportunity discovery through entrepreneurship.

1.2 Evolving Perspectives on Innovation

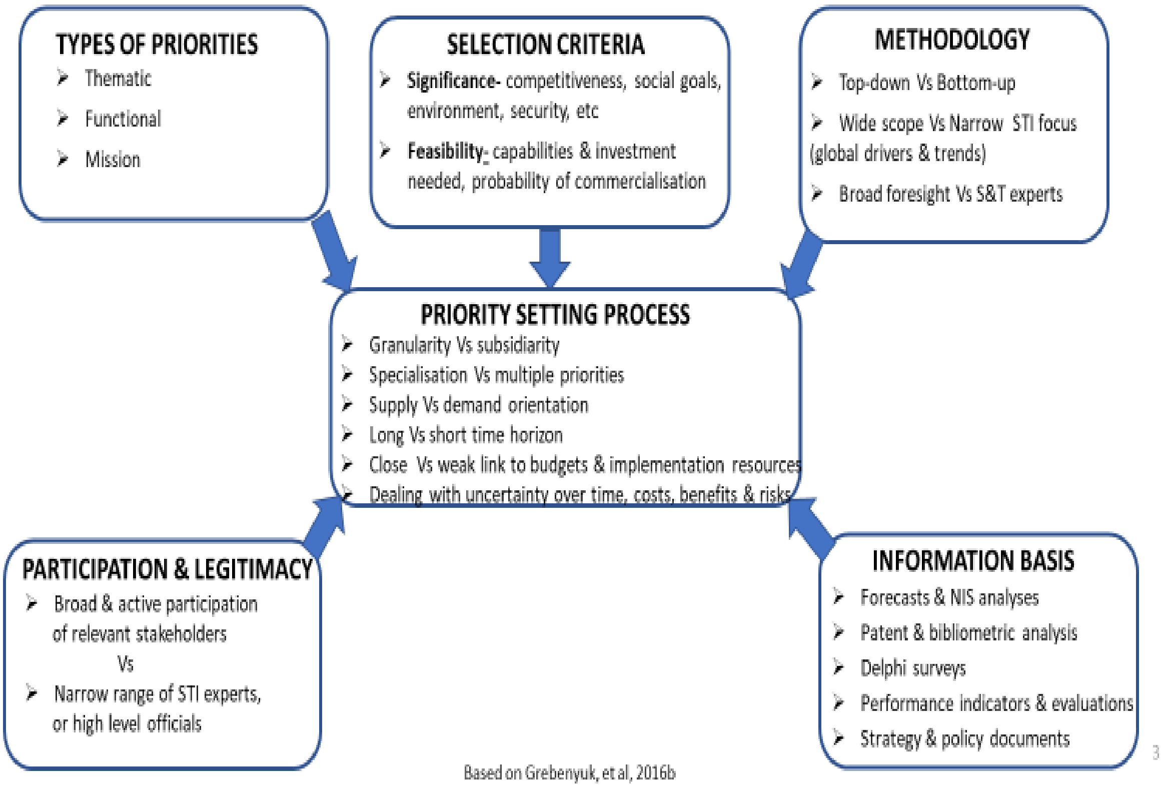
Understanding of the role of innovation in economies and societies, and of effective innovation policy, is continually evolving. This report discusses several aspects of innovation frameworks that are particularly relevant to innovation policy:

- Innovation is relevant to all activities- industrial (including services), social, administrative, policy
- While major innovations can be transformative, ongoing incremental innovation is essential for productivity growth
- Innovation often draws on knowledge from many fields and sources and involves close interaction among (and within) organisations
- Patterns of innovation, and the sources of knowledge used, are markedly different in different sectors
- The capabilities of firms to acquire, adapt, apply and improve knowledge is a critical element of an innovation system – it is one determinant of the rate of productivity growth and the demand for knowledge from all sources
- Entrepreneurship is a form of business experiment that can identify new scope for value creation
- Firms' potential and propensity to innovate is shaped by their capability, but also by their access to skilled human resources, markets, knowledge, finance, supportive institutions, high quality suppliers etc- ie firms innovate in the context of sectoral, regional and national innovation systems.
- The report includes a discussion of recent developments in innovation policy that are based on new insights into innovation and on experience with policy implementation.

1.3 International Approaches to STI Priority Setting

There are many options in the scope, objectives and design of STI policy setting processes, as summarised in the following diagram:

Overall Model of STI Priority Setting Design Options



1.3.1 National Approaches and Dominant Trends in Priority Setting

The report assesses the approach to STI priority setting in nine countries: Australia, Chile, China, Europe (selected countries) Korea, Japan, Malaysia, Singapore and Taiwan. The assessment is organised around eight dimensions of the design of STI priority setting systems:

1. Scope and content of STI priorities: As STI has a pervasive and increasing role across the economy and society and all areas of public administration, what is the scope of STI priorities?
2. STI governance and leadership: Who is responsible for developing STI priorities, how are these priorities integrated with other areas of public policy, how is legitimacy established, and how are the views and interests of different stakeholders coordinated?
3. Processes of priority setting: What issues are considered, information sources used, and assessments conducted?
4. Approach to consultation & participation in priority-setting: Who contributes at what stage to identifying and selecting priorities?
5. Types of STI priority: To what extent do priorities focus on capability in a specific area of science or technology, on improving the performance of the innovation system or on social, environmental, economic (etc) objectives to which STI contributes?
6. Integrating innovation goals: As innovation is broader than S&T, is shaped by policy in areas beyond S&T and has wide ranging impacts, how is the ‘I’ integrated with the S&T?

7. Implementation of priorities: What policy instruments are used to drive implementation and to what extent is the detail of broad priorities delegated to lower-level actors, such as funding agencies, Ministries etc?
8. Monitoring, evaluation and systemic learning: How do all actors in the STI system, including the priority setting and implementation component, improve their capability and effectiveness?

1.4 International experience with STI Priority Setting – Some Key Implications

The nine diverse and detailed country case studies are set out in Appendix 1- and summarised in Part B. In our view the key points that we have drawn from international experience provide useful guidelines for STI priority setting in Vietnam. We have emphasised in Part B and in Appendix 1 that while different countries may follow similar principles in their approach to priority setting the specific characteristics of their approaches will be shaped by their context and experience.

The following points identify what are likely to be some of the main implications of that international experience for STI priority setting in Vietnam.

Scope and Content of STI Priorities

- STI priorities needs to be thoroughly integrated with, and reflect, broader national ambitions.
- Innovation is important for a wide range of policy objectives and involves much more than S&T. Innovation performance is shaped by economic incentives, management capability and business culture – which in largely determine the demand for new knowledge and the willingness to innovate
- Building capabilities throughout the innovation system to absorb knowledge and to learn to improve technology, collaborate and innovate, will shape the demand side without which investments in the supply of knowledge through investment in R&D will have few benefits.
- The role of technology acquisition from foreign sources is a component of STI priorities.
- Important priorities will be those transformative opportunities to remove barriers and seed self-reinforcing dynamics that drive a widening process of upgrading.

Governance and Leadership

- Priority setting is an issue for all levels of the innovation system - the national level and the level of research organisations, sectoral agencies, universities, funding bodies etc.
- Strategic STI policies that have been developed with stakeholder participation, and that provide a clear *vision* and high-level goals and priorities, guide funding bodies, research organisations, universities and enterprises to develop operational priorities.
- STI Councils with participation by key Ministries and major stakeholder groups, and chaired by the head of government, contribute to the legitimacy and effective coordination of STI priorities and implementation.

- An effective priority-setting system requires capable and resourced participants committed to learning about: priority setting processes; the outcomes and lessons of previous priorities and approaches; research and innovation systems, and new challenges and opportunities.

Priority-Setting Processes

- Developing a comprehensive range of information on which to base decisions and sharing (and discussing) the analysis of that information with participants in the STI priority setting process, is an essential investment of time and resources.
- A critical source of insight is previous experience in selecting and implementing priorities. Learning from that experience, and engaging all major stakeholders in such reviews, contributes to building a shared perspective on the national (regional, sectoral) context and the challenges faced.
- Empowering organisations close to STI activity with significant scope for making decisions on the allocation of resources at the detailed/tactical level- and ensuring that they are accountable for those decisions – will strengthen the overall STI system.

Approach to Consultation & Participation in Priority-Setting

- Sharing among participants in the STI system the assessments of trends and opportunities (eg foresight studies) that inform priority setting, contributes to the quality of participation and in turn to the legitimacy and influence of the STI priorities.
- A shared perspective based on sound analysis and extensive consultation also contributes to aligning the future actions of STI system participants.
- High-level councils with representation by relevant ministries and the significant stakeholders from research and industry, and national conferences with similar participation, are mechanisms that can be used for participation and consultation. Well-designed foresight can also enable wide consultation.

Types of STI Priority

- There is a role for all three types of STI priority – thematic, functional and mission-oriented.
- When combined in an overall strategy these can be synergistic, particularly when the need for complementary capabilities to ensure a 'path the impact' is kept in perspective.

Integrating Innovation Goals

- STI policies that focus on the supply-side often lead to problems of poor knowledge transfer. The users of knowledge need to be active participants in STI priority setting, and the requirements for strengthening and orienting demand need to be addressed in STI priorities.
- Including mission-oriented initiatives in the policy mix can facilitate cooperation among Ministries and the development of public-private partnerships. The requirement within such approaches for ongoing evaluation can be a powerful mechanism for policy and strategy learning.

Implementation of Priorities

- The priorities of an STI system are to a significant extent emergent, in that they develop from an interaction of top-down and bottom-up priorities and processes. High-level priorities cascade through the levels of an STI system and are interpreted and translated into actions at each level.

- International experience is that decision-making about the detailed allocation of resources is most effective when decentralised and made by those ‘close to the action’. A system with a high level of autonomy but with targets, monitoring, accountability and a tolerance for failure is one that will learn more rapidly and empower the participants.
- As most countries aim to avoid a narrow definition of thematic priorities, while nevertheless providing direction to innovation policy, many have developed broad programs addressing a set of interrelated technology targets. Their targets and approaches usually evolve over time as more is learnt.
- An organisation with responsibilities, and authority, for coordination (horizontally, across sectors, and vertically, across layers of implementation) and also at least oversight of monitoring and evaluation, can help to reduce fragmentation and duplication. Many countries have some form of high-level council or committee with participation from major stakeholder groups, which facilitates coordination among government departments and between the public and private sector.

Monitoring, Evaluation and Systemic Learning

- International experience indicates that monitoring and evaluation plans should be incorporated into policy design and lead to specification of the data needs and the criteria for evaluation. This experience also indicates that evaluations are most effective in promoting policy learning when they are independent and the results made public.
- The priority setting process itself should be evaluated not in terms of success or failure, but rather to identify what can be learnt to improve the next iteration. This is characterised as ‘double-loop learning’, which entails the modification of goals or decision-making rules in the light of experience. This may require not only a change in the design, but also a revisiting of the organization's underlying norms, policies and objectives.

1.5 Initial Broad Recommendations

The Draft Socio-Economic Development Strategy (SEDS) has clearly been informed by analyses of Vietnam’s innovation system and by the experience of the S&T Development Strategy of 2011-2020. The SEDS provides a large part of the foundation for STI priority setting. In Part C we have sought to identify the particular elements in the Draft SEDS that have implications for functional, thematic and mission-oriented STI priorities.

Here we emphasis what we see, on the basis of our current knowledge of the Vietnamese context, as the most important priorities – focusing on horizontal priorities and on governance issues.

Horizontal priorities

- The experience both of Vietnam’s 2011-2020 S&T Development Strategy, and of STI development internationally, emphasizes the importance of the managerial, technological and innovation capabilities of firms. An effective STI strategy must include strategies for the ongoing upgrading of firms’ capabilities.
- Sectoral strategies, informed by analyses and consultation with all stakeholders, can identify opportunities and barriers to upgrading and growth. Such strategies can include targeted

measures to strengthen firms, identify measures to stimulate investment, innovation and collaboration and communicate to government issues that require attention.

- It will be important to ensure that foreign investment into Vietnam contributes not only to production capacity, but– through knowledge transfer and in-house innovation activity – also to building Vietnam's innovation capacity. The experience of several countries provides exemplars for effective approaches to actively promote such 'spillovers'.
- Entrepreneurs discover, create and pursue opportunities based on emerging markets, under-used resources, or the application of capabilities or new technologies. They have a vital role in an economy and innovation system. While assessments of the entrepreneurial ecosystems in Vietnam will be essential, it is likely to be important to ensure that early stage and growth funding is available, and that regulation and the anti-competitive behavior of major firms are not significant disincentives for entrepreneurs. Continuing to strengthen STEM education and introducing entrepreneurship courses into higher education will also contribute to building the potential for entrepreneurial activity.

Governance

- A review, with participation by all relevant Ministries and major industry associations, of the outcomes of the S&T Development Strategy of 2011-2020 would be valuable for the current strategy development. It would contribute to an informed and shared view of the strengths and weaknesses, both of those strategies and of the approach to priority setting.
- STI systems are open systems, characterized by complexity and uncertainty, with many actors and diverse interactions. Planning to learn is as important as learning to plan. A key objective of strategies for STI is to enable rapid learning by all actors –learning about opportunities, their own and others' strengths and weaknesses, how to collaborate to address constraints, how to build capabilities to improve performance and to innovate. Monitoring and evaluation can play a role in stimulating learning, if it is accepted that mistakes, failures and unforeseen problems are both inevitable and opportunities to learn and improve. Developing an evaluation culture should be an aspect of STI strategy. Similarly, pilots and policy experiments are explicitly designed to enable learning.
- Autonomy combined with clear mandates, assessment and accountability drives change more effectively than prescriptive control. Where research organisations and universities are funded on the basis of performance agreements (ie the organisations are required to have an explicit strategy with goals and relevant indicators) they have flexibility in achieving their missions and incentives to learn to be more efficient and effective.

Thematic and Mission-Oriented Priorities

- In Part C we list a set of basic principles for identifying major thematic STI priorities. Areas likely to stimulate positive feedbacks and hence increasing returns are particularly important. Positive feedbacks drive growth and upgrading, leading to increased production capacity, deepening capabilities and a widening range of participating firms and organisations. These are the dynamics of cluster growth, but also of successful sectoral and regional innovation systems. These areas will often begin as small niches where there is an alignment of relevant capability and opportunity. For example, these could be opportunities to expand roles in global value chains to build higher value adding positions, or the application of advanced digital or biotech technologies to otherwise 'low tech' sectors such as resource processing or service industries. There are two roles for government in relation to these growth foci: identifying and seeding early emergence; removing barriers to growth. One option for undertaking these roles, where integrated policy and public-private joint initiatives are essential, is the formation of an Innovation Agency with a broad and flexible mandate to pursue these roles and to undertake pilots.

- The pervasive significance of the digital technologies of Industry 4.0, and the objectives set out in the Sustainable Development Goals (SDGs), are likely to be foci for major mission-oriented STI policies.

2 INTRODUCTION

This report has been prepared as an output of the Policy Exchange Activity 3 (PE3) project - ‘Supporting the development of Vietnam’s Science Technology and Innovation Strategy 2021-30’. This project is a component of the Aus4Innovation program funded by the Australian Department of Foreign Affairs and Trade (DFAT), with co-contributions from DFAT’s Innovation Exchange (IxC), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

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"Innovation governance [Is a] key challenge, and it requires developing the necessary institutional set-ups, procedures and practices for agenda setting and prioritisation, implementation and policy learning."[1] The overall objective is to match future capabilities (organisational, policy, innovation, research, management, technical) with likely future opportunities and challenges. Hence, priority setting for STI has two key objectives:

- Steering activities in the STI system toward achieving social, economic and environmental goals. This is based on identifying the investments in science, technology, innovation, and related activities, that are likely to have the greatest impacts in relation to those goals. Investments involve financial, human and organisational resources.
- Facilitating the coordination of different actors and activities involved in the innovation system in order to improve overall efficacy and efficiency.

STI priorities usually include three dimensions, each with different implications for the types of (a priori and ex-post) assessment and the types of organizational capability required:

1. **Functional or horizontal** priorities that aim to improve the performance of the national (or regional) innovation system, for example by raising the level of collaboration among actors and overcoming ‘system failures’.
2. **Thematic** priorities focusing on areas of science, technology and industry considered to be important for competitiveness, security, prestige or other objectives. In most countries the emphasis is on emerging areas that have broad relevance of high relevance for priority industries.
3. **Mission-oriented** priorities addressing social challenges, often requiring inter-disciplinary and inter-sectoral approaches based on a systems perspective of what is needed to achieve an objective.

Identifying which investments in which elements of STI will have the greatest impacts over time requires an understanding of the relationships between S,T and I. It also requires an understanding of the strengths and weaknesses of a nation’s innovation system.

The report is organised in the three parts:

Part A discusses the frameworks for overall STI policy. The first section reviews the role of strategies for STI in economic development with a focus on the successful East Asian economies. The second

[1] OECD, 2005, p.7

section reviews general frameworks for innovation management and policy. Over the past 30 years there has been a transformation in understanding of innovation processes and of the role of innovation in the economy. The major elements this transformation and it's implications for policy are discussed. This section concludes with an outline of recent developments in innovation policy. The final section of Part A draws out one particular thread of the discussion in the first two sections - the role of learning in priority setting systems.

Part B summarises the key points from the nine country cases studies: Australia, Chile, China, Europe (selected countries) Korea, Japan, Malaysia, Singapore, and Taiwan. The summary includes an assessment of the key challenges in STI priority setting and also identifies some of the key implications for Vietnam of the diverse international contexts, approaches and experience. The detailed country case studies are in Appendix 1.

Part C discusses the policy context for STI priority setting in Vietnam. Innovation policy frameworks provide one of the foundation components for priority setting; Vietnam's development priorities and strategies provides another. The first section of this part discusses some of the pragmatic principles for selecting priorities from long lists of candidates. The following sections review the draft of Vietnam's Socio-Economic Development Strategy (SEDS): 2021-2030, drawing out the indirect and direct implications for STI priorities. The SEDS has clearly been informed by analyses of the performance of Vietnam's innovation system.

Appendix 1 sets out the detailed country case studies.

3 PART A FRAMEWORKS FOR STI

3.1 STI and Development

All countries face continuing challenges in decisions about the most productive investments in STI and in linking investments in research in publicly funded research organisations to capability development and innovation in enterprises. The role of government is particularly important in the exploration, development and diffusion of new ‘general purpose technologies’[2]. Knowledge from publicly funded research organisations flows to firms through many channels. Overall, the most important of these has been knowledge transfer through people, via education, mobility of personnel and informal networks[3].

The innovation systems perspective emphasises the central significance of processes of knowledge (ie information and competence) acquisition and the roles that interaction among actors and institutions (ie policies, customs, culture) have in stimulating and shaping learning[4]. In relation to institutions, this perspective draws attention to the importance of a broad range of institutions– including education, trade and investment, and industrial relations policies, and social norms and policies that engender trust - that are often considered outside the scope of STI analysis and policy. The perspective also emphasises the importance for knowledge flows of informal linkages among organisations.

From the innovation systems perspective it is learning throughout an economy that raises productivity and builds capability. Rather than focus on a few high -tech or high -R&D sectors and firms, it emphasises the role of diffusion of knowledge and hence of the absorptive capacities of all firms: ‘..the rate of technical change and of economic growth [in a wide range of countries] depended more on efficient diffusion than on being first in the world with radical innovations and as much on social innovations as on technical innovations’ [5].

In the industrialised countries, the industrial, research, technology and education organisations in the innovation system, and the diverse range of policies that influence them, have co-evolved over long time periods[6]. As a consequence, a complex set of complementarities – a division of innovative labour – has developed. The participants and policies, and their relationships, continue to evolve, with significant re-adjustments from time to time. Nevertheless, innovation systems are complex and any policy intervention involves a level of uncertainty regarding both the diagnosis of the source of problems and the likely impacts of policy measures. Consequently, policy is unavoidably experimental. All participants in innovation systems are continuously learning how to be effective and how to interact with other participants.

In the many countries that have moved from low levels of productivity and innovation capability to ‘catch up to the global frontier’ government policy has played a key role. However, the policies that have been critical in each country and the roles of the private sector, state-owned firms, foreign-owned firms, universities and publicly -funded research organisations have varied widely – each

[2] Scott-Kemmis, 2018; Bresnahan & Trajtenberg, 1995; Blumenthal, 1998.; Mowery, D.C., 2006 ; Mowery & Simcoe, 2002; National Research Council, 1999.

[3] Salter,et al 2000; Florida, 1999.; Bruneel, et al., 2010.

[4] Lundvall et al define an innovation system as: The national innovation system is an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economic structures which determine the rate and direction of innovation and competence-building emanating from processes of science-based and experience-based learning. Innovation system research and developing countries Lundvall et al, 2009. p.6,.

[5] Freeman, 1995, p. 10

[6] For example: Fagerberg et al, 2008.

country has developed a unique path, shaped by both the national context and by the prevailing global technological and economic context. However, there are some generalisations that can be drawn from that diverse experience[7]:

- Quality education at all levels is an essential foundation for all other investments;
- Targeting at the level of specific industries and technologies has enabled a concentration of effort and this targeting has often focused on dynamic sectors with high rates of growth in output and productivity, such that capabilities developed will be more likely to have increasing returns;
- Catching up to the global frontier often involved innovation in the organisation of production and technological learning, for example, mass production in the US, corporate R&D in Germany, JIT and TQC in Japan, OEMs in Korea and Taiwan[8]
- The development of technological and managerial within enterprises is essential for developing absorptive capacity for knowledge acquisition from foreign and domestic sources. The role of publicly funded research organisations must be assessed in relation to how they contribute to enterprise-level capability building[9].
- The effective acquisition of foreign technology – ie the absorption of technical knowledge – is a key process, but there are many channels, for example: public domain published knowledge, education overseas, immigration, licencing, FDI, reverse engineering[10].
- Incremental innovation is as important as radical/breakthrough innovation and sustainable productivity growth is driven by continuous improvement through adaptation and incremental innovation to product and process technology and to organisational and managerial systems. Adaptation and incremental innovation depend on technical and managerial capabilities in enterprises, usually closely linked with production activities. Research capability in publicly funded research organisations cannot substitute for technical and managerial capabilities in enterprises.
- As the complexity of technology at the global frontier has increased, so also has the role of investments in high-level education and of public and private R&D, in facilitating knowledge acquisition.

Public sector S&T organisations have had a key role in industrial development in countries such as Japan, Korea and Taiwan. But this role has had several important characteristics:

- It has been oriented to actual or potential users and on developing user capabilities;
- It has usually been organised in specific structures focused on applied science and on user engagement, so that there is extensive interaction and collaboration with users;
- The acquisition of foreign technology, the advancement of that technology, transfer of knowledge to users(though training, collaborative research, mobility of staff, spin-offs, pilot plants) and problem-solving in user firms, have been the primary missions;

[7] Fagerberg & Godinho, 2004; Shin, Jang-Sup, 1996; Amsden; Cappelen & Fagerberg; Beasley, 1990; Chang, Ha-Joon, 2002; Wade, 1990; Ebner, 2007.

[8] Fagerberg & Godinho, 2004

[9] Teece, 2000; Mazzoleni & Nelson, 2007; UNIDO, 2005.; Bell & Figueiredo, 2012; Dutrénit, 2004.

[10] Hobday, 2000.

- In their initial years such S&T organisations often recruit expatriates who have worked in applied research or in industry in leading developed countries;
- Investment in public sector S&T organisations has been complemented by broader policies that drive productivity improvement and develop capability in industrial firms;
- The role of public sector S&T organisations can only be effective when users develop strong absorptive capacities, have an demand for relevant knowledge, can express priorities that shape public sector technology acquisition, development and transfer objectives, and support investment in public sector research;
- As industry-relevant technical expertise is likely to be with the researchers and engineers of industry-oriented S&T organisations, these personnel are more likely to understand the changing issues in industry and to re-orient resources in response to changing goals and challenges. While detailed high-level planning is likely to stifle that essential responsiveness, strong oversite is essential to ensure that the interests of researchers (or of a few dominant users) does not dominate the allocation of investments in research- this is a key reason why users must contribute to the evaluation of research and industry programs and centres.

Even in countries working at the frontier of new technologies, such as the US, direct commercialisation of university research is a minor channel of knowledge diffusion to industry – the public literature, the employment of graduates, conferences and informal networks are much more important channels. Mazzoleni. and Nelson (2005) report that: *respondents in most industries reported that publications, information disseminated at meetings and conferences, informal interactions with university researchers, and consulting, were the most important conduits through which draws on university research results. Contrary to current conventional wisdom, most industries reported that patents played little role in technology transfer* (p.33)[11]. In most industries patents played little role in technology transfer[12].

Insights from The Experience of Countries that Have Managed Successful Catch-Up.

The challenges for STI policy for sustaining the performance of a NIS is different from those where the objective is rapid technological catch-up. There is no single model of catch up strategies – the role of major local firms, SOEs, SMEs and MNEs has been very different in different countries.

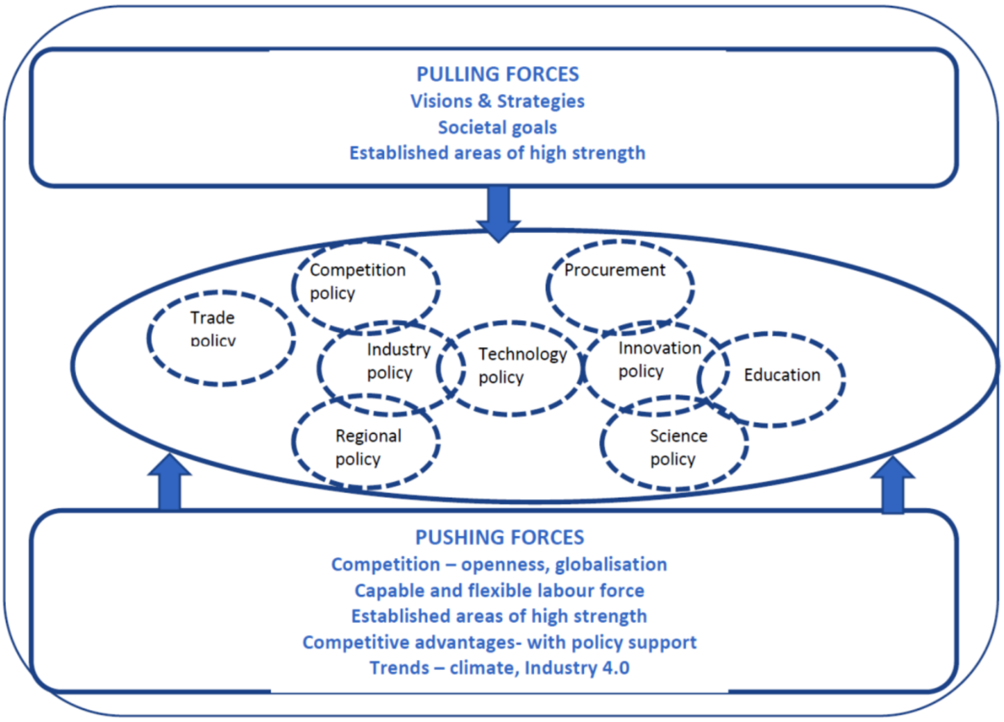
- **Implications of Uncertainty**
  As STI policy operates under high uncertainty the approach must be experimental and evolutionary, maintaining analysis and evaluation, modifying policy in the light of learning and change in the context. Effective approaches will build on success, increasing investment as uncertainty declines and addressing problems in areas of limited success. Industry and innovation policy is in many respects a search process. Policy learning and the modification of policies and interventions is essential in order to respond to emerging problems and opportunities, better understanding of problems and opportunities and to change in the external context. The rise of China, US-China tensions, the potential impacts of climate change and the development of Industry 4.0 – all increase the levels of uncertainty.

[11] Mazzoleni & Nelson, 2005.

[12] See, for example: Malerba & Nelson, 2011; Albuquerque et al, 2015; Baycan & Stough, 2013.

- **Coherence and Coordination**
  A characteristic of those countries that have developed and implemented effective catch-up strategies is the coherence of the overall policy settings and the effective coordination across inter-related areas of policy. In many cases, high-level councils or agencies with broad mandates and high-level support enable coordination. See diagram.

Figure A.1: The Complex Context of STI Priorities



Adapted from: Aiginger & Rodrik, 2020.

Sectoral Strategies and Coordination
As the dynamics and patterns of innovation differ significantly between sectors, sector level strategies and sector-level coordination are essential. Hence, mechanisms for analysis, engagement, collaborative learning and planning can support sectoral growth. The development of public-private 'partnerships' across planning, research, training and evaluation enable coordination and raise the effectiveness of policy and investment. Hence, as well designed and effectively implemented sectoral strategies are essential, the capabilities of sectoral research and policy organisations is a key issue.

- **Stimulation the emergence of endogenous drivers of upgrading**
  The key objectives of strategies for industry, technology and innovation is to simulate the formation of a cumulative process of capability development that generates positive feedbacks and progresses through a sequence of stages of rising dynamism, learning and value adding. Policy settings must also evolve with these development sequences.
- **The Managerial and Technological Capabilities of Firms**
  Firms in industrialising economies seeking to 'catch-up' to the global knowledge frontier develop their capabilities sequentially through stages with different foci of

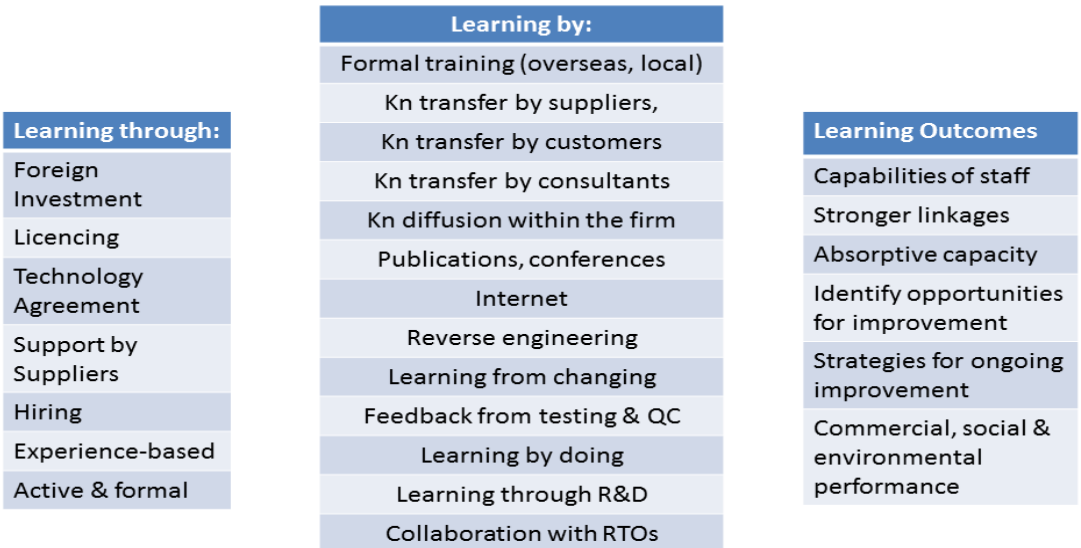
learning– Table 1- and different channels of knowledge acquisition – Figure 2. Unless firms develop the capabilities to absorb knowledge (from local or international sources) and to adapt product (including services) and process technologies they will lack the capacity to respond to many types of technology and innovation policy and hence will be unable to benefit from investments in public sector research, and will not provide a demand for knowledge that provides signals for public sector investments in research. A lack of capabilities in firms diminishes the returns to investment in public sector research. The incentives for firms to invest in upgrading and the availability of producer services (consulting, training, finance) is hence critical for effective research and innovation policy. In many industrialising countries the level of ongoing support of firms has been related to their performance in meeting agreed development goals.

*Table A.1:   Stages of Catch-up through Learning**

	Stage I	**Stage II**	**Stage III**	**Stage IV**
Stages of Catch-up	Duplicative Imitation	Duplicative Imitation	Creative Imitation	Real Innovation
Patterns of Catching-up	Path-following	Path-following/ stage-skipping	Stage-skipping	Path-leading, path-creating
Learning Objectives	Ooperational skills	Production/ process technology	Design technology	Product Development technology
Learning Mechanism	Learning by doing	Learning by producing, organising, following foreign design	How to Learn: in-house R&D, Overseas R&D, PPP R&D consortium	Co-development strategic alliance

- Based on the Korean case – after Patarapong Intarakumnerd,

Figure A.2: Firm Level Capability Development



- **Roadmaps to Impact**
  In view of the importance of coordination (particularly through shared 'visions'/strategies), coherence, and cumulative causation, setting out 'paths to impact' based on 'theories of change' help to connect research, industry, technology and innovation policy. This approach can also be the basis for identifying related policy areas and for meaningful targets and milestones.
- **Challenges and Opportunities in Transitions**
  Evolving transitions, including the ongoing impacts of and of policies to address climate change, and the development and applications of Industry 4.0 technologies, open opportunities for new entrants in specific **application** niches where competitive positions have not yet been established. Collaboration with users, including public sector users, will be critical to pursuing these opportunities.
- **Entrepreneurship and Discovery of Opportunities**
  High rates of new firm startups enables higher rates of exploration and discovery of new opportunities for value creation and increases the potential for the emergence of major new firms and industries. However, the quality of startups is also important. Higher quality entrepreneurship is characterised by founders with ambitions to grow the venture, and with experience and education, receiving strong support from experienced mentors and advisors

3.2 Frameworks for Innovation Management and Policy

Since the 1990s, innovation policy in most countries has been increasingly influenced by the innovation systems perspective. However, in most cases the development of innovation policies is also influenced by other drivers. Apart from the political context of decision-making that shapes goals, priorities and acceptable policy approaches, innovation policy is also shaped by:

1. Other theories about the processes of innovation, including the long influential 'market failure' perspective leading to an emphasis on the role of R&D in general and the role of public sector research as a key driver of innovation in industry, in particular.
2. 'Best practice' exemplars of innovation policies and specific organisational models from other countries. However, while these exemplars often capture the attention of politicians and policy makers, experience indicates that, unless carefully adapted, policies rarely transplant successfully.
3. Initiatives in response to identified problems in the innovation system. Both the identification and framing of problems, and the options for addressing those problems, will unavoidably be shaped by theoretical frameworks held by, and the interests, of stakeholders.

In developed countries innovation systems and innovation policies have evolved over decades. That evolution has also been shaped by policies and developments in other policy domains, particularly science, industry, education, trade, environment, security etc., for which innovation was not a major or perhaps significant objective.

A recent development in Europe, although long an aspect of US innovation policies, has been the development of 'innovation missions' addressing major social goals.

Innovation Systems Perspectives

The innovation systems perspective emphasises the central significance of processes of knowledge (ie information and competence) acquisition and the roles that interaction among actors and institutions (ie policies, customs, culture) have in stimulating and shaping learning[13]. In relation to institutions, this perspective draws attention to the importance of a broad range of institutions– including education, trade and investment, and industrial relations policies, and social norms and policies that engender trust - that are often considered outside the scope of STI analysis and policy. The perspective also emphasises the importance for knowledge flows of informal linkages among organisations.

From the innovation systems perspective it is learning throughout an economy that raises productivity and builds capability. Rather than focus on a few high -tech or highR-&D sectors and firms, it emphasises the role of diffusion of knowledge and hence of the absorptive capacities of all firms: '..the rate of technical change and of economic growth [in a wide range of countries] depended more on efficient diffusion than on being first in the world with radical innovations and as much on social innovations as on technical innovations' [14].

3.2.1 Innovation Policy Foundations.

Evolving Perspectives on Innovation

Innovation has become a significant focus in many fields, including economics, management, policy studies, organisational studies, history, geography and sociology. Each field has developed distinctive, and often complementary, frameworks and research methods. Even within economics quite different approaches to conceptualising innovation have developed[15].

There is now a large and diverse international community of innovation scholars and an extensive and rapidly growing body of knowledge. New perspectives from innovation studies have implications for innovation metrics. In considering appropriate innovation metrics for the Australian economy and society, this review considers seven key learnings from innovation studies:

- Innovation is a pervasive and broad phenomenon, and its characteristics vary across sectors
- Innovation has different levels of significance and novelty
- The knowledge base has widened and innovation is increasingly interactive
- Sectoral patterns of innovation
- Capabilities and management in innovation
- Entrepreneurship as a key form of innovation
- National, regional and sectoral innovation systems

This section summarises state-of-the-art thinking about innovation in modern economies, and the evolution of innovation in the context of rising investment in intangible capital, the growth of the service economy, and the uptake of digital technologies.

[13] Lundvall et al define an innovation system as: The national innovation system is an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economic structures which determine the rate and direction of innovation and competence-building emanating from processes of science-based and experience-based learning. Innovation system research and developing countries Lundvall et al, 2009. p.*6.*

[14] Freeman, 1995, p. 10.

[15] Malerba & Brusoni, 2007

3.3 Innovation is pervasive and broad

The historical foundation of innovation policy is in linear models that assumed new scientific knowledge was the key input to innovation. It was assumed that progress in science was the key limiting factor and that investment in science in the public sector and subsidies for research in the private sector (to address 'market failures') would be sufficient to ensure economic benefits. While sectors such as biotechnology are closely linked to frontier science, most sectors are not. In most industries the linkages to science are indirect, largely through people-embodied knowledge, and often have long lead times[16].

In some industries, typically those that are R&D intensive and 'science-based,' interaction with universities and research organisations is a major source of new ideas and knowledge. In others, links with the knowledge infrastructure are more indirect and interactions with customers, suppliers and competitors are much more important. Therefore, a singular focus on R&D in 'high tech' sectors is a narrow beam that will fail to illuminate a great deal about innovation[17].

Innovation is a pervasive and broad phenomenon, and its characteristics and those of innovation processes vary across sectors. Innovation is important in the **public sector** – a large component of the economy of most OECD countries – and includes education, defence, health, social services, and administration[18]. There is also a growing focus on the role of the public sector in supporting innovation in other sectors through its policies, for example through regulation and procurement[19]. The significance of innovation in the **service sectors** has been recognised as they now dominate economic activity in OECD economies, including Australia, and the nature of services innovation has become a focus of analysis[20]. Frameworks, concepts and methods are being developed to understand and characterise activity in the new field of **social** innovation[21]. Advances in **software and hardware** provide sophisticated toolkits that enable users to undertake significant product and process adaptation and re-design[22].

There are many types of innovation beyond product, service and process innovations, including organisational[23], managerial[24], and marketing innovations. All are significant sources of value creation. Different types of innovation are often interrelated, as a major product or service innovation may be linked to process and organisational innovations. Interrelated innovations are often associated with new business models, so it is useful to characterise business model innovation, such as a high street shop moving to a virtual e-commerce site, as a type of innovation.

The factors that drive and shape innovation vary between sectors, and as such a policy that promotes innovation in one sector may be ineffective in others[25]. For example, patterns of innovation in services sectors are different from those in manufacturing sectors, usually involving more interaction with users through processes of experimentation and continuous development.

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[16] Salter & Martin 2001.

[17] Dodgson, 2018.

[18] Osborne & Brown, 2013.

[19] For example, a special issue of the journal Research Policy focuses on mission-oriented R&D, an contains an extensive set of case studies on public-sector innovation for public-sector missions as well as for adoption within the civilian economy (Research Policy. Volume 41, Issue 10, December 2012).

[20] Gallouj & Savona, 2009; Gallouj & Djellai, 2010; Djellal, et al 2013.

[21] Moulaert, 2013; Bekkers et al., 2013.

[22] Colecchia, 2006 and von Hippel, 2005.

[23] Sapprasert &Clausen, 2012.

[24] Damanpour & Aravind, 2012.

[25] Pavitt, 1984; Hirsch-Kreinsen, 2008; Grimpe &Sofka, 2009.

3.4 Innovation has different levels of significance and novelty

Innovation ranges from incremental to radical or revolutionary. The cumulative impact of many incremental innovations can be as significant as a radical innovation. Innovations at the more radical end of the innovation spectrum often open trajectories of ongoing incremental innovation. Some technologies (for example the steam engine, internal combustion engine, or integrated circuit) have pervasive impacts over time. They evolve through continuous improvements that lead to exponential and sustained trajectories of improvement in performance and declines in cost – these have been termed General Purpose Technologies (GPTs). Inter-related innovations linked to GPTs lead to the emergence of new 'technology systems' (for example electricity, steam). These new technology systems sustain waves of structural change that lead to the emergence of new inter-related innovations industries and the transformation of national and regional innovation systems – i.e. to the emergence of new 'techno-economic paradigms'[26].

While 'new to the world' innovations indicate a high level of novelty (and hence risk and uncertainty) the majority of innovations are at lower levels of novelty. These 'new to the industry' or even 'new to the firm' innovations are associated with processes of knowledge diffusion.

3.5 The knowledge base has widened, and innovation is increasingly interactive

There is substantial evidence that the knowledge base for innovation in most sectors has become increasingly diverse and complex. To maintain currency many firms have increased their level of collaboration with other firms and organisations, rather than try to maintain such a broad knowledge base in-house[27]. Innovation is therefore increasingly a distributed activity with a complex division of innovative labour[28].

The extent of interaction with external organisations has generally increased over the past fifty years and the mechanisms of that interaction (alliances, contracting, formal or informal collaboration) have become more diverse in a trend toward 'open innovation'[29]. In many sectors, users are active participants in innovation or have significant role in shaping the rate and direction of innovation in suppliers[30].

The effective acquisition of external knowledge is particularly important for small firms and hence for overall innovativeness. In Australia small firms account for a particularly high proportion of employment, as they do in other countries. Absorptive capacity, or the capacity to acquire, assimilate, transform, diffuse and apply imported knowledge, is therefore an important issue for innovation policy (see further discussion in section 6.2.5). Firms with high absorptive capacity are more likely to interact with research organisations, innovate, and make effective use of new production and product technology. Differences in absorptive capacity mean that firms have unequal access to innovation-related information and information flows through networks. The resulting information asymmetries are central to understanding innovative behaviour and knowledge diffusion.

The increasing role of external interactions in innovation means that firms are now embedded in 'innovation networks'. The extent and quality of innovation networks is an external resource of significance for firm-level innovation capacity. Inter-organisational relations in innovation networks include market and non-market interactions for which trust and social capital are important

[26] Lipsey et al. 2005, Perez, 2010.

[27] Herstad et al. 2014.

[28] Aslesen & Freel, 2012. Dahlander & Gann, 2010.

[29] Chesbrough, 2003; Dahlander & Gann, 2010; Aslesen & Freel, 2012; Colecchia, 2006.

[30] Von Hippel; The role of demand in shaping and driving innovation is discussed further below.

foundations. Such networks are increasingly international due to the globalisation of value chains, the rise in international investment and the wider dispersion of research and innovation capacity[31].

Capabilities and management shape innovation

Management decisions regarding innovation tend to be based on perceptions and assumptions rather than purely objective analysis, due to the inherent complexities and uncertainties of innovation. Innovative activity and outcomes at the firm level are shaped by management perceptions of (inter alia) demand, opportunity, risk, capability to design and implement innovation programs, and probability of appropriating the benefits of innovation[32]. Innovation performance at the firm level is shaped by (inter alia) investment (financial, human resources, relationship capital), capabilities (human resources, culture, organisation and routines) and external relationships – all of which are the result of current and prior management decisions and the development path of the firm[33].

Analysis of the development and innovation behaviour of firms has emphasized the evolutionary processes of learning and investment through which firms develop capabilities, routines and assets – demonstrating that business organisations, markets and technologies co-evolve[34]. In the context of more rapid change, a firm's capacity to develop new capabilities and assets ('dynamic capabilities') is particularly important[35]. The competencies and culture of the firms in a sector, region or economy are shaped by their history, and that legacy must be taken into account in predicting and assessing the impact of innovation policy instruments. For example, incentives for R&D are likely to be ineffective if firms have no ambitious strategies for innovation due to lack of competition or demand, short planning horizons or lack of competence. Determination of the most effective policy levers for encouraging innovation requires staying abreast of current and emerging innovation practices in firms[36].

Firms innovate in the context of regional and national innovation systems

The development of the innovation systems perspective has had a significant impact on innovation studies and presents a central challenge for innovation policy, indicator design and analysis. The innovation systems perspective emphasises the extent to which firms' industrial, economic, institutional and social context influences their innovation strategy and activity[37]. From this perspective, the scope for innovation policy and analysis widens to include, for example, education, the finance system, regulation and procurement across the public sector, social institutions[38], networks and linkages. Innovation systems can be analysed at a national, regional, sectoral or technology level[39]. Borras and Edquist (2016) counsel policy makers to consider "*all* important economic, social, political, organizational, institutional and other input factors that influence the development, diffusion and use of innovations"[40].

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[31] Herstad, et al., 2014.

[32] Teece, 2006.

[33] Teece, 2010.

[34] Martin, 2012.

[35] Dynamic capabilities - "the skills, procedures, organizational structures and decision rules that firms utilize to create and capture value" (Teece 2010, p. 680); Zollo and Winter, 2002.

[36] Dodgson, 2017.

[37] Fagerberg, 2013, Martin, 2012; Akçomak & Ter Weel, 2009; Baumol, 2002; Baumol et al.. 2007.

[38] Including the role of social institutions in shaping trust, risk tolerance, and social capital more generally – Fagerberg, 2013.

[39] Nelson, 1993; Lundvall, 1992; Dodgson et al., 2011.

[40] Borras & Edquist, 2016.

The innovation systems approach presents a challenge in the design and construction of innovation-related metrics. A diverse range of organisations, relationships and institutions are potentially brought into scope and the boundary of an innovation system is indeterminate. One promising approach is to specify the most critical 'functions' of an innovation system and aim to develop indicators for these, for example:[41]

- Generation of knowledge (e.g. R&D)
- Diffusion of knowledge (e.g. education, linkages facilitating knowledge flows)
- Skill formation (e.g. training programs)
- Provision of finance (e.g. financial and capital markets)
- Level and shaping of demand (through standards, regulations, procurement)
- Institutional continuity and change (laws, attitudes, behaviours)

There have been three particularly important extensions of the innovation systems approach, which share the same underlying conceptual framework but enable different policy foci[42].

- Regional innovation systems[43]
- Sectoral innovation systems[44]
- Technology innovation systems[45]

A significant application of the innovation systems approach, particularly drawing on technology innovation systems, has been the development of frameworks for policy aiming to promote experimentation and to drive socio-technical change through, for example, 'strategic niche management,' 'transition management,' or 'strategic innovation system management'[46]. As technologies, industries and societies co-evolve, innovation systems must also evolve in response[47]. However, the drivers and processes of system-level evolution are not well understood.

3.5.1 Recent Developments in Innovation Policy

The following discussion briefly outlines several of the major recent developments in innovation policy development and analysis.

1. Implicit and explicit innovation policy

Until the 1980s innovation policy focused on R&D measures and some other areas with a view to direct impacts on innovation. However, it has been recognised increasingly that policies in many areas have impacts on innovation, for example, trade and investment, education, environmental regulation, government purchasing. Hence, a nation's overall innovation policies include explicit

[41] Fagerberg, 2013; Hekkert & Negro, 2009; Hekkert, et al., 2006.

[42] Borras & Edquist, 2006 argue that national, regional & sectoral innovation systems complement each other.

[43] Cooke and Morgan, 1998; Saxenian, 1994.

[44] Malerba & Adams, 2014.

[45] A focus on the actors, knowledge flows and institutions at the level of specific technologies enables a more useful understanding of the dynamics of innovation as a basis for policy to address 'barriers' to desirable change; Bergek, et al., 2008; Hekkert, et al. 2006; Hekkert & Negro, 2009; Geels, 2002.

[46] Geels, 2002; Geels & Schot, 2007; Markard et al., 2012; Kemp et al. 1998; Winskel & Moran, 2008; Foxon & Pearson, 2008.

[47] The 1982 work of Nelson & Winter, An Evolutionary Theory of Economic Change, is the most cited work in the field of innovation studies – Martin, 2012.

innovation policy designed for the purpose of promoting and shaping innovation, and implicit innovation policies, or those policies in other areas that have largely unintended and indirect impacts on innovation.

2. Widening the scope of innovation

Explicit innovation policies in most countries, at least until the 1990s, focused on 'high tech' sectors and on R&D measures. However, innovation is vital for productivity growth in all sectors of the economy and all types of organisation, and much of that innovation does not involve R&D. The scope of innovation policy widened to take into account innovation in services sectors, in 'low-tech' manufacturing and in the public sector.

3. Appropriation and Patenting

There has long been an emphasis on the importance of formal intellectual property (IP) protection, and patenting in particular, to enable innovators to appropriate the benefits of their innovation by preventing others from copying the innovation. However, studies have shown the in most sectors patenting is of little significance and most firms focus on lead times and secrecy to protect their innovation and if they use formal IP they more often use trade marks than patents.

4. Innovation Systems and Learning

The innovation systems perspective emphasises the role of interaction and learning in innovation, and the extent to which those core processes are shaped (ie promoted, oriented, limited, blocked) by wider social, economic, industrial and cultural context (often termed 'framework condition' or institutional context). Much innovation in firms involves increasingly wide and significant interaction- with other firms in the region, country or internationally, or with research or education organisations. All participants in innovation systems learn- ie accumulate capabilities and assets to contribute to innovation in specific fields, with specific other organisations and in specific spatial contexts – as a result of their path of development – ie the specific challenges, investments and experiences they undergo.

5. Regional Innovation Policy

Because innovation involves interaction among organisations and also involves cumulative learning about an area of innovation and about effective interaction, organisations in a specific region often develop a specialisation based on a shared knowledge base or asset. In some cases the depth of that specialisation, the level of investment in learning by organisations, and the level of interaction among the actors in a region, leads (over time) to nationally or internationally significant 'clusters' or 'regional innovation system'.

Innovation policy in most countries has recognised the significance of clusters and regional innovation systems and sought to enable and support the development of sectoral and regional innovation promotion organisations and networking activities.

There is however an inherent policy tension that follows from this recognition- one that is also related to the development of national competitive advantages. Where initial investments in education, research, new infrastructure etc stimulate the growth of a dynamic national or regional innovation ecosystem, in which capabilities and assets development is driven increasingly by endogenous drivers, a process of increasing returns is evident. Clearly not all investments into firms, industries, research initiatives or regions are likely to seed an ongoing endogenously driven development of capability and innovation. Many will however increase the attractiveness of a firm, industry, organisation or region for further investment.

Hence, innovation policy must be concerned with improving the performance of existing higher performing firms, industries, organisations and regions, while seeding improved performance in other firms, industries, organisations and regions – and providing continued incentives to those that respond effectively to that seed investment.

6. The challenge of coordination

As policies in many areas of government have impacts on innovation through their roles in the innovation system, innovation is essential for achieving policy objectives in many areas of government (including health, environment, transport, energy etc), and innovation in various forms has a critical role in all areas of the economy, facilitating some level of coordination across government departments and across the major actors in innovation (business, government, research, education) is essential for effective innovation policy. Innovation policy is no longer the domain of only S&T Ministries.

There have been three responses to the challenge of coordination:

- Reviews of national innovation policies and performance generally attempt to consider all of the major actors and *processes* (see below) in the innovation system with a view to at least raising awareness of the role of various policies;
- Most countries have some form of high level innovation 'council' that serves as coordination and advisory bodies and bring together representatives of the major actors in the innovation system;
- Some countries (eg Sweden) have formed independent innovation agencies, generally governed by boards appointed by government, to design and manage broad innovation programs and studies (Glennie & Bound, 2016).

7. Knowledge flows and innovation ecosystems

In most countries innovation policies have long emphasised both formal R&D and knowledge flows from public sector research organisations. However, policy research has shown consistently that few firms have direct links with public sector research organisations while most interact with customers and suppliers in innovation and draw on a diverse range of often informal sources for the knowledge they use for innovation. This research has two other key findings:

The absorptive capacity of firms – ie their capacity to identify, acquire and apply new knowledge from external sources – is critical for effective knowledge flows, and high levels of capability in the public sector cannot substitute for capability in firms;

The output of research organisations that is vital for the effective development and performance of innovation systems is capable people. This is generally and overall more important the direct transfers of technology from research.

8. The role of diffusion, demand and users

The economic impact of innovations arises from their widespread use, beyond their initial introduction, and hence it is the diffusion of an innovation and of new knowledge that is vital for productivity growth. The process of diffusion of a new innovation and related knowledge is an active rather than a passive process and usually involves the adaptation and modification of the innovation/knowledge for specific contexts and applications -ie it involves some level of innovation. This again emphasises the importance of widespread technological and managerial capabilities.

Similarly, innovation studies have shown the importance of users in innovation – users and suppliers are often active participants in 'innovation ecosystems'. Users not only shape the level and characteristics of demand for new products and services but often collaborate with suppliers to develop new products and services. Capable and demanding users help to drive the dynamism of an innovation system.

9. Sectoral Innovation Systems

Processes of innovation are different in different sectors – it is not appropriate to generalise. In some sectors, such as pharmaceuticals and biotechnology, formal R&D and links with public sector research are vital for innovation, as the knowledge base draws directly on advances in science. Hence, formal R&D in firms and knowledge flows from science are core mechanisms for learning by firms. On the other hand, in many engineering industries there are few direct links with science or with research organisations. Much of the innovation arises from interaction with suppliers and with users. This is also the case in many service sectors and SMEs in many industries, where there is often little formal R&D.

Hence, the relationships between the main actors in innovation - firms, their customers and suppliers, research organisations, regulatory agencies, education and training organisations – vary across sectors and innovation policies need to take that into account.

10. Entrepreneurial Ecosystems

Several regions around the world have developed conditions that stimulate and support high levels of technology-based/ growth-oriented entrepreneurship – eg Silicon Valley and Cambridge UK. As is the case with regional innovation systems, there are clearly strong local factors (that have developed over time) that contribute to these very spatially concentrated entrepreneurial ecosystems.

Many regional governments have sought to learn from international experience and promote the development of a dynamic entrepreneurial ecosystem in their region – typically a city. None have achieved levels of success similar to Silicon Valley, but many have achieved significant success and there are clearly opportunities to learn from that experience.

11. Uncertainty and the need for experiments

Innovation necessarily involves a level of uncertainty regarding, for example, technical feasibility, commercial feasibility, market acceptance, and competitor actions. The higher the level of novelty of the innovation for a particular context, the higher the level of uncertainty. Uncertainty is a barrier to firms' investment of resources into innovation and entrepreneurship. Policy has a role in reducing, where possible, the levels of uncertainty, for example in providing access to information and support services.

Similarly, innovation policy initiatives involve uncertainties that arise from incomplete knowledge, the complexity of innovation systems and the future decisions of the many actors. New policies are inevitably also policy experiments, which is why learning as much as possible from policy initiatives in other countries and contexts, and conducting pilots as explicit policy experiments are approaches to reducing uncertainty levels.

12. Key Processes in the Innovation Systems Perspective

As noted above, the innovation systems perspective has become increasingly influential in shaping approaches to innovation policy. The application of that perspective has lead to two particular types of assessment.

First, as national innovation systems evolve over time with complex interactions (co-evolution) between IST, industrial structures and policies the design and the impacts of individual IST policies will be shaped by the overall set of policies. Hence, it is now seen as important to consider the overall ‘policy mix’, its coherence and complementarities.

Second, while some early innovation system assessments focused on the structure of innovation systems, the concept was always about the dynamic processes through which nations (or regions or sectors) accumulated capability and invested in and interacted for innovation. Hence, the core of the perspective was the extent to which key processes (or functions) enabled, shaped and drove innovation and whether there were impediments to the operation of those functions. There are different approaches to characterising those core processes and the sub-processes that make them up – Table A.3 provides one approach as an example of how this framework might be used.

Table A.2: Illustrative STI Policy Framework

Policy Focus	Scope	Typical Policies	Challenges
Science	Promotion of science education and research in universities and research organisations	Education – particularly at the graduate level Funding of research International collaboration	Rising cost of research infrastructure Balancing criteria of excellence with potential utility (Pasteur’s Quadrant etc)
Technology	Development of national capabilities in key technology areas	Funding of research and of acquisition from international suppliers in identified key technology areas Development of supporting infrastructure	Selecting technology priorities Developing Industrial Research Institutes that support knowledge acquisition and capability building/diffusion
Innovation	Encouragement of the development, in firms, of capability and of new or improved goods, processes and services.	R&D funding and subsidies for firms Support for capability development (eg consulting, training staff of SMEs in technology and innovation management, etc.) Technology adoption subsidies for firms for modernization Subsidies for firms to acquire licenses to new technology Subsidies for firms to hire skilled science and engineering graduates Manufacturing / agriculture etc. extension services to help identify firm needs for new technology	Development of supporting infrastructure (standards, consulting, collaboration, coordination, training, intermediaries for knowledge transfer..) Incentives for upgrading management and technological capabilities Developing strong absorptive capacity Ensuring effective spillovers from MNEs Effective linkages with research organisations

		Finance subsidies for innovation, such as Venture capital Support for inter-firm collaboration and networking on innovation Use of government procurement to stimulate innovation Improving commercialisation of public research Advisory services for developing improving management capabilities in firms.	

Table A.3: Innovation Policy Tools – an Innovation System Functions Perspective

Key Processes	**Major Components**	**Typical 'problems' or barriers.**	**Relevant Policy Instruments**
Entrepreneurial experimentation and incubation	Growth-oriented entrepreneurial activity Development of entrepreneurial ecosystems	Lack of incentives for entrepreneurship Lack of mentors and support Lack of venture finance	Entrepreneurship policy Training for entrepreneurs Development of grants and prizes for tech-based start-ups Development of incubators Subsidies for venture capital funds
Knowledge	Output of R&D organisations Imported technology Education Firms' investment in knowledge acquisition Diffusion Interactive learning	Few links between RTOs and enterprises Low demand for knowledge No incentives for FDI to transfer technology R&D & education not aligned with demand Lack of technological and management capabilities in enterprises	Increase investment in public sector R&D Incentives for R&D in enterprises Incentives for RTO – Business collaboration Development of grants and prizes innovation Policies to support collaboration Innovation network policies Cluster policy
Competence Development	Formal training for skill development Training within firms Challenge driven experience Consultancy services	Lack of training in enterprises Lack of appropriate skill development in training organisations Consultancy services underdeveloped and little used by enterprises	Policies for skills and training Technical and managerial services and advice
Finance for Enterprises	Finance for enterprise growth Finance for entrepreneurs	Provision of finance limited Capital markets underdeveloped	Subsidies for venture capital funds
Demand	National & international customers Government procurement	Public sector procurement not used to promote local innovation	Develop regulations and standards Pre-commercial procurement

	Regulations – product, environmental		
Drivers of Change in the Institutional Context.	Coordination through committees, councils etc Policy evaluation and learning Organisational innovation – new organisations Institutional innovation- new regulations, programs, laws etc	Coordination ineffective so innovation policies are fragmented Little policy learning	Future Technology Analysis ,eg foresight Form councils with broad representation Integrate monitoring and evaluation all innovation polies and funding. Mission-Driven socio-economic challenges Transformational programs building new industries and major capabilities

3.6 The Role of Learning in Research and Innovation Policy and Analysis

A requirement for effective STI priority-setting is the systematic building of capacity, through all the players in the STI system, to engage effectively in the establishment, interpretation, implementation and evaluation of priorities. This requires not only the commitment of sufficient resources to modify the behaviour and ambitions of participants in STI, but also of capturing and applying the learning of those involved in the priority setting process.

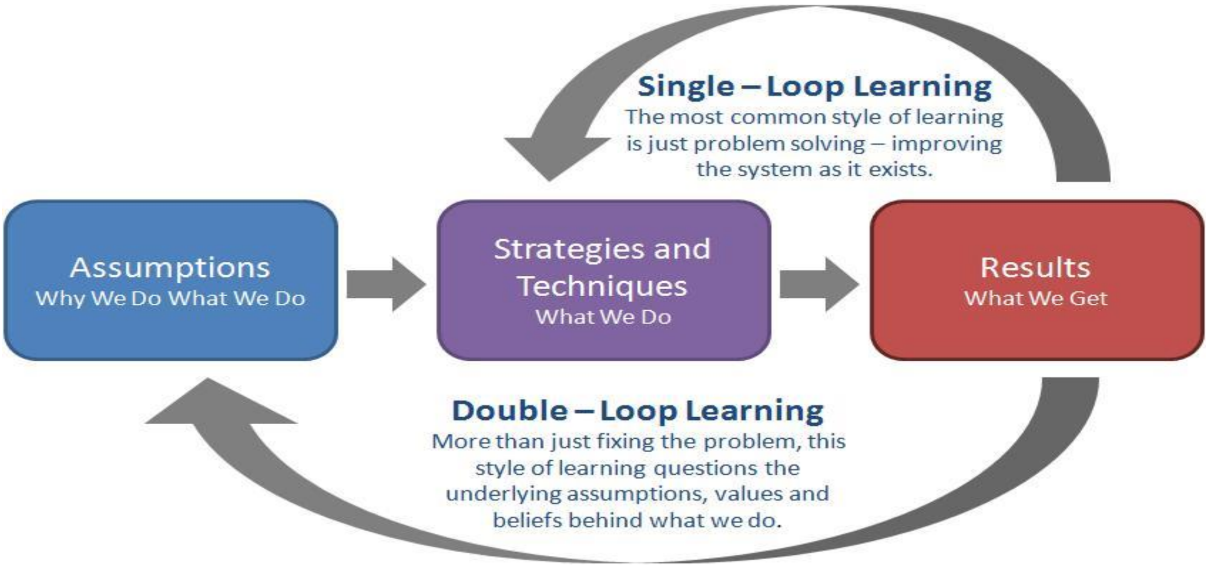
Experience shows that foresight programs and research and innovation policies co-evolve through processes of learning, engaging a widening range of stakeholders. Three 'layers' of learning are involved:

- Learning about the design and management of foresight studies – much of which can be learnt from the experience of other countries- See Figure I.1
- Learning how different interests and areas of knowledge can contribute to foresight and how outcomes from foresight can be translated into policy options – this is learning that develops in a specific context over time through dialogue, interaction, networking between those involved in both the foresight process and the policy domain. The experience in Europe is that the range of stakeholders who become involved in this process of 'communitive capacity building' widens over time beyond the research and research policy 'community' to include an increasingly diverse range of social groups.
- Collective learning regarding the legitimacy of foresight and the 'visions' that are developed – a process that will depend in part on the involvement of stakeholders from business and civil society[48].

Hence, there is a need to construct and evaluate the priority setting process not in terms of success or failure, but rather what can be learnt to improve the next iteration. This is characterised as 'double-loop learning', which entails the modification of goals or decision-making rules in the light of experience. This may require not only a change in the design, but also a revisiting of the organization's underlying norms, policies and objectives.

48 Anderson & Anderson, 2014.

Figure A.3: Incorporating Double Loop Learning



Learning, the accumulation of capability, is the central process of development. As development involves sequential upgrading of capabilities (organisational, managerial, technological, design, marketing etc) it requires addressing increasing levels of challenge. One essential aspect is policy learning and developing effective approaches inevitably involves some trial and error and experiment. Hence, STI policy has a key role in directing, driving and empowering the overall process of learning.

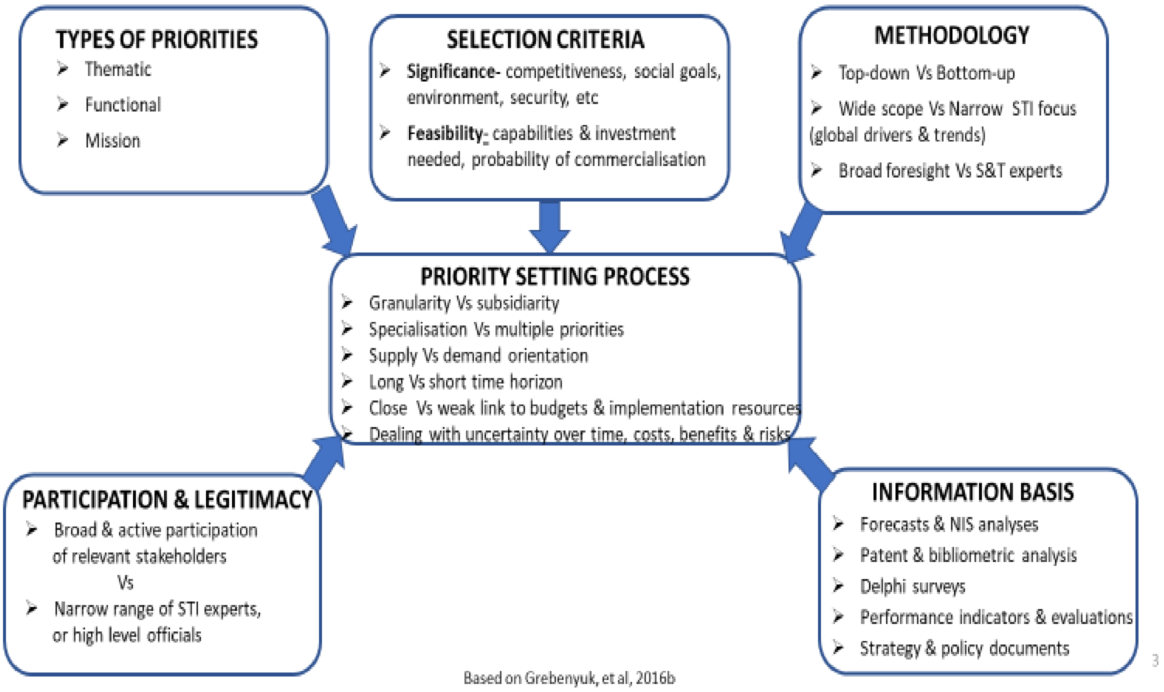
Appropriate targeting can focus learning efforts in those areas with the greatest benefits and spillovers. In developing an initial list of candidate targets it is important to focus (but not exclusively) on those developments that are likely to drive technology enabled transformations of industry and social activity. But the development of strategies is a part of a continuous and interactive learning process. From that perspective it is better to take risks and be more or less right most of the time than to analyse with a view to being right all of the time and to specify in detail what policies should be.

4 PART B INTERNATIONAL EXPERIENCE IN STI PRIORITY SETTING – DIFFERENT CONTEXTS, SIMILAR CHALLENGES AND DIVERSE APPROACHES

4.1 Introduction

There are many options in the scope, objectives and design of STI policy setting processes. Figure B.1 provides an overview of the key design options. Table B.1 shows some examples of the major types of STI priority setting approaches in several countries.

Figure B.1: Overall Model of STI Priority Setting Design Options



Part B summarises the key points from the nine country cases studies: Australia, Chile, China, Europe (selected countries) Korea, Japan, Malaysia, Singapore, and Taiwan. It is organised around a similar structure as the country case studies, although some categories have been combined for this summary. Hence, this summary is organised in eight sub-sections:

1. **STI Priorities: Scope and Content**: As STI has a pervasive and increasing role across the economy and society and all areas of public administration, what is the scope of STI priorities?
2. **STI Governance and Leadership**: Who is responsible for developing STI priorities, how are these priorities integrated with other areas of public policy, how is legitimacy established, and how are the views and interests of different stakeholders coordinated?
3. **Processes of Priority Setting**: What issues are considered, information sources used, and assessments conducted?

4. **Approach to Consultation & Participation in Priority-Setting:** Who contributes at what stage to priority setting?
5. **Types of STI Priority**: To what extent do priorities focus on capability in a specific area of science or technology, on improving the performance of the innovation system or on social, environmental, economic (etc) objectives to which STI contributes?
6. **Integrating Innovation Goals**: As innovation is broader than S&T, is shaped by policy in areas beyond S&T and has wide ranging impacts, how is the I integrated with the S&T?
7. **Implementation of Priorities**: What policy instruments are used to drive implementation and to what extent is the detail of broad priorities delegated to lower level actors, such as funding agencies, Ministries etc?
8. **Monitoring, Evaluation and Systemic Learning**: How do all actors in the STI system, including the priority setting and implementation component, improve their capability and effectiveness?

Each of the eight sub-sections follows a similar format: an identification of the challenges and decisions that decision makers must address; an outline of international experience in relation to those challenges and decisions; a discussion of some of the implications of that experience for Vietnam.

4.2 The Importance of Context

However, in reviewing international experience and considering its relevance for Vietnam it is essential to consider the context of each country. – economic, industrial, structural, social, technological, historical, and administrative. Three dimensions of context are particularly significant for the STI priority setting.

First, as discussed above, the extent of prior experience of priority setting must influence the design of the process and the mechanisms of consultation and implementation. Where there has been a systematic evaluation of the outcomes and impacts of investments and policies based on previous priorities, and the wide dissemination of those evaluations, there is a shared understanding among participants.

Second, the stage of development, the economic structure of a country and the strength of the national and regional innovation systems, influence the roles of different actors and the significance of different sources and channels of knowledge. A country at or near the international technology frontier will be more dependent on endogenous sources of new knowledge than one at an earlier stage of capability accumulation, where international technology transfer is likely to be more important. A country in which industry has limited capabilities and few links with the knowledge infrastructure is a more challenging context than a country where local firms have strong absorptive capacities and invest in innovation, and where the complementarities and relationships between firms and research organisations are well developed.

Third, there are time periods when radical innovations begin to emerge and disrupt established industries and change societies. For example, the OECD STI Outlook 2018 draws attention to “a number of ‘game-changers’, notably the rise of artificial intelligence which holds the potential for revolutionising the scientific process, creating new poles of STI activity and opening up new opportunities for countries to benefit from science and innovation. At the same time, issues of privacy, digital security, safety, transparency and competition have all risen up the policy agenda, defying quick solutions and demanding new and coordinated policy responses.”[49] Quite clearly, the

[49] OECD, STI Outlook 2018, Paris.

disruptors of new classes of technologies, the threat of climate change, the need for sustainability, and the changing global political order, signal that priority setting must be conducted in a full awareness of the changing context.

4.3 STI Priorities- Scope and Content

4.3.1 Decisions & Challenges

STI involves many domains – basic research, education, training, standards, foreign investment, entrepreneurship, etc – and is increasingly important in many areas of government - trade, transport, communications, commerce, health, environment, defence and security etc. Hence, STI-related policy coherence and complementarity will be a challenging goal to achieve. Nevertheless, STI priorities needs to be thoroughly integrated with, and reflect, broader national ambitions:

"[in] *innovation policy, co-ordinated, strategic actions are needed to induce a coherent policy framework for dynamic innovators and structural change... Innovation is not a purely technological phenomenon, it involves both technological and non-technological changes that bear on economic and social development. Innovation may be organisational, institutional, design-related or involve other significant changes having economic value. Innovators are affected by incentive systems and regulations that have various sources and rationales, and interfaces between government and the private sector are evolving and gaining in importance*."[50]

While innovation is important for a wide range of policy objectives, it also involves much more than S&T. Innovation performance is shaped more by economic incentives, management capability and business culture – which in large part determine the demand for new knowledge and the willingness to innovate – than by (in particular) the generation of S&T in public sector research organisations.

4.3.2 International Experience

Whereas in the past STI priority setting focused on the selection of key technologies and within that on research, the scope of STI priority setting has progressively widened. In most countries the scope and hence the content of STI priorities more explicitly addresses improving the performance of national and regional innovation systems and the role of STI in social and environmental objectives. While this is also the case in China and Taiwan, the emphasis in these countries remains more narrowly focused on national strategies for achieving international competitiveness and economic growth. In most Asian economies, STI is a very high-level explicit priority and the role of top-down planning, while declining, remains strong. Consequently, in these countries, STI policy is closely linked to industry policy. In those countries at an earlier stage of development, still building a strong innovation system, technology acquisition from foreign firms is a major and explicit aspect of STI priorities. This is the case in China, and in the past was the case for Japan, Korea and Taiwan.

International competitiveness and economic development goals remain key determinants of the content of STI priorities in Europe, and the United States. Priorities at the national level are usually defined broadly and the more detailed priorities are developed by lower level councils or programs. However, social and environmental goals have become more important in selecting which STI issues are significant. There has also been a greater concern with strengthening identified areas of underperformance in innovation systems, including research-industry links. At both the sub-national and national level there has been an increasing focus on potentially transformative technologies

[50] OECD, 2005, p.19

(such as AI or biotechnology) with pervasive impacts51. Smart specialisation in Europe is one example of that focus. Developing comprehensive strategies for Industry 4.0 is another.

Whereas in the past STI priority setting focused on the selection of key technologies and within that on research, the scope of STI priority setting has progressively widened.

4.3.3 Implications for Effective Priority Setting in Vietnam

Vietnam's national development strategy, including its industry policy, provide much of the framework and driving ambition for STI priorities.

Pursuing STI in priority areas often depends on building strengths across the innovation system. This is partly because many leading technologies are linked to a diverse range of other technologies. For example, the benefits of AI (and most digital technologies) depend on capabilities in many potential sectors that could use AI, such as health, manufacturing, agriculture, media, etc. Hence, rather than seeking high levels of STI performance in a few narrow areas, strengthening the overall innovation system is critically important. To that end building capabilities throughout the innovation system to absorb knowledge and to learn to improve technology, collaborate and innovate, will shape the demand side without which investments in the supply of knowledge through investment in R&D will have few benefits.

For Vietnam, foreign firms are a major source of knowledge about technology and technology management. The role of technology acquisition from foreign sources is a component of STI priorities, as is ensuring the capacity to absorb and apply this knowledge.

Important priorities will be those transformative opportunities to remove barriers and seed self-reinforcing dynamics that drive a widening process of upgrading- these are the dynamics that build industry clusters and entrepreneurial ecosystems.

4.4 STI Governance and Leadership

4.4.1 Decisions and Challenges

Setting priorities for STI policy and investment requires institutions and relationships that can support a comprehensive, long term, but flexible approach. This requires appropriate governance:

"*Innovation governance becomes the key challenge, and it requires developing the necessary institutional set-ups, procedures and practices for agenda setting and prioritisation, implementation and policy learning.*"[52]

A useful OECD report defined the scope and capabilities for innovation governance[53]:

- recognising system characteristics (strengths, weaknesses, problems, development potential)
- defining the focus and the topics for political action (ie agenda setting)
- making diverse players co-ordinate their activities in and beyond their policy field

[51] See, for example, Grillitsch, et al, 2019.

[52] OECD, 2005, p.7.

[53] OECD, 2005.

- implementing these policies
- learning from previous experience (*e.g.* from evaluation)
- making adjustments over the complete policy cycle.

Strong political leadership is usually essential for the development of an **overarching vision** that will can provide a legitimate basis for shared agendas:

"Political leadership has a strong integrative potential. Visions play an important role, as they communicate rationales, objectives and preferences, and as such create a legitimate basis for priorities that may be difficult to argue for or justify. Effective visions also facilitate co-ordination between ministries and agencies through joint understanding of the goal of common efforts.'[54]

STI governance is highly knowledge-intensive and hence **learning by all participants** in priority setting is critical. It is also essential to: '*to generate and distribute knowledge that helps develop joint understanding across policy cultures and rationales… Comprehensive innovation policy has much to gain from organising information and learning systems that help policy makers develop an integrated focus on innovation… learning-oriented governance system should rely more on flexible, decentralised management practices, open learning and flexibility. A high degree of self-organisation under a broader strategic objective would support such governance*[55]."

Policy learning requires not only effective ex-post monitoring and evaluation, but also ex ante analysis of issues- this is discussed further below.

4.4.2 International Experience

In most European countries strategic STI priorities are shaped by high-level councils, with participation by relevant Ministers and representatives of major stakeholder groups, often chaired by the Prime Minister or equivalent. Governments seek to determine the vision and policy agenda, but they do not do so under circumstances of their own choosing - the history of previous decisions and the global economic and technological context limits the scope. Priorities at this level generally focus on horizontal policies[56], mission-oriented initiatives[57] or broad areas of science or technology. In such market-based economies most specific technology selection decisions are made by companies and hence priority-setting at a national level generally avoids being too narrow and focused on specific technologies and areas of innovation. Detailed priorities are also developed within Ministries or major funding programs, often with input from advisory councils – the councils and committees, at all levels, often have an advisory rather than decision-making role. In Australia the Chief Scientist plays an active role in bringing focus on specific issues.

There are also often a range of advisory boards that review performance and challenges and contribute to the development of priorities. Priorities are increasingly horizontal or mission-oriented, but focused key technology initiatives are formed from time to time.

In most Asian economies, STI is a very high-level explicit priority and the role of top-down planning, while declining, remains strong. High-level councils and conferences with participation by major stakeholders play an increasing role.

[54] OECD, 2005, p15.

[55] OECD, 2005, p.12-13.

[56] For example, improving the commercialisation of research outcomes, or improving the availability of venture capital. Kuhlmann et al, 2010; Pelkonen, 2006.

[57] See for example, Mazzucato, 2018.

In most East Asian economies STI is an explicit high-level priority strongly supported by government as a central element of development strategy. Priority setting has a stronger top-down influence, but the extent of consultation has been increasing. Councils and national conferences with participation by major stakeholder groups have had increasing influence in shaping STI priorities. In the case of Taiwan, the Office of Science and Technology, which is governed by a board with representation by relevant Ministries and major stakeholders, approves the STI strategy and budget.

With the increasing importance of STI for many Ministries and regions, and the increasing devolution of decision-making, coordination is an ongoing challenge in all countries. In many countries STI Councils with high-level participation or innovation agencies with a 'whole of government' mandates have reduced (but rarely overcome) coordination problems Generally, Ministries of S&T can only play an effective coordination role if they carry out that role on behalf of and are supported by the Prime Minister, or equivalent. While competition among Ministries and regions for funding and for mission mandates is increasing it is not always unproductive.

4.4.3 Implications for Effective Priority Setting in Vietnam

An essential foundation for priority-setting is establishing broad support for the concept that priorities should be set, realising that a substantial diffusion of resources across a wide range of fields will not generate international competitiveness.
Priority setting is an issue for all levels of the innovation system - the national level and the level of research organisations, sectoral agencies, universities, funding bodies etc.

Strategic STI policies that have been developed with stakeholder participation, and that provide a clear *vision* and high-level goals and priorities, guide funding bodies, research organisations, universities and enterprises to develop operational priorities.

STI Councils with participation by key Ministries and major stakeholder groups, and chaired by the head of government, contribute to the legitimacy of priorities and hence also to reducing the problems of effective coordination.

An effective priority-setting system requires capable and resourced participants committed to learning about: priority setting processes; the outcomes and lessons of previous priorities and approaches; research and innovation systems, and; new challenges and opportunities.

4.5 Processes of Priority Setting

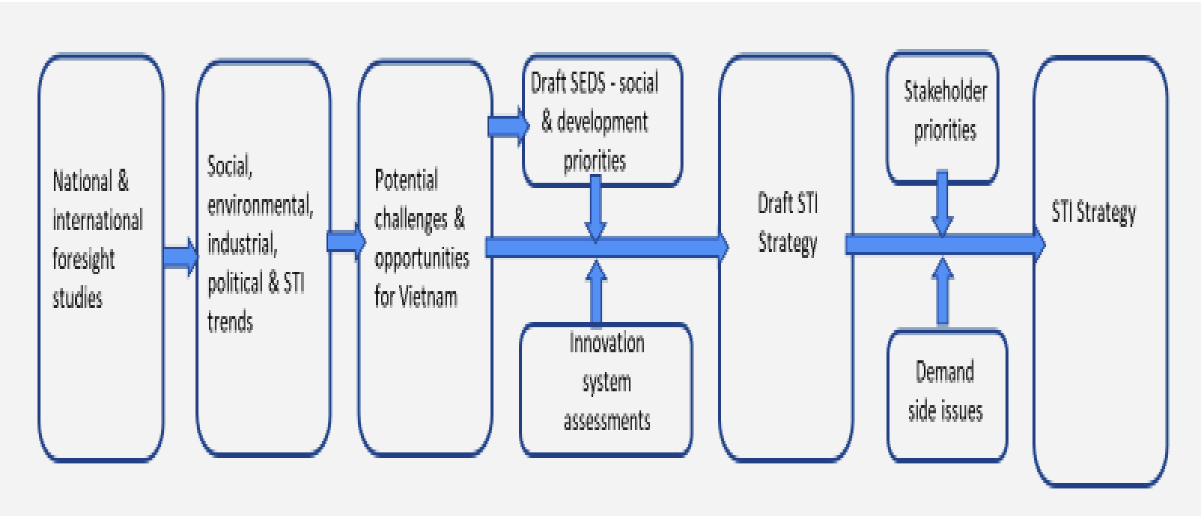
4.5.1 Decisions & Challenges

While Figure C.1 provides a schematic of an overall process, one of the critical issues is addressing complexity, uncertainty and a lack of information. Predicting the speed and direction of technological (and social and economic) development, and the likely impacts of policies, over extended time horizons involves high levels of uncertainty. The complexity of the interactions of social, economic and environmental dimensions, particularly over a longer planning horizon, also raises the importance of learning effectively from the evaluations of past measures (from all countries). This in turn raises the importance of indicators that provide insights on the contribution of past priorities and initiatives to achieving socio-economic and other objectives. Other challenges include:

- moving from the assessment, the long list of potential priorities, to the selected priorities
- linking priorities to the allocation of resources

- deciding what information sources and analyses will be used for an initial identification of STI priorities
- determining what level of specificity/granularity of priorities there be in the STI strategy.

Figure B.2: Foresight and Priority Setting- a possible approach in Vietnam



4.5.2 International Experience

Consultation with a range of stakeholders, which is a key element of the STI priority-setting process in all countries, is discussed further below. The discussion here focuses on information inputs to the process.

There is no international best practice in STI priority setting – processes vary across countries and few countries would consider their approach to be ideal. This reflects the complexities and uncertainties involved. The approaches in each country are shaped by their histories and institutional and industrial structures. Technology assessments, including foresight, have been widely used, but are not standard approaches. One finding of an OECD study of governance in the early 2000s was that agenda setting and prioritisation in OECD countries was often weakly linked to strategic intelligence[58].

Three primary sources of input to priority-setting shape the process in all countries. One of the perspectives that comes from consultation with stakeholders is insight on the demand side – how do firms and research organisations see the priorities and what support do they need to achieve their objectives?

A second key source is the evaluation of experience with previous policies and priorities. All participants will have views on this, which will be more or less systematic, self-serving and informed. A well-developed culture of performance assessment and evaluation, with independent reports made public, contributes to a shared perspective on achievements and problems.

Strategic intelligence, including foresight, has been an important input to priority-setting in all the countries reviewed here. In most European countries, foresight assessments are carried out by independent organisations, although often commissioned by government agencies or councils. Such foresight studies may be national or regional and focused on a sector or technology. They inform all of the participants in priority-setting processes, contributing to consensus building, rather than be a

58 OECD, 2005, p.48.

direct source of recommendations. In most of the major Asian economies, foresight has been a more direct influence on priorities- although that influence may be declining in some cases. Again, foresight studies may be national or regional and focused on a sector or technology. They are more often conducted by government agencies established in order to conduct foresight and related studies. National conferences in Taiwan and China are large consultative process that aim to develop a high level of consensus – an approach that is challenged by the rapidity of change. Both in Europe and in Asia foresight studies draw on the increasing range of 'megatrend' assessments, scientometrics, and bibliometric and patent databases.

4.5.3 Implications for Effective Priority Setting in Vietnam

Developing a comprehensive range of information on which to base decisions, and sharing (and discussing) the analysis of that information with participants in the STI priority setting process, is an essential investment of time and resources.

A critical source of information and insight is previous experience in selecting and implementing priorities. Learning from earlier strategies and initiatives, and engaging all major stakeholders in such reviews, contributes to building a shared perspective on the national (regional, sectoral) context and the challenges faced.

Empowering organisations close to STI activity with significant scope for making decisions on allocation of resources at the detailed/tactical level- and ensuring that they are accountable for those decisions – will strengthen the overall STI system.

4.6 Approach to Consultation & Participation in Priority-Setting

4.6.1 Decisions & Challenges

Priority-setting processes often achieve their objectives as much or more by developing a shared framework and vision as by direct influence on allocation decisions throughout an innovation system. A well-designed and participatory approach, that has sound legitimacy, helps to build consensus around goals that support coordination at the national level, and also at the organisational and regional level. The process can facilitate a collective learning process leading to visions of the future that are shared by more stakeholders. Such participation also increases the levels of commitment to and accountability for outcomes among participants.

4.6.2 International Experience

The approaches to consultation vary widely. In countries that use Future Technology Assessments such as Foresight, these assessment processes usually facilitate extensive consultation as inputs to the foresight. The results of such assessment exercise are then normally used by high-level committees to inform decision making.

As noted above, effective priority-setting and implementation requires coordination among national-level stakeholders and lower-level actors. There are different approaches to this challenge - some countries seek to strengthen coordination through the creation of Councils with advisory roles, or, as in China and the UK, agencies with substantial funding, coordination and evaluation roles.

In most developed economies, broad and largely indicative priorities are set by high level councils or committees, with participation by representatives of key stakeholders in government, industry and research. In countries with broad high-level priorities for science and research, a high degree of delegation to research funding bodies and competitive allocation, much of the detailed decision making is ‘bottom up’, with, from time to time, significant new funding initiatives where governments have identified the need to build capability in specific fields of knowledge.

In China and in Taiwan, and from time to time in Australia, national-level conferences are designed to provide an opportunity for many stakeholders to contribute views on priorities. In Korea and Chile the scope for broad participation in priority setting remains very limited.

4.6.3 Implications for Effective Priority Setting in Vietnam

Sharing information on the knowledge base and assessment methods for priority setting with participants in the STI system contributes to the quality of participation and in turn to the legitimacy and influence of the STI priorities.

A shared perspective based on sound analysis and extensive consultation also contributes to aligning the future actions of STI system participants – apart from the formal STI priorities.

High-level councils with representation by relevant ministries and the most significant stakeholders from research and industry, and national conferences with similar participation, are two mechanisms that can be used for facilitating participation and consultation. Well-designed foresight can also be a mechanism for consultation.

4.7 Types of STI Priority

4.7.1 Decisions & Challenges

The priorities developed through priority setting processes can be of different types[59]:

- Thematic- addressing fields of science and technology (such as digital technologies or biotechnology), or specific technologies, - and related capabilities;
- Mission-oriented policies – addressing broader socio-economic or technological goals and the range of capabilities and incentives to achieve those objectives[60];
- Functional – addressing systemic characteristics of innovation systems and improving the level of coordination among actors and in integrating the many dimensions of policy[61], including finance, design, training, standards etc.[62].

Hence, a key ‘agenda setting’ decision is what level of emphasis will each of these types of focus receive.

[59] Based on Georghiou & Harper, 2011.

[60] For example: Mazzucato, et al., 2020.

[61] As the scope of ‘technology policy’ includes measures to influence all actors relevant for the generation of knowledge and technologies, the commercialisation of technologies and the diffusion and application of technologies, it subsumes innovation policy and much of science policy- Gassler et al, 2004; 2007.

[62] Priority setting processes can help to address system failures in an NIS:

- coordination failures among policies and organisations;
- communication failures among actors;
- market failures that arise particularly to uncertainty, long term strategies and appropriability issues.

4.7.2 International Experience

In the past, the emphasis in most countries was on thematic priorities, particularly significant emerging technologies, including general-purpose technologies, and enabling areas of science. More recently, STI priorities in most countries include all three types of priority.

The significance of functional priorities has increased over time and such priorities have become more explicit, and informed by analysis, as the national innovation systems perspective became more influential.

STI missions have long been important in the United States and have again become more significant in Europe, but in this case reflecting a demand to bring the capabilities of science and technology to bear on objectives beyond competitiveness and security. Mission-oriented priorities were a dominant type of priority in Europe up until the late 1980s, when they largely fell out of favour. There were several notable successes, such as nuclear power, high speed rail and mobile telephony, but also notable failures, such as in Personal Computers.

Thematic priorities have generally continued to be most significant in Asia, along with an emphasis on industrial competitiveness. However, the role of demand side (pull) factors has also increased along with growing community concern about social and environmental objectives. Functional priorities have become more important in recent years in Taiwan[63], Malaysia and Singapore.

4.7.3 Implications for Effective Priority Setting in Vietnam

There is a role for all three types of STI priority – thematic, functional and mission-oriented – although each has different implications for knowledge to inform decisions and capabilities for implementation

When combined in an overall strategy these can be synergistic, particularly when the need for complementary capabilities to ensure a ‘path to impact’ is kept in perspective.

4.8 Integrating Innovation Goals

4.8.1 Decisions & Challenges

Science policy, innovation policy and industry policy have different objectives, stakeholders and requirements for effective governance. How to build appropriate and effective links, at the policy level, and at the level of individual programs and organisations remains an ongoing challenge.

4.8.2 International Experience

There has been a clear trend in most countries to more closely integrate S&T goals with industry and innovation goals –the national innovation systems perspective has influenced policy approaches.

In the past the focus of policy was on the supply side and the problem of weak integration was seen as one of inadequate technology transfer from research organisation to industry and other users. This approach remains common in most Asian countries. However, approaches that address more directly the demand-side, or have an overall systems-based policy design, have developed:

[63] Karo,2018.

- In many countries, the innovation systems perspective and a greater recognition of the importance of SMEs, has underlined the role of the absorptive capacity of enterprises in the demand for and hence diffusion of knowledge. Most countries have introduced initiatives to more directly address the demand side of the innovation system, by focusing on the capabilities of firms and their incentives to innovate.
- In Europe and the United States, mission-oriented programs (including 'smart specialisation') develop integrated approaches that take into account the range of participants and capabilities needed to achieve such objectives as the development of a new industry or the solution of a complex technological, social or environmental problem.

While the concept of innovation has widened to include non-technology innovation (such as service, organisational and business model innovation), and recognising that innovation does not necessarily involve R&D, innovation policy instruments in most countries remain focused on R&D-related technological innovation.

4.8.3 Implications for Effective Priority Setting in Vietnam

STI policies that focus on the supply-side generation of new knowledge, lead to problems of poor knowledge transfer, unless that supply is shaped by a strong and capable demand for knowledge from users. The users of knowledge need to be active participants in STI priority setting, and the requirements for strengthening and orienting demand need to be addressed in STI priorities.

Including mission-oriented initiatives in the policy mix, with their systems perspective, can facilitate cooperation among Ministries and the development of collaboration on research between public and private actors. The requirement within such approaches for ongoing analysis of the context and the outcomes of experience can be a powerful mechanism for policy and strategy learning.

4.9 Implementation of Priorities

4.9.1 Decisions & Challenges

Coordination of policy implementation at the national level can reduce fragmentation and duplication, but it must be clear who is responsible and able to influence all Ministries and other stakeholders.

There is a range of policy instruments that can be used to support implementation of STI priorities:

- strategic guidance
- broad funding programs to pursue thematic and functional goals
- competitive funding
- Indirect measures, such as fiscal incentives.

Promoting enterprises to actively acquire and effectively apply technologies, from all sources, is an important component of implementation.

4.9.2 International Experience

Effective **coordination** is an ongoing challenge. In those countries with market economies and pluralist STI policies, coordination is loose and is enabled by consultation and advisory mechanisms and councils/committees etc at different levels, and on reviews, from time to time, at the level of industries, major technologies or policy issues. However, several countries have developed ‘innovation agencies’ that operate with high levels of autonomy and bring together a range of functions: analysis of opportunities, consultation and networking, engagement with stakeholders, funding, facilitating collaboration, funding capability development (where necessary for effective knowledge transfer) and evaluation[64].

In Europe ongoing program evaluations support accountability and, over time, encourage greater transparency and coordination.

In many Asian economies insufficient coordination among Ministries limits the effectiveness of STI priority setting. In Singapore and Taiwan, strong high-level Councils support coordination.

Different countries emphasise different approaches to **implementation** at the strategic and operational level. Agencies, councils, national budget measures, indirect incentives (eg fiscal measures) and broad policy programs are typically involved in implementation at the strategic level, although new agencies or programs can be created to pursue specific major priorities. A diverse range of mechanisms are used for implementation at the operational level: funding bodies, agency and program budgets, competitive funding, new programs or centres, and performance agreements. Many countries emphasise the use of time-limited funding programs to pursue broad thematic or functional priorities. This approach provides flexibility both with the policy focus and with the approach to implementation, as more is learnt about the issues and participants.

Most developed economies have quite broad high-level priorities with delegation to research funding bodies and programs that develop more specific goals and allocation mechanisms. Funding bodies then typically balance assessments using different criteria: the quality of the proponents and the proposal, the probability of success, and the potential impact on capabilities or innovation/problem solving. Many countries have different research funding schemes and organisations for basic research and applied research.

4.9.3 Implications for Effective Priority Setting in Vietnam

Ultimately, the priorities of an STI system are to a significant extent emergent, in that they develop from an interaction of top-down and bottom-up priorities and processes. High-level priorities cascade through the levels of an STI system and are interpreted and translated into actions at each level. Hence, the capacities at each level to interpret and implement priorities is vital[65].

Once a system for STI priority-setting and implementation is designed, it is useful to ensure that, beyond normal probity requirements, bureaucratic interference and rule-making is minimised;recognising that in any priority setting exercise there are losers that may need to be engaged in supporting the larger process, and adapting their interests to the new priorities.

Decision-making about the detailed allocation of resources is most effective when decentralised and made by those ‘close to the action’. A system with a high level of autonomy but with targets, monitoring, accountability and a tolerance for failure is one that will learn more rapidly and empower the participants. Decentralised decision-making (subsidiarity) is nevertheless guided by an overall vision and shared values and culture.

As most countries aim to avoid a narrow definition of thematic priorities, while nevertheless providing direction to innovation policy, many have developed broad programs addressing a set of interrelated technology targets. Their targets and approaches usually evolve over time as more is learnt. Participants in such programs may constantly negotiate strategies, milestones and allocation decisions.[66]

[64] For example, Glennie & Bound, 2016; Breznitz,et al, 2018.

[65] Hellström, et al, 2017.

An organisation with responsibilities, and authority, for coordination (horizontally, across sectors, and vertically, across layers of implementation) and also at least oversight of monitoring and evaluation, can help to reduce fragmentation and duplication. Many countries have some form of high-level council or committee with participation from major stakeholder groups, which facilitates coordination among government departments and between the public and private sector. Effective coordination depends on legitimacy, which in turn depends on broad and adequate participation in the development of priorities. To some extent, such councils can provide a continuous foresight, developing a stronger alignment among diverse stakeholders based on shared visions of the future. Ministries in turn have to give up part of their autonomy in favour of a national innovation policy66.

4.10Monitoring, Evaluation and Systemic Learning

4.10.1 Decisions & Challenges

Monitoring and evaluation is most effective when integrated into the STI priority setting process and strategic plan. The implementation and assessment of monitoring and evaluation requires coordination by an organisation with a recognised mandate and with the capabilities for the task.

4.10.2 International Experience

In most countries evaluation, at the national, regional, sectoral or program level and at the level of research organisations, policies, programs and projects, has become more important - complementing ex ante evaluations. Evaluations are usually carried out by independent organisations or committees, involve extensive consultation, and are published. Evaluation is an increasing sophisticated area in STI policy with increasing collaboration with experts in academia and specialised consultancies. The use of Randomised Controlled Trials (RCT) and other new methods is becoming increasingly common. In Australia, the Department of Industry has established a well-resourced evaluation unit that has been a model around Commonwealth agencies. NESTA in the UK is another leading example.

Monitoring and evaluation has become more important for reviewing the relevance of priorities, the level of implementation and the impacts of measures – it is a vital element of the learning process.

As noted, Innovation Councils, with broad participation, can support the long-term strategies and promote ongoing coordination and evaluation and hence also policy learning. In Europe, evaluation of organisations, projects and programs has been increasingly integrated into funding schemes and is a key mechanism of policy learning - for the direct participants and for policy designers.

Evaluation is also an increasingly important feature of STI governance in Asia. In China, in particular, policy experiments have been used as an active approach to policy learning.

4.10.3 Implications for Effective Priority Setting in Vietnam

International experience indicates that monitoring and evaluation plans should be incorporated into policy design and lead to specification of the data needs and the criteria for evaluation. International experience also indicates that evaluations are most effective in promoting policy learning when they are independent and the results made public.

[66] Djarova & Zegveld, 2009; Magro, et al, nd; Berghäll & Kiander, J., 2003.

The priority setting process itself should be evaluated not in terms of success or failure, but rather to identify what can be learnt to improve the next iteration. This is characterised as 'double-loop learning', which entails the modification of goals or decision-making rules in the light of experience. This may require not only a change in the design, but also a revisiting of the organization's underlying norms, policies and objectives.

5 PART C DEVELOPMENT OBJECTIVES AND TECHNOLOGY FIELDS AND TRAJECTORIES

5.1 Basic Principles for Priority Selection- Options for Thematic Priorities

1. The safest strategy (fewest problems with wasted investment) is not to identify any priority areas, but to create good framework conditions that improve the capabilities of all firms. This is essentially the OECD view. However, a sole reliance on this approach is not very useful for countries that aim for rapid economic development.
2. It makes sense to prioritize areas that are essential parts of the economy and where there is already an existing innovation system - for instance agriculture, aquaculture and in some cases resource processing. The chances of failure here is probably the lowest possible.
3. For science-based and high-tech fields where the expectation is the development of high value-added product and potential export markets, there may be opportunities in prioritizing areas where there is already some private sector activity - which is more likely to ensure absorptive capacity and complementary assets and to enable interaction with research organisations. [This is the approach that Denmark took for prioritizing marine telephony and biotech, for which they were successful. Germany, Singapore and the Netherlands took this approach for biotechnology in the 1990s/2000s and it largely failed in all of them, but there were positive, unexpected spin-offs - for instance it may have helped Singapore become a provider of export health services.]
4. For science-based and high-tech fields where the expectation is the development of high value-added product and potential high growth export markets, but where there are very limited capabilities in the private sector, there may be opportunities in prioritizing areas where there is some public sector expertise. This would require a portfolio investment approach, since many of these priority areas are likely to fail. Within this option and additional criteria is those investments that are likely to generate strong externalities, in terms of capabilities that support innovation and productivity improvement in many other sectors. This option would require very high levels of sustained investment, effective industry policies that enable the emergence (or attraction) of strong firms and significant risk of failure.
5. A related option is a focus on those highly knowledge-intensive technology fields where knowledge acquisition and research in the public sector can be developed to support capability development in the industry sector (and the public sector) in order that firms (and public sector organisations) can be effective users, adapters and improvers of imported technology. This approach is likely to be relevant for the application in industry and government of Industry 4.0 technologies and of 'green' technologies.
6. There are likely to be **niche** markets, where for historical reasons there is strong local capabilities or high levels of local demand, and achieving strong performance may not require the levels of investment or time scales characteristic of option 4. In most countries it is entrepreneurs who discover and develop these niche opportunities – a major reason why a vibrant entrepreneurial ecosystem is important.
7. Industry strategies to upgrade positions on global value chains and to increase the level of spillovers from MNE investment are likely to require supportive research strategies.

5.2 Indicative Priorities from the Draft Socio-Economic Development Strategy- An Interpretation to assist developing STI Indicators

5.2.1 STI Development Goals and Strategies in the SEDS

Goal

Strongly develop STI to create breakthroughs improvements in the productivity, quality, efficiency and competitiveness of the economy.

Strategies

Re-orient STI to the Development of the Technology & Innovation Capabilities of Enterprises

- Develop STI and the NIS with the enterprise as the centre
- Develop and improve the operational efficiency of the national innovation system and increase the orientation toward a business-centric ecosystem
- Develop and improve the start-up ecosystem,
- Develop policies and financial mechanisms to encourage enterprises to participate in R&D and innovation- aim that by 2030 40% of enterprises will have innovative activities
- Develop a more competitive business environment that incentivises enterprises to apply technology and raise productivity
- Encourage foreign-invested enterprises to form R&D and innovation centers in Vietnam.
- Encourage technology acquisition from international sources and improve the capacity of enterprises to absorb and master technologies and to innovate
- Strengthen linkages between business and those research organisation and universities which focus on improving the capacity of enterprises to acquire, own and step by step participate in creating new technologies.
- Develop S&T-based and high-tech enterprises, high-tech enterprises
- Promote the role of STI funds in promoting research, start-up innovation, technology transfer and application

Review and Strengthen the Governance and Management of STI Programs

- Fundamentally renovate the mechanism of state budget management for science and technology, implementing the State's mechanism of ordering scientific and technological research projects [what does this mean?]
- Clearly define targets and action programs of the development and application of STI to all aspects of activities, all levels, all sectors and all regions.
- Restructure and align science and technology programs and tasks to address more effectively social needs and raising the level of value-adding in value chains

- Select and focus on supporting research and technology development applications for a number of key sectors and fields, and in evaluating the performance of STI take improving the technological level of the economy as a key criterion
- Strengthen the capabilities of STI in Vietnam so that new directions of research can effectively focus on priority technologies and that capability can be applied to innovation.
- Develop and improve the operational efficiency of the national innovation system and increase the orientation toward a business-centric ecosystem
- Experiment with policy initiatives through pilots, including through initiatives to transfer and apply new technologies, technological innovations and business models
- Improve the capacity and efficiency of research facilities/infrastructure, national key laboratories, and high-tech zones
- Maintain investment in basic scientific research, particularly in areas related to 'core technologies', including digital technologies
- Develop social sciences and humanities, and combine with natural sciences, to contribute to achieving the goals of the socio-economic strategy, including by encouraging creativity
- Emphasise the application of STI, promoting R&D that is focused on applied research and commercialisation

Review and Strengthen the Governance and Management of STI Organisations

- Increase the autonomy of public S&T research organisations
- Promote S&T research in universities and training organisations – in association with market demand.
- Strengthen the management of STI and enable innovative approaches to research management and knowledge transfer

Raise the Level and Effectiveness of Technology Transfer and Business-Research Linkages

- Increase the role of market mechanisms, including in technology transfer, supported by laws, policies and organisations
- Promote S&T research in universities and training organisations – in association with market demand
- Experiment with policy initiatives through pilots, including through initiatives to transfer and apply new technologies, technological innovations and business models
- Strengthen the management of STI and enable innovative approaches to research management and knowledge transfer
- Implement digital transformation in government, the production sector and social organisations
- Strengthen linkages between business and those research organisation and universities which focus on improving the capacity of enterprises to acquire, own and step by step participate in creating new technologies
- Develop S&T-based and high-tech enterprises, high-tech enterprises

- Promote the role of STI funds in promoting research, start-up innovation, technology transfer and application
- Develop the network of intermediary and technology transfer organisations

Strengthen STI Infrastructure and Regulation

- Strengthen the protection and enforcement of IP
- Expand and improve the system of standards and regulations harmonized with international standards
- Improve the capacity and efficiency of research facilities/infrastructure, national key laboratories, and high-tech zones
- Develop a database of S&T and an S&T market, and connect national centres with STI-related centres in all locations
- Develop the network of intermediary and technology transfer organisations

Develop International Linkages that Support Vietnams STI Development

- Encourage foreign-invested enterprises to form R&D and innovation centers in Vietnam.
- Promote international integration and cooperation in S&T, diversify and select strategic partners (based on their capabilities in advanced S&T), link cooperation in S&T with economic cooperation
- Develop a network of Vietnamese involved in STI abroad and attract their participation and contribution to STI development in Vietnam
- Encourage technology acquisition from international sources and improve the capacity of enterprises to absorb and master technologies and to innovate

5.2.2 Industry Development Goals and Strategies

Goal

Step up the restructuring of the economy in association with renewing the growth model, ensuring the substance and efficiency; developing a digital economy; promote rapid and sustainable growth on the basis of macroeconomic stability

Strategies

Promote transformation in all sectors through the Fourth Industrial Revolution technologies and business models.

- Continue to promote industrialization and modernization on the basis of science and technology, innovation and achievements of the Fourth Industrial Revolution.
- Accelerate the restructuring of service industries based on modern technology, apply the achievements of the Fourth Industrial Revolution in service sectors such as finance, banking, insurance, legal and medical services. education, training, transportation, postage, logistics, trade, etc.

Focus on Developing Knowledge-intensives industries with higher levels of value addition

- Speed up the development of a number of key economic sectors and domains with great potential, advantages and space to motivate growth in the spirit of catching up, advancing along and surpassing in a number of areas with the region, the world.
- Apply high technology in manufacturing organization to create substantial changes in a number of industries, create spillover effects and lead to restructuring of the entire industry, improve competitiveness and deeper participation in global industrial value chain.
- Develop industrial sector in a harmonious combination of width and depth, with a focus on in-depth development, creating a breakthrough in improving productivity, quality and competitiveness of products. To strive to increase the industrial share of GDP in 2030 to over 40%; the added value of processing and manufacturing industry per capita will reach over USD 2,000. Focus on restructuring the industry associated with raising technology level, innovation and digital transformation, fully exploit the opportunities of the fourth industrial revolution and competitive advantage. Promote digital transformation, production and business methods in industrial enterprises, increase connectivity, access to information and data to increase new business opportunities and increase the ability to participate in global value chains and area.
- Develop a number of priority industries, new industries, and high-tech industries, ie. information and telecommunications technology, electronics industry, robotics manufacturing industry, automobiles, integrated equipment for automatic operation , remote control, software manufacturing, digital products, information security industry, pharmaceutical industry, biological products, environmental industry, clean energy industry, renewable energy creating, intelligent energy, processing industry, manufacturing for agriculture and new materials associated with the application of energy-saving technology, raw materials. Further develop the textile and footwear industry, focusing on high-value-creating stages associated with intelligent and automated production processes.
- Promote internal industry restructuring in the direction of increasing high value-added industries and moving to high value-added stages in the value chain of each industry. To promulgate modern technology and production standards.

Develop the Knowledge-intensity and Level of Value add in Resource-Based Industries

- Promote agricultural restructuring, exploit and bring into play the advantages of tropical agriculture, develop large-scale concentrated commodity agriculture in the direction of modernization and areas specializing in high-quality goods. Strongly develop hi-tech agriculture, clean agriculture, organic agriculture and bio-agriculture, meeting common food safety standards.
- Develop high-tech industrial animal husbandry, encourage the development of high-efficiency and environmentally friendly farms and farms. Develop aquaculture on both the sea and inland water surfaces towards industrialization, extensive and improved farming; improve the efficiency of offshore fishing, develop ocean fishing.
- Raise the level of research, application and transfer of science and technology, strongly develop hi-tech agriculture in order to create a breakthrough in productivity, quality and industry governance, improve the quality of human resources in agriculture.

Strengthen the Performance of Supporting Industries & Development of Industry Clusters

- Develop a number of basic industries to meet the needs of the basic production means of the economy such as energy industry, mining, metallurgy, chemicals, fertilizer, materials and mechanics.
- Focus on developing supporting industries and forming industry clusters in a number of priority industries such as manufacturing, high technology and information technology industry. Strengthen the linkages between FDI sector, especially multinational corporations and domestic enterprises in developing supply chains of industries. Develop a number of key telecommunication and information technology enterprises that well perform the leading role in technological infrastructure, a foundation for the digital economy and digital society in the context of the fourth industrial revolution.
- Improve the construction industry's capacity, ensure adequate design and construction of modern and complex construction works in all fields with all sizes and competitiveness, expanding the operation market abroad.
- Promote restructuring the tourism industry, build and upgrade the production value chains of tourism products and related services to make tourism truly a key economic sector. Tourism contributes about 14-15% of GDP and increases the proportion of the service sector in GDP to over 50%.

5.2.3 Overall High-Level Functional Priorities

STI Strategy

- Re-orient STI to the Development of the Technology & Innovation Capabilities of Enterprises
- Review and Strengthen the Governance and Management of STI Programs
- Review and Strengthen the Governance and Management of STI Organisations
- Raise the Level and Effectiveness of Technology Transfer and Business-Research Linkages
- Strengthen STI Infrastructure and Regulation
- Develop International Linkages that Support Vietnams STI Development

Industry Strategy

- Promote transformation in all sectors through the Fourth Industrial Revolution technologies and business models.
- Focus on Developing Knowledge-intensives industries with higher levels of value addition
- Develop the Knowledge-intensity and Level of Value add in Resource-Based Industries
- Strengthen the Performance of Supporting Industries & Development of Industry Clusters

5.2.4 STI Thematic Priorities

Fields of S&T

- Digital technologies/ Industry 4.0, 5G and post-5G connectivity, artificial intelligence blockchain, 3-D printing, Internet of things, network security
- Mechatronics and automation
- Biomedical electronics
- Clean energy
- Environmental technologies and biology

Industrial Sectors

- Digital/ ICT Sectors
    - information and telecommunications technology, electronics industry,
    - robotics manufacturing industry,
    - integrated equipment for automatic operation ,
    - remote control
    - software manufacturing
    - information security industry,
- pharmaceutical industry & biological products,
- environmental industry,
- clean energy industry /renewable energy, creating, intelligent energy,
- processing industry,
- manufacturing for agriculture and new materials associated with the application of energy-saving technology,
- textile and footwear industry based on intelligent and automated production processes.
- agricultural industries - tropical agriculture, large-scale concentrated commodity agriculture, hi- tech agriculture, clean agriculture, organic agriculture and bio-agriculture, high-tech industrial animal husbandry, high-efficiency and environmentally friendly farms and farm - productivity, quality and industry governance, improve the quality of human resources in agriculture
- aquaculture on both the sea and inland water towards industrialization
- Fishing offshore and ocean.
- basic industries - energy industry, mining, metallurgy, chemicals, fertilizer, materials & mechanics.
- Construction
- Tourism

5.2.5 Implications for Social Sciences- a preliminary approach

The social science cover a broad range of disciplines, as shown in Table D.1. Table D.2 indicates some of the social sciences relevant to the functional STI priorities identified in the SEDS.

Table C.1: Social Science Disciplines[67]

Demography and social statistics, methods and computing

- **Demography** is the study of populations and population changes and trends, using resources such as statistics of births, deaths and disease.
- **Social statistics, methods and computing** involves the collection and analysis of quantitative and qualitative social science data.

Development studies, human geography and environmental planning

- **Development studies** is a multidisciplinary branch of the social sciences which addresses a range of social and economic issues related to developing or low-income countries.
- **Human geography** studies the world, its people, communities and cultures, and differs from physical geography mainly in that it focuses on human activities and their impact - for instance on environmental change.
- **Environmental planning** explores the decision-making processes for managing relationships within and between human systems and natural systems, in order to manage these processes in an effective, transparent and equitable manner.

Economics, management and business studies

- **Economics** seeks to understand how individuals interact within the social structure, to address key questions about the production and exchange of goods and services.
- **Management and business studies** explores a wide range of aspects relating to the activities and management of business, such as strategic and operational management, organisational psychology, employment relations, marketing, accounting, finance and logistics.

Education, social anthropology, and linguistics

- **Education** is one of the most important social sciences, exploring how people learn and develop.
- **Social anthropology** is the study of how human societies and social structures are organised and understood.
- **Linguistics** focuses on language and how people communicate through spoken sounds and words.

Law, economic and social history

- **Law** focuses on the rules created by governments and people to ensure a more orderly society.
- **Economic and social history** looks at past events to learn from history and better understand the processes of contemporary society.

Politics and international relations

- **Politics** focuses on democracy and the relationship between people and policy, at all levels up from the individual to a national and international level.
- **International relations** is the study of relationships between countries, including the roles of other organisations.

Psychology and sociology

- **Psychology** studies the human mind and try to understand how people and groups experience the world through various emotions, ideas, and conscious states.
- **Sociology** involves groups of people, rather than individuals, and attempts to understand the way people relate to each other and function as a society or social sub-groups.

Science and technology studies

[67] UK Economic and Social Research Council

- **Science and technology studies** is concerned with what scientists do, what their role is in our society, the history and culture of science, and the policies and debates that shape our modern scientific and technological world.

Social policy and social work

- **Social policy** is an interdisciplinary and applied subject concerned with the analysis of societies' responses to social need, focusing on aspects of society, economy and policy that are necessary to human existence, and how these can be provided.
- **Social work** focuses on social change, problem-solving in human relationships and the empowerment and liberation of people to enhance social justice.

Table C.2: : Social Sciences Directly Relevant to the SEDS Functional Priorities

Social Sciences[68]	**STI Capabilities of Enterprises**	**Governance & Management of STI Programs**	**Governance & Management of STI Organisations**	**Tech Transfer & Business-Links**	**STI Infrastructure & Regulation**	**International Linkages**
Demography						
Social statistics, methods & computing						
Development studies						
Human geography						
Environmental planning						
Economics						
Management & business studies						
Education						
Social anthropology						
Linguistics						
Law						
Economic & social history						
Politics						
International relations						
Psychology						

[68] Social science disciplines based on UK Economic and Social Research Council

Sociology						
Science and technology studies						
Social policy						
Social work						

6 Appendix: INTERNATIONAL APPROACHES TO STI PRIORITY SETTING

6.1 Introduction

This Appendix provides a reasonably detailed discussion of the approach to STI policy setting in several countries. In order to focus the discussion on the key design choices and to facilitate a comparison of the approaches and experience of the selected countries, a standard framework has been developed: Table App.2. As the scope of 'technology policy' includes measures to influence all actors relevant for the generation of knowledge and technologies, the commercialisation of technologies and the diffusion and application of technologies, it subsumes innovation policy and much of science policy[69]

6.1.1 National Approaches and Dominant Trends in Priority Setting

In many countries these approaches to priority setting co-exist and complement each other. In most OECD countries the approach to defining, developing and implementing 'functional' and 'thematic' priorities is largely through negotiation among a diverse range of actors.

Table App.1: Structure of R&D subsidies in five large countries (2003, %)[70]

Country	Traditional mission-led approach	Key Technologies	Innovation System
USA	64	30	5
Japan	17	69	14
Germany	19	26	65
United Kingdom	42	12	46
France	41	17	42

6.2 Approaches to Priority Setting in Europe

6.2.1 Development of Approaches to Priority Setting in Europe

The development of priority setting is often characterised as involving four stages[71].
Traditional mission-led approach, with a focus on key military technologies: 1940s – 1950s.

- Focused on public sector actors and a 'science-push' rationale;
- Extended to nuclear energy, space and aerospace in the 1950s, and hence to also non-military objectives;
- Decision-making by selected experts from main government, research and major corporates.

Key Industrial technology mission approach focused on 'key' industrial technologies: 1960s-70s.

- Most often developed in support of 'catch-up' industrial and technology strategies in Europe, Japan and Korea;

[69] Gassler et al, 2004; 2007.

[70] Source: Gassler, et al, 2007.

[71] Gassler et al, 2004; 2007.

- The scope included the private sector and a clearer orientation to diffusion and capability objectives and measures;
- The list of 'priority' technologies tended to increase over time and converge on a similar list in many countries;
- New methodologies of technology assessment, technology roadmapping and technology foresight were developed to aid selection processes;
- Rationales for intervention emphasised competitiveness agendas, the scope for efficiency in innovation and the challenge for the private sector in responding to new major shifts in the knowledge base, particularly in the case of general-purpose technologies of wide relevance throughout industry.

Table App.2: Framework for Assessing National STI Priority Setting Approaches

1. **What—Scope Of STI/ Priorities for What?**

    - In most countries future technology analysis and priority setting focuses on research policy and on industry policy, particularly in relation to the priorities for building capabilities in enterprises.

2. **Approach to Governance- Role of Planning (Vs Framework Conditions Etc)**

    - Most developed economies do not carry out systematic top-down planning for STI, but rely on forms of future technology analysis that then inform decisions about priorities in research agencies and in government agencies.

3. **Level and Extent of High-Level Leadership of STI as a Priority**

    - Many countries have a high-level council that provides oversight of STI policy but generally has an advisory or consultative, rather than a policy-making or directive role.

4. **Who – Organisations Involved In Priority-Setting**

    - In most developed economies broad and largely indicative priorities are set by high level councils or committees, with participation by representatives of key stakeholders in government, industry and research.

5. **How – Processes of Priority Setting**

    - In some countries this decision making is informed by Future Technology Assessments, such as Foresight.
    - Criteria include: socio-economic goals; building new competencies; addressing identified NIS problems; supporting industry development goals

6. **Approach to Consultation- Who, to What Extent**

    - The approaches to consultation vary widely.
    - In countries with a broad high-level priorities for Science and Research, high degree of delegation to research funding bodies and competitive allocation, much of the detailed decision making is 'bottom up', with, from time to time, significant new funding initiatives where governments have identified the need to build capability in specific fields of knowledge.
    - In countries that use Future Technology Assessments such as Foresight, these assessment processes facilitate extensive consultation. The results of such assessment exercise are normally used by high-level committees as a basis for decision making.

7. **Horizontal and Thematic Priorities**

- In most developed economies the focus of STI policy has been on:
    - Horizontal policies – addressing identified problems in innovation systems

- Responding to the emergence of general-purpose technologies, such as biotechnology and digital technologies
- Missions – ie programs often spanning many technologies and sectors that aim to pursue social goals, eg climate change[72].

[72] For example: Mazzucato, et al, 2020.

- Thematic: Sectoral or enabling capabilities of relevance to many sectors.

8. Integrating Innovation Goals

- There has been a clear trend in most countries to more closely integrate of S&T goals with industry and innovation goals – the strong influence of the national innovation systems perspective is an expression of this- this Section C, for a discussion of innovation and targeting.
- Nevertheless, the governance of S and T and I (and industry policy)remain separate, if more closely related- building appropriate and effective links, at the policy level and at the level of individual programs and organisations remains an ongoing challenge in all countries.

9. Implementation of Priorities

- Most developed economies have quite broad high-level priorities with delegation to research funding bodies and programs that either develop more specific strategies goals or manage competitive research funding schemes. Funding bodies typically balance assessments based on criteria of: excellence of the research and potential impact on capabilities or innovation/problem solving. Many countries have different research funding schemes and organisations for basic research and applied research.
- However, several countries have developed 'innovation agencies' that operate with high levels of autonomy and bring together a range of functions from analysis of opportunities, consultation and networking, engagement with stakeholders, funding, facilitating collaboration, funding capability development where this may be necessary for effective knowledge transfer, evaluation.

10.Coordination of Implementation

- In those countries with market economies and pluralist STI policies, coordination is loose and is enabled by consultation and advisory mechanisms and councils/committees etc at different levels, and on reviews, from time to time, at the level of industries, major technologies or policy issues.

11.M&E and Policy Learning and Adaptation of Policies

- In most countries evaluation, at the level of research organisations, policies programs and projects, has become more important- they complement ex ante evaluations.
- Evaluations are usually carried out by independent organisations or committees, involve extensive consultation, and are published.

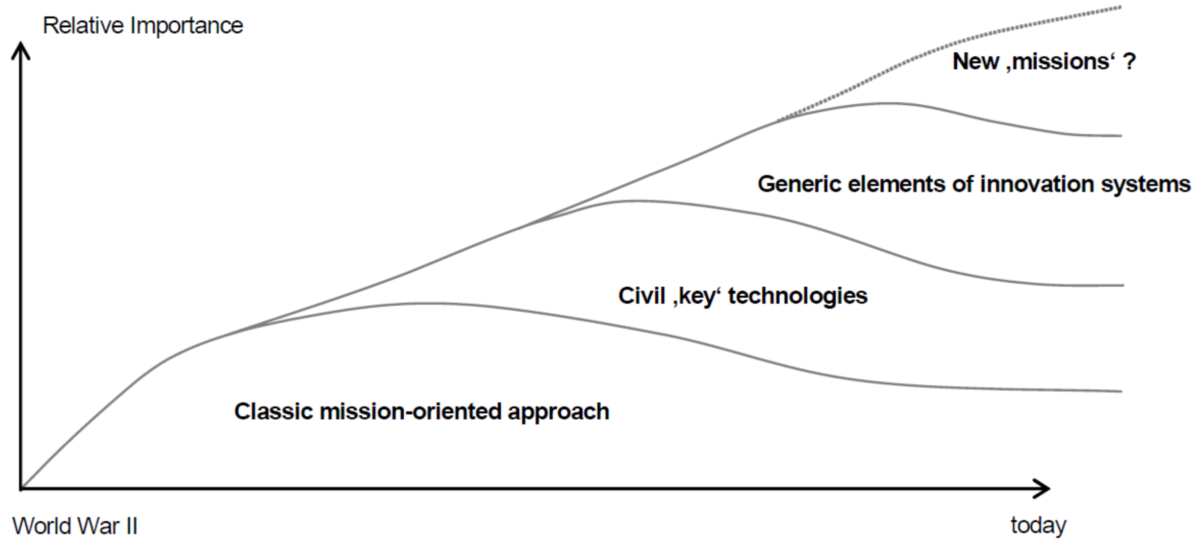
Innovation systems-oriented approach focused on the functioning of organisations and policies: 1980s-1990s.

- Criticism of priority-setting emphasised the challenge of uncertainty and as result to risks of the wrong decisions, of waste of resources and of lock-in to selected paths.;
- Experience also showed the risk of dominance of vested interests in influencing decisions.

- New understanding emphasised the importance of the 'functions' of innovation systems, the central role of firms in innovation and diffusion, the importance of interactions to enable knowledge flows, and the importance of learning and cumulative capability development, including of design and other non-research activities.
- The challenge of facilitating cooperation among firms and research organisations led, in many countries, to the development of new non-government program management organisations with skills in innovation and a neutral position in relation to stakeholders. For example, Vinnova in Sweden, TEKES in Finland and Enterprise Ireland in Ireland, have broad 'system level' responsibilities and programs, along with high levels of autonomy. The shift from narrowly defined 'thematic' priorities has also involved a shift of emphasis away from thematic research organisations and toward broad and flexible programs of support, open to a wider range of actors, including firms.

As discussed further below, since about 2000 in most European countries the dominant approach has been social mission-led focusing on technologies seen to be particularly relevant for addressing challenges in eg, ageing, new health concerns, environmental sustainability, security: 2000s. This new form of 'thematic' priorities has in most OECD countries been combined with the range of 'functional' priorities based on the Innovation Systems framework.

Figure App.1: Approaches to STI Priority Setting in Europe



Source: Gassler, et al, 2007

The challenge of finding an appropriate method for identifying, assessing, defining and selecting priorities, whether thematic or functional was largely met in the 1980s and 1990s by a reliance on foresight and technology assessment- but the use of these approaches has since declined. This is the case for two reasons: the view has grown that the detailed selection is best left to the private sector and the market; the key challenges and the high potential thematic fields(eg ICT, biotech, nanotechnology) are actually very similar in most countries. Hence, priority setting at the national level is now generally focused on the priority attached to innovation and on broad thematic and functional priorities, leaving to funding councils, programs and research performers, the translation into specific priorities and strategies.

As in other EU countries priority technology areas are defined at a broad strategic level and organised as programs that develop public-private research networks, promote regional cluster initiatives and encourage innovation in small and medium enterprises and start-ups, rather than have the level of focus on ‘Key Technologies’ as in the US and Japan. More recently the focus has shifted to the research under-pinning technologies relevant to social challenges and problems, for example in ‘green’ technologies. Priority setting in this type of approach usually involves a wider range of stakeholders representing social groups beyond research and business.

In many European countries the role of technology assessment, roadmapping and foresight in the selection of priorities has declined in importance and there is greater reliance on bottom-up and consultative processes[73]. Forms of ‘strategic intelligence’ using such planning tools, along with monitoring and evaluation, are also used at the program and organisation level – where there is often a requirement by funding bodies for an explicit strategic approach. At the same time there is less emphasis on narrowly defined technological priorities, leaving this largely to firms and the market[74]. Consequently, research and technology policy design and management has become very complex. It involves broad and diverse objectives with a large range of actors and is developed and implemented through a diverse set of instruments.

In 2007, the Department for Innovation, Universities and Skills (DIUS) was assigned overall oversight and responsibility of all UK innovation activities. DIUS’s Annual Innovation Report addressed the innovation-related activities across government departments. In the UK all evaluations have had to be contracted out to external evaluators and are held throughout the life of a program or organisation.

In some European countries there are research councils for specific areas of research as well as sector or technology-specific research centres which conduct foresight studies and other planning assessments in their area of interest – and which in a sense institutionalise a basic set of thematic priorities.

> *“Councils are either set up as expert councils (like the Austrian Council or the SIAC in NZL) or political councils (like the Korean one) or a mixture of both (like the Dutch Innovation Platform). The most far-reaching effort is probably to be seen in the Netherlands, where the ‚Innovation platform’ not only seeks to coordinate S&T, but also innovation policy matters. On the other end of the spectrum are the more ‚modest’ approaches restricted to the coordination of a specific corner of S&T policy. An example in case would be ‚Research Councils UK’ (RCUK), an umbrella institution aiming at the coordination of the seven individual research councils strategies and priority settings.” Glasser, et al. 2004, p93*

Implementation of priorities at the strategic level has been generally through councils, programs and sometimes the creation of a new agency. At this level, white papers and similar strategic statements aim to signal priorities. At the more operational level the mechanisms of implementation are typically through budgets, competitive funding, performance agreements, new support schemes or new funding programs.

6.2.2 Foresight and Priority Setting in Europe

In many European countries, and in Russia, foresight studies inform STI priority setting - by governments and also by other stakeholders in the national innovation systems. Foresight studies identify global developments relevant to STI, analyse country’s competitive advantages and opportunities to build new strengths and review the outcomes for previous policies. At the EU level,

[73] Glasser et al, 2004 and 2007, comment that the value of such techniques has been strongly questioned and are now used in a more modest way, largely to facilitate consultation and develop shared perspectives; and

[74] Gassler, et al, 2007.

the ERAWATCH program and the Research and Innovation Observatory have contributed to the development of the major EU Framework Programs, including 'Horizon 2020'.[75]

Priorities at the European Union level are developed through consultations between the European Commission, the European Parliament, and the European Council - a wide range of stakeholders from all EU member states are also consulted. The Directorate General for Research and Innovation of the European Commission drafts the initial draft priorities. This is then submitted to the European Parliament and the European Council where they are widely debated by a wide range of interest groups at the EU level and at the national and regional level. The final draft is submitted to the European Parliament for final approval. The final approved priorities are then developed into work programs and then form the basis of calls for proposals for R&D projects under the Framework programs.[76]

The Horizon 2020 program has three core priorities:

- **Excellent Science** (€24,4 billion)
    - European Research Council (€13 billion)
    - Marie Sklodowska-Curie Actions (€6,1 billion)
    - Future and Emerging Technologies (€2,6 billion)
    - Research Infrastructures (€2,6 billion)
- **Industrial Leadership** (€18 billion)-
    - Leadership in Enabling and Industrial Technologies (€13,5 billion), Information and Communication Technologies; Micro- and Nanoelectronics, Photonics; Nanotechnology and Advanced Materials; Biotechnology; Advanced Manufacturing Processes; and Space.
    - Access to Risk Finance (€2,8 billion),
    - Innovation in SMEs (€616 million).
- **Societal Challenges** (€31,7 billion) -increasing efficiency of research and innovation
    - Health, Demographic Change and Wellbeing (€8 billion);
    - Food Security, Sustainable Agriculture and Forestry, Marine & Maritime and Inland Water Research, & Bioeconomy (€4 billion);
    - Secure, Clean and Efficient Energy (€5,7 billion);
    - Smart, Green and Integrated Transport Systems (€6,8 billion);
    - Climate Action, Environment, Resource-Efficient and Raw Materials (€3 billion);
    - Europe in a Changing World - Inclusive, Innovative and Reflective Societies (€1,3 billion);
    - Secure societies - protecting freedom & security of Europe and its citizens (€1,7 billion);
    - Science for and with Society (€0,5 billion).

[75] European Commission (2015).

[76] Grebenyuk et al., 2016.

Future-Oriented Technology Analysis (FTA) / Strategic Policy Intelligence
Foresight is one group of a wider range of methods that are used to inform priority setting and policy development. Foresight is a generic term and can involve many quite different approaches and methods[77]. European foresight studies have typically used literature reviews, expert panels and scenarios to develop insights into the likely future evolution of technologies, the dynamics of demand and supply that are likely to shape that evolution, and the types of capability likely to be needed to respond to opportunities and challenges. Foresight exercises can provide a platform and process that promotes collaboration and coordination among actors, including between the public and private sectors[78].

'Mission-Oriented' Innovation Policies

Many governments have pursued 'mission-oriented' innovation initiatives within their portfolio of STI policies. The long-running DARPA program in the US is one example. Recently, there has been renewed interest in such approaches. For example, some countries are developing strategies for a greener economy or for greater wellbeing for an ageing population. Missions can be in any area of challenge, environmental, demographic, economic, or social, that provide justifications for action, and strategic direction for funding policies and innovation efforts.

According to Mazzucato (2019) innovation missions should be:

> "*…feasible, draw on existing public and private resources, be amenable to existing policy instruments, and command broad and continuous political support…create a long-term public agenda for innovation policies, address a societal demand or need, and draw on the high potential of the country's science and technology system to develop innovations*." (p.66)

Mazzucato cites Germany's Energiewende strategy as an example. This strategy aims to address climate change , phase out nuclear power, improve energy security by substituting imported fossil fuels with renewable sources, and increase energy efficiency:

> "..*Energiewende is providing a direction to technical change and growth across different sectors through targeted transformations in production, distribution, and consumption. This has allowed even a traditional sector like steel to use the 'green' direction to renew itself… mission-oriented policies should be focused on ways to provide sectors with transformation policies—fewer subsidies and more focused policies that reward investment and innovation that meet a need*."[79]

Smart Specialisation Policies in Europe

A new approach identifying priorities emerged in 2009, after the global financial crisis, with IBM's championing of a 'Smarter Planet' vision. This emphasised how a new generation of intelligent systems and technologies, more powerful and accessible than before, could be used to create smarter power grids, food systems, water, healthcare and traffic systems. Computational power was being infused into things no one had thought of previously as computers: phones, cars, roads, power lines, waterways and food crates. A trillion connected and intelligent things were becoming an 'internet of things', producing vast amounts of data. Sophisticated analytics and algorithms were needed to analyse the data and put it to use.

The concept of smart cities originated at the same time with an emphasis on" leveraging innovative technologies to enhance the quality and performance of urban services, to reduce costs and resource consumption, and to engage more effectively and actively with their citizens. They deploy

[77] Georghiou, et al, 2008.

[78] Miles, 2005. UK Foresight: Three cycles on a Highway. International Journal of Foresight and Innovation Policy, 2(1), pp 1-34.

[79] Mazzucato, 2019, p.68.

smart devices, sensors and software to equip existing infrastructure with the equivalent of digital eyes and ears enabling more efficient and effective monitoring and control of energy and water systems, transportation networks, human services, public safety operations – basically all core government functions”[80].

The emphasis has progressively shifted from just the rollout of smart technology to include a smart populace supported by smart governance. Hence, the OECD defines smart cities as “initiatives or approaches that effectively leverage digitalisation to boost citizen well-being and deliver more efficient, sustainable and inclusive urban services and environments as part of a collaborative, multi-stakeholder process”.[81]

The concept of smart cities and regions has taken a strong hold in the past decade in Europe, but also in Japan and Korea[82], essentially as a new approach to developing an effective collaborative and co-creative innovation eco-system, rather than a priority-setting mechanism in its own right. Approaches have included smart city innovation ecosystem resources such as testbeds and ‘Living Lab’ facilities, and agenda setting and road-mapping which balance bottom-up and top-down approaches.

Smart City strategies are: “based on an assessment of the future needs of cities and innovative use of ICTs embodied in the broadband Internet…These strategies are also based on a new understanding of innovation, grounded in the concept of open innovation ecosystems, global innovation chains, and on citizen empowerment for shaping innovation. These new ways of innovation are characterised by the emergence of new forms of collaboration among local governments, research institutes, universities, citizens and businesses.”[83] In operating in this way, these programs have evolved new embedded approaches to setting priorities at the community or city level.

Smart specialisation is a form of mission-oriented policy and was integrated into the EU’s cohesion policy for 2014–2020. Within the EU, smart specialization, which focuses on ‘place-based innovation’ is seen as “..*a better alternative to a policy that spreads research and development (R&D) investments thinly across several frontier technology and research fields, and as a consequence fails to make much of an impact in any one area*.[84]” The smart specialisation approach aims to encourage investment in initiatives that build capabilities and competitive advantage (ie not, or not only, new technologies) in areas that complement a country’s assets- ie differentiated specialisation. Approach is targeted (and hence non-neutral), aiming specific technological, social, environmental, or industrial objectives, and the actors connected with them. While initially focusing on a specific set of actors, essentially for ‘proof of concept’, the scope for high spillovers is an important criteria for project selection and management. The European Commission set up a smart specialization strategy (S3) platform to provide advice to regional authorities on how to design and implement their S3[85].

A ‘Guide’ to developing and implementing S3 sets out six steps:

§Analysing of the regional context and potential for innovation – eg technological infrastructure, entrepreneurial environment, collaboration activity and potential, intra and inter-regional and global linkages.

[80] IBM, 2009.

[81] OECD, 2018b.

[82] See for example European Parliament, 2017.

[83] EC, 2012.

[84] Foray, 2018, p.818.

[85] https://s3platform.jrc.ec.europa.eu/.

- Developing relevant governance arrangements for collaborative leadership, and including industry, government, education and research, etc.
- developing a shared long-term vision for the regional economy, society and environment and communicating this widely.
- developing priorities for initiatives in a limited number of niche innovative research areas and technologies (which is likely to include social and organisational innovation) through a process of 'entrepreneurial discovery'.
- developing a road map and action plan for implementation, encouraging some experimentation through pilot projects, and evaluating outcomes before larger investments.
- Embedding mechanisms for formative, developmental and summative monitoring and evaluation to support ongoing adaptation and refinement of the Strategy[86].

Smart specialization aims to facilitate a process of change in a region that leads to transformative activities and consequently to structural change. To be effective such a strategy needs to engage the private sector in the identification of opportunities and in co-investment in realizing those opportunities. Foray (2018), one of the architects of the policy, emphasizes that S3's, because as mission-oriented policies they are focused on overall performance objectives, are inherently systemic and approaches address whatever aspect of an innovation system that requires strengthening. S3s are also not focused on high-tech or on R&D:

"..differentiation of innovation capacities, needs, and opportunities at a regional level necessarily implies that the reality of innovation is not reduced to high-tech and cutting-edge research. Innovation is widely distributed over the whole spectrum of sectors (not just high tech) and invention processes (not only formal R&D). For many regions, the point is not inventing at the frontier but rather generating innovation complementarities in existing sectors. These types of complementarities ..represent the key to economy-wide growth in regional economies. This means that a transformative activity, depending on what the objective of transformation is, can involve actions like training programs, the formation of new managerial and engineering skills, quality control and certification processes, as well as technology adoption.."[87]

Smart specialization policies are challenging to implement and require a high level of granularity- ie analysis and action with a high level of specificity in terms of location, sector and actors. Hence, the capacity to implement a mission-oriented policy involves both central strategic decision-making, governance, and evaluation capabilities and decentralized and entrepreneurial information and initiatives. Mission-oriented policies ".. *have an experimental nature. The objectives targeted represent, by definition, experiments; some will work and some will not….. The development of the transformative activity should thus be informed by a discovery process regarding opportunities, constraints, and challenges. As such, the process of entrepreneurial discovery is characterized by a strong learning dimension*."[88]
This aspect of mission-oriented policies emphasized the importance of effective monitoring and evaluation activities and capabilities. More generally the experience of implementing S3 in the EU has shown the importance of developing new structures, a new culture, and new in government agencies:

> "*The establishment of priorities (according to the analysis of the desired structural changes, the comparison between existing capacities and opportunities, and the identification of the correct level of granularity), the development of transformative activities corresponding to these*

86 Foray et al, 2012, 18-25).

87 Foray, 2018, p.821.

88 Foray, 2018, p.827.

priorities (which involves the deployment of various instruments to respond to the different obstacles and difficulties, observing the right sequences, and integrating innovation and diffusion), and finally recognition of the experimental dimension of this policy (entrepreneurial discovery, flexibility and monitoring, and spillovers) all represent challenges that must encourage public agencies to invent new structures and change their political practices and culture."[89]

89 Foray, 2018, p.830

6.2.3 Germany[90]

Germany's research system is decentralised with autonomous universities and public sector research organisations.

STI Priorities- Scope and Content

The STI priorities address the STI aspects of social, scientific and technological issues.

Approach to Overall STI Governance

Future technology analysis, along with the assessment of socio-economic and environmental challenges shapes the initial framework along with high-level political objectives.

Level and Extent of High-Level Leadership of STI as a Priority
The Commission of Experts on Research and Innovation of the German parliament (appointed by the Chancellor of Germany) provides advisory support on research policy issues and conducts expert evaluation of STI projects and of Germany's overall S&T development level.

Participation In Priority-Setting

The Ministry of Education and Research (BMBF) is responsible for research policy, the Federal Ministry for Economic Affairs and Energy supervises development of innovation and technology policy, while other ministries provide support to R&D in the areas of their responsibility.

In addition to these broad priorities, Germany also develops programs at the level of sectors and fields of STI, for example: ICT 2020; Framework biotechnology; 6th Energy Research Programme of the Federal Government. States also develop strategies focused on the industries in their region and priorities are also set by research funding and management organisations, including the Max-Planck Society, Fraunhofer Society, Helmholtz Society, and Leibnitz-Society which overall involve more than 100 research institutions in Germany. These STI centres and associations coordinate their STI priorities with federal and regional ministries.

Processes of Priority Setting
Priority setting combines top-down and bottom-up approaches and priorities are set at different levels: national, regional and by individual research organisations. Research priority setting is by the Ministry of Education and Research (MER)and innovation and technology policy priorities by the Ministry of Economic Affairs & Energy.

The Federal Ministry of Education and Research (BMBF) Foresight Program is a key tool for assessing future R&D priorities. Based on a 15-year horizon, these studies contribute to setting the agenda and priorities for the national research and innovation policy. Although commissioned by the Federal Ministry of Education and Research, they are usually carried out by a consortium comprised of research organisations – although a wide range of experts are used and stakeholders consulted. Technology assessment is also carried out with the parliamentary "Technology Assessment Bureau", affiliated with the Karlsruhe Institute of Technology (KIT). The foresight studies identify major "prospective trends" and assesses their likely significance and impacts. These assessments of anticipated trends and challenges are widely disseminated among all stakeholders - politicians, members of executive agencies, industry, academia, and general public[91].

90 This note draws on Grebenyuk et al 2016.

91 Grebenyuk et al., 2016. p.27.

The Foresight studies are other assessments are used to prepare draft strategy documents.

Ongoing foresight studies on a four-year cycle review progress and identify emerging trends- these largely set the context for priority setting. Analyses associated with Foresight review global trends in research and technology and also review emerging national social and economic developments. These analyses engage national and international experts.

Approach to Consultation
The findings of foresight studies and recommendations based on these findings are shared with a diverse range of stakeholders.

Initial advice is provided by: the advisory board of experts from business and research that advises MER; and the national parliament has an independent commission of experts on research and innovation' to the national parliament; the German Council of Science and Humanities (which includes experts from industry, research and other sections of society).

Foresight studies, commissioned by the MER and carried-out by research organisations, have a central role in shaping the innovation and research priorities. These studies involve extensive consultation.

Horizontal and Thematic Priorities

The approach includes individual programs for high priority areas, eg ICT; Biotech; Energy.

Integrating Innovation Goals

Most goals are established with explicit innovation objectives and hence planning is intended to be systemic.

Implementation of Priorities

The main policy priorities are set out in the German High-Tech Strategy. High-level priorities for research, technology and innovation, based on the high-level socio-economic priorities, provide a broad coordination of public and private priorities:

"Thematic R&D programmes serve as the main STI policy implementation tool. The Federal Ministry of Education and Research supervises most of these programmes, while the Ministry for Economic Affairs and Energy is responsible for R&D programmes on energy, transport, and space. Ecology, environmental protection, and nuclear safety research are the domain of the federal ministry, which bears the same name. Similarly, issues related to R&D on food quality, agriculture, and consumer protection are supervised by the Federal Ministry of Food, Agriculture and Consumer Protection."[92]

Coordination of Implementation

Thematic R&D programs managed by the national Ministries are the key mechanism to implement the high-level national strategies and priorities with mechanisms to facilitate coordination among Ministries. Tenders are often used to manage the distribution of research and innovation funding. As well as contributing to the development of national

92 Grebenyuk et al., 2016. p.28

and regional priorities, research organisations and other associations develop their own priorities, taking into account the higher-level priorities. Public-private partnerships have a major role in the research and innovation system and hence enable public-private coordination.

M&E and Policy Learning and Adaptation of Policies

The Foresight studies commissioned by the MER and the Technology Assessment Bureau of the national parliament carry-out ongoing assessments of performance. The performance of each of the research and innovation programs is monitored and evaluated

German High-Tech Strategy[93]
-coordinated with the EU 2020 strategy
Focus challenges for economy and society:

- climate, energy;
- health care, food;
- mobility;
- security;
- communications.

Priority research fields:

- Digital economy and society
- Sustainable economy and energy
- Innovative world of work
- Civil security
- Healthy living
- Intelligent mobility

2020 Action Plan, Priority "Future Projects":

- CO_2-neutral, energy-efficient and climate-adapted cities
- Intelligent energy generation systems
- Renewable energy resources as an alternative to oil
- Combating illness with personalised medicine
- Improving health through targeted preventive measures
- and nutrition
- Independent living for senior citizens

93 Grebenyuk et al., 2016

- Sustainable mobility
- Secure identities
- Internet-based services for the economy
- Industrie 4.0 (4th-generation industry)

6.2.4 United Kingdom[94]

Scope and content of STI Priorities

In 2011 the Department of Business, Innovation and Skills published an overall STI strategy the UK Innovation and Research Strategy for Growth 2011. In 2012 the Department identified 11 high priority sectors for which, along with industry, it developed specific strategies, eg Strategy for Life Sciences, and Agricultural Technology Strategy. These strategies identified key technologies and outlined strategies to achieve development objectives.

Approach to Overall STI Governance

The focus of the foresight studies is thematic planning, but other government initiatives address framework conditions.

Level and Extent of High-Level Leadership of STI as a Priority

The Council for Science and Technology is the high-level coordinating body, chaired by the Prime Minister (PM).

Participation In Priority-Setting

The Department of Business, Innovation and Skills has been the key agency developing STI priorities in the UK. Many advisory bodies and boards, at many levels, contribute to developing and implementing STI priorities. These include the Parliamentary Office of Science and Technology and the Parliamentary and Scientific Committee, Technology Strategy Board (now Innovate UK), Higher Education Funding Council for England (HEFCE), and the Council for Science and Technology. The Council for Science and Technology consults the prime minister and government ministers on strategic aspects of STI policy, and provides information and analysis support for making decisions aimed at maintaining a high level of British research and development activities.

Processes of Priority Setting

Foresight studies are one of the key inputs to the analysis of trends and opportunities, including by the Horizon Scanning Centre.

Reviews are ongoing by many organisations from the Council for S&T to independent organisations. Foresight studies often focus on specific issues, which might be a problem area identified by a government department or an emerging area of economic or social potential, as well as broad spectrum studies. Participation in such studies engages a wide range of stakeholders. Reviews typically consider assess existing competitive advantages and the outcomes of earlier STI strategies and investments. The national foresight and assessment studies also draw on European STI assessment programs including: the European Technology

94 This note draws on Grebenyuk et al 2016; for more information on the approach to foresight and horizon scanning see the Government Office for Science at https://www.gov.uk/government/organisations/government-office-for-science.

Watch program; ERAWATCH program; and Research and Innovation Observatory of the Horizon 2020 Policy Support Facility.

The Horizon Scanning Centre implements short-term projects on specific issues with 10-15-year horizons. The obtained results are applied by various government ministries and other agencies in policy shaping. [See http://www.bis.gov.uk; www.foresight.gov.uk]

Approach to Consultation

There is extensive consultation and debate among all participants in the NIS. Consultation draws on a wide range of analyses, which have usually been informed by extensive consultation, the advisory bodies of government agencies develop proposals for priorities.

Horizontal and Thematic Priorities

Priority topics are either Problem-oriented, which can be broad and are often m=nominated by ministries; or areas of S&T considered to have high potential for innovation. Identified topics are then the starting point for intensive assessment and consultation by the R&D community, government agencies, research councils and other stakeholders.

Integrating Innovation Goals

The approach to thematic planning considers innovation issues from the start, aided by the extent of consultation with all stakeholders. This leads to a more systemic approach to strategies.

Implementation of Priorities

Announcement of priorities and strategies in White Papers, policy appears and national strategy documents. Implementation develops through several mechanisms:

- New funding for new programs-and Centres[95] eg in IT or biotech
- Priority setting at the level of research funding councils, taking into account the national priorities, and developing more detailed priorities.

Based on the higher-level strategic documents research councils develop R&D programs that set more detailed priorities, which are then implemented via R&D projects.

Catapult Centres established in each priority area provide access to equipment and technologies for both companies and public sector research groups.

Coordination of Implementation

The Council for Science and Technology is the high-level coordinating body, chaired by the PM

M&E and Policy Learning and Adaptation of Policies

As noted, the Foresight studies and ongoing monitoring and evaluation mean that policies and strategies are often modified and new issues are regularly incorporated into initiatives. There are continuous studies, reviews and consultations.

The UK Industrial Strategy and Implementation Plan [Department for Business, Innovation and Skills, 2014] identified eight "great technologies" where the UK has potential to become a world leader:

95 The Industry Strategy of 2014 created Centres in Cell Therapy, Digital, Energy Systems, Future Cities, High Value Manufacturing, Offshore Renewable Energy, Satellite Applications, Transport Systems.

- Big data and energy-efficient computing;
- Satellites and commercial applications of space;
- Robotics and autonomous systems;
- Synthetic biology;
- Regenerative medicine;
- Agri-science;
- Advanced materials and nanotechnology;
- Energy and its storage.

The Plan identified several priority technology areas in the medium term [Innovate UK, 2014]:

- graphene;
- energy-efficient computing;
- new visualisation technologies;
- quantum technologies;
- synthetic biology;
- technologies which do not require animal testing;
- energy storage.

6.2.5 Finland

Scope of STI Priorities

STI priorities address both socio-economic and STI issues.

Approach to Governance

Finland has a number of high level consultative and decision-making bodies with particularly high levels of inclusion.

Level and Extent of High-Level Leadership of STI as a Priority

S&T priority setting happens on many levels and in many organisations.

Organisations Involved In Priority-Setting

A wide range of actors in the innovation system contribute to shaping priorities: the national Parliament and Government, the Research and Innovation Council, the Ministry of Education, Science and Culture, other Ministries, Academy of Finland, R&D funding and performing agencies, including Tekes and Sitra.

The four research councils of the Academy of Finland - Biosciences and Environment, Culture and Society, Natural Sciences and Engineering, and Health – each appointed by the government, contribute to priority setting.

Processes of Priority Setting

The National Foresight Network, of the Sitra Foundation, coordinates the foresight network jointly with the PM’s Office, supported by the Government Foresight Group. The studies of challenges facing Finland and opportunities inform all stakeholders, at all levels.

The Technology Barometer measures Finland's techno-scientific competence and its performance capacity based on the level of its economic and societal development[96].

Approach to Consultation

The foresight network is an open network and includes representatives of government ministries and other agencies, regional organisations, universities, private companies, and research centres.

Horizontal and Thematic Priorities

Priority setting includes both thematic and horizontal priorities, although the major STI strategies focus on thematic goals.

Integrating Innovation Goals

Business Finland, previously the Finnish Funding Agency for Technology and Innovation funds innovation in Finland, and is directed by the Finnish Ministry of Employment & the Economy.

Implementation of Priorities

The Academy of Finland allocates funding on a competitive basis to the best researchers and research teams and international peer review is used to assess research applications. The main mechanisms of priority implementation are decision-making processes based on impact assessments and evaluations.

Coordination of Implementation

As the priorities are developed through the inclusive foresight networks they have high legitimacy and influence.

M&E and Policy Learning and Adaptation of Policies

"*There are continuous monitoring activities and evaluation mechanisms that are regularly implemented. Various evaluations have had a strong emphasis on policy learning and policy implementation…. Many policy documents recommend broad STI policy, decentralised governance structures, policy planning, experimentation and agility*."[97]

96 https://www.tek.fi/en/technology-future/technology-barometer.

97Grebenyuk et al., 2016. p.40.

6.3 Asia-Pacific Economies

6.3.1 Australia

STI Priorities- Scope and Content

The official Australian government document on science and research priorities points out that Australia depends on science and research to increase productivity, achieve sustainable economic growth, create jobs, and improve national well-being. The role of science, research and innovation for increasing productivity has been a central theme of several government policy statements[98] and holds bipartisan support.

Addressing practical national challenges and problems is also an important objective of establishing national science and research priorities. The Australian government science and research priorities statement states "*Like other countries Australia's capacity to support research is finite. With diverse investments in research across multiple agencies and many processes, we must ensure that we build our capacity to pursue research of particular importance to us as a nation.*"

Each of the nine research priorities has a number of associated critical practical research challenges that will drive actions in these priority areas.

Approach to Overall STI Governance

Historically, Australian government research (STI) priorities have focused on framework conditions and have mainly horizontal, aiming to affect the whole innovation system. The priorities listed below from the 2009 Powering Ideas innovation agenda show that they are innovation system-wide, not focussing on particular sectors. The priorities not only focus on the business sector but also aim to improve the quality of policy delivery in the public sector.

Priority 1: Public research funding supports high-quality research that addresses national challenges and opens up new opportunities.

Priority 2: Australia has a strong base of skilled researchers to support the national research effort in both the public and private sectors.

Priority 3: The innovation system fosters industries of the future, securing value from the commercialisation of Australian research and development.

Priority 4: More effective dissemination of new technologies, processes, and ideas increases innovation across the economy, with a particular focus on small and medium-sized enterprises.

Priority 5: The innovation system encourages a culture of collaboration within the research sector and between researchers and industry.

Priority 6: Australian researchers and businesses are involved in more international collaborations on research and development.

Priority 7: The public and community sectors work with others in the innovation system to improve policy development and service delivery

More recently, a broad sectoral approach has dominated industry policy priorities. The government rationale has been that the research priorities should "build on or align with" Australia's

98 See the Abbot's government 2014 Industry, Innovation and competitiveness agenda and Rudd's 2009 government Powering Ideas: An innovation agenda for the 21 Century.

comparative advantages.[99] This rationale was present on 2015 statement on research priorities, which list nine priority areas:

- Food
- Soil and Water
- Transport
- Cybersecurity
- Energy Resources
- Advanced Manufacturing
- Environmental Change
- Health

Section 4 discusses the process of priority setting.

Level and Extent of High-Level Leadership of STI as a Priority

The National Science and Technology Council is the peak advisory body to the Prime Minister and other Ministers on science and technology. This council was created in November 2018; it took the place of the former Commonwealth Science Council.[100] The council focuses on the key science and technology challenges facing Australia, ensuring the government receives the best independent advice possible. The Council role is to identify research challenge projects and oversee horizon-scanning reports into long-term science and technology priorities, providing expert advice on issues such as health, emerging technologies and education.

The council is chaired by the Prime Minister, with the Minister for Industry, Science and Technology as Deputy Chair. Australia's Chief Scientist is the Executive Officer. The Chief Executive of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) serves as an ex officio member. The council also includes appointed scientific expert members.

The council commissioned, former Australian chief scientist, Prof Ian Chubb to look at science and research priorities and corresponding practical research challenges. The present science and research priorities came out from this process.

Participation in Priority Setting

The National Science and Technology Council

The NSTC role is to commission work on science, technology, research and innovation priorities and approved (or not) the respective recommendations derived from the findings. For example, in 2015 the Commonwealth Science Council (The National Science and Technology Council was formed in 2018) considered the recommendations on science and research priorities put forward by the independent work led by Prof Chubb. The council recommended that all recommendations be adopted by the government immediately.

The Chief Scientist

Australia's Chief Scientist provides high-level independent advice to the Prime Minister and other Ministers on matters relating to science, technology and innovation. The Chief Scientist also holds the position of Executive Officer of the National Science and Technology Council to identify challenges and opportunities for Australia that can be addressed, in part, through science. The Chief

99 See Industry, Innovation and Competitiveness Agenda (p.47).

100 Before the Commonwealth Science Council, the Prime Minister's Science Engineering and Innovation Council had these functions.

Scientist can be appointed to ex-officio roles at the discretion of the government. The Chief Scientist reports to the Minister for Industry, Science and Technology, and also works closely with the Prime Minister both in his role as Executive Officer of the National Science and Technology Council and in order to provide detailed scientific advice.

An important role of the chief scientist, on behalf of the National Science and Technology Council, is the commission of horizon scanning reports, which present independent and timely analyses to guide decision-makers through the decade ahead. Horizon scanning reports are produced by the Australian Council of Learned Academies (ACOLA). Examples of these reports are:

- The Role of Energy Storage in Australia's Future Energy Supply Mix
- The Future of Precision Medicine in Australia
- Synthetic Biology in Australia: An outlook to 2030
- Deployment of Artificial Intelligence and what it presents for Australia
- The Internet of Things: Maximising the benefit of deployment in Australia
- Future of agricultural technologies

Innovation Science Australia

Innovation Science Australia (ISA) is an independent statutory board of entrepreneurs, investors, researchers and educators that advises the Australian government on innovation, research and science matters. ISA also has the role of monitoring and overseeing a number of innovation programs and coordinating the government's investment in innovation, science and research. ISA reviews the performance of the science and innovation system and stimulates public discussion and debate about innovation and science.

In terms of STI priorities, the minister for science, technology and innovation can, when appropriate, asks the ISA board to provide expert advice to inform the implementation of the government priorities.

Department of Industry

The department of industry that also includes the portfolios of science, technology and innovation is the key agency responsible for the implementation of STI priorities. The Industry Growth Centres Initiative is how science research and innovation are implemented on the industry front. The government is funding six Growth Centres in sectors of competitive strength and strategic priority. These six growth centres align with six out of the nine priority areas listed in section 1.

- The Advanced Manufacturing
- Cyber Security
- The Food and Agribusiness
- The Medical Technologies and Pharmaceuticals
- The Mining Equipment, Technology and Services
- Oil, Gas and Energy Resource

The Growth Centres are not-for-profit organisations, each led by a board of industry experts. The government has tasked the Growth Centres with leading cultural change in their sectors. They focus on:

- increasing collaboration and commercialisation
- improving international opportunities and market access
- enhancing management and workforce skills
- identifying opportunities for regulatory reform

Each centre has its own Sector Competitiveness Plan describing:

- the 10-year strategy for the sector
- identified regulatory reform opportunities
- Industry Knowledge Priorities such as skills and research requirements

The department administers the Initiative, oversee surrounding policy, and support the growth centres advisory committee.

Other Departments

Several other portfolio departments collaborate with the department of industry through the activities of the growth sectors. The Prime Minister & Cabinet (PMC) department, on the other hand, has a more strategic role. For example, the 2015 Australia Government Industry Innovation and Competitiveness Agenda was led by PMC. The document highlights the importance of science and research priorities and a sectoral approach with the guiding principle of 'existing (sectoral) strengths.' The document points out that the government does not see a role for subsidies and direct intervention in industries to 'pick winners'.

Australian Research Council

The Australian Research Council (ARC) supports fundamental and applied research and research training through national competition across all disciplines. Clinical and other medical research is primarily supported by the National Health and Medical Research Council. Besides, the ARC encourages partnerships between researchers and industry, government, community organisations and the international community.

The ARC's Industrial Transformation Research Program (ITRP) offers a suite of funding schemes in priority areas. These priorities are consistent with the six high-growth sectors established under the Industry Growth Centres initiative (see above under Department of Industry). The program funds research hubs and research training centres in the six high-growth sectors. The program also supports high degrees by research students and postdoctoral researchers in gaining real-world practical skills and experience through placement in the above-mentioned sectors.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO)

CSIRO, the national science agency, has used the concept of national flagships for almost 20 years. The Flagships address complex challenges by forming large-scale multidisciplinary research partnerships with Australian universities and publicly-funded research institutions, the private sector and selected international organisations. Recently, the use of missions to address national challenges has been commonly used.[101]

CSIRO has listed six challenges, which could bolster Australia's COVID-19 recovery and build long term resilience via partnership. CSIRO has called for collaboration with the government, universities, industry and the community to tackle these challenges:

1. Food Security and Quality: Achieve sustainable regional food security and grow Australia's share of premium AgriFood markets.

2. Health and Wellbeing: Help enhance health for all through preventative, personalised, biomedical and digital health services.

101 https://www.csiro.au/en/Showcase/Challenges-missions.

3. Resilient and Valuable Environments: Enhancing the resilience, sustainable use and value of our environments, including by mitigating and adapting the impacts of climate and global change.
4. Sustainable Energy and Resources: Build regional energy and resource security and our competitiveness while lowering emissions.
5. Future Industries: Help create Australia's future industries and jobs by collaborating to boost innovation performance and STEM skills.
6. A Secure Australia and Region: Help safeguard Australia from risks (war, terrorism, regional instability, pandemics, biosecurity, disasters and cyberattacks.

Processes of Priority Setting

In Australia, at the highest level is the National Science and Technology Council, which commissions work on STI priorities. The NSTC's decisions about priorities may be informed by work undertaken by the Chief Scientist as he has the role of advising the government on science and technology horizon scanning. The ISA board also can inform the priority process but usually through the implementation of specific programs. CSIRO runs a parallel process on priorities that are highly aligned with most (but not all) the national priorities. As CSIRO's CEO is also part of the NSTC, CSIRO is likely to be involved in the process of priority setting.

It is not unusual that governments, particularly new elected governments, start with a review of the STI system. The government set up the terms of reference for the review. The review is usually commissioned to be undertaken independently or sometimes by a task force in the principal STI agency (e.g. Department of Industry). The review, which includes an extensive consultation process with business, academia, peak bodies, etc. produces a significant report on the state innovation system with several policy recommendations. The government responds to the review with a national strategy. This national strategy may support some or all the recommendations, priorities or targets recommended in the review. This was the process followed after the 2007 election. The Strategy Powering Ideas, Innovation for 21 Century included a number of priorities and targets (see section 2).

The process of ideas for priority setting is relatively open. For example, academic work on the area of management capabilities became the centrepiece for the development of a significant federal government program for improving management capabilities in the business sector.

Approach to Consultation- Who, to What Extent

Consultation is an important part of STI priority setting in Australia. It occurs both as a mechanism of gathering key opinions and ideas from stakeholders but also to legitimise the process. A typical review of the STI system (which may include priorities and targets) organises several roundtables with key stakeholders in addition to an open consultation in which stakeholders and the community are invited to write public submissions.

Within the government, as indicated in section 4, the chief scientist, the NSTC the ISA board are important sources the advice. The chief scientist, in particular, uses several mechanisms to keep the government up to date with STI changing environment in Australia and globally. In addition to the horizontal scanning activities discussed above, the chief scientist and its team use the Rapid Research Information Forum (RRIF) is a forum for rapid information sharing and collaboration within the Australian research and innovation sector. The RRIF enables timely responses to be provided to governments based on the best available evidence. RRIF also informs the Chief Scientist's interactions and collaboration with other national chief scientific advisers. It has particularly active during the COVID 19 crisis. Examples of several key pieces of advice to ministers produced through the RRIF are listed below. All this information is public in the chief scientist's website.[102]

- Viability of SARS-CoV-2 on surfaces
- Most promising COVID-19 therapeutics
- The impact of COVID-19 on women in the STEM workforce
- The most promising vaccines for COVID-19
- Impact of the pandemic on Australia's research workforce
- Learning outcomes for online vs in-class education
- The predictive value of serological testing during the COVID-19 pandemic
- Monitoring wastewater to detect COVID-19
- Likelihood of COVID-19 reinfection
- Seasonality of COVID-19: Impact on the spread and severity

ISA is the key mechanism for consultation with the business sector, particularly in relation to existing programs and priorities.

Horizontal and Thematic Priorities

In Australia, like in most developed economies, the focus of STI policy has been on horizontal policies addressing identified problems across the innovation system. These priorities represent the bulk of the STI priorities considered by the government. They may vary considerably from areas such as increasing STEM education in girls to university-business collaboration and increasing business R&D. Many of the Federal and also State level STI programs aim to address these horizontal priorities. In some cases, new horizontal priorities have been incorporated to the government policies when strong evidence have produced about the existence of gaps in the innovation system. This was the case of the development of the Enterprise Connect program to address issues of management capabilities in firms.

Data from the Science Research and Innovation budget tables (Table 1) shows the funding allocation from R&D major projects (more than $100 million) by type of research programme characterised as horizontal, general-purpose or sectoral.[103] About 61 per cent of the R&D funding went to what we could call horizontal priorities, and this includes Australia's largest R&D program, the R&D Tax incentive. Table 2 shows when the R&D budget allocation is disaggregated by socio-economic objective about 30 per cent goes to general advancement of knowledge.

The SRI budget tables also show that the key program supporting the science and research priorities in the business sector, the Industry Growth Centres and the associated commercialisation fund, received $20 million in 2018-19 financial year.

102 https://www.chiefscientist.gov.au/RRIF.

103 This classification has been done by the author.

Table App.3: Australian Government R&D programs and activities valued at over $100 million in 2018-19 and 2019-20

Program/activity	2018-19	2019-20	Type of research program
R&D Tax Incentives - Refundable	1,691	1,706	Horizontal
Research Training Program	1,022	1,021	Horizontal
Research Support Program	890	889	Horizontal
NHMRC Research Grants	842	856	Sectoral/General purpose
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	830	827	Sectoral/Missions/General Purpose
(ARC) - National Competitive Grants Program	760	780	Horizontal
Defence Science & Technology Group (DST Group)	466	461	Sectoral
Medical Research Future Fund	221	387	Sectoral/General purpose
R&D Tax Incentives – Non-Refundable	358	276	Horizontal
Australian Nuclear Science & Technology Organisation (ANSTO)	241	254	Sectoral
Australian Renewable Energy Agency (ARENA)	238	227	Sectoral
National Institutes Program - ANU Component	201	202	Horizontal
Geoscience Australia	183	189	Sectoral
Cooperative Research Centres Programme	167	182	Horizontal
National Collaborative Research Infrastructure Strategy	160	179	Horizontal
Australian Antarctic Division	113	116	Sectoral
Australian Centre for International Agricultural Research (ACIAR)	107	100	Sectoral
Total	8,490	8,652	

Science Research and Innovation Budget Tables

Table App. 4: Total Australian Government investment in R&D by socio-economic objective (2019-20)

Socio-Economic Objective (SEO)	**Per cent**
01. Exploration and exploitation of the Earth	4.9%
02. Environment	3.1%
03. Exploration and exploitation of space	0.6%
04. Transport, telecommunications and other infrastructures	2.8%
05. Energy	5.4%
06. Industrial production and technology	16.4%
07. Health	17.2%
08. Agriculture	8.1%
09. Education	0.4%
10. Culture, recreation, religion and mass media	0.4%
11. Political and social systems, structures and processes	5.7%
12. General advancement of knowledge: R&D financed from General University Funds	22.2%
13. General advancement of knowledge: R&D financed from other sources than GUF	7.4%
14. Defence	5.4%

Total										100.0%

Science and Research Priorities by portfolio	Food	Soil and water	Trans't	Cyber Sec'y	Energy	Res's	Adv. Manuf	Env't	Health	Total
Agriculture and Water Res.	19	20	0	0	0	1	0	14	2	56
Industry, Innov & Science	5	4	4	2	5	5	4	4	4	37
Defence	0	2	1	1	0	1	0	1	4	10
Education and Training	1	1	1	2	1	1	1	1	1	10
Health	1	0	0	0	0	0	0	1	8	10
Infrastructure, Regional Dev.	0	0	4	0	0	0	0	0	0	4
Environment and Energy	0	0	0	0	0	0	0	1	0	1
Prime Minister and Cabinet	0	0	0	0	0	0	0	0	1	1
Total	26	27	10	5	6	8	5	22	20	129

Science Research and Innovation Budget Tables

Integrating Innovation Goals

The present Department of Industry, Science, Energy and Resources is responsible for the innovation portfolio. The research portfolio is under the Department of Education, Skills and Employment. There has been an increasing effort to integrate science, technology and innovation. Although the machinery of government process usually merges or separates the science, technology, innovation and research portfolios, innovation system ideas are well understood in the departments dealing with these areas. For example, the department of education looks for increasing collaboration between universities and business from the perspective of the university sector. At the same time, the industry department does it from the business sector perspective. For both departments increasing collaboration between these two sectors is very important and have programs supporting this type of collaboration.

The increasing focus on improving the commercialisation of public research has been driven by a number of new programs in the Department of Industry but also in the CSIRO. At the same time, venture capital funding and programs supporting entrepreneurship have become a more significant share of the total funding for STI.

Table App. 5: Number of programs addressing science and research priorities by portfolio

Source: Science Research and Innovation Budget Tables

Implementation of Priorities

The implementation of the STI priorities takes place through the allocation of resources and funding in concrete programs. Some long-standing programs have run for several years that address deficiencies in the innovation system or different market or information failures. Examples of these programs are the R&D Tax incentive, the Cooperative Research Centres, the funding for the National Health Medical Research (NHMRC), the National Institutes Program and Research Training Program. These types of programs take the lion's share of the A$ 9 billion of public funding for research.

Table App.5 lists the 129 programs that, in some way, address the national research priorities. According to the budget tables, there are 584 R&D and non-R&D federal government programs supporting the innovation system.

As it was mentioned above, some of the programs addressing priority areas address at the same time horizontal priorities such lack of collaboration or development of management capabilities.

Coordination of Implementation

The department of industry is the key coordinating agency on STI policies and priorities across the federal government. This includes both other departments but also other science performing agencies such as Australian Bureau of Agricultural and Resource Economics and Sciences, CSIRO, Australian Research Council, Bureau of Meteorology, Defence Science and Technology Organisation, National Health and Medical Research Council.

The department of industry also provides secretariat support for the National Science and Technology Council (explained above) and National Climate Science Advisory Committee. The Innovation Science Australia Board and the Chief Scientist work very closely with the department of industry and are physically co-located in the same building.

Implementation of priorities takes place through the 129 programs shown in Table 3. Implementation is a bottom-up process that occurs in individual department and science performing agencies. Funding and resources dedicated to the STI priorities represents a small part of the A$ 9 billion of public funding dedicated to support the innovation system.

Monitoring, Evaluation and Policy Learning and Adaptation of Policies

Monitoring and evaluation of STI programs is well established in the Australian federal government. Periodic independent evaluation is embedded in many STI programs. In the last few years, the evaluation activity has been formalised by the creation of an evaluation unit in the Office of the Chief Economist in the Department of Industry. The evaluation strategy 2015-19 developed by this unit provides a framework to guide our evaluation and performance measurement of programs and policies. This strategy:

- outlines our approach to performance measurement and reporting, according to good evaluation practice
- establishes a protocol for policy and program areas to plan for evaluation across the lifecycle of a program
- provides a strategic, risk-based, whole-of-department approach to prioritising evaluation effort, and shows how evaluations may be scaled based on the value, impact and risk profile of a program
- describes how evaluation findings can be used for better decision-making

The evaluation plan 2018-22 provides a practical guide for the evaluation and monitoring of program and policies. Firstly, it establishes a priority system for evaluations based on five criteria:

- total funding allocated for the program
- internal priority (importance to the department's and Australian Government's goals)
- external priority (importance to external stakeholders)
- overall risk rating of the program
- track record (previous evaluation, strength of performance monitoring, lessons learnt)

Based on these five criteria, three evaluation tiers are developed:

- Tier one: programs of the highest priority and strategic importance

- Tier two: second-order strategic importance with moderate funding, public profile and associated risk.
- Tier Three: lesser strategic importance, low risk, or terminated programs of lesser priority and single payment grants

The evaluation plan 2018-22 includes four type of evaluations:

Post-commencement evaluations are a ‘check in’ on a program soon after its commencement and are primarily for Tier One programs. This type of evaluation focuses on the initial implementation, design and delivery to identify issues early on. Post-commencement evaluations provide recommendations for decision-makers to take corrective action on operational matters early on in the program’s lifecycle. Post-commencement evaluations focus on reporting to internal stakeholders.

Monitoring evaluations draw on performance information to monitor a program’s progress post-implementation. A monitoring evaluation provides an opportunity to test the program’s data sources, to see whether they are providing the required performance information and can consider evidence of short-term outcomes. This gives an indication of performance, contributes to the measurement of the department’s strategic objectives and forms a basis for future reviews.

Impact evaluations are usually large and more complex evaluations or undertaken on pilot programs. These evaluations commonly occur at least three years post-implementation and measure medium-term and long-term outcomes. They may also assess value for money. Where possible they test outcomes against a ‘counterfactual’ (what would have happened in the absence of the program) and may include research about program alternatives to allow comparison of results.

Review evaluations are required for some programs because it is legislated.

Evaluations are usually carried out by independent organisations or committees, involve extensive consultation, and are published after a period.

Although these evaluation procedures are not specific for programs involving STI priorities, most of the programs involving priorities need to follow these guidelines.

6.3.2 China

Overall Perspective

China's rapid economic growth since the mid-1980s has been enabled by the export-oriented industrialisation strategy with elements of strong top-down planning. Foreign investment has been a significant source of production capacity and also of the core industrial technologies. In many industries key components have been imported and the level of value adding in China has been low. More recently the focus of policy has emphasised indigenous innovation – from 'made in China to created in China' - and has increasingly set goals of achieving international leadership in major technology trajectories by 'leapfrogging'. The 15 year Medium and Long Term Plan for the Development of Science and Technology (MLP) set out ambitious objectives in basic science, engineering and frontier technologies. It continues the state-led and mission driven approach to STI that developed, particularly from the 1980s, but evolved from recognising S&T as one of the key productive forces of the economy, to a focus on S&T development and education as a source of vitality, to strengthening the innovation system to support indigenous innovation.

China's STI policy from 1950, evolved through a series of phases, with the phase from 2005 focused on developing a firm-centred innovation system. The State Council had set up a Science Planning Commission as early as 1955, assembling over six hundred scientists to compile the first such planning, *Planning Framework for Long-Range Prospects in S&T Development (1956–1967)*[104.] By 2020 China had drafted and issued eight national science and technology Medium and Long-Term Strategic Plans.

For most of that period, priority setting in China has been essentially top-down with centralized planning and a focus on large scale initiatives with ambitious goals. However, there has been a long running debate about the relative effectiveness of top-down priority setting with allocations of funding focussed on major programs, and more pluralist approaches with more scope for allocation decisions by research councils, universities and regions. The current system retains a high level of top-down planning with increasing decentralisation. The scope of STI policy and the extent of participation have both widened over time. [105]

Over the ten years from 2010, China's investment in R&D grew at about 15% per annum - rates of patenting have also grown rapidly106. Since the mid-1990s business enterprises have been the dominant performers of R&D; by 2018 the business sector accounted for about 80% of R&D spending with the great majority of that by domestically-owned firms. Foreign-owned firms, however, account for about 40% of high-tech exports. There are perhaps 1000 R&D centres in China established by foreign MNEs, largely in ICT.

In January 2006, China initiated a 15-year "Medium- to Long-Term Plan for the Development of Science and Technology." The MLP calls for China to become an "innovation-oriented society" by the year 2020, and a world leader in science and technology (S&T) by 2050. It commits China to developing capabilities for "indigenous innovation" and to leapfrog into leading positions in new science-based industries by the end of the plan period. According to the MLP, China will invest 2.5% of its increasing gross domestic product in R&D by 2020, up from 1.34% in 2005; raise the contributions to economic growth from technological advance to more than 60%; and limit its dependence on imported technology to no more than 30%.

104 Wang, P. and Li, F., 2019. China's organization and governance of innovation–A policy foresight perspective. *Technological Forecasting and Social Change*, *146*, pp.304-319.

105 Benner, at al 2012.

106 Wu, Y., 2012. Trends and Prospects in China's Research and Development Sector. *Australian Economic Review*, *45*(4), pp.467-474.

Chinese policy and the growth of its economy attracted many MNEs to establish operations in China either for the domestic market or for exports. The Chinese Government encouraged FDI into selected industries and then initiated a “technology-for-market” strategy. This enabled foreign companies and JVs to have access to the domestic market in return for transferring technology to domestic firms or setting up R&D centres. MNEs have had a major role in developing Chinese production capacity and exports, and, through required technology transfer, developing the technological capabilities of suppliers and partners. Many developed R&D facilities to support product adaptation for the local market. The development a large pool of scientists and engineers and, to some extent, incentives from the government encouraged many MNEs to expand their R&D to not only support production in China but to form part of their global innovation strategies - there are several hundred MNE R&D centres in China, some with thousands of R&D staff. Since the 1980s Chinese government policy has emphasised knowledge transfer from MNEs in China and provided a range of incentives to facilitate those spillovers. This has been an important component of STI policy and development.

China has both sector-specific policies and technology-specific policies. For example, the Made in China 2025 policy, is focused on the integration of smart technologies in manufacturing and on 10 priority sectors, including aviation, biopharmaceuticals, agricultural technology and robotics. In 2015, the CCP and the State Council announced a policy of “deepening the reform of the system and mechanism and accelerating the implementation of the innovation-driven development strategy” which aimed to boost indigenous innovation.

STI Priorities- Scope and Content

In developing STI policy there has been a gradual recognition that innovation policy must extend far beyond S&T and touch on many areas of economic, industrial, education and other policy areas. This long process of policy development has involved: ‘historical reflection, grass-roots experimentation, top–down trial and error in designing and revising policy’, as well as learning from the experience of other countries[107].

It is important to note that industry policy, focusing on the development of enterprises and high-tech industries, has increasingly complemented innovation policy: ‘industrial policy promotes technological progress in industry, regulates industrial structure, leads the direction of industrial development, and enhances industrial competitiveness through providing subsidies and supports to specific industries. Fiscal policy provides support, subsidies, and guidance to technological innovation activities through fiscal input; tax policy reduces R&D costs and innovation investment risks, and increases expected revenue of R&D by providing various preferential tax treatment to enterprises or levying special taxes’. It is also considered that ‘S&T, industrial, financial, tax, and fiscal policies have been combined together to form a steadily more coherent, integrated package of innovation policies.’[108]

An emphasis on developing the national innovation system was expressed in a series of reforms of STI policy from 2014, with a major national innovation strategy announced in 2016: ’*Chinese thinking on innovation, once focused on science and the products of research and development (R&D), has come to appreciate the larger ecosystem involving market forces, financial and legal arrangements, intellectual property (IP), and the role of entrepreneurship for incentivizing economic actors to incur risks of innovation. The government Innovation Driven Development Strategy identifies stages for*

107 OECD. 2008. OECD Reviews of Innovation Policy: China. OECD, Paris., p. 392

108 Liu, et al 2011p.918 This paper notes that MOST have used tax incentives and trade promotion and restriction as explicit (usually considered as industry policy measures) innovation policy instruments.

such societal transformations, which cannot be realized without a knowledge production system capable of genuine creativity[109].

The National Medium and Long -Term Science and Technology Development Programs (2006-2020) (MLP) set out objectives of raising the overall level of investment in R&D and the level of MFP while reducing dependence on imported technology. The plan sets out the broad principles seen as essential for achieving the ambitions of greater indigenous innovation and leapfrogging to international leadership in areas of technology. The plan also identifies priority areas and eight areas of frontier technologies- within each of these priority projects are identified. A range of large national mega programs in engineering and science are also identified, including protein science, quantum research, nanotechnology, climate change and stem cell development. The final sections of the plan address the overall policy framework for implementation, including tax policies, high-tech industry zones, assimilation of imported technology, reform of the IP regime and policies to strengthen human resources, including by recruiting talent from outside China.

The MLP identified 16 key state projects

1. electronic components,
2. high-end general chips,
3. basic software,
4. technology for manufacturing extremely large integrated circuits,
5. new-generation broadband wireless mobile telecommunications,
6. high-end numerically controlled machine tools and basic manufacturing technology,
7. development of large oil and gas fields,
8. large nuclear power plants with advanced pressurized water reactors or high temperature gas-cooled reactors,
9. control and treatment of water pollution,
10. development of genetically modified biological species,
11. development of important new drugs,
12. control and treatment of AIDS and other major contagious diseases,
13. production of large aircraft,
14. high-resolution Earth observing systems, and
15. launching manned space flights, and
16. lunar exploration projects.

Areas and programs identified in China's MLP (15-year science plan)[110]	
Key areas	**Engineering megaprojects**
Agriculture Energy Environment	Advanced numeric-controlled machinery and basic manufacturing technology Control and treatment of AIDS, hepatitis, and other major diseases

109 Cao & Suttmeier, 2017.MOST, 2016.

110 Cao, C., Suttmeier, R.P. and Simon, D.F., 2006. China's 15-year science and technology plan. *Physics today*,*59*(12), p.38.

Information technology industry and modern services

Manufacturing

National defense

Population and health

Public securities

Transportation

Urbanization and urban development

Water and mineral resources

Frontier technology

Advanced energy

Advanced manufacturing

Aerospace and aeronautics

Biotechnology

Information Laser

New materials

Ocean

Core electronic components, high-end generic chips, and basic software

Drug innovation and development

Extra large-scale integrated circuit manufacturing and technique

Genetically modified new-organism variety breeding

High-definition Earth observation systems

Large advanced nuclear reactors

Large aircraft

Large-scale oil and gas exploration

Manned aerospace and Moon exploration

New-generation broadband wireless mobile telecommunications

Water pollution control and treatment

Science megaprojects

Development and reproductive biology

Nanotechnology

Protein science

Quantum research

The complete MLP consists of the MLP outline, the complementary policy measures and the complementary policy implementation details. The MLP complementary policy covered ten issues: S&T investment, tax incentives, financial support, government procurement, technology transfer from abroad, assimilation and secondary innovation, IPR, S&T human resources, education and science popularisation, S&T innovation platform and coordination. Under coordination of the Office of the MLP Leading Group, MOST, NDRC, Ministry of Finance, Ministry of Personnel and the China Central Bank oversaw 12 research groups involving 200 researchers from 23 ministries, which drafted the complementary MLP policy[111]. The strategies to support the MLP priorities include, for example:

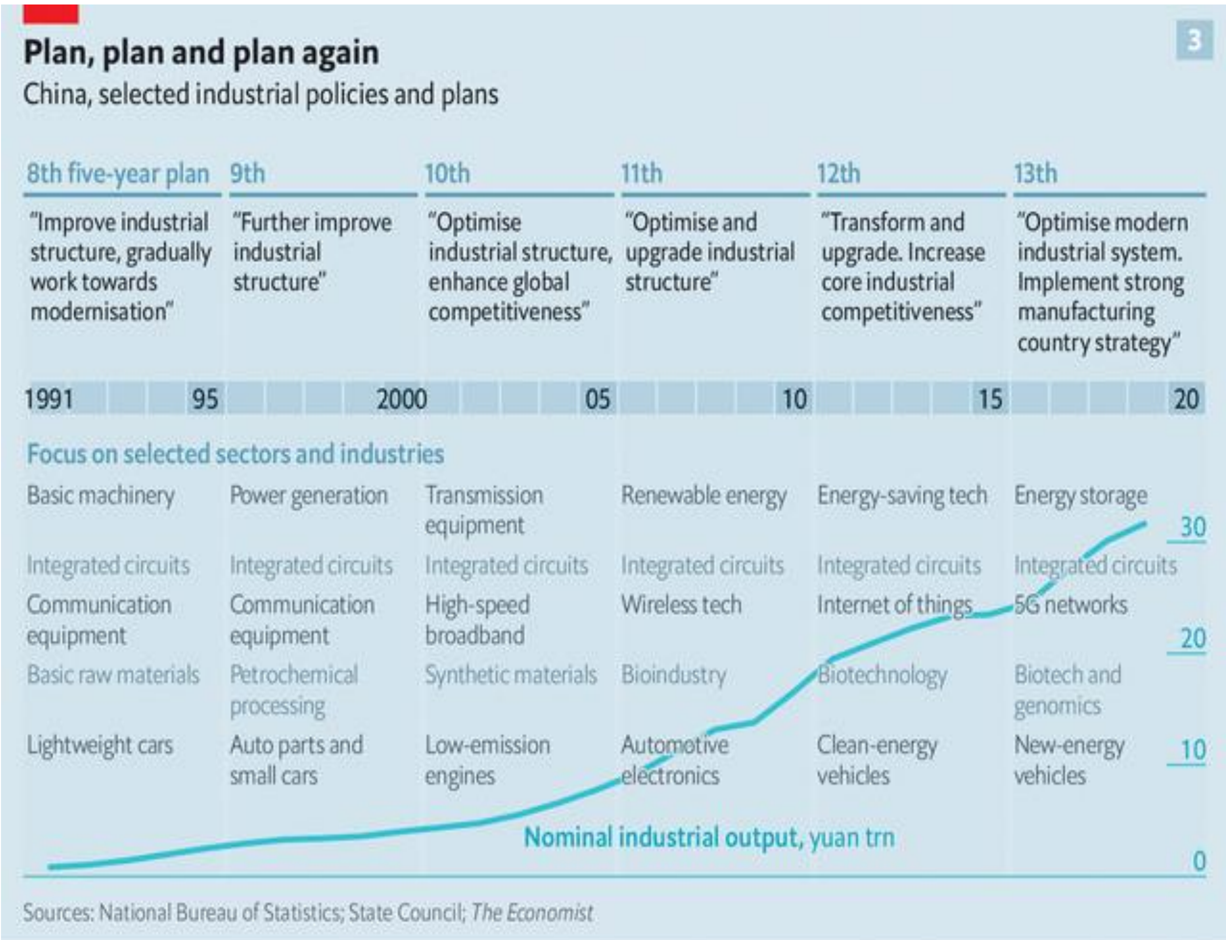
- accelerating the creation of independent “well-known” Chinese brands,
- supporting the technology innovation in SMEs,
- issuing corporate bonds for qualified high-technology enterprises,
- regulating the management of start-up investment funds and the debt-financing ability of start-ups,
- building research-orientated universities,
- promoting state-supported high technology and new technology industry development zones,
- establishing guidelines and funding for venture capital investment,
- creating tax policies supporting the development of start-ups, and
- attracting back talented individuals who have studied abroad.

111 Li, L., 2009. Research priorities and priority-setting in China. VINNOVA analysis.

A third component of the plan deals with ongoing reforms in S&T and the further development of an integrated national system of institutions supportive of research creativity and technological innovation. It highlights important objectives pertaining to the continued reform of several government research institutes, changes in the management of S&T, and the need to encourage Chinese industrial enterprises to assume a leading role in the nation's innovation system. Furthermore, it includes policies to promote industrial research and support for small and medium-sized enterprises. The new emphasis on the central role of industry reflects growing concerns that China's companies are not generating enough intellectual capital to support the introduction of new, commercially viable products and services[112].

The MLP has been elaborated through the 11th, 12th, 13th five-year plans. Figure 1 provides an overview of the priorities in the last six five-year plans. In January 2013 and addendum to the 12th five-year plan further emphasised the goal of strengthening the national innovation system to support indigenous innovation, and also strengthening regional innovation systems.

Figure App.2: China's Industry Policies



Source: The Economist.

When the MLP was released the General Office of the State Council also released "A Summary Sheet on Regulations of Some Supporting Policies for Implementing the MLP" which specified the tasks of agencies in formulating detailed implementation policies[113].

112 Cao, C., Suttmeier, R.P. and Simon, D.F., 2006. China's 15-year science and technology plan. Physics today,59(12), p.38.

113 Sun and Cao, 2018

The overall S&T program includes major mission programs (there were 16 selected Mega-Engineering Projects in the last Medium and Long Term Plan (MLP)) and the Basic Program. The Mega Projects are top-down priorities and are: '*intended to address the perceived weakness of Chinese companies in investing in long-term and high-risk R&D projects. The mega projects are administrated through a top-down system, guided by top government leadership, coordinated by planning agencies and financial ministry, and carried out by industrial ministries in their fields*.' (Li, 2017, p60)

The Basic Program includes a number of broad initiatives (usually launched with new five year plans), including the National Key Technologies R&D Program, the State Basic R&D Program, and the Agriculture S&T Transfer Fund, programs that support the development of research organisations, and more specific programs such as those focused on SMEs.

The majority of funding is for major missions and within that is focused on leading research organisations. The National Science Foundation of China (which was inspired by the US NSF and was formed in 1985) distributes funding more on the basis of excellence, but still with an emphasis on impacts on technology development. Objectives around diffusion (ie raising technology capabilities throughout industry) and on infrastructure building for STI, have been sub-goals within the major programs, rather than the focus of major programs. The 'Torch' Program, which aimed at promoting high-tech industry, and the 'Spark' Program which promoted the use of S&T applications in rural development, were diffusion-oriented measures- but they accounted for less than 2% of the S&T budget in 2008.

A series of national programs (largely funded by MOST) have been initiated since 2006, with the overall aim of driving the development of high value-added and skill intensive industrial development. These include Fundamental Programs- which account for the majority of the funding, and; Major Programs which focus on generic technologies, strategic products and major construction projects, and account for perhaps 25% of MOST funding[114].

The 13th Five-Year Plan for STI (2016-2020) further emphasised the goal of greater indigenous innovation. Key projects included aero engines, quantum computing and communications, AI, intelligent manufacturing (robotics, 3D), smart grids, and 'clean coal' –strategic technologies and key research domains where 'breakthroughs' are expected by 2030. Other policy announcements by the State Council have emphasised the strategic importance of artificial intelligence and outlined a strategy for its development. The plan also emphasised the need for 'talent development' through education and training in China and overseas. The plan does not specify the details for implementation, nor does it address funding levels or sources. The plan also included objectives of increasing the level of international STI collaboration.

The, MLP, the 13th Five-Year Plan and other initiatives have developed a suite of policies for 'frontier technologies, as shown in Table App.6.

Engagement with international S&T is an important element of Chinese S&T policy and was explicitly addressed in the 13dth Five Year Plan. One aspect of this engagement if participation in the governance of international institutions relevant to S&T and innovation, including the establishment of technology standards. The Chinese role in international programs in energy, health, climate change, for example, is increasing and is increasingly significant. Another is participation in multilateral and bilateral research cooperation, where the level of Chinese activity has grown strongly.

Recent reforms have integrated the STI programs into five streams[115]:

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114 Wu, Y., 2019. China's research and development sector: Progress and outlook. In China's Quest for Innovation (pp. 71-89). Routledge.

115 Appelbaum, R.P., Cao, C., Han, X., Parker, R. and Simon, D., 2018. Innovation in China: challenging the global science and technology system. John Wiley & Sons.

- Basic research
- Major national S&T programs
- Key national R&D programs
- Special funds for innovation
- Special funds for human resources and infrastructure.

Table App.6 Frontier technology-related policies and policy objectives, China

Frontier technology	Policy, strategy, plan	Objectives
Smart manufacturing: Made in China 2025	• Action Plan on Implementing the Guiding Opinions of the State Council on Promoting "Internet Plus" (2015-2018)	• Develop a new economic model and facilitate industrial innovations and e-commerce through integrating cyberphysical systems, cloud computing and big data with traditional manufacturing industries
	• Intelligent Manufacturing Development Strategy (2016-2020)	• Upgrade key areas of traditional manufacturing to digital manufacturing • Implement key tasks (setting up intelligent manufacturing standards, establishing industrial Internet and information security systems, and developing industrial software)
	• Development Plan for the Robotics Industry (2016-2020).	• Increase annual production of industrial robots, enhance product functionality and quality to international standards and achieve breakthroughs in critical robot components • Apply service robots to home services, rehabilitation, rescue and public safety
Smart cities	• Notice on Carrying Out National Pilot Smart Cities	• Utilize modern science and technology, and integrate various information resources to improve urban planning, construction and management
	• Interim Measures for the Administration of National Smart Cities	• Set out criteria for cities to apply for becoming pilot smart cities
	• Pilot Index System for National Smart Cities	• Sets up indexes to measure the performance of smart cities
Big data	• Planning Outline for the Construction of a Social Credit System (2014-2020)	• Improve government integrity, the credibility of the judicial system and the trustworthiness of companies and citizens through the establishment of a social credit system
Artificial intelligence	• "Internet Plus" Artificial Intelligence Three-year Action Implementation Plan (May 2016)	• Develop emerging AI industries and create a market worth more than $15.7 billion by 2018 through supporting: platforms for AI resources; innovation in intelligent products; their applications into homes, vehicles and unmanned systems; and deeper integration of AI and robotics
	• New Generation of Artificial Intelligence Development Plan (July 2017)	• Bring AI technology and applications up to global standards by 2020; achieve major breakthroughs in AI theory by 2025; and reach a global leading position in AI theory, technology and application by 2030
	• Three-year Action Plan to Promote the Development of New Generation Artificial Intelligence Industry (2018-2020)	• Support high-end AI products, speed up the industrialization of AI and widen the application of AI
	• AI Standardization White Paper (January 2018)	• Establish a unified and comprehensive set of standardizations

Blockchain technology	• Blockchain Technology and Application Development White Paper (2016)	• Identify potential blockchain applications • Support the development and enforcement of blockchain standards
	• Key Points on Informatization and Software Standardization (2018)	• Set up a national technical standardization committee for blockchain and participate in relevant international standardization activities
Intelligent Vehicles	• Intelligent Vehicle Innovation and Development Strategy (January 2018) (in draft stage)	• Adopt an open and inclusive approach to support intelligent vehicle innovation • Establish a national leading group for innovation and development of intelligent vehicle • Improve intelligent vehicle-related regulations and standards to remove market access obstacles • Establish an intelligent vehicle security management system • Protect personal safety and privacy

ESCAP 2018. p.93

Complementary initiatives have been developed by specific Ministries, for example, the Ministry of Education has a program for developing the capabilities of universities for both teaching and research.

There has been a major focus on developing S&T Industrial Parks and Technology Business Incubators to facilitate research-industry links and spill-overs from MNEs research and production operations[116].

Made in China

In 2014 (?) a new 10-year road map, Made in China 2025, was launched. This emphasised both manufacturing and innovation capabilities. Some suggest that the emphasis in MIC 2025 was on manufacturing excellence rather than on indigenous technology – even though there are many similarities in prioritised areas of technology[117].

The 13th Five Year Plan for STI (2016-2020) also incorporated specific measures and related metrics for pursuing the goals of 'Made in China 2025' (MIC 2025), announced in 2014[118]. Both of these policy announcements include a goal of technological self-reliance. The MIC 2025 plan details nine strategic tasks, including: to encourage innovation and the use of digital technology in manufacturing; to improve the quality and efficiency of manufacturing; to enforce green manufacturing methods; to globalise Chinese brands; and to improve service-oriented manufacturing and manufacturing-service industries.

The plan specified 10 designated priority sectors:

1. Advanced marine equipment and high-tech vessels;
2. Advanced rail and equipment;
3. Agricultural machinery and technology;
4. Aviation and aerospace equipment;
5. Biopharmaceuticals and high-end medical equipment;

116 ESCAP 2019 Establishing Science and Technology Parks: A Reference Guidebook for Policymakers in Asia and the Pacific. ST/ESCAP/2862 UN ; Fabre, G. & Grumbach, S., 2012. The World upside down, China's R&D and innovation strategy.

117 Some suggest that the MIC2025 was a large and inclusive list rather than a set of carefully considered priorities. 'Blooming for the Glory of the State' The Economist, , Aug. 15, 2020.

118 China STI. The 13th Five-year National Plan for Science, Technology and Innovation of the People's Republic of China. 2016. State Council (2006), Medium-to-Long Term Program of National Science and Technology Development 2006-2020, available on the Chinese government website (www.gov.cn). State Council (2011), 12th Five-year Programme 2011-2015, available on the Chinese government website (www.gov.cn).

6. Integrated circuits and new IT technology;
7. High-end electronic equipment;
8. High-end manufacturing control machinery and robotics;
9. Low and new-energy vehicles;
10. New and advanced materials

Approach to Overall STI Governance

There are many participants in the development of Chinese STI priorities, either as formal or informal advisors or as decision makers. Some major initiatives, such as the Mega Projects of the MLP, are clearly top-down priorities largely implemented by public sector organisations – although the implementation of such priorities will involve participation in lower-level decisions by others. In other cases the broad goals of programs are developed through consultative processes, as explained below, and allocated through competitive processes. Regional governments are active investors and decision-makers in STI and competition between regions is a driver of policy development.

As the focus of policy has shifted from R&D to the dynamism of the innovation system, and from the performance of R&D in government laboratories to the innovation performance of firms (which now account for the great majority of R&D expenditure) so the priorities of STI policy have focused on capability building (particularly through education) and on incentives for innovation in firms and for entrepreneurship. The Made in China 2025 road map is in many ways a return to an earlier phase of top-down planning.

High-Level national conferences are organised to announce and explain major new STI priorities- Table 1.

Table App.7: National Conferences Communicate New Priorities

Time	Name	Significance
March 1978	National Science Conference	Deng Xiaoping emphasised that S&T is a productive force, that intellectuals are part of the working class, and that S&T is vital for China's development. One particularly important outcome was the rapid growth in the number of Chinese students sent overseas to learn.
March 1985	National Science and Technology Working Conference	"Decision on the Reforms of the S&T System" released by the CCPCC. Further initiatives to enhance the economic orientation of the S&T system
May 1995	National Science and Technology Conference	This conference initiated a re-focusing of S&T and an emphasis on quality. A major re-organisation of research institutes followed, with closures and mergers, as well as the formation of new centres. Initiatives to attract back to China scientists who had stayed and were working abroad. These reforms significantly increased the number of Ministries and agencies active in innovation policy making, increasing problems of coordination.
August 1999	National Conference on Technological Innovation	The CCPCC and the State Council issued the "Decision on Strengthening the Technological Innovation, Developing the High Technology and Realizing Industrialization". This focused on strengthening the national innovation system and improving commercialisation.
January 2006	National Science and Technology Conference	CCPCC and the State Council issued "Medium- and Long-Term Plan for the Development of Science and Technology (2006–2020)" (MLP) with a strategy for China to become an "innovation-oriented country" by 2020

based on building a capability for indigenous innovation. Due to the wider scope of innovation policy the number of agencies involved in innovation policy further increased.

Sources: Liu et al. 2011; Fabre & Grumbach, 2012.

Level and Extent of High-Level Leadership of STI as a Priority

There has been very strong support for STI from the paramount leaders, since Deng Xiaoping in the 1980s. There is no question that the Central Committee of the Communist Party has emphasised the central role of STI in economic and social development – and indeed to importance of later for the former. The State Leading Group for Science, Technology and Education, which is responsible for coordination and evaluation of STI strategy, includes heads of STI, education and economic agencies. The Group often draws on briefing by research leaders when considering specific technology issues. The Chinese Academy of Sciences and the Chinese Academy of Engineering also have advisory roles.

Participation in Priority Setting

A Chinese Communist Party Central Committee (CPPCC) document is the most authoritative and usually has the most influence and impact. The next most influential is a law by the National People's Congress (NPC) – the NPC's Standing Committee and the Committee on Science, Technology, Education, and Health, has the authority to drafts, enacts, and amends STI laws, which are usually prepared by the relevant Ministries. Following that an administrative statute formulated by the State Council. The details of implementation are set out by Ministries under the State Council through regulations[119].

The State Council produces the five-year plans[120] and these and related statements by the government have a strong influence throughout all levels of government. The **Leading Group on Science, Technology, and Education** of the State Council (LGSTE), chaired by the premier and comprising heads of ministries involved in S&T, studies and reviews major S&T and education policies and programs. The LGSTE is key mechanism of coordination across different agencies under the State Council and in different regions, and it monitors performance.

The LGSTE released the Guideline for the National Medium and Long Term Science and Technology Development Programs (2006-2020)- which is currently the overarching document for STI policy and a major step in the transition from a Soviet style model to a more market-based approach[.121,122].

An Inter-Ministerial Joint Committee (IMJC) convened by MOST was formed after 2013. It includes participation by the Ministry of Finance, the National Development and Reform Commission (NDRC), and some relevant ministries. The IMJC has a mandate for S&T development strategy, proposing program tasks and guidelines and is responsible for overseeing those new professional research management organizations that administer research funding. The IMJC is supported by the Strategic Consultation and Comprehensive Review Committee (SCCRC). This group, composed of experts from universities, government research institutes, and industry, has already contributed to the Thirteenth Five-Year Plan for STI[123]. Both the IMJC and the SCCRC are linked to China's State Leading Group of Science and Technology System Reform and Innovation System Construction.

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119 Liu, F.C., Simon, D.F., Sun, Y.T. and Cao, C., 2011. China's innovation policies: Evolution, institutional structure, and trajectory. *Research Policy*, *40*(7), pp.917-931.

120 Wu, Y., 2012. Trends and Prospects in China's Research and Development Sector. *Australian Economic Review*, *45*(4), pp.467-474.

121 The development of this plan extended over 2003 and 2005 and over 3000 experts in natural science, engineering and social sciences contributed. Lan, X. and Forbes, N., 2006. Will China become a science and technology superpower by 2020? An assessment based on a national innovation system framework. *Innovations: Technology, Governance, Globalization*,*1*(4), pp.111-126.

122 Cao, et al, 2013.

123 Cao & Suttmeier, 2017

National Development and Reform Commission (NDRC) has the key responsibility to drive China's technological advance from an economic perspective. It is responsible for formulating policies related to enterprise innovation and high technology and manages and implements major S&T programs such as the State Major S&T Achievement Industrialization Program, the State Key Industrial Testing Program, and the National Engineering Research Center Program.

The **Ministry for Science and Technology** (MOST) has a key role in formulating S&T policy, through contributing to the Medium and Long Term Plan and the five year plans, and in dispensing funds. However, many Ministries with S&T activities have their own budgets and programs. MOST is responsible for many STI programs at the national level, including R&D from research funding to commercialisation, promoting enterprises innovation (in conjunction with the NDRC). MOST also has programs to develop High Tech parks. Importantly MOST also collaborates with other Ministries with STI-related roles, including Education, Health, Industry & IT and Agriculture.

Ministry for Science and Technology (MOST)

Structure

- Department of Policies, Regulation and Supervision: research on S&T development, provides guidelines on commercialisation, drafts regulations, monitors the performance of research institutes
- Department of Innovation and Development:- drafts laws on S&T development and innovation, evaluates innovation performance, promotes and guides regional S&T development.
- Department of Resource Allocation and Management: advises on allocation, drafts policies, assess plans and budgets.
- Department of Basic Research: responsible for a diverse range of planning, management and coordination in relation to basic research.
- Department of International Cooperation

Functions[124]:

1. Responsibility for drawing up S&T development plans and policies, drafting related laws, regulations and departmental rules and guaranteeing implementation.
2. Responsibility for drafting the National Basic Research Programme, the National High-tech R&D Programme and the S&T Enabling Programme.
3. Teaming up with other organisations in scheme demonstration, assessment, acceptance and policymaking of major S&T special projects and providing advice on major changes.
4. Compiling and implementing plans for national laboratories, innovative research bases, national S&T programmes and research conditions so as to promote infrastructure-building and resource-sharing.
5. Formulation and supervision of S&T plans according to policies, drafting policies on hi-tech commercialisation in conjunction with other departments and guiding the national high-tech industrial development zones.

124 Li, L., 2009. Research priorities and priority-setting in China. *VINNOVA analysis*. p. 11.

6. Drawing up policies and measurements to enhance rural and social progress in S&T, thus improving the national livelihood.
7. Issuing policies to encourage synergies between enterprise, universities and research institutes, promoting the application and demonstration of scientific discoveries and technological inventions and improving the innovative capacity of enterprise.
8. Proposing institutional reforms and supervising establishment and restructuring of research institutes.
9. Responsibility for budgeting, final accounting and supervision of S&T funds. Also, proposing major policies and measures to relevant departments on the rational allocation of S&T resources.
10. Responsibility for appraising the National S&T Award, drawing up plans on S&T talent team-building and proposing policies.
11. Drafting plans and policies on science popularisation, technological market and S&T intermediaries. It is also responsible for issuing confidential measures and managing S&T assessments and statistics.
12. Drawing up policies on S&T cooperation and exchange through bilateral and multilateral channels, guiding relevant departments and local governments in international interaction, appointing and supervising S&T diplomats and facilitating aid to and from China.
13. Undertaking other tasks assigned by the State Council.

To enable coordination and increase its influence MOST has developed effective alliances with National Development and Reform Commission and the Ministry of Finance – the two most important players in the Chinese economy. However, the role of MOST in running S&T programs declined after the reforms of the 1980s and that of other S&T related ministries increased. Following reforms from 2014 MOST is required to work more closely with other ministries[125].

One of the significant reforms from 2014 was the establishment of several professional research funding organisations, which will take over the administration of programs from MOST and other ministries with S&T missions. Prior to this change about 30 different agencies administered government R&D funding through about 100 competitive programs, resulting in serious inefficiency[126]. Each of the new research funding organisations will have panels of experts to make funding decisions.

The **Chinese Academy of Science** (CAS) became a major performer in the Chinese STI system with multiple functions, but its future scope and role is under review. The CAS manages three universities, and 130 national laboratories and engineering centres and 100 research institutes- many focused on basic science. According to Cao and Suttmeier, 2017, the CAS has been undergoing a process of reform that involves the re-organisation of the institutes and the CAS universities. The CAS has also had a significant advisory role in S&T policy-making through its academicians (along with academicians of the advisory organisation, the Chinese Academy of Engineering), and these provide services to support decision making related to engineering and technology.

125 Sun, Y. and Cao, C., 2018. The evolving relations between government agencies of innovation policymaking in emerging economies: A policy network approach and its application to the Chinese case. *Research Policy*,*47*(3), pp.592-605.

126 Cao & Suttmeier, 2017.

Provincial governments implemented S&T programs based on the national plans. S&T policy making organisations within provincial governments have significant roles in setting priorities for industrial development, in funding research and in establishing research institutions:

'To foster growth, local governments cultivate close ties with local firms, regardless of their ownership. In regions without the presence of strong SOEs, local governments such as in Guangdong and Zhejiang especially promote private entrepreneurship and non-state sector. Chinese local governments provide various forms of subsidies, loans and cheap lands to industrial firms, build industrial parks and startup incubators, and many of them invest venture funds in entrepreneurial firms.' Li, 2017, p63.

Bark (2001) provides an insightful approach to characterising the different priorities of interest groups in the process of setting priorities- Table AAA. Over time, the processes have had to integrate or perhaps add a wider range of interests.

Table App.8 Chinese S&T policy cultures – a taxonomy127

	Bureaucratic	**Economic**	**Academic**	**Civic**
Developmental goals	National strength and security	Economic growth	Expansion of knowledge	Better society
Doctrine of policy making	Interventionist	Liberalist	Autonomy	Participation
Preferred policy instruments	Planning, 'picking winners'	Market forces, commercialization	Peer review, institution-building	Public debate, technology assessment
Fundamental ethos	Authoritarian, hierarchical	Entrepreneurial	Scientistic	Populist
Interest group constituency	Defense sector, industrial ministries	New technology firms, enterprise managers	Research institutes, universities	Student movement, dissident journalists

Recently, the interests and perspective of major private sector firms have become more influential: *"The domestic private sector, particularly larger firms, have been playing a major part in the formulation of policies related to frontier technologies and in spurring the development and adoption of such technologies. Four domestic technology companies (Baidu Inc., Alibaba Group, Tencent, and iFlytek Co., Ltd.) were selected in November 2017 by the Ministry of Science and Technology as the first members of the AI National Team to build open innovation platforms. Baidu will focus on autonomous driving, Alibaba Group on smart cities (the "City Brain" project), Tencent on medical imaging and iFlytek on voice intelligence." 128*

Processes of Priority Setting

Foresight studies have had an increasing role in priority setting in China. Table 9 lists the many studies since the 1990s.

127 Baark, E., 2001. The Making of Science and Technology Policy in China, International Journal of Technology Management, 21 (1/2), 1-21). p.9.

128 ESCAP 2018. Evolution of Science, Technology and Innovation Policies for Sustainable Development: The Experiences of China, Japan, the Republic of Korea and Singapore. p.47.

Table App.9: Technology foresight practices in China (national level).

TF activity	TF activity	Time span of implementation	Major sponsors	Research content	Time of foresight
Exploratory period	The national critical technology selection	1992–1995	National Science & Technology Commission a; Institute of Scientific & Technical Information of China	4 Fields	–
	The critical technology selection for social & economic development in the next 10 years;	1993–1997	National Planning Commission b; National Science and Technology Commission;	10 Fields	Next 10 years
	Technology forecast for national critical fields	1997–1999	National Economic and Trade Commission	3 Fields	-
Rapid development period	The technology forecast and critical technology selection in high-tech fields of China;	2003–2005	MOST	9 Fields	Next 10 years
	Technology foresight toward 2020 in China	2003–2005	Chinese Academy of Sciences (CAS), Institute of Policy and Management (IPM)	8 Fields	Toward 2020
	Strategic research on scientific and technological development roadmaps of major fields in China toward 2050	2007–2009	Chinese Academy of Sciences (CAS)	18 Fields	Toward 2050
Maturation period	National technology foresight	Launched in 2013	CASTED/MOST	13 Fields	Next 5–10 years
	Engineering S&T development strategy research toward 2035 in China	Launched in 2015	Chinese Academy of Engineering (CAE); National Natural Science Foundation of China (NSFC)	8 Fields of engineering technology	Toward 2035

a In 1998, the National Science and Technology Commission was renamed the Ministry of Science and Technology (MOST).

b In 2003, the National Planning Commission and other departments were integrated as the National Development and Reform Commission; the National Economic and Trade Commission and other departments were integrated as the Ministry of Commerce of the People's Republic of China.

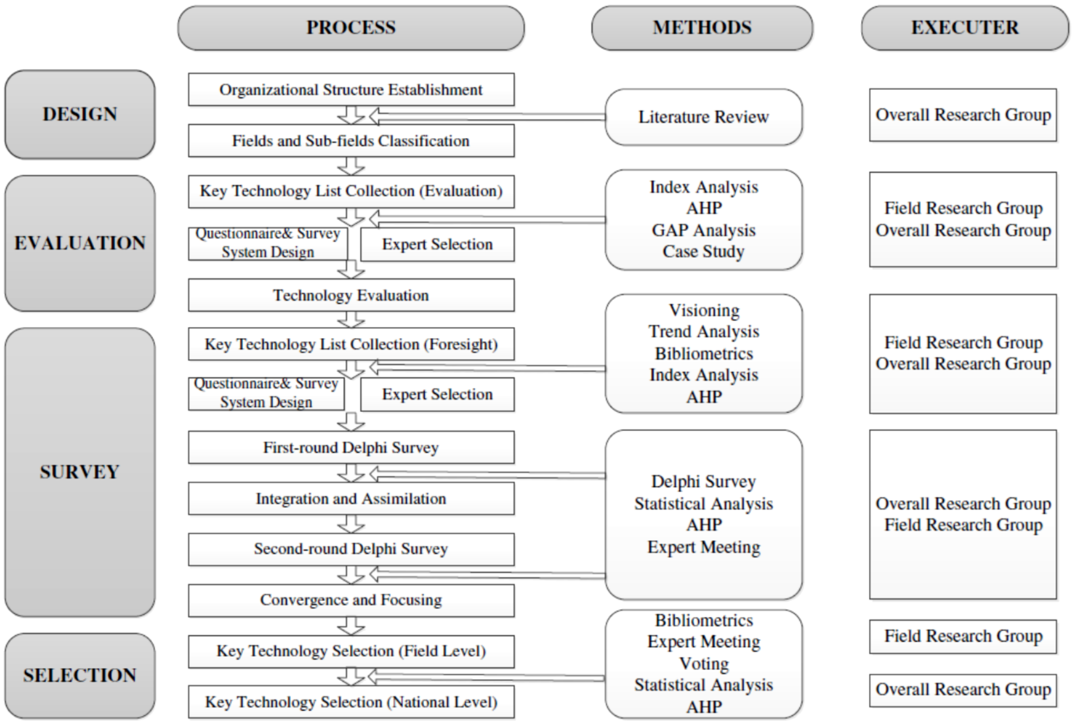
Source: Li, N., Chen, K. and Kou, M., 2017. Technology foresight in China: Academic studies, governmental practices and policy applications. *Technological Forecasting and Social Change*, *119*, pp.246-255.

From 2003 to 2005 the Institute of Policy and Management (IPM) of the Chinese Academy of Sciences (CAS) conducted a “Technology Foresight Toward 2020 in China,” involving analysis of S&T requirements for development objectives, based on scenario analyses, two rounds of Delphi survey, and expert panels. The survey and expert panels involved over 70 leading Chinese experts, 400 other specialists in eight groups and 63 specific technology groups. After identifying 737 key technologies through this Delphi process a survey of over 2000 Chinese experts assessed the significance and feasibility of developing these technologies. These assessments contributed to the Medium and Long-Term Scientific and Technological Development Plan. MOST also conducted a foresight study from 2003 to 2005, though which almost 4000 experts were surveyed to assess more than 1000 ‘optional technologies’, and select over 100 ‘critical national technologies’ relevant over the following ten years.

The use of foresight for regional STI strategy development in China has also grown. For example, the Science and Technology Commission of Shanghai Municipality (STCSM), through the Shanghai Institute for Science of Science (SISS) has conducted regional technology foresight.

More recently large-scale technology foresight activities at the national level have been led by the Chinese Academy of Science and Technology for Development (CASTED), under MOST. The 2013 CASTED foresight used a large scale Delphi approach and focused on major societal and innovation challenges in 13 fields, including information, biology, new materials, manufacturing, earth observation and navigation, energy, resources and environment, population and health, agriculture, ocean, transportation, public security, and urbanization (Li et al, 2017). Through the surveys, scenarios and technology roadmaps CASTED selected 280 key technologies.

Figure App.3: Framework for CASTED national technology foresight, 2013



Source: Li et al, 2017

The CAE and NSFC collaborated in a program - "Engineering S&T Development Strategy Research Toward 2035 in China" – that used bibliometrics, patent analysis, Delphi and technology roadmaps to identify and select priorities in 11 fields, 93 sub-fields and 833 technologies. The Delphi survey involved 8400 experts and elicited 30,000 questionnaire responses. An analysis of likely future demand, based on six scenarios, was conducted in parallel. After detailed analysis of the first round, a second round Delphi survey was conducted. This led to proposals for : "developmental targets, critical development fields, key technologies requiring breakthroughs, major projects needing constructing, and fundamental research directions of priority development for China's engineering S&T toward 2035.."(Li et al, 2017. p. 250.

A foresight study that had begun in 2002 contributed to the development of the MLP. Chinese Ministry of Science and Technology, through it's National Research Center for Science and Technology for Development, a part of MOST and including the Research Group on Technology Foresight, conducted a Delphi-based foresight survey. This was designed to cover only ICT, biotech and new materials. The first stage of the survey addressed project design, analysis of socio-economic needs in China and S&T trends and topic selection. The next stage, which identified 200 key technologies, involved surveys of over 1000 experts and workshops. Experts were asked to assess, for each area of nominated technology: level of current expertise, time of realisation of technology development, likely socio-economic and environmental consequences, national relevance, likely impacts on established industries, the gap between China and leading countries, the R&D base in China, and IP rights in the next five years.[129]

According to Li (2009) the MLP-making process can be roughly classified into four phases:

Phase 1: organisational preparation for MLP

The leading group was established in June 2003, consisting of the Premier, State Council Secretary *and* senior level officials from 23 ministries and ministry-level organisations. An expert consultation group for the overall strategy for the MLP was formed consisting of 20 senior scientists

Phase 2: Strategic Studies

The process of strategic studies was open - over 2,000 scientists, engineers, policy experts, corporate executives, officials from universities, ministries and corporations participated, with many workshops for discussing research reports focused on identifying critical problems and research opportunities in 20 areas considered to be of central importance. A website was created for collecting ideas and suggestions from the general public There was also a forum with international experts in November 2003. The research reports on the 20 issues had a common structure: the international situation; the domestic situation and demand; problems needing to be solved; suggestions and proposals for priority projects and policies.

Phase 3: Drafting process

Based largely on these reports, a drafting group - from the government, MOST institutes and Tsinghua University – worked closely with senior leaders and selected stakeholders to develop a draft MLP, through 12 revisions.

Phase 4: Ratification

The draft was reviewed by the Leading Group and then by the Politburo of the CCP. A national conference was organised in 2006 to initiate implementation of the MLP.

MLP Principles for Selection[130]

Priority Themes for Planning

A priority theme is defined in the MLP as technological groups in priority fields and needing development for specific tasks (goals), with a sound technological basis and able to make breakthroughs in the near future.

The principles for determining a priority theme are whose technologies which are:

- Conducive to solving the bottlenecks and improving capacity for sustainable economic development.
- Conducive to mastering the key technologies and generic technologies and improving the core competence of industries.
- Conducive to solving major public interest S&T problems and improving the capacity of public services.
- Conducive to developing dual technologies (military and civil) and improving national defence capacity.

The MLP sets out 68 priority themes in the 11 priority fields.

Mega-Engineering Projects

The basic principles for selection were:

- Close links with the major demands of economic and social developments,

129 Johnston, R. 2005. Technology Planning in Major Asian Countries: An Analysis of Recent Foresight Reports from China and India & Comparison with Japan and Korea. Australian Centre for Innovation, University of Sydney

130 Li, L., 2009. Research priorities and priority-setting in China. *VINNOVA analysis*.

- nurturing strategic industries so that they have their own core intellectual property rights and improve their indigenous innovation capability.
- Emphasising those key generic technologies which will improve industrial competitiveness as a whole and drive improvement.
- Solving the most challenging bottlenecks in economic and social developments.
- Linking civil and military uses of major strategic significance to national security and national strength generally.
- Suitability to national contexts and affordability.

Cutting-edge technologies and scientific areas

The principles used for selecting cutting-edge technologies were:

- Represent the developmental direction of world-class technology.
- Drive the formation and development of emerging industries in China.
- Be conducive to industrial upgrade, allowing leapfrogging.
- • Have a talent base and an R&D base.

The MLP selected as 'cutting edge' technologies: biotechnology, IT, new materials technology, advanced manufacturing technology, advanced energy, marine technologies, laser and aerospace technology. The principles for selecting the eight cutting-edge scientific areas were:

- Driving development of the basic sciences
- Being a good research basis
- Representing national strength and characteristics
- Being conducive to improving China's position in the world.

As discussed above, priority setting has been both top-down and bottom-up. The role of the LGSTE and the mechanisms of consultation are also discussed above. In identifying major priorities for the high-level MLP or five-year plan, there is consultation among government Ministries and with expert advisory committees. Many assessments and reviews contribute the development of priorities, including foresight assessments[131].

Most STI initiatives are announced within the context of five-year plans developed through these consultation mechanisms, but some initiatives are formed in response to identified problems in the STI system. Major initiatives have been developed following representations to the political leaders by leading scientists. On such initiative led to the formation of National Natural Science Foundation of China, within the Chinese Academy of Science, to provide research funds for basic research in the natural sciences, with the allocation determined by the CAS. Hence, there is some scope for influential scientists and business people, outside of government, to propose new issues or solutions to recognised problems. The overall processes of priority-setting involve formal approaches, but that provide significant scope for stakeholder participation- within the scope of high-level priorities determined within the top levels of government.

131 Li, N., Chen, K. and Kou, M., 2017. Technology foresight in China: Academic studies, governmental practices and policy applications. Technological Forecasting and Social Change, 119, pp.246-255.

China has also actively sought to learn from the experience of other countries, and in some cases follow models developed elsewhere. One example is the Natural Science Foundation of China, modelled on the US NSF, and another is the major program of S&T Parks.

A major reform in the mid-1980s required many applied research institutes to be market-oriented and financially self- sustainable, was a form of priority setting. According to Appleabaum et al, (2018), from the mid-1990s, priority setting shifted to focus more on those activities that enterprises were less likely to undertake (basic research, education, pre-competitive R&D, non-commercial missions); an approach labelled 'anchoring one end, freeing up the other'. This approach led to a greater focus of funding on the highest strategic objectives. For example, the State Basic Research and Development Program (973 Program), initiated in 1997, focused resources based on three criteria[132]:

- Projects that attempted to solve problems associated with China's economic, social and technological development;
- Projects related to relevant and major basic research problems;
- Projects where for one reason or another China could be at the frontier of international research.

Consultation

After major issues are identified the government initiates assessment studies, including workshops with international participation, and these involve extensive consultation across government, STI organisations and corporate executives. In some cases websites enable general public inputs to policy development. In the case of the 14th Five-Year Plan for Economic and Social Development, the Government has sought public opinion through a website.

The China Association for Science and Technology (CAST), an organisation with membership by Chinese scientific and engineering societies, has developed expertise for policy analysis and can act as a think tank in STI policy. With chapters at universities, research institutes, and enterprises, CAST can also contribute both the policy implementation and evaluation[133].

Integrating Innovation Goals

China's STI priorities have recently been increasingly driven by Innovation-related objectives:

- enabling technological leapfrogging and improving linkages between research and industry; and,
- promoting high value-added industry and the restructuring of industry from low-tech to high-tech, to move up the value chain.

Innovation policies up the MLP of 2006 are shown in Table 2.

Table App.9: Characteristics of Innovation Policies[134].

Period	Key Policies
1985-1994	Establishment of High-Tech parks/industrial development zones

132 Appelbaum, R.P., Cao, C., Han, X., Parker, R. and Simon, D., 2018. *Innovation in China: challenging the global science and technology system*. John Wiley & Sons.

133 Cao & Suttmeier, 2017.

134 Based on Liu, F.C., Simon, D.F., Sun, Y.T. and Cao, C., 2011. China's innovation policies: Evolution, institutional structure, and trajectory. *Research Policy*, *40*(7), pp.917-931.

	A range of major funding initiatives from basic to applied research and commercialisation: State High-Tech R&D Program, State Key S&T Achievement Promotion Program, State Engineering Technology R&D Promotion Program (run by the SSTC, now MOST). Initiatives to promote the acquisition and absorption of foreign technology: Regulations on the Encouragement of Technology Importation Contracts, and Regulations on the Work of Absorbing and Assimilating Imported Technologies"
1995-2005	Increased focus on innovation, through a portfolio of policies in which financial incentives became as important as S&T and industry policies, and there was greater alignment and coordination among policies, reducing bureaucratic balkanisation: • Measures to develop an environment conducive to business growth, • Government procurement, • Institutional reform requiring research organisations to be more market oriented – with hundreds becoming the internal R&D unit of an enterprise or an enterprise themselves- with supportive financial and tax policies, • Greater emphasis on the increasing knowledge application, eg the Law on the Promotion of S&T Achievement Conversion in 1996 (enacted by the NPC), Decision on Strengthening Technological Innovation, Developing High Technology and Realizing Industrialization by CCPCC and the State Council, • Support for private S&T-related enterprises to make these the main driver of innovation, including support for startups and SMEs, particularly through fiscal, financial and tax policies ("*Taken together, these policies began to shift the locus of innovation toward firms and away from primary reliance on government-run research institutes*." Liu et al, p.922) • *Industry policy was adapted to support innovation in each sector through identifying key technology import and technology development priorities – in 2001 MOST and the* State Development and Planning Commission (SDPC) developed guidelines on key priorities for high-tech industrialization

In the development of the last MLP there was considerable debate about the roles of technology acquisition from foreign firms and from indigenous innovation, with many economists arguing that a much greater reliance on indigenous technology development would be very expensive at this stage of China's development. There was also debate about the role of major top down national projects, such as the mega projects. The questioning of these top down projects was influenced by the criticisms of the effectiveness of such national programs as the National High-Technology Research and Development Program (the so-called 863 program) and the National Basic Research Program (the 973 program) and hence criticisms of the level of control and the approach to resource allocation by MOST[135].

Within the STI community there was often a greater emphasis on building national innovation capacity and increasing 'self-reliance'. The National Strategy of Innovation-Driven Development announced by the State Council in 2016 set ambitious goals for achieving leadership in areas of international innovation. A wide range of policies support those goals, including R&D support, excluding foreign competition in some markets, encouragement of offshore investment by Chinese firms, technology transfer from foreign investors.

This increasing focus on 'catching-up' in advanced technologies has led to '*market-oriented reform of the S&T system and innovation-oriented economic reform…. [shifting] innovation policy from the speeding up of technology transfer from laboratories to production to the encouragement of mass innovation and entrepreneurship .. In particular, China's innovation policy agendas have evolved*

135 Cao, C., Suttmeier, R.P. and Simon, D.F., 2006. China's 15-year science and technology plan. *Physics today*,*59*(12), p.38.

from the recognition of S&T as a productive force to the reform of the S&T system, then to the initiation of the strategy of "revitalizing the nation through the science and education."[136]

Indigenous innovation is a high priority objective and a range of policy tools are used[137]:

- Infrastructure – particularly high-tech parks
- Incentives for Foreign R&D facilities
- Grants – for R&D, but for priority sectors also tax concessions, incentives for purchasing local equipment, relief from health and pension costs for retired staff etc
- Subsidies for capital expenditure on equipment and discouragement (often by informal or indirect means) of importing foreign equipment, which in some cases has amounted to provincial governments providing highly expensive production facilities for free
- Procurement- using government procurement with a strong bias to local suppliers
- Market enabling measures- reducing, through anti-monopoly laws, the market share of major foreign firms
- Standards – formulating national and particularly international standards.

Collaboration between enterprises and universities and research institutes increased strongly in the early 1990s. The Knowledge Innovation Program (KIP) supports a group of research institutes to develop 'world-class' research and transfer results to industry, and link China with international research. Some assessments conclude that China's STI policies have focused on knowledge generation and have neglected support for innovation, particularly in private firms and SMEs[138].

Spin-offs from research organisations and universities have had an important role in developing innovation capacity and high-tech industry. Policies announced in 2016 give some research organisations the right to benefit from and commercialise IP from publicly funded research, allow academics to work part-time in companies and to benefit from technology transfer[139].

An important component of innovation policy is the extensive support for entrepreneurship. Perhaps the most important mechanism is the government investment in private venture capital funds[140].

Some analysts note that as innovation activity in business has increased, a higher proportion of R&D has been directed to 'market-driven R&D'. This has raised concerns that investment in longer term basic and applied research, and innovation capacity building, is not adequate to sustain innovation performance[141].

Implementation of Priorities

Participation in MOST's Major Programs is through competitive applications by firms, with selection based on firms' capabilities and prior experience- large firms account for a larger share of funding than their share of output. SOEs have usually been favoured over privately owned firms, although

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136 Sun, Y. and Cao, C., 2018. The evolving relations between government agencies of innovation policymaking in emerging economies: A policy network approach and its application to the Chinese case. *Research Policy*, *47*(3), pp.592-605., p.594.

137 Wolff, Alan Wm. "China's Drive Toward Innovation." *Issues in Science and Technology* 23 (3), (Spring 2007).

138 Benner et al, 2012; The Economis. (2009) 'China's struggling smaller firms. Small fish in a great pond', 10 September 2009. The Economist 'Entrepreneurship in China. Let a million flowers bloom', 10 March 2011.

139 Cao & Suttmeier, 2017.

140 Băzăvan, A., 2019.

141 Wu, Y., 2019. China's research and development sector: Progress and outlook. In *China's Quest for Innovation* (pp. 71-89). Routledge.

their performance is lower than that of shareholder firms[142]. As noted, some initiatives provide incentives for universities to develop capacities and to collaborate with enterprises.

Much of the funding is concentrated in leading universities and research organisations. Funding in the education budget has aimed to develop a 'critical mass' of 100 world class universities, which a higher level of focus on the top 40.

As the scope of STI has widened and many more Ministries and other organisations become significant actors in the innovation system, coordination has become a greater challenge – and a weakness that is widely recognised[143]. Many commentators consider that personal connections and status strongly influence the allocation of research funding. Evaluation of researchers relies largely on the number of publications in peer-reviewed journals. It is argued that this drives researchers to focus on short-term, low-risk, and hence low-quality research. Evaluation has also become an increasing problem. It is recognised that reliance on reputation or the number of publications are inadequate for providing incentives for a focus on innovation and problem solving[144].

Monitoring, Evaluation, Policy Learning and Adaptation of Policies

There is an increasing level of commitment to formal research evaluation, and International approaches to evaluation have been introduced145. Evaluations are usually carried out by independent organisations or committees, involve extensive consultation, and are published. A lack of real professional independence lead to limits in the effectiveness of peer-review and research evaluation[146].

The Inter-Ministerial Joint Committee (IMJC) is also supported by a national management information and reporting system. In relation to S&T programs, this organisation collects information on budgets, personnel, research progress, outcomes, and evaluations and assessments- and to some extent makes this performance information available[147].

Competition and experimentation are characteristics of the STI policy regime. The different regions interpret and implement policies developed at the national level with different emphasis and approaches leading to a strong element of competition among regions. At the regional and particularly national level there is an explicit experimentation with major policy policies and hence a trial and error approach[148]:

"In almost every case, when Chinese government plans to undertake reforms, it starts with a pilot project in a limited area. The most successful experiments have gained fame and have been implemented nation-wide, whereas many other have been closed forever. The Torch Program, launched in 1988, established the first high-tech industrial development zones and science parks across the country, in an effort to build Silicon Valley-type clusters that serve as dynamic platforms for innovation .. In 2009, the first National Innovation Demonstration Zones (NIDZs) were further established in Beijing, Wuhan and Shanghai, also meant to serve as experimentation platforms for new policy mixes.." (Băzăvan, 2019. p.119738)

142 Shi, X., Wu, Y., Fu, D., Guo, X. and Wu, H., 2019. Effects of national science and technology programs on innovation in Chinese firms. *Asian Economic Papers*, *18*(1), pp.207-236. This study finds that stricter enforcement of intellectual property law, which restricts the scope for enterprises to copy the innovations of other firms, increases the incentives for firms to invest in R&D and to collaborate with universities.

143 Appelbaum, R.P., Cao, C., Han, X., Parker, R. and Simon, D., 2018. *Innovation in China: challenging the global science and technology system*. John Wiley & Sons.

144 Cao, et al, 2013; Han & Appelbaum, 2018.

145 Applebaum, et all 2018.

146 Cao & Suttmeier, 2017.

147 Cao & Suttmeier, 2017.

148 Băzăvan, A., 2019.

Ongoing Challenges for STI Priority Setting and Implementation

The Chinese STI system and the policies that aim to support, steer and develop it are diverse, complex and continually evolving. Not surprisingly many commentators note various types of problem that limit the effectiveness of policy and influence performance. For example:

- Developing 'whole of government' approaches that integrate the views and approaches of different Ministries and regional governments in the formation of priorities and in the implementation of policies remains a challenge – although the level of coordination and collaboration has improved over the last decade. The Plan for Development of Science and Technology (2006–2020) facilitated greater coordination.
- Intellectual property protection has been a long running issue for the Chinese government and for foreign investors. While IP regulation has become stricter, particularly to encourage more indigenous innovation. Foreign firms see China as a vast and vital market, as well as a major production platform for export, bit many remain concerned about the level of protection and continue to not transfer their advanced technology to China.
- Underdeveloped institutions enable corruption to develop and poor standards of accounting and of quality to continue, as do significant environmental problems.
- Incentives do not always elicit the behaviour that is intended. Applebaum, et al, 2018, suggest that many firms seek and receive subsidies for R&D but do not have a commitment or strategy for innovation. Similarly, researchers seek to publish more papers rather than conduct original research- a focus on quantity over quality probably applies to publications and patenting. Many regions have established 'high tech' parks, but in reality many are largely engaged in assembly rather than research and innovation. As FDI is likely to lead to faster growth in output and employment, regional governments and High Tech Park managers often encourage this investment.
- Applebaum et al, 2018 suggests, that S&T-related policies and programs tend to accumulate, rather than be replaced, so that older and less effective measures remain adding to complexity and enabling the continuation of mediocre firms and research programs. A context of policy complexity and uncertainty favours large firms and SOEs, while discouraging startups that must compete for capital and talent.
- State-owned companies account for a large share of output and receive a large share of government support for R&D, but are generally less innovative than the more dynamic private firms.
- The high levels of disparity in development between the coastal regions, that have attracted the majority of foreign and local investment, and the still much poorer inland regions remains.

6.3.3 Chile

Context

Chile has been considered an economic success story particularly in the Latin American region, where it has been so-called the 'South American tiger'. However, in contrast to the East Asian counterparts, endogenous science, technology and innovation have played a relatively minor role in Chile's economic growth over the last three decades. While foreign direct investment and entrepreneurship have flourished, Gross Expenditure in R&D as ratio of GDP has remained flat and under 0.36 per cent with businesses' R&D expenditure (BERD) contribution less than 0.15 per cent.

Chile has continued to strengthen its comparative advantages in natural resources derived export industries such as mining, agriculture, fisheries and forestry, while the service sector has driven growth domestically.

Economically, Chile has followed for decades a particularly orthodox model of free market economic development with ambitious programs of privatisation, limited government intervention and low tax regimes. Sectoral prioritisation has not been important in the government agenda, open markets have favoured sectors with existing comparative advantages in mining and agriculture.

Despite decades of economic growth and achieving international competitiveness in resources based sector, policymakers and academics have been concerned about the lack of STI endogenous capabilities and the weakness of the business sector as a driver of the national innovation system. The recent creation of the Ministry for Science, Technology, Knowledge and Innovation in 2018 has been the latest effort to promote STI as an important factor driving broader objectives than economic growth and competitiveness. These objectives include productive development and sustainability. In short, it looks to reshape the relationship between STI and the society.

Scope and Content of STI

Since middle 2000s the guiding principle behind STI policies has been competitiveness. In 2005, the government created by law the National Council of Innovation for Competitiveness to provide direct advice to President about the identification, design and implementation of policy and actions to strengthen innovation aiming the improvement of competiveness and development in Chile.[149]

A number of programs and policy instruments ranging from entrepreneurship to scholarships programs, to subsidies for business R&D have as a principal long term aim the improvement national competitiveness. Policy documents usually refer to competitiveness in general.

Very recently, the government white paper produced by the National Council for Science, Technology, Knowledge and Innovation (which replaced the National Council of Innovation for Competitiveness sets the ambition to transform Chile in a developed country. For achieving that Chile will require a vital change in the role of science, technology and innovation and an increasing link to entrepreneurship. The White paper outlines the change in the national strategic direction from competitiveness to development.[150]

Approach to Governance

Historically STI has played a secondary role in the Chilean public policy. The Nation Commission for Science and Technology (CONICYT) was created in 1967 to advise the president of Chile in the planning and promotion of science and technology in Chile. Historically, many of the funding mechanisms came as ad hoc loans from international institutions such as the World Bank and the

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149 Balbontin et al 2018.

150 Gobierno de Chile, 2019.

Inter-American Development Bank (IDB)[151] to strengthen capabilities in areas such as agriculture or to development scholarship programs for overseas postgraduate studies or new programs. Since 1990s funding has been more systematic and consistently included in the budget process. More recently, there have been an increasing diversity of new programs covering STI areas in a similar way than other OECD countries. These include programs supporting clusters, tax incentives for business R&D (funded from royalties paid by the mining industry), support for centres of excellence in research, support for entrepreneurship and star-ups, and since 2014 support for strategic and sectoral areas.

According to the budget tables for 2017, almost 70 percent of the government total science, technology and innovation expenditure goes to non-sectoral/horizontal competitive programs.

Level and Extent of High-Level Leadership of STI as a Priority

Chile, like other countries, has a high level policy committee, the National Council for Science, Technology, Knowledge and Innovation (former National Innovation Council for Development that advises the president on STI matters. The council has the role of provide a long term strategy for STI and scan the development of global trends in science, technology and innovation. This council is also responsible for the national White Paper on science, technology and innovation.

This council consist of seven members that includes two representatives from academia, one representative from the business sector, one representative from a NGO (at the moment wildlife conservation society) and the ministers for economy and for science, technology, knowledge and innovation.

Organisations Involved in Priority-Setting

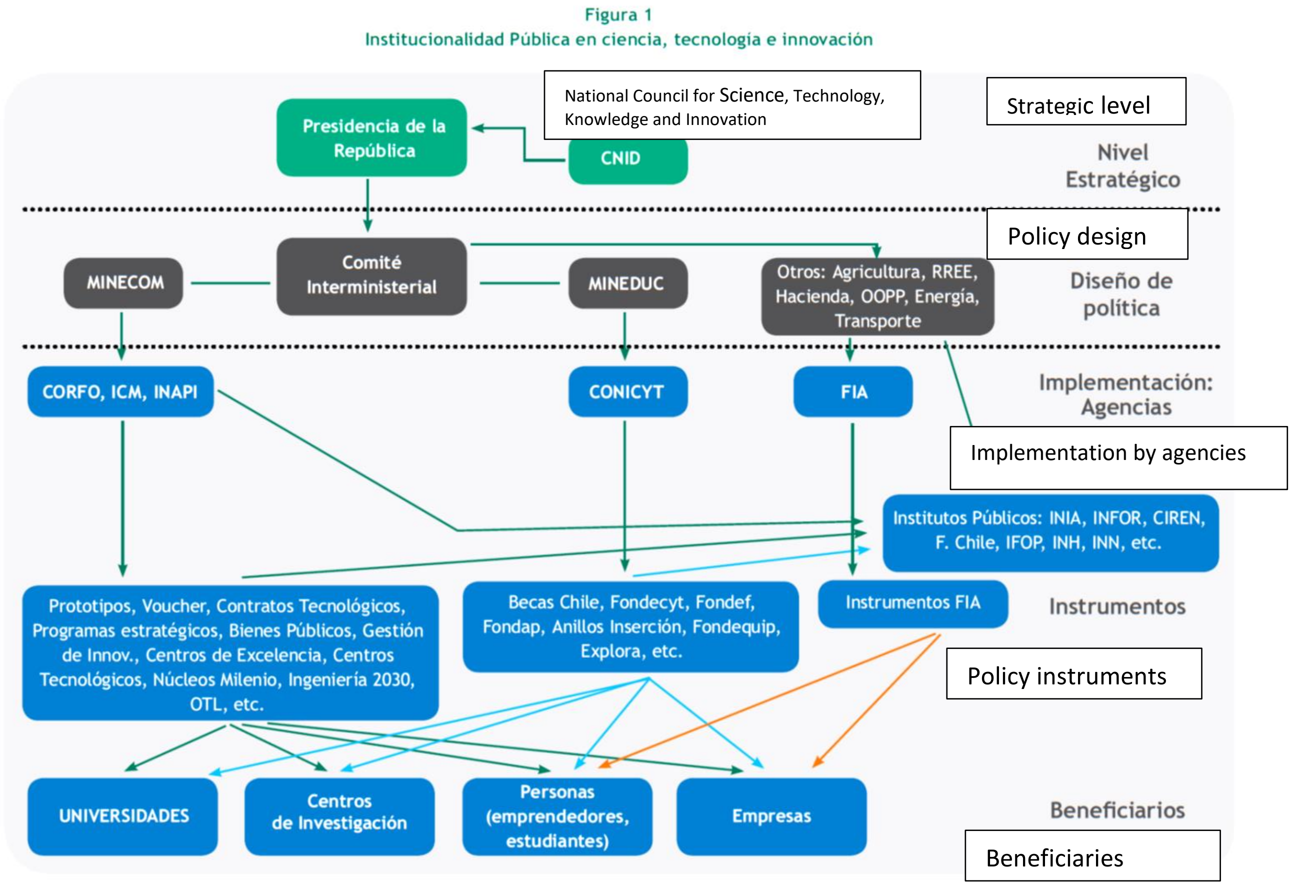
Figure 1 shows the main ministries, agencies and committees involved in the STI decision making in Chile. At most strategic level is the National Council for Science, Technology, Knowledge and Innovation (explained above) that advises the president of the Chile. This council has the key strategic input in STI prioritisation both as at horizontal and sectoral/fields level. The recently released White outlines nine priority areas phrased as challenges including astronomy and its spillovers, renewable energies, smog in Santiago and others. These are listed in section 8.

Until the recent creation of the ministry for science, technology, knowledge and innovation in 2018, the ministry of economy and the ministry of education were the key agencies in policy design with the ministry of agriculture, the ministry of energy and ministry of transport also participating in this process. An inter-ministerial committee acted directly with the instructions coming from the present office.

After the creation of the ministry for science, technology, knowledge and innovation the role of the other ministries on matters related to STI will be reduced as the newly created ministry will be responsible for advising and collaborating with the President of Chile on the design, formulation, coordination, implementation and evaluation of policies, plans and programs destined to promote and strengthen science, technology and innovation derived from scientific-technological research. This ministry also incorporates the National Commission for Scientific and Technological Research (CONICYT) that until recently was the main implementation agency for science and technology policy and programs.

151 Ibid p.9.

Figure App.4 Public Institutions in the administration of science, technology and innovation in Chile



Fuente: Elaboración propia, basado en Benavente (2006), Bravo-Ortega & Eterovic (2015) y comision Philippi (2013).

Processes of Priority Setting

The process of STI administration has experienced significant changes since the law for the creation of the new ministry for science, technology, knowledge and innovation was approved. This law came after a major review of the public STI system, which highlighted the coordination problems associated with the ministry of economy and ministry of education as key agencies behind the STI. The new model gives a critical role National Council for Science, Technology, Knowledge and Innovation as a long term strategic planner and the Ministry of for Science, Technology, Knowledge and Innovation as key agency in the design, coordination, implementation and evaluation of STI policies and programs and to the Ministry of Economics a reduced role in STI having only the portfolio of entrepreneurship.

The new ministry has three objectives[152]:

- To provide the Chilean government with a new institution for science, technology and innovation that allows Chile to engage successfully and as key player of the four industrial revolution through the improvement of the functions and structures for the STI administration
- To make STI a relevant part of the development of Chile's public and private sectors.

152 https://www.minciencia.gob.cl/mision-y-vision

- Organise, strength and provide strategic focus to the national system of science, technology and innovation.

In the past, the process of priority setting operated in a similar way to any other countries with a combination of top-down initiatives coming from the advisory committee to president of the republic and a bottom-up priorities coming from different ministries with STI activities or associated research agencies or laboratories. This bottom-up component of prioritisation is expected to continue, however, the enhanced role the National Council for Science, Technology, Knowledge and Innovation and the respective ministry is already clear in the recently released white paper. The council commission STI horizon scanning assessments that may create new priorities.

Approach to Consultation

Based on the review of the different government's documents, consultation outside the public sector does not seem extensive. For example, the public consultations that characterise the several STI reviews in Australia, are not common feature in the Chilean system.

However, Chile's STI system has a number research institutes associated to ministries as well private-public organisations such as Fundacion Chile, which actively engage with government agencies in a bottom-up process to fund their priority projects. Additionally, the university sector is well represented in the National Council for Science, Technology, Knowledge and Innovation. This council consults and collaborates with a significant number of STI and industry experts as well commissions reports in thematic areas of strategic interest for Chile.

Horizontal and Thematic Priorities

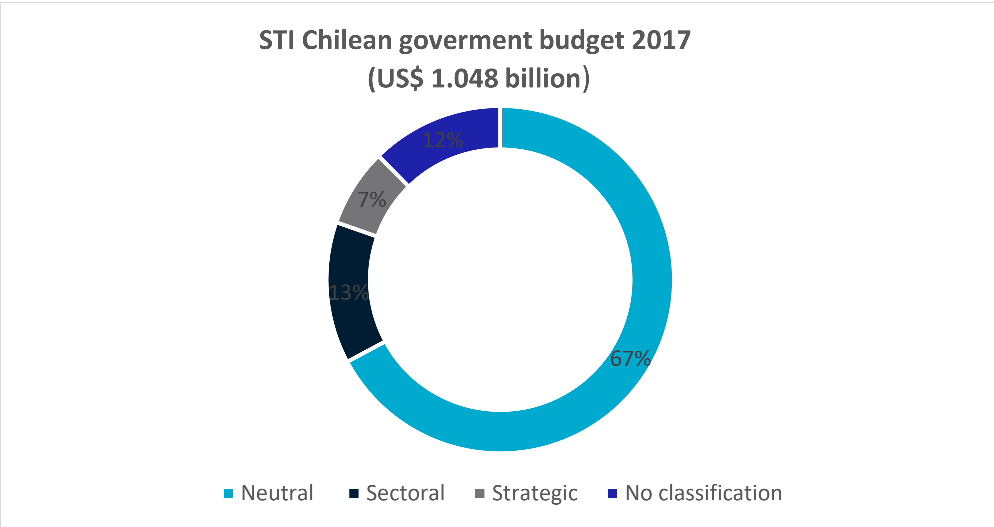
The division of innovation in the Ministry of Economy classifies programs and policies in three types:

Neutral: the program does not have a sectoral focus in the moment that opens to applicants

Sectoral: the program has a sector focus (e.g. mining, agriculture or forestry) but has not objective to solve a particular problem.

Strategic or Mission oriented: the program has as objective to solve a particular problem in a particular sector or area (for example reducing emissions).

Based on this classification, a historical analysis of the science, technology and innovation budget over the last decade, shows that neutral policies have taken the lion's share of the STI budget in Chile reaching a maximum of 74% in 2011 and a minimum of 66% in 2016. The 2017 STI budget that was about US$1.048 billion shows that together sectoral and strategic programs only totalled 20% of the total STI budget.



Source: Balbontin et al, 2018

The 2019 white paper[153] shows a particular focus in nine national thematic challenges, although no indication of funding is provided. The Nine national challenges are:

- Astronomy and its spillovers
- Solar energy
- Energy from the sea
- Santiago 500 anniversary without smog
- National strategy for artificial intelligence
- Interface Ocean-Earth
- Naturals disasters mitigation
- Water and climate change
- Quantum computing and software

Integrating Innovation Goals

In Chile, the framework of innovation systems has been followed implicitly and explicitly by policymakers. The OECD notes that since early 2000s there was a growing political awareness of the importance of innovation for the Chile's future translated into two bold decisions: the creation of an Innovation Council for Competitiveness entrusted with the mission of proposing guidelines for a long-term national innovation strategy; and the introduction of a specific mining tax to increase resources available to implement this strategy.[154]

The creation of the Ministry of Science, Technology, Knowledge and Innovation in 2018 has been the last effort to integrate these four areas under one portfolio. The 2019 White Paper indicates that there were five pillars of Chile's innovation ecosystem: science, technology, knowledge, innovation and entrepreneurship. The entrepreneurship area still remain under the ministry of the economy and its development agency (CORFO) still in charge of number of business innovation programs.

Implementation of Priorities and Coordination

As show in Figure 1, five key agencies (CORFO, CONICYT, ICM, INAPI and FIA)[155] and a number of public research institutes under relevant ministries have been responsible for the implementation of STI programs.

The newly created Ministry of Science, Technology, Knowledge and Innovation is expected to be the agency responsible for coordinating STI policies across the Chilean government. This includes the selection and funding of national priority areas as indicated in the recently released white paper. However, as different ministries and agencies are responsible for developing and implementing their own programs, and sectoral priorities, it is expected that this will continue with an increasing role of the ministry of science as coordinating agency. As many other countries, the ministries and agencies STI priorities are included in the budget process and reviewed by the Ministry of Finance.

Monitoring, Evaluation, Policy Learning and Adaptation of Policies

153 Gobierno de Chile, 2019.

154 OECD, 2007.

155 CORFO: Development agency under the Ministry of Economy; FIA: Foundation for Innovation in Agriculture; ICM: Initiative Scientific Millennium; INAPI: National Institute of Industrial Property; CONICYT: Nation Commission for Science and Technology.

From 2001 Chilean government has implemented an ex-ante evaluation of all government programs. Ex ante evaluation of social programs is undertaken by the ministry of Social Development and the Budget Office undertakes the evaluation of all other non-social government programs including STI related programs. The objective of the ex-ante evaluation is to ensure that objectives are clear and doable, alignment between the program's eligibility criteria and target the right population, and the collection of data and indicators that allow the further monitoring of the program and evaluation.

Post-evaluation and monitoring of STI programs is also undertaken by the Budget Office. In the last ten years, 13 STI programs have been evaluated. Table 1 shows a summary of the programs and the main finding from the evaluation.

Chile has experienced a significant change in its focus to STI. The recent creation of the Science, Technology, Knowledge and Innovation reflects the learning from the past decades and the need for better coordination and more strategic focus of these areas.

Table App. 10: Ex-post Evaluations of Government STI programs (2008-2017)

Program name	**Institution**	**Evaluation type**	**Year**	**Finding**
Adoption and generation of technological capabilities for innovation	Innova Chile	Evaluation of Government program (EPG)	2017	Good performance
Support for enterprise innovation	Innova Chile	EPG	2017	Good performance
Scholarships Chile	CONICYT	EPG	2017	Sufficient
Postgraduate National Scholarships	CONICYT	EPG	2017	Sufficient
Fund for Scientific & Technological Development (FONDEF)	CONICYT	EPG	2016	Sufficient
Millennium scientific Initiative program	CORFO	EPG	2014	Sufficient
Program for researchers' engagement	CONICYT	EPG	2013	Insufficient
National Fund for National Development of Science and Technology (FONDECYT)	CONICYT	EPG	2013	Sufficient
Innovation fund for regional competitiveness	Subdere	EPG	2011	Insufficient
Program for excellence in science and technology research	CONICYT	EPG	2010	Modification in design

Source: Balbontin et al, 2018

6.3.4 Korea

Context

Korea has a relatively high R&D intensity, a well-educated labour force, supportive innovation framework conditions, many knowledge-intensive and internationally competitive firms, and a strong ICT infrastructure: ‘*Almost three-quarters of Korean R&D is performed by business, with 88% in manufacturing in 2010, second only to Germany; 48% was carried out in a single sector, Radio, television and communication equipment, by far the largest share among OECD countries. BERD grew by 9.5% a year in real terms during the decade to 2010, rising from 1.70% of GDP in 2000 to 2.80% of GDP in 2010. The structure of BERD shows that R&D is mainly conducted by large manufacturing conglomerates ... Much government support to the business sector goes to SMEs. …Although Korea has relatively high public-sector expenditures on R&D, its universities and research publication outputs rank comparatively low by international standards. Its university research sector has only recently started to perform a larger share of public sector R&D and still produces small numbers of PhDs in S&E. The research system is also heavily skewed towards thematic R&D which is largely applied and development-oriented with a focus on industrial technologies, basic research increased to 35% of the total in 2012 and government support is more recently placing greater emphasis on “high-risk, high return” research*.’156

Korea’s STI policy objectives and approaches have changed significantly over time, as summarized in Table App.11 and Table App.12. In particular STI policy objectives have been broadened from a focus on industrial development and competitiveness to overall economic and social development objectives including sustainable and inclusive development:

“At the turn of the century, the Republic of Korea had narrowed the technological gap with leading advanced economies and achieved strong economic growth. STI policy was reoriented to address a broader and more complex set of challenges, First, its objective was shifted to comprehensive development that incorporated social and environmental concerns. Second, the previous export-led industrialization strategy had to be rethought in the light of increasing competition from accelerated development of such newcomers as China, and rapid population ageing. Third, the accelerated pace of technological development necessitated building innovation competencies to compete with technologically leading countries. The previous model of technology diffusion would no longer be effective. Fourth, the existing university education system needed strengthening in order to encourage creativity and diversify competencies for innovation-led growth.” ESCAP, 2018, p.27

Table App.11 Evolution of science, technology and innovation policy objectives and measures, Korea

	Pre-industrialization (1945-1959)	Catch-up phase (1960-1999)	Post catch-up (2000-present)
Strategic STI Policy objectives	Developing basic capabilities for industrial and economic growth	Sustaining strong economic growth by narrowing technology gap with the United States	Addressing economic, social and environmental challenges, and enhancing innovation-led growth
Key policy measures	Providing external support for technology imports and building domestic industrial capacity Establishing science and technology institutions	Supporting conglomerates to accelerate technology transfer and diffusion Making industry selections and rationalization Building domestic R&D capacity through government-funded	Sustaining industrial competitiveness advantage through strengthening basic research, investing in future technologies and new industries Supporting SMEs

156 EU, 2019.

research institutes and national R&D projects Expanding science and technology education	Developing a national innovation system through public-private partnerships

Source: ESCAP 2018. p.22

Table App.12: Development of Industry and Technology in Korea

	Industrial development	Technology development	Highlight
1960s	● Develop import-substitution industries ● Expand export-oriented light industries ● Support producer goods industries	● Strengthen S&T education ● Deepen scientific and technological infrastructure	1960: $79 ● Labour
1970s	● Expand heavy & chemical industries ● Shift emphasis from capital import to technology import ● Strengthen export-oriented industrial competitiveness	● Expand technical training ● Improve institutional mechanism for adapting imported technology ● Promote research applicable to industrial	1970: $253 ● Labour and capital
1980s	● Transform industrial structure to one of comparative advantage ● Expand technology-intensive industry ● Encourage manpower development and improve productivity of industries	● Develop and acquire top-level scientists and engineers ● Perform national R&D projects efficiently ● Promote industrial technology development	● 1980: $1655 ● Capital and technology
1990s	● Promote industrial restructuring and technical innovation ● Promote efficient use of human and other resources ● Improve information networks	● Reinforce national R&D projects ● Strengthen demand-oriented technology development system ● Institutional reforms	● 1990: $5890 Technology and innovation
2000-2003	● Move towards High tech and high value-added industries ● Develop IT industry ● Search the next generation engine of growth	● Strengthen national and regional innovation systems ● Internationalise R&D systems and information networks ● R&D increase in IT, BT, NT, ET, CT	2000: $9823 ●Innovation and KBE

Source: Hong, 2015, p.67

The Scope of STI Priorities

The S&T Basic Plan is the top-level STI policy document in Korea. It is a mandatory legal planning process established every five years by the Korean government.

In response to a perceived crisis of competitiveness, and in order to promote a stronger and more integrated STI policy, the Roh Administration (2003 - 2008) raised the level of the S&T Minister to Deputy Prime Minister and founded the Office of Science, Technology, and Innovation (OSTI) under the Ministry of Science and Technology[157]. The changes in governance reflected a major change in approach[158]:

"S&T-related policy was emphasized as a central national agenda. This promotion of S&T policy coupled with economic policy led to the conception of an "innovation-led economy," heralding innovation's emergence to the center of economic policy. Along with this, the scope of innovation policy was expanded from science and technology to a wider spectrum of policies required for resolving social issues. Innovation activities are no longer confined to strengthening the competitiveness of science and technology and private companies, but are connected to efforts to improve quality of life and balance regional development." (Seong and Song, 201, p, 102)

In recent plans the Government investment focused on new technology, such as information technology, biotechnology and environmental technology, to support growth industries and inclusive and sustainable development. This included the development of 30 green technologies, with investment in green technology R&D increasing from $1.8 billion in 2009 to $2.8 billion in 2012. Ten 'high priority action tasks' (for example in chronic diseases, cybercrime and food safety) were also selected by other ministries and they developed a Comprehensive Implementation Plan for Science and Technology-based Solutions to Social Problems[159].

Table App.13: Number of Future Technologies by Major Issue Groups- 5th Foresight

Major Issue Group	No. of Technology	Technology Name (Example)	Technology Description (Examples only)
Social Infrastructure	51	Decision-making Software to Support the Optimization of Building Maintenance Construction	Development of tool to select optimum choice & support decision-making considering the impacts of lifetime carbon emissions, the energy efficiency of the buildings, the indoor comfort and the cost for renovation of the buildings
Ecosystem and Environment Friendliness	59	Real-time Water Quality Monitoring and Management System Using Remote Exploration	Real-time continuous water quality monitoring and management system through remote sensor data processing, utilization, and integration operation including geostationary space, polar orbit resolution, geostationary orbital satellite images and multi-species / unmanned aerial vehicles
Transportation and Robotics	43	Underwater Rescue Robot	Robots to rescue people underwater in the event of a marine disaster
Medical and Life	47	Customized Heterologous Artificial Organ Cultivation System Using Individual Gene Map	Technology to replace human organs with minimum immune response (e.g. rejection of transplant) through gene manipulation of experimental animals using individual genes when cultivating a personalized organ for transplant
Manufacturing and Convergence	48	High-performance Electronic Component Printing Technology for Wide Flexible Devices	Technology to manufacture electronic component to secure leading manufacturing capability and originality in leading technology for the

157 Seong & Song, 2013.

158 Hong, 2015, p.83 suggests that: "The fundamental problem of Korea's NIS and S&T governance [at that time] was that the system was designed for the era of imitation and became inefficient and created bottlenecks for an era of innovation."

159 ESCAP, 2018.

			development of new functional products
Information & Communication	39	Haptic technology for Realization of Virtual Reality	Technology to generate a visual image and sound wave in a three-dimensional format that stimulates the visual and tactile sense in 3 dimensions to express virtual space information in real space

Source: KISTEP, 2017

Approach to Governance- Role of Planning (Vs Framework Conditions Etc)

The approach to priority setting is largely centralised and top-down with a focus on thematic priorities- very much following the approach in Japan. Priorities based on 'growth industries' and related 'key technologies', identified through TF studies, are linked to R&D subsidies in the selected thematic areas[160].

MOST, established in 1967 as the Science and Technology Agency, had the responsibility for formulating and coordinating STI policy and implementation. The Science and Technology Review Committee, established in 1973, took over the coordination function. This committee was chaired by the Prime Minister and included 14 ministers with science and technology responsibilities. This committee was widely seen as ineffective both in terms of coordination and in driving a clear link between STI policy and allocation decisions in the government budget[161].

This committee was replaced by the Science and Technology Ministerial Meeting in 1997 as part of a wider reform, the Special Law of Science and Technology Innovation. From 1998 the Minister of Science and Technology chaired the meetings. In 1991 the Presidential Advisory Committee for Science and Technology (PACST) was established as an advisory body, but began to take on a role in coordinating STI policy. PACST's role was to recommend long-term science, technology and innovation strategies. In 1999 National Science and Technology Council (NSTC) was established and it took over from other co-ordinating organisations. However, coordination and linking policy and practice have been continuing challenges, for several reasons[162]:

- MOST'S lack of power, particularly as the R&D activity of other ministries increased and they resisted coordination;
- Coordination by organisations chaired by the Prime Minister were subverted by coordination by organisations chaired by the president;
- The weak links between and the government budget process;
- Specialists advising on priorities lacked engagement in and understanding of the budget processes and budget bureaucrats lacked STI knowledge;
- A lack of STI statistics and indicators;
- Coordinating organisations changed frequently and met irregularly.

The Science and Technology Framework Law of 2001 was the most significant for STI as it determined the institutional framework for all STI rules and regulations. STI policy encompasses industry, human resources and balanced regional development. Under this law the NSTC was commissioned with evaluating national R&D programs, proposing the R&D budget and co-ordinating of R&D programs.

160 Yulek, & Han, 2017.

161 Hong, 2005.

162 Hong, 2005.

Level and Extent of High-Level Leadership of STI as a Priority

In the early 2000s the Minister for S&T was raised to the status of Deputy Prime Minister, signally the central role of STI in overall policy.

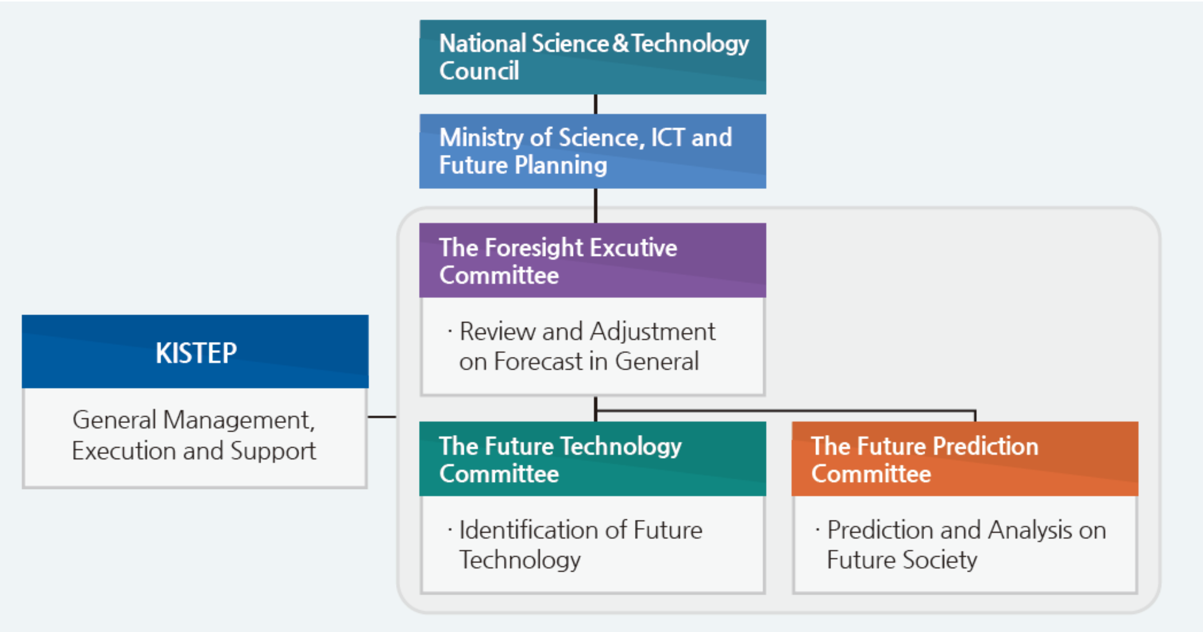
Organisations Involved in Priority-Setting

MOST has been the principal organization responsible for foresight studies, but, for planning within their areas of responsibility, other ministries have also conducted foresight studies: Ministry of Commerce, Industry and Energy (MOCIE), Ministry of Information and Communications (MIC), Ministry of Environment, the Ministry of Construction and Transportation, and the Ministry of Health and Welfare[163]. As many of these Ministries have large R&D budgets and there are sector-oriented government research organisations, both of which bring a conservative orientation to priority setting.

TF studies have been carried out by the Technology Foresight Center of the Korea Institute of Science and Technology Evaluation and Planning (KISTEP), a government-funded research institute in the area of S&T policy, R&D planning and evaluation, within the Ministry of Education, Science and Technology.

The implementation of the Fifth TF involved three committees under the overall guidance of KISTEP- Figure App.4. The identification of the mega-trends and significant trends identified in the TF is shown in Table App.14

Figure App.5 System for Implementation of the 5th Science and Technology Foresight



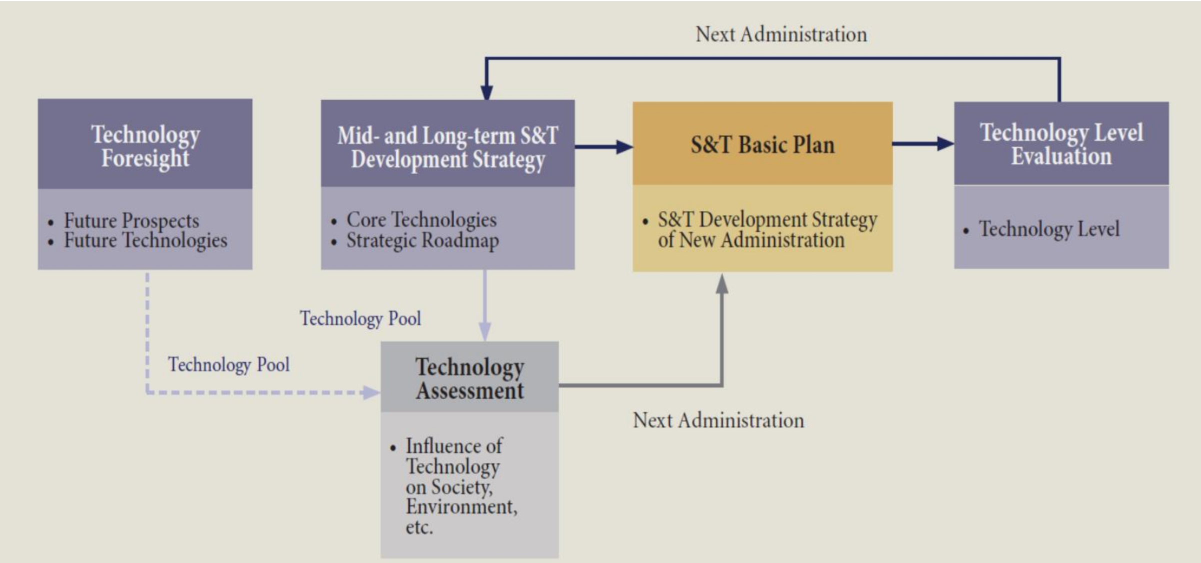
Source: KISTEP, 2017

Processes of Priority Setting

Korea develops a new S&T Basic Plan every five years and all S&T planning at the national level is linked to the S&T Basic Plan. A Mid and Long-Term S&T Development Strategy, selects national core technologies based on technology foresight (TF), and this is a foundation for each S&T Basic Plan – Figure App.5.

163 Choi, Y., 2003.

Figure App.5 STI Planning in Korea.



Source: Choi & Choi, 2015, p64.

For each of a set of 'future technologies' the S&T development strategies also set out a strategic roadmap. Future technologies are identified through a process with several stages:

- Foresight and Technology Assessment activities.
- Technology Evaluations are conducted every two years benchmark Korean performance against other countries;
- Technology Assessments, conducted annually and focused each year on only one targeted technology or S&T-related development. These assessments use a range of experts from the natural and social science and the humanities to assess the positive and negative of developments on society, the economy and the environment[164].

Technology Foresight (TF)

TF has had a major influence on STI priority setting in Korea. However, Hwang, et al (2011, p.425) note: "the government, a key stakeholder, has lost interest in TF due to the ambiguity of transforming TF outcomes to actual action plans". While, Choi and Choi (2015, p.64) note that: "The importance attributed to Korea's technology foresight (TFs) has grown with every round of TF. TFs have consistently provided background information that feeds into policies and medium and long-term S&T strategies."

In 2001 the "S&T Framework Law" required that TF studies are to be carried out regularly and further specifies that the findings are to be applied in S&T policy and that KISTEP is to be the managing organization. – Table App.14. In the early 2000s, the influence of TF on STI policy waned, but has since revived.

Table App.14: STI TF Studies in Korea.

	1st	2nd	3rd	4th	5th
Title of the report	Future technology of Korea	Future technology of Korea	Prospect of future society & future technology of		Discovering Future Technologies to Solve Major

164 Choi & Choi H. (2015).

			Korea – challenges and opportunities		Issues of Future Society
Survey: Preparatory	June 1992-May 1993	May 1997-May 1998	July -December 2003	2010-2012	2015-16
Delphi	August 1993-September 1994	June 1998-October 1999	June 2004-August 2004 (online)		
Survey areas	5	15	8	8	
Survey subjects/ technologies	1,174	1,155	761	652	267
Time horizon	1995-2015 (20 years)	2000-2025 (25 years)	2005-2030 (25 years)	2010-2035	2015-2040
Methods	Brainstorming, ·Delphi Survey	Brainstorming, Delphi Survey	Bibliometrics, Expert panels, SWOT analysis, Conferences	Horizon Scanning, Delphi Survey, Scenario Planning	Horizon Scanning, Delphi,·Scenario Planning, Tipping Point Analysis
Survey items	Degree of expertise, Importance index, Technology level, Realization time, Degree of confidence, Constraints	Adding "policy measures"	Adding "leading country" & "who will fund". Revised 3rd TF in 2007 considered the technology & society relationship	Considered the relationship between technology & society and possible negative impacts.	
Application			The 2nd Master Plan for Science & Technology (2008-2012)	The 3rd Master Plan for Science & Technology (2013-2017)	The 4th Master Plan for Science & Technology (2018-2022)

Sources: Hwang, et al. 2011; Choi & Choi, 2015; KISTEP, 2017

In the 2000s the semi-independent Delphi surveys were replaced by a 'whole-of-government' planning process, expressed in the 'Vision 2025' (2000), a National Technology Roadmap, and the '21st Century Frontier R&D Program'- See Tables App.15

Table App.15: The Long-term Vision for S&T Development toward 2025 (2000)

Stages

1. ***First Step* (by 2005):** Place the Korean scientific and technological capabilities at competitive levels with those of the world's twelve leading countries, and ahead of other Asian nations, by mobilising resources, expanding industrialised infrastructure, and improving relevant laws and regulations.

2. ***Second Step* (by 2015)**: Stand out as the hub of research in the Asia-Pacific region, actively engaging in scientific studies and creating a new atmosphere conducive to the promotion of R&D.

3. ***Third Step* (by 2025):** Secure a scientific and technological competitiveness in selected areas comparable to those of G-7 countries by forging ahead in specific sectors.

Key Objectives

- ***Knowledge, Information, and Intelligence-based Society*** - a society that provides infrastructure through which individuals, businesses and organisations can function in the most efficient way
- ***Society of Healthy Life*** - a society that enables its members to live healthy lives based on the development of science and technology in the areas of medicines, health and other related areas
- ***Sustainable Society*** - a society where human beings and the environment coexist in a mutually prosperous way
- **Val*ue-creating Industrial Structure*** - a society that enables conventional industries to survive and grow by helping them adapt to new technologies
- ***Enhanced National Security and Prestige*** - a society that can make the best use of new science and technology for national security, disaster prevention, food supply, and social integrity.

Source: Johnston, 2005; Government of the Republic of Korea, 2000

Table App.16 The National Technology Road Map [165]

The key technologies vital for global competitiveness in 10 years

I. Building an Information-Knowledge- Intelligence Society	*Supplying efficient/stable and clean energy*
Anytime, anywhere, any device communications	· Efficient use of energy
· Digital convergence	· Acquisition of future energy
· Intelligent computing	· Source and high value energy
· Ubiquitous network	***III. Advancing the Environment and Energy Frontier***
· Mobile & wearable IT Device	*Pleasant and healthy life*
Innovation in Contents and Service	· Reduction of environmental pollution
· E-commerce	· Recycling system harmonising with environment
· Business services	· Management of sustainable eco-system
· Knowledge/Information Society	*Supplying efficient/stable and clean energy*
Ambient Intelligence	***IV. Upgrading the Value of Major Industries of Korea Today***
· Intelligent man-machine interface	*Next generation transportation*
· Intelligent robot	· New automotive systems
· Intelligent home appliance	· New ocean transportation systems
· Intelligent building/home	· New railway systems
· Intelligent transport system	*Advancing residential building and social infrastructure*
· Intelligent medical system.	· Integrated transport system
II. Aiming at Bio-Healthpia	· User-friendly advanced construction
New drug discovery and development	· Sustainable natural resources and effective development of national land
· Cardiovascular	*Mechatronics*
· Anticancer agent	· Next generation manufacturing system
· CNS	· Advanced precision mechanical system
· Pulmonary	*Diversification of new materials*
· Metabolism	· New functional information materials/devices
· Immune System	· Nano materials

165 Johnston, 2005, p36-8

· Vaccines

Innovation in disease management
· Diagnostics
· Rehabilitation systems
· Medical Imaging systems
· Cell Therapy
· Gene Therapy
· Prognostic system

III. Advancing the Environment and Energy Frontier

Pleasant and healthy life
· Reduction of environmental pollution
· Recycling system harmonising with environment
· Management of sustainable eco-system

·Highly functional metals/ceramics/polymers/textiles

V. Improving National Safety and Prestige

Entering the aerospace age
· Satellites
· Development of launch vehicle
· Development of UAV
· Development of Helicopter

Food security and resources preservation
· Establishment of food self-sufficiency

The Fourth Technology Foresight (2008) looked ahead to 2035 and was developed through three stages:

1. An assessment focused on future social needs using analysis of megatrends and then identifying relevant S&T aspects- this stage also drew on foresight studies in other countries, particularly those of Japan. The work also included bibliometrics, SWOT, expert panels and conferences[166].
2. Identification of future technologies, using an iterative Delphi method, along with assessments of implementation issues, sources of knowledge, the main actors in innovation and application and relevant government policies – this process explicitly took into account technology push factors (based on trajectories of likely technology evolution) and technology pull factors based on the scope for technologies to address social needs. This stage sought a higher level of resolution by focusing on eight sub-sectors: information/communication, machinery/manufacturing, space/aerospace/marine, life/health, environment/disaster, energy/resources, parts/material, and construction/transportation.
3. Creation of scenarios for a range of application domains, such as homes, schools, hospital, factory, city, which facilitates a wider community engagement with the TF process and the S&T Plans.

The 2008 Korean TF exercise built on the lessons learnt from the previous studies. Figure App.6 provides an outline of the process, which involved the identification of five 'mega-trends' and then the identification of 20 'future issues'. For the study eight industry/technology sectors had been specified and structured by these sectors 25 'needs related to S&T were identified – Table App.17. Finally, 200 future technologies were selected and for each an assessment was made, by sector/technology experts, on the timeline for their commercial availability, within an horizon of 40 years. The estimated timelines of future key technologies in the energy & resources sectors is shown in Figure App.7. Finally, 90 technologies were identified as national key technologies for the next five years, from 2008 to 2012 and this priority list shaped the second S&T Framework Plan in Korea.

166 Hwang et al, 2011.

Figure App.6: 2008 Korean TF Exercise

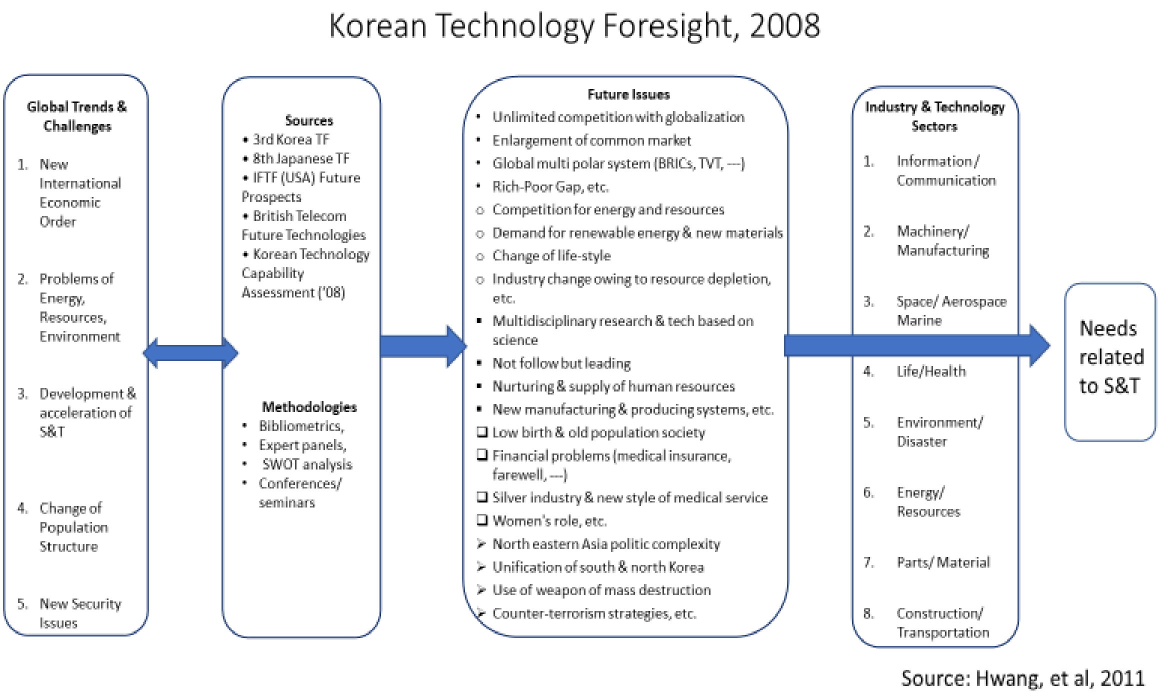
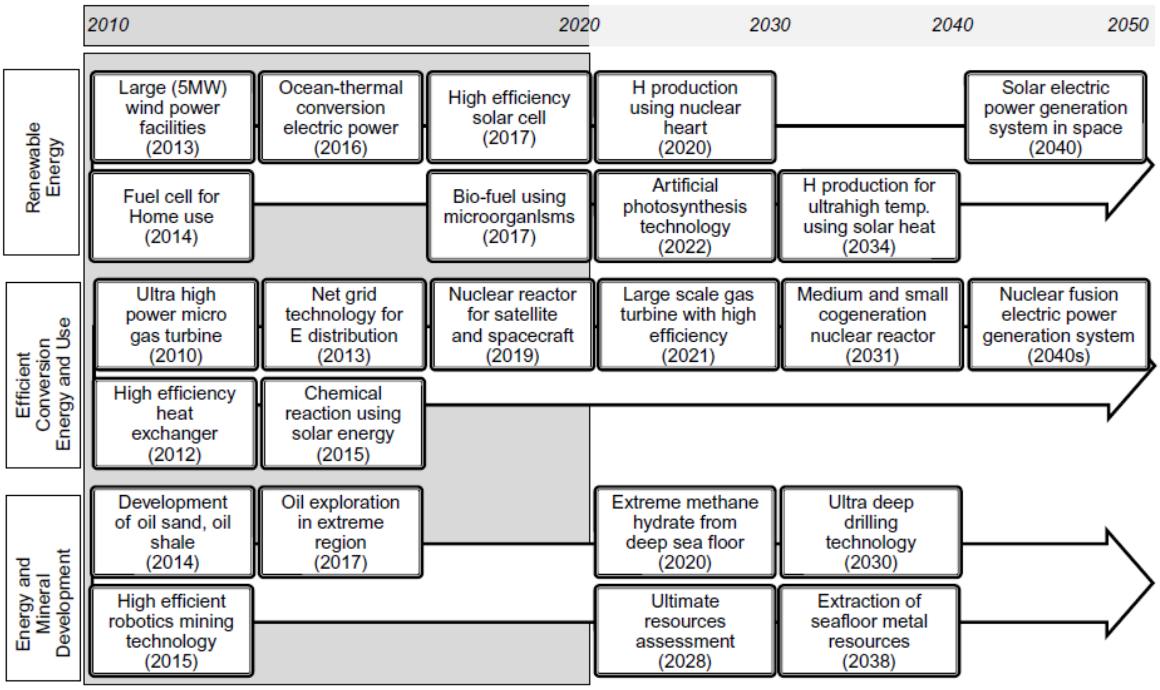


Table App.17: Needs Related S&T Issues Identified in 2008 TF

Industry and Technology Sectors	Needs Related S&T Issues
Information/ Communication	• IT based new industries • Development of fusion technologies with IT • Enlargement of cognitive ability & new communication service
Machinery/ Manufacturing	• New value creation in production & manufacturing • Demand on intelligent producing system • New industries including intelligent robot, etc.
Space/ Aerospace & Marine	• ST for military use and life convenience • Next generation aerospace (ex, S-UAV) • Surveillance and management of the sea, etc.
Life/Health	• Demographic impacts on health promotion and life extension • Prevention and cure of new disease • Demand on high tech medical facilities and service
Environment/ Disaster	• Maintenance of bio-diversity with environmental. • Global climate change technology • Accuracy of weather forecast and monitoring

	• Response ability on natural and artificial disaster, etc.
Energy/ Resources	• Demand on renewable energy • High efficiency in using resources and energy • Exploration of new energy and resources, etc.
Parts/ Material	• Acquisition of generic technology • Acquisition of emerging industries • Fusion and combined technology development, etc.
Construction/ Transportation	• Demand on new space and green technology • Improvement of old city infrastructure • Speedy and convenient transportation, etc.

Figure App.7: Estimated Timelines of Future Key Technologies in the Energy & Resources Sectors- 2008 TF.

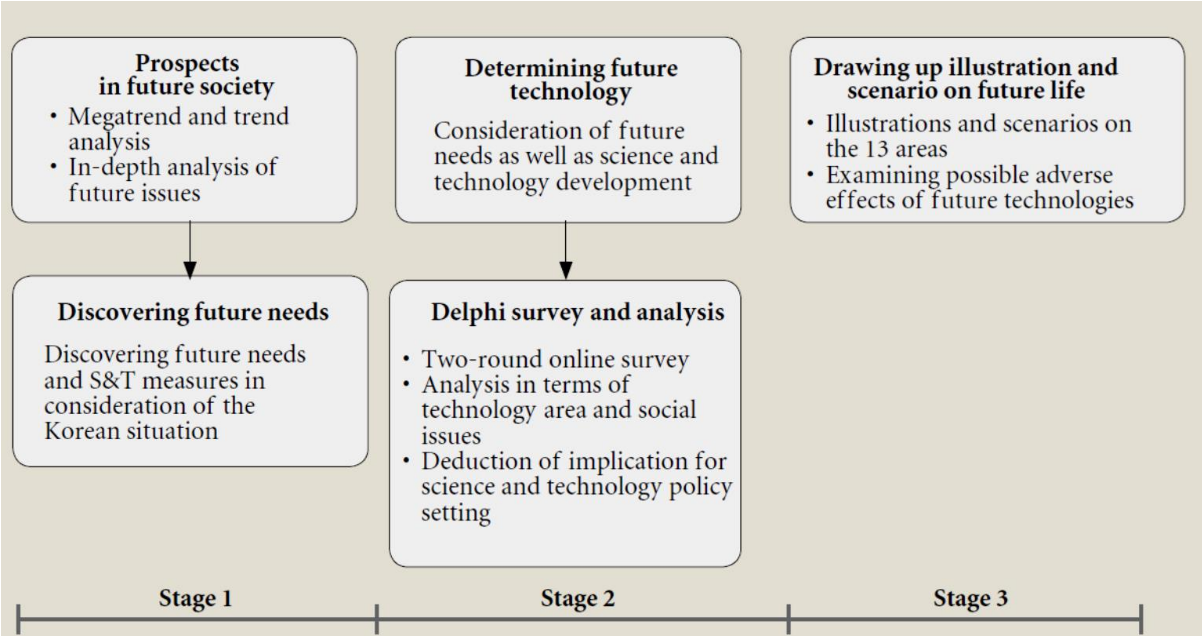


Source: Hwang et al, 2011.p. 425

The second S&T Framework Plan in Korea, 2008-2012, used outcomes of the 2008 TF to identify 90 key national technologies.

The 4th Korean TF (2010-2012) used a three stage Delphi process and included an assessment of future needs- Figure App.8. Like the third TF is considered a range of ‘mega trends’ and first order related developments – Table App.17. Social issues have had a larger role in more recent STI planning and policy, but the appropriateness of the STI institutions for addressing these issues is questioned (Seong, et al 2016.)

Figure App.8: Approach to Developing the Fourth Korean TF



Source: Choi & Choi, 2015, p.57

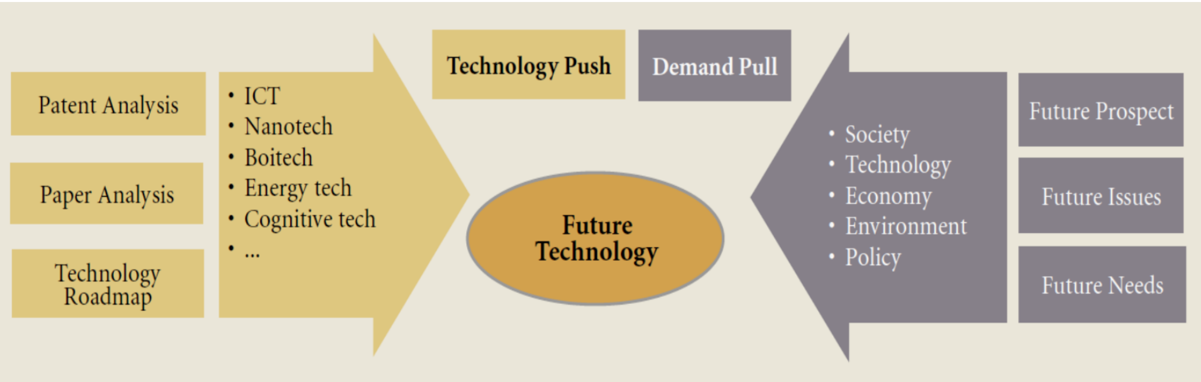
Table App.17: Megatrends and Trends of the Fourth TF

Megatrend	Trend
Further globalization	• Integration of the global market • Multi-polar world order • Globalization of workforce • Extension and diversification of the governance concept • Rapid spread of epidemics
Increasing conflicts	• Deepening of conflicts between peoples, religions, and nations • Increase in cyber terrorism • Increase in risks of terrorism • Greater polarization
Demographic changes	• Continuously low birth rates and ageing populations • Increase in urban population globally • Changes in the concept of family
Greater cultural diversity	• More cultural exchanges and multicultural socialization • Improvements in women's status
Depletion of energy and resources	• Increased demand for energy and resources • More shortages of food and water • Greater use of energy and natural resources as weapons

Greater climate changes and environmental problems	• Greater global warming and increases in abnormal weather phenomena • More environmental pollution • Changes in ecosystems
Continuing rise of China	• Increase in China's economic influence • Increase in China's diplomatic and cultural influences
Development and convergence of science and technology	• Development of information technology • Development of life science technology • Development of nanotechnology

The Fourth TF used a range of methods and sought to consider technology push drivers and a wide range of demand side factors – Figure App.9. The Delphi survey drew on over 6000 responses for the first round and over 5000 for the second. The survey questions were more comprehensive than in earlier TFs – Table App.18.

Figure App.9 Methods to Identify Future Technologies Used in Korea's Fourth TF



Source: Choi & Choi, 2015, p.59

Table App.18 Delphi Survey Items of the Fourth TF

Survey item	Survey content
Technology level	Nation at the forefront of the technology level Korea's technology level
Technological implementation time & social distribution time	Implementation time, and general public use time in Korea Realization time & general public use time in most-advanced tech nations
Technological implementation measures	Main actors in R&D The need for collaborative research
Role of government	The need for government investment Government priority measures to be implemented
Importance in future society	Contribution with respect to technology aspects; public benefits; and to the economy and industry.
Possibility of negative effect	Possibility of negative effect caused by general public use

Institutions involved in research	Local and international research institutions
Interrelationship with future trends	Relationship to 22 future trends

Source: Choi & Choi, 2015, p.60

The 652 future technologies identified by the 4th TF were reviewed by committees that were responsible for the national R&D budget and by the ministries with STI-related R&D activities. Finally, 120 national strategic technologies were selected and identified the Third S&T Basic Plan.

The 5th TF, 2015-2016, had three objectives:

1. predicting the future society considering the internal and external environmental changes, and predicting and analyzing the future technologies expected to appear up to 2040, based on the development of S&T and future social demand;
2. contributing to STI planning and policy;
3. predicting the *tipping points* of technology in terms of social uptake, with a focus on those major innovative technologies likely to have an impact on the real lives of the people.

Table App.19: 5th TF Trends and Mega-Trends

Mega Trend	**Trend**	**STEEP**
Human Empowerment	Increased Life Expectancy	Social
	Self-centered Society	
	Decrease in Birth Rate	
	Empowerment of Women	
	Expansion of Human Capability	Technological
	Hyper-speed Transportation	
	Artificial intelligence and Automation	
	Development of New Materials	
	Opening of the Space Age	
Innovation through Hyper connectivity	Digital Network Society Social	Social
	Hyper-connectivity Technology	Technological
	Network-driven Transition of Power	Political
	Acceleration of E-democracy	
Deepening Environmental Risk	Aggravated Food Crisis	Environmental
	Energy Imbalance	
	Water Deterioration Crisis	
	Increase in Natural Disasters	
	Deepening Ecosystem Destruction	
Intensification of Social Complexity	Deepening of International Conflict	Social
	Expansion of Cultural Diversity	
	Deepening Socioeconomic Inequality	
	Creation through Fusion of S&T	Technological
	Increased Side Effects from Technological Advances	
	Increase in Social Disasters	Environmental
	Increased Health Risk Factors	
	Raising of Unification Issue	Political
	Increased Liquidity of International Power	
	Evolution of Security Threats	
Reorganization of the Economic System	Global Population Movement	Social
	Expansion of Urbanization Social	
	World Population Growth	

	Enhancement in the Connectivity of the Global Economy Emergence of Developing and Emerging Countries Expansion of China's Global Influence Spread of New Economic System Change in the Structure of the Labor Field Continuing Low-growth Risk in Developed Countries Invigoration of Greenomics Shift in Manufacturing Paradigm Change in Market Pattern	Economical

STEEP (Social, Technological, Environmental, Economic and Political)

Source: KISTEP, 2017

Based on the results of the trend analysis and further assessments, a set of 40 major issues was identified. For each of these major issues a technological capability requirement (need) was defined; for example for the major issue, *Development and Expanded Supply of Renewable Energy*, the defined response was *Bio-ethanol Efficiency Improvement Technology.*

The 'technology push' side of the TF was developed through time-series analysis on each research field to identify new and emerging technology and research fields in order to construct a Science Map, which was then used by experts to identify likely significant new technologies. Among these candidates were “innovative technologies” defined as technologies with the potential significant impacts on the everyday lives of the public – 24 such technologies were selected.

For the 5th TF KISTEP defined *future technologies* as '*concrete technologies (products, services, systems, etc.) that will be technically realized by 2040 and are likely to have a significant impact on science, technology, society and economy in the Republic of Korea'167*. The list *of 267 future technologies* was based on an initial set of candidates based on needs/technological capability requirement assessment and the knowledge maps based on the six future issue groups identified through the analysis of the major issues and the links between them- Table App.19.
The characteristics, importance, timing of realization, and required government policies were assessed for each of the 267 candidate future technologies through a two round Delphi survey using 4,133 science and technology experts. The Delphi surveys were used to rate each of the future technologies in terms of eight criteria[168]:

- Technological Criteria (5-point System)
  - Innovativeness
  - Uncertainty
  - Negative Impacts
- Significance (5-point System)
  - Scientific
  - Public
  - Economic/ Industrial
- Year Realized (Year)

167 KISTEP, 2017, p.14.

168 The full list and ratings is at https://www.kistep.re.kr/en/c3/sub4.jsp.

- Government Policy (Top Priority)

Evaluations and Technology Roadmapping

As noted above evaluations at the level of technologies and roadmapping have important roles in assessment for the TF studies and in implementation of STI priorities:

> *"The Technology Level Evaluation targets the national strategic technologies as indicated in the S&T Basic Plan, and takes place every two years. The Technology Level Evaluation exercise compares the technological levels of Korea, the United States, China, Japan, and the EU using Delphi survey methods, patent analyses, and research paper analyses. Those who devise strategic roadmaps for national core technologies use the results of this evaluation as inputs. The Technology Assessment evaluates the positive and negative impacts caused by new S&Ts on areas such as the economy, society, culture, ethics, and the environment... Korea conducts a Technology Assessment annually, and as part of this assessment surveys not only experts from the humanities, social sciences, and S&T, but also members of the public." (Choi & Choi, 2015, p.64-5)*.

Technology Road Mapping is the main foresight method at the sector level, where it is used by both government and private corporations and thinktanks. Anderson, et al (2014, p.10) report that many leaders of STI planning in Korea consider that: "*a sector-level approach is needed because national technology foresights do not supply sufficient details for making the necessary planning and prioritization in sector level R&D…[and] that Korea must move beyond doing national-level foresights because their outputs are too superficial to be implemented in actual R&D programs*."

Many large corporations in Korea have used technology roadmapping (TRM) for planning their innovation strategies. The Korean government attempted to use TRM at the national level in 2002. A large effort was organized with 74 teams of experts and 751 participants overall, drawn from industry, academia and research. The TRM focused on 'visions' in five areas: Building an Information-Knowledge-Intelligence Society; Aiming at Bio-Healthpia: Advancing the Environment and Energy Frontier; Upgrading the Value of Existing Major Industries of Korea; and Improving National Safety and Prestige. This focus led to identifying 99 key technologies. However, one of the key participants in the project – and in other Korean foresight studies - concluded that the analysis, based largely on the views of S&T experts, did not sufficiently integrate socio-economic factors into the analysis and hence did not bring useful insight into the demand-supply interaction[169].

Approach to Consultation

The extensive TF studies engage a large number and wide range of sector and technology experts, but as the scope of STI policy has widened the appropriateness of these approaches has been questioned. According to Schlossstein & Park (2006) the first and second TF studies had limited impacts on policy, which, they suggest, was due to: "*exclusion of key stakeholders and weak government commitment to implement results*"[170].

Horizontal and Thematic Priorities

STI planning in Korea focuses on thematic priorities. Following the reforms of the early 2000s, there has been a greater focus on the NIS, although in practice the focus remained on the government led and funded aspects of the NIS.

Integrating Innovation Goals

169 Choi, 2013.

170 Andersen et al, 2014.p. 9.

As noted above the Office of Science, Technology, and Innovation (OSTI) was set up by the Roh Administration (2003 - 2008) and this change in governance reflected a major change in approach[171]. OSTI's staff were recruited from the Ministry of Science and Technology, other ministries, and the private sector. The OSTI's key role was facilitating coordination of policies, across Ministries, by supporting the National Science and Technology Council (NSTC) and the S&T Ministerial Meeting. However, the OSTI was closed down in 2008 as a result of government restructuring. Seong and Song suggest that:

"OSTI failed to build the appropriate governance for integrated innovation policy.. In the case of Korea moreover, the country now has to pursue post-catch-up innovation that goes beyond the previous developmental era's catch-up innovation, and policies promoting the exploration and experimenting of new directions are more important than the effective achievement of defined targets. The governance adopted by the OSTI in contrast was closer to the top-down approach often adopted in catch-up innovation…. No ministry welcomed the idea of submitting to the OSTI in its coordination activities based on budget authority when its agenda-setting capability or political influence was weak. This is why there were attempts to nullify the OSTI" (Seong and Song, 201, p, 110)

While these inter-ministerial tensions remain, the was a return to the role of Technology Roadmaping in the more recent STI planning.

The integration of innovation goals into STI planning has been limited by the high level of uncertainty in foresight studies: *"High uncertainty for the direction of S&T progress has linked to poor performance in foresight activities. Those emerging technologies such as information technology, biotechnology, nanotechnology, etc. are regarded as the new driving forces of technological progress, but in reality, there is no clear sign for the future direction of progress in those areas."*[172]

Implementation of Priorities

Implementation issues, in terms of the uptake of new technologies, have been explicitly considered in TF studies. However, several commentators have noted a weak level of links between priorities identified in TF studies and government budget allocations.

Coordination of Implementation

The challenge of coordination among the major ministries and with the private sector increased in complexity and significance over time: "*Some ministries attempted to seize power and set up duplicate research institutes and programmes; this resulted in inefficient R&D investments. Co-ordination of the science and technology function within the government was weak….Various ministries' overlapping policy measures have resulted in smaller-scale resource allocation and inefficient management of funds instead of greater efficiency through inter-ministerial cooperation.. Another problem is that competitive regional development plans for technologies, technoparks, regional innovation centres, etc., have resulted in duplicate programmes and poor project selection*"[173]

M&E and Policy Learning and Adaptation of Policies

According to Hong (2015 p.74, 76) "..*the fundamental problem of the Korean NIS was the non-existence of a function for reviewing and co-ordinating government R&D programmes. Quite often myopic projects were pursued instead of long-term strategic projects. Duplications and uncoordinated priority setting resulted in inefficient resource allocation…..Monitoring and evaluation*

171 Seong & Song, 2013.

172 Choi,,2013, p.6.

173 Hong, 2015, p.74, 76.

*of national R&D programmes were not well developed. Superficial evaluations prevailed and participation of the private sector in the evaluation process was minima*l."

6.3.5 Malaysia

The economic development of Malaysia has been marked by both successes and challenges. Since its independence, Malaysia has moved from an economy based on primary commodities to one driven by manufacturing and services, with the third highest GDP per head among the ASEAN nations. However, in the past two decades the dynamism of the Malaysian economy has progressively lessened. “The previous ‘virtuous cycle’ – driven by a combination of comparative advantage of low labour costs, favourable framework conditions and targeted incentives to attract FDI – which transformed Malaysia into a thriving manufacturing export platform has lost momentum as its economy matured and moved up the income scale.”[174]

The OECD has recommended the Malaysian economy be reshaped to deliver more innovation-driven productivity gains. The Government has recognised the challenge and made efforts to advance its STI capacity. There has been a strong increase in the number of researchers, and new universities have been created. GERD increased steadily until 2016, but has declined since then. As the OECD put it, “the results of this effort have not lived up to the high expectations.”

The commitment of Malaysia to develop an effective STI system is demonstrated by the First National Science and Technology Policy (1986-1989), The Industrial Technology Development : A National Action Plan (1990-2001), and The Second National Science and Technology Policy and Plan of Action (2002 – 2010). These contributed to the largely structural priorities of enhancing national R&D, forging partnerships between publicly funded research organisations and companies, enhancement of commercialisation through the National Innovation Model, and development of new knowledge-based industries.

During the early 2010 there was an apparent focus on the use of foresight, with roadmaps developed for the following sectors:

- Environmental Sciences
- Advanced Material Sciences
- Agriculture Sciences
- Life Sciences
- Chemical Sciences
- Mathematics & Physical Sciences
- Computer Sciences & ICT
- Health & Medical Sciences
- Engineering Sciences
- Humanities & Social Sciences[175]

However there is no evidence that this approach is still very influential.

A National Policy on Science, Technology and Innovation 2013-2020 was described as grounded on five fundamental foundations, which may seem rather opaque and lacking in specificity to the outside observer:

174 OECD, 2016.

175 https://www.myforesight.my/.

- STI for Policy - STI should be mainstreamed and implemented by all ministries, agencies, private sectors and relevant stakeholders;
- Policy for STI - the nation's STI capacity and capabilities should be enhanced in terms of institutions, mandates, management, personnel, funding and deliverables;
- Industry Commitment to STI - strengthening industry STI capabilities to play a more active role through various incentives and measures.
- STI Governance - reinvigorating the nation's existing STI framework in order to enhance the execution of policies and provide mechanisms to ensure commitment by all parties towards the development of STI in the country; and
- STI for a stable, peaceful, prosperous, cohesive and resilient society – to provide an environment which encourages creativity, risk taking, and rewards market-driven ideas.

These foundations were required to embody six "strategic thrusts", which can largely be seen as structural priorities:

- Advancing scientific and social research, development and commercialisation
- Developing, harnessing and intensifying talent
- Energising industries
- Transforming STI governance
- Promoting and sensitising STI
- Enhancing strategic international alliances.

The first of these 'thrusts' was transformed into thematic priorities reflecting a strong societal perspective:

- Biodiversity
- Cyber Security
- Energy Security
- Environment and Climate Change
- Food Security
- Medical & Healthcare
- Plantation Crops & Commodities
- Transportation & Urbanisation
- Water Security

But the track record of Malaysia on being able to effectively implement priorities, regardless of the effort that has gone into their formulation, is addressed only by a set of very general prescriptions:

- Formulate a Science, Technology and Innovation (STI) Act for orderly implementation of the national STI agenda in 2013
- Strengthen and streamline STI related councils

- Transform and enhance PRIs' governance to ensure efficient management and effective implementation of their core functions
- Provide greater autonomy to public and private IHLs and PRIs to spur industry collaboration and entrepreneurship.

There is strong evidence that it is the structure and governance of the Malaysian STI that has proved a major impediment to effective priority setting.

Thiruchelvam [176] characterises Malaysia's NIS as:

- being largely public-sector driven despite being supply-side in orientation;
- reflecting a strong political commitment to STI but weak delivery and execution;
- marked by a sound institutional framework but weak management - "weak institutional leadership at all levels has resulted in needless duplications and lack of focus. There are far too many public agencies engaged in STI resulting in lack of focus and thinning of resources. The Ministry of Science, Technology and Innovation (MOSTI) which is expected to play the coordinating role in this agenda is too weak to perform this task."
- suffering from poorly developed linkages.
- limited attention to enhancing absorptive capabilities.
- lacking focus: "Malaysia's public sector research funding program is characterised by far too many areas of funding as well as too many schemes."

These views of the inadequate governance of the Malaysian STI system, and the extent to which this has impeded the effective operation of priority setting are reinforced by the OECD's review of Malaysian innovation policy. They state: "the many commendable initiatives undertaken during this period to support the emerging knowledge economy have been confronted with weaknesses in governance, and difficulties in implementing reforms of an increasingly complex system of innovation. More co-ordination appears to be needed among actors and policies, and funding requires some prioritisation". One strong indicator is that as funding for STI has grown, so have the number of institutions involved. At the time of their report there were 44 agencies and 10 ministries engaged in initiatives to support STI activities.

"All agencies charged with the implementation of strategic plans and programs, are confronted with the complexity in organisational structures, programs and instruments. Frequent changes in the system further add to its complexity and reduce transparency. The competition between institutions to keep and even sometimes extend their prerogatives in STI has triggered successive rounds of change in the STI policy landscape. This instability tends to reduce the system's effectiveness as, more than most other policy areas, it requires time to build the necessary relationships of trust, develop a shared understanding and send clear signals to all the actors in the STI system... Conflicting guidance is also a major problem - several STI advisories co-exist with partially overlapping remits".

A counter example of an apparently very effective priority setting initiative in Malaysia is provided by the National Green Technology Policy. This was launched by the Prime Minister in 2009 with the purpose of making green technology one of the essential factors for economic growth and coincidently decreasing the energy consumption rate. The staged objectives entails achieving both a system transition, from a conventional one to green technology, and the building of a whole new sectoral system of innovation.

176 Thiruchelvam, 2017.

To achieve the latter, the different policy actions include increasing foreign direct investment in green technology, upgrading national research capability and the domestic green tech industry in order to become a major global producer of green technology. Implementation is the sole responsibility of the GT Corporation (GreenTech Malaysia).

In addition, a National Green Technology Council, chaired by the Prime Minister, was established to provide high-level co-ordination between ministries, agencies and other stakeholders. Under the National Green Technology Policy, a green technology roadmap was created in order to define the main challenges, indicators and mechanisms of green technology expansion and implement the most successful policies. In essence, this priority-setting program involved the creation of a new, commanding system of governance for this field.

The central message to be taken from the experience of priority setting in Malaysia is the need for adequate attention to all the stages of priority-setting. It is not simply the exceedingly complicated business of determining what is an appropriate priority for a particular country. A shortlist would include:

- establishing broad support for the concept that priorities should be set, realising that a substantial diffusion of resources across a wide range of fields will not generate international competitiveness;
- designing and conducting a process to select a limited set of priorities involving participants from as wide a spread of interests as possible;
- designing appropriate mechanisms and resources to direct funds where they are most likely to be effective, with minimal duplication;
- establishing clear measures of metrics and accountability;
- ensuring that once a system is designed, that, beyond normal probity requirements, bureaucratic interference and rule-making is minimised;

recognising that in any priority setting exercise there are losers that may need to be engaged in supporting the larger process, and adapting their interests to the new priorities.

6.3.6 Singapore

In their seminal book, *Research Foresight: Priority-Setting in Science,* Martin, and Irvine, [177] pointed to seven essential features of such strategies: (i) agreement that planning is necessary, if only to expose the issues; (ii) agreement that consensus is necessary to move ahead; (iii) inclusion of decision-makers to grant authority and (iv) of experts to give legitimacy to the final decisions made; (v) an advance commitment to act on the findings; (vi) having the resources necessary to analyse trends and capacities and to plan, and eventually exploit, the recommendations; and (vii) disseminate the findings to those whose involvement and participation will be required.

Singapore's strong record in progressively developing their capability to identify and articulate priorities, both thematic and structural, to support the pursuit of the priorities through adequate resourcing, to engage the appropriate players in pursuing the objectives collaboratively, to assess the operation and inadequacies of implementation and to learn from them in order to formulate the next set of priorities, adjusted both to this learning and the changing needs and environment of the country, suggests they have adapted Martin and Irvine's dictum to their own purposes very effectively.

It has been suggested[178] that the combination of the Singaporean government's strong commitment to fostering education, the priority given to natural sciences and engineering, partnerships with leading international universities and research institutes, and the creation of publicly funded research centres linked to industrial needs that created a carefully managed mechanism combining institutional development by government and informal priority setting by the epistemic community: "It was the very creation of a critical mass of researchers at the outset which allowed the effective distribution of incentives in a later phase … policy sequencing is one key to success… This allowed for policy learning in the epistemic community, which could so maintain its influence (or at least connection) with policy making, leading to better informed policy addressing the perspectives of both companies and research establishments."

The evolution of this capacity for effective priority setting can be seen through the successive Five-year plans, initially called 'Science and Technology Plans' and 'Research, Innovation and Enterprise Plans' since 2015.[179]

On the catch-up and industrialisation phase to2010 Singapore transitioned to a technology and capital-intensive economy. The goal of STI policy was to create modern high-value-added industries and foster innovation to remain competitive and ensure economic growth. Singapore built its R&D capacity, promoted SMEs, particularly for technology-based innovation, and invested heavily in human capital.

The first National Technology Plan 1995 focussed on economically driven R&D, with the injection of S$2 billion by the National Science and Technology Board. It served as a blueprint for R&D development in nine thematic sectors: information technology; microelectronics; electronic systems; manufacturing technology; materials technology; energy, water, environment and resources; food and agro technology; biotechnology; and medical sciences. The second five-year plan doubled the budget to $4 billion to assist in develop Singapore's S&T infrastructure around the same nine sectors.

In the Science and Technology Plan 2005 the focus was shifted towards knowledge- and technology-based innovation, which were seen as the next economic growth drivers. To reflect this change, the NSTB was renamed as the Agency for Science, Technology and Research (A*STAR), with the goal of

177 Martin & Irvine, 1989.

178 Box & Engelhard, 2006.

179 The Plans are given the year date of completion ie the 2020 Plan was launched in 2016.

driving mission-oriented research that advances scientific discovery and technological innovation. Whereas previously the focus was on manufacturing, largely as suppliers and contract manufacturers for multinationals, the new emphasis was on IT, software, Internet applications, biotechnology and life sciences.

There was also a committed effort to recruit leading international scientists and forge international collaboration and partnerships. Local capacity was also enhanced, with the number of research scientists and engineers in Singapore growing from 28 in 1990 to 87 per 10,000 of the labour force in 2004. This is an example of a structural priority, with clear measurable indicators of its direct effect, and broader analysis of the flow-on effects on the economy.

In 2006, the Research, Innovation and Enterprise Council (RIEC) was established, composed of high level government officials, prominent industry leaders, and internationally renowned members of the scientific community. A National Research Foundation (NRF) was also formed to support the RIEC through policy formulation and implementation.

The Science and Technology Plan 2010 allocated S$13.55 billion to promote R&D - $5 billion for longer-term strategic programs, $7.5 billion for economic-oriented R&D and related investment promotion activities, and $1.05 billion for academic research. The goal was to achieve a GERD of 3% of GDP by 2010. Environmental and water technologies and the interactive and digital media sectors were identified as rapid growth areas for development.

1. The 2015 Plan was named the Research, Innovation and Enterprise 2015 Plan. It built on the momentum set in the 2010 plan with 6 key “thrusts”:
2. Continued emphasis on basic science and knowledge as basis of future innovations.
3. Focus on talent attraction and development, positioning Singapore as choice location for researchers
4. Greater emphasis on competitive funding as a selection means for the best ideas for optimal resource allocation
5. Fostering greater synergies between private and public and more funding for multi-disciplinary breakthrough science
6. Heavier weighting of R&D to promote positive economic outcomes
7. Strengthen support for commercialisation to encourage development of products and services.

The Research Innovation Enterprise Council (RIEC), the body that sets the strategic direction for national R&D, dedicated 70 %of Singapore’s five-year R&D budget to achieving economic outcomes in 2015, five percent more than the budget five years previously.

The most recent Research, Innovation and Enterprise 2020 Plan provides an extensive report on progress towards achieving structural priorities. These include the international standing of Singapore’s universities, which have steadily risen in global rankings, progress in becoming a nexus for international R&D collaboration, with the Campus for Research Excellence and Technological Enterprise (CREATE) having established 15 joint research programmes between local universities and ten top overseas institutions, the establishment of more than twenty research institutes under A*STAR that straddle the spectrum from fundamental to applied research, the growth of the pharmaceutical industry in Singapore, with A*STAR working with 30 leading pharmaceutical companies from around the world and A*STAR’s approach to open innovation which has seeded a new food, nutrition and consumer care innovation cluster in Singapore that has led to the creation of over 1,000 R&D jobs.

The government committed $19 billion to research, innovation and enterprise in this Plan prioritised in four strategic technology domains where Singapore has competitive advantages and/or important national needs. These are advanced manufacturing and engineering, health and biomedical sciences, urban solutions and sustainability, and services and the digital economy.

The Plan also announced s continued shift towards more competitive funding (from 20% of public funding for research in RIE2015 to 40% in RIE2020) to support the best teams and ideas, and more 'White Space' funding (from $1.6 billion in RIE2015 to $2.5 billion in RIE2020) to allow greater flexibility in reprioritising funding towards areas of new economic opportunities and national needs as they arise over the next five years.

Since the mid-2000s, innovation has increasingly been a central component of the Government's broader economic policy. The scope of STI policy has been broadened and deepened towards building an innovation-centred economy. Under the Smart Nation Initiative the Government is investing in new areas of innovation. A new agency, Government Technology Agency, or GovTech, which is aimed at transforming how the Government delivers public services to its citizens, is rolling out various platforms, such as a service to make the payment of tuition easier for citizens, and a trade information and management system for businesses. It is intended to leverage big data analytics, artificial intelligence and machine learning to transform public service delivery. Through investments in public sector innovation, it has also become a consumer of the innovation it seeks to foster. Simultaneously, it has adopted a holistic approach to innovation, increasing its application to non-technological areas, such as supporting innovations in productivity, human resources and financial management in SMEs. These latest advances in the scope of structural priority setting reflect a growing interest in and a need for priorities that are determined by societal needs and opportunities, forming a new class of mission-oriented priorities.

The progressive development and application of priority setting in Singapore has produced a key advance in the capacity of its STI infrastructure, through the growing number of participants with experience and competence in priority formulation and execution, extending down to the intermediate and operational levels. This poses the desirable challenge regarding the appropriate division of tasks between these levels, with the policy level being in charge of the broad strategic orientations and budget allocations, and the more operational levels concretising thematic and structural priorities.

The experience and effectiveness of the priority setting processes in Singapore offer a number of signal lessons for Vietnam, which is still largely at the 'catch-up' phase of development.

First is the need to construct and evaluate the priority setting process not in terms of success or failure, but rather what can be learnt to improve the next iteration. This is characterised as 'double-loop learning', which entails the modification of goals or decision-making rules in the light of experience. This may require not only a change in the design, but also a revisiting of the organization's underlying norms, policies and objectives.

Second is the systematic building of capacity, through all the players in the STI system, to engage effectively in the establishment, interpretation, implementation and evaluation of priorities. This requires not only the commitment of sufficient resources to modify the behaviour and ambitions of researchers, but also of capturing and applying the learning of those involved in the priority setting process.

Third, priority setting for science and technology needs to be thoroughly integrated with, and reflect, the broader national ambitions. Singapore has committed to becoming a 'Smart Nation', "where citizens live meaningful and fulfilled lives empowered by digital technology, where digital connectivity leads to stronger community bonds and many more opportunities for Singaporeans to pursue their aspirations and contribute to Singapore's future.[180] This focus is being applied to reshape the priorities in all aspects of the STI system.

Finally, the OECD STI Outlook 2018 draws attention to emerging technological and social disruption. For example, "a number of "game-changers" stand out, notably the rise of artificial intelligence which holds the potential for revolutionising the scientific process and new poles of STI activity are taking root, opening up new opportunities for countries to benefit from science and innovation. At the same time, issues of privacy, digital security, safety, transparency and competition have all risen up the policy agenda, defying quick solutions and demanding new and coordinated policy responses."[181]

Quite clearly, the disruptors of new classes of technologies, the threat of climate change, the need for sustainability, and the changing global political order, signal that priority setting must be conducted in a full awareness of the changing context.

180 RIE2020 Plan.

181 OECD, STI Outlook 2018, Paris.

6.3.7 Taiwan

Scope of STI Priorities

In Taiwan, science, technology and more recently, innovation prioritisation has been an integral part of the national development plans. Science, Technology and Innovation (STI) prioritisation has been critical in guiding the different stages of development of Taiwan. While there has been an increasing focus on science, research and engineering as a way to develop a skilled and competent workforce through the education system, innovation and technology diffusion priorities have played a central role in Taiwan's industry policy not only for building capabilities in firms but also for creating new industries and supporting them into international competition.

Most of the literature, including World Bank's reports, acknowledges the central role of government in changing the basis of comparative advantages of Taiwan's economy by prioritising particular industries and systems of production (for example changes from OEM to ODM and OBM[182]).

A historical review over the last 50 years shows that important changes in the economy were in alignment with the aims of national plans and priorities. Taiwan changed from a labour-intensive export-oriented economy in the 1960s to a capital-intensive economy in the 1980s by promoting state-owned firms in chemical and heavy industries. Technology transfer policies and the government research institutes (e.g. ITRI) were critical for the establishment of the semiconductor industry and science parks in the 1990s. Broader objectives such as the increasing focus on the environment were present in the 2000s 'Green Silicon Island' vision and the Challenge 2008 National Plan. The recent 5+2 Industrial Innovation Plan is part of a broader national vision to make Taiwan a more equitable society but also a 'critical force' in the global economy.

The role of STI as a critical instrument to achieve this vision is put forward in the 2015-2018 White Paper on Science and Technology. The White Paper proposes eight strategies to achieve the vision.

- Bridge the gap between the supply and demand for skilled human resources by advancing science and technology entrepreneurial environment
- Establish Taiwan as a global leader in green technology by creating a low-carbon intelligent society
- Implement effective mechanisms for sustainable development by making economic growth compatible with the environment
- Establish intellectual property portfolios as a way to strengthen industry innovation
- Accelerate intelligent industrial upgrading by prioritising emerging industries
- Build a prosperous and vibrant society by providing safety and security, and promoting a smart and healthy living
- Build a diverse and inclusive society by implementing sustainable regional-urban development

Approach to Overall Governance

The approach to the governance of STI prioritising has evolved significantly in Taiwan. Top-down policymaking processes have been replaced by more consultative mechanisms with stakeholders from the private sector, universities and think-tanks.

182 OEM: Original Equipment Manufacturing; ODM: Original Design Manufacturing; OBM: Original Brand Manufacturing.

Currently, STI priority setting comprises both a top-down process and a bottom-processes. The National Science and Technology Conference, convened every four years, is the key platform for developing the National Science and Technology Development Plan. At the same time, a significant input for this conference is the four-year national plan that provides the national vision as well as guidelines influencing STI priorities. The conference offers a two-way communication integrating top-down policy directions and bottom-up demands and ideas from key stakeholders. Key stakeholders from industry, governmental, academic and research sectors participate in this conference.

The National Science and Technology Development Plan results from consensus positions and conclusions achieved at the National Science and Technology conference. This plan is approved by the Executive Yuan.

While Taiwan's government is heavily involved in STI planning has also been involved in providing framework conditions affecting the innovation system. For example, the government has had a key role in establishing science parks with the explicit objective of developing strong industry-academia linkages. The Hsinchu Science Park established in 1980 has been an enormous success hosting the giants TSMC and UMC semiconductor foundries and well as two universities specialised on electronic engineering. More recently, it established science parks in central and southern Taiwan. These parks, due to their strategic position, connected by high-speed rail, and close to pools of talented engineers and scientists, have attracted high technology local and international companies. In 2017, the combined income from the three science parks was about U$78 billion, with 71% of this income coming from exports.[183] In the last national plan, there is an increasing focus on supporting other framework conditions such as entrepreneurship.

Level and Extent of High-Level Leadership of STI as a Priority

A significant difference between Taiwan and developed OECD western economies is that the Executive plays a higher role of leadership and involvement in developing the national development plan. STI issues are a central part of this national plan. This national plan contents several major projects or programs including those about science, technology and innovation.

The weight of STI on Taiwan economic planning is present the 2021-2024 national development plan released in July 2020 by the National Development Council. This plan shows Taiwan's future path for economic growth and foreign relations. According to the plan, a top priority is that Taiwan achieves a commanding position in the global supply chains in six core strategic Industries. This is expected to be completed by cultivating talents, spurring investment, easing regulations and helping local businesses build up brands with global reach. Taiwan's president in her inaugural speech also refers to these industries as the pillar of the new economic model. The six core strategic industries are:

- Information and digital technology
- Cybersecurity
- Biotech and medical technology
- National defence
- Green and renewable energy
- Strategic stockpile industries

Organisations Involved In Priority-Setting

At the highest level is the Executive Yuan's Board of Science and Technology (BOST). Even though its name only includes the words of science and technology, innovation is a critical area of responsibility

183 https://topics.amcham.com.tw/2019/03/new-directions-for-taiwans-science-parks/.

for this board. BOST is chaired by the Premier, who is a chief minister of the Executive. BOST includes all relevant ministers with portfolio responsibilities for STI such as the ministry of science and technology, economic affairs, national development, finance & budget, infrastructure, education, health, culture and agriculture. This board also includes selected prominent researchers and business people. The board has a key role in STI prioritisation as it is responsible for approving the National Science and Technology Development Plan and decisions about STI resources allocation in the budget. It is also responsible for reviewing the national S&T agenda and vision. It has the Office of Science and Technology, which serves as administrative and secretarial support.

The National Development Council (NDC) is the policy planning agency Taiwan's government executive branch[184] responsible for the four-year national plans. NDC works with Ministry of Science and Technology (MOST)[185] coordinating national level STI policies and programs, including prioritisation, presented in the national development plan. In the development of the four-year national plan, the Ministry of Science and Technology, the Ministry of Economic Affairs (MOEA), other ministries and local governments are consulted in relation to STI aspects of their portfolios. Each involving agency is responsible for consulting with the private sector, think tanks, and relevant stakeholders during formulating of the science, technology and innovation policies.

In short, NDC established the broad national guidelines including resolutions on science, technology and innovation in the national development plan. MOST takes responsibility for planning and coordination science and technology policies and MOEA focus on industrial innovation.

As explained in section 2, MOST is responsible for the National Science and Technology Conference, National Science and Technology Development Plan and the Science and Technology White Paper. The latest National Science and Technology Development Plan (2013-2016) established seven goals, 27 strategies and 58 necessary measures. The seven goals were:

- Raise Taiwan's Academic and Research Status
- Strategise Intellectual Property Arrangement
- Promote Sustainable Development
- Bridge Academic Research and Industrial Application
- Advance Top-Down National Science and Technology Projects
- Promote Innovation in Sci-Tech Industry
- Address Taiwan's Human Resource Crisis in Scientific and Technological fields

From these goals, the fifth goal: 'Advance Top-Down National Science and Technology Projects' is specific about sectoral prioritisation through projects that are of critical national importance[186], the other six goals a more horizontal in nature and are discussed below.

The government drafts a white paper on science and technology two years after the release of the National Development Plan. The science and technology white paper provides the government's vision for scientific and technological development, implementation strategies, and an analysis of the STI current situation in Taiwan and selected countries

184 NDC was formed on 22 January 2014 after the merging of Council for Economic Planning and Development, Research, Development and Evaluation Commission, part of the Public Construction Commission and part of the Data Management Processing Centre of the Directorate General of Budget, Accounting and Statistics.

185 The Ministry of Science and Technology (MOST) was created from the former National Science Council in 2014.

186 The six Nation Science and Technology Projects listed in the latest National Science and Technology Development Plan are: Networked Communications Program (NCP), National Program on Nano Technology (NPNT), National Program for Intelligent Electronics (NPIE), National Science Technology Program on Energy (NSTP); National Research Program for Biopharmaceuticals (NRPB); and the Taiwan e-Learning and Digital Archives Program (TELDAP).

Processes of Priority Setting

There is not a straight-forward linear process of priority setting in Taiwan's bureaucracy and policymaking. Priority setting occurs at several levels of political or policy responsibility. There are a number of feedback loops as well as top-down and bottom-up mechanisms between different agencies, stakeholders, boards and committees.

However, it is useful to start with the National Science and Technology Conference, explained in section 2. This conference serves as the primary mechanism to gather ideas about priorities from key stakeholders in the Taiwan innovation system. These stakeholders' priorities are discussed in the context of the national development plan, which provides directions about the national vision, economic priorities, industry targets and role of science, technology and innovation.[187] The agenda for the conference may include ad hoc topics such as the results from a national foresight exercise or deep dives on particular scientific or technological trends.[188] The key outcome of the National Science and Technology conference is the National Science and Technology Development Plan.

Some of the priorities proposed in the National Science and Technology Conference may be included in the National Science and Technology Development Plan if they receive enough support in the conference. STI priorities included in the National Science and Technology Development Plan are approved by Executive Yuan's Board of Science and Technology. Finally, the science and technology white paper presents the official vision for scientific and technological development and the implementation strategies.

The other high-level process, which is explicit at STI prioritisation and targeting, is the National Development plan explained above. The latest National Development Plan includes the 5+2 Industrial Innovation Program, which targets seven critical areas driving the next phase of innovation in Taiwan (see Infographics in Figure App 10.). The national science and technology projects[189] (see footnote 5) that expect to help to solve critical gaps in the innovation system are also ways in which priorities are established.

Approach to Consultation

Taiwan has democratised its policymaking process considerably. The Taiwan agenda 21 legislation lists a number of principles to be considered in the development of policies. One of the principles is the need for transparent and open policy processes enriched by widespread consultation as a means to achieve consensus.

The richness of actors in the Taiwan innovation system facilitates consultation for developing STI policy. The national conferences, including the National Science and Technology, are the principal consultative processes for developing STI policies. [190]

The Executive Yuan's Board of Science and Technology is a diverse board with at least six members from the industry sector. The board works closely with the Ministry of Science and Technology in formulating the National Science and Technology Development Plan in conjunction with the National Science and Technology Conference. The BOST assists the Premier in S&T policy decision-making and serves as a platform for coordinating related government agencies and domestic policy-research institutes.

187 See for example the 5+2 Industrial Innovation Program proposed by the President Tsai Ing-wen.

188 https://stli.iii.org.tw/en/epaper_hx.aspx?auid=851.

189 These national R&D projects are also called Top-Down National Science and Technology Projects.

190 In addition to the National Science and Technology Conference, the government employs various major conferences and meetings to achieve a consensus on STI policy directions. These are: the Executive Yuan's Strategy Review Board Meeting on Industry, the Executive Yuan's Strategy Review Board Meeting for Industrial Science and Technology, the Advisory Board Meetings of the Executive Yuan, the Science and Technology Development Advisory Conference, and the National Industrial Development Conference. See 2015-2018 Science and Technology White paper https://www.most.gov.tw/most/attachments/71f29c3f-0532-41c3-a088-c90a3f84600a.

Agencies with science portfolios often consult independently with the private sector, think tanks, and relevant stakeholders during formulating of their science, technology and innovation policies and programs.

Horizontal and Thematic Priorities

Taiwan policymakers have followed implicitly or more recently explicitly innovation system approaches to identify gaps and problems in the economy and industry. Academics, however, have used NIS approaches as a tool to criticise government policies.[191]

There has been a clear evolution to more horizontal policies from an initial sectoral focus. The driving theme of industry policy has been industrial upgrading through innovation. The latest National Science and Technology Development Plan report argues the common Taiwanese strategy of OEM/ODM manufacturer for big multinationals needs to change. The report provides an analysis of South Korean firms that produce their own brands and argues that it should be a model for Taiwan electronics manufacturing.

Historically, Taiwan has used broad policies to promote technology diffusion, industry-research collaboration, supporting intellectual property, science parks, R&D targets and promoting technology-based exports. The promotion of brands and the certification of products “well made in Taiwan” has been an essential aspect of developing high-quality exports of manufacturing products.

Competence building has been an important policy theme for education and STI policies.[192]

However, in the past, Taiwan also has followed concrete import substitution policies to replace critical imported products of high value-added. A good example is the bicycle industry.[193]

The recent 5+2 Industrial Innovation Program, a key part of the latest National Development Plan promotes several policies. From developing a competitive agriculture sector (New Agriculture) to an Asian Silicon Valley (see Figure App.10). Some of these policies have elements of a mission, for example, the Green Energy Industry Development or the creation of the Asian Silicon Valley in the city of Taoyuan, near to the main international airport.

Integrating Innovation Goals

Although often names of agencies, conferences and plans use the words of science and technology, policies and actions show that science, technology and innovation are well integrated. Looking at the key policies of MOST and MOEA, innovation is a common area in both agencies. Below are listed the current key policies for both ministries

Ministry of Science and Technology

- Funding research grants and awards
- National science and technology projects
- Administration of science parks
- Artificial intelligence innovation ecosystem plan
- Green energy innovation plan

Ministry of Economic Affairs

- Industrial innovation and R&D

191 Balaguer et al,2008.

192 Ibid.

193 Chu, 1977.

- Strengthen support for start-ups and SMEs
- Energy Transition Promotion Scheme
- Enhancement of water resources management and flood preparedness
- Enhancing foreign trade and economic patterns and diversity
- Improving the investment environment

MOST supports the green energy and artificial intelligence plan through different support mechanisms including funding for research infrastructure, funding for R&D grants and collaboration with other agencies, research institutes and private sector.

Implementation of Priorities

To understand the implementation of STI priorities is useful to look at the national science and technology development plan. This plan has four goals, 18 strategies, and 57 specific measures. Seventeen different ministries and other agencies implement this plan. The implementation of the specific measures may include funding for R&D or commercialisation programs, funding for training of personnel in particular STI areas, funding for research infrastructure, award and prizes, etc. Each of the agency reports annually to MOST on the status of the implementation.

In Taiwan there is not an innovation agency; the main responsibilities for STI rest on the MOST and the MOEA. According to the 2015-2018 Science and Technology White paper (p.30)[194], the central government's budget for STI was $NTD 93.8 (A$ 3.6 billion) with 41% allocated to MOST and 28% to MOEA.

Coordination of Implementation

The Executive Yuan's Board of Science and Technology (BOST) has a prime role in reviewing the country's STI vision but also carries out inter-agency coordination. Each agency with an STI portfolio relies on its own STI budget to implement the government's STI policies through programmes approved in the science and technology national development plan.

Four main types of organisations are the final performers of research and innovation programs. First, it is Academia Sinica (equivalent to the academy of science) and universities that mainly focus on basic research and some applied research. Secondly, there are a large number of research and technological institutes and state-owned enterprises that belong to ministerial portfolios. For example, the Industrial Technology Research Institute (ITRI) and Information Industry Institute (III) that are part of the MOEA. Thirdly, non-profit institutes, hospitals and other research organisations that receive government funding and finally, private enterprises recipients of grants or other direct and indirect benefits from government programs.

In short, implementation is similar to most OECD market economies, in which the budget process determines the allocation of resources to different agencies. Then, agencies run their own processes for distributing funding to recipient organisations. What is different in Taiwan system, it is the more hierarchical and strategic role of the Executive Yuan, which ensures that downstream processes are aligned national vision of STI in the national development.

17. Monitoring, Evaluation and Policy Learning and Adaptation of Policies

Monitoring and evaluation at the level of program do not differ substantially from the methods used in Australia and other OECD western countries. However, MOST and BOST provide guidelines about

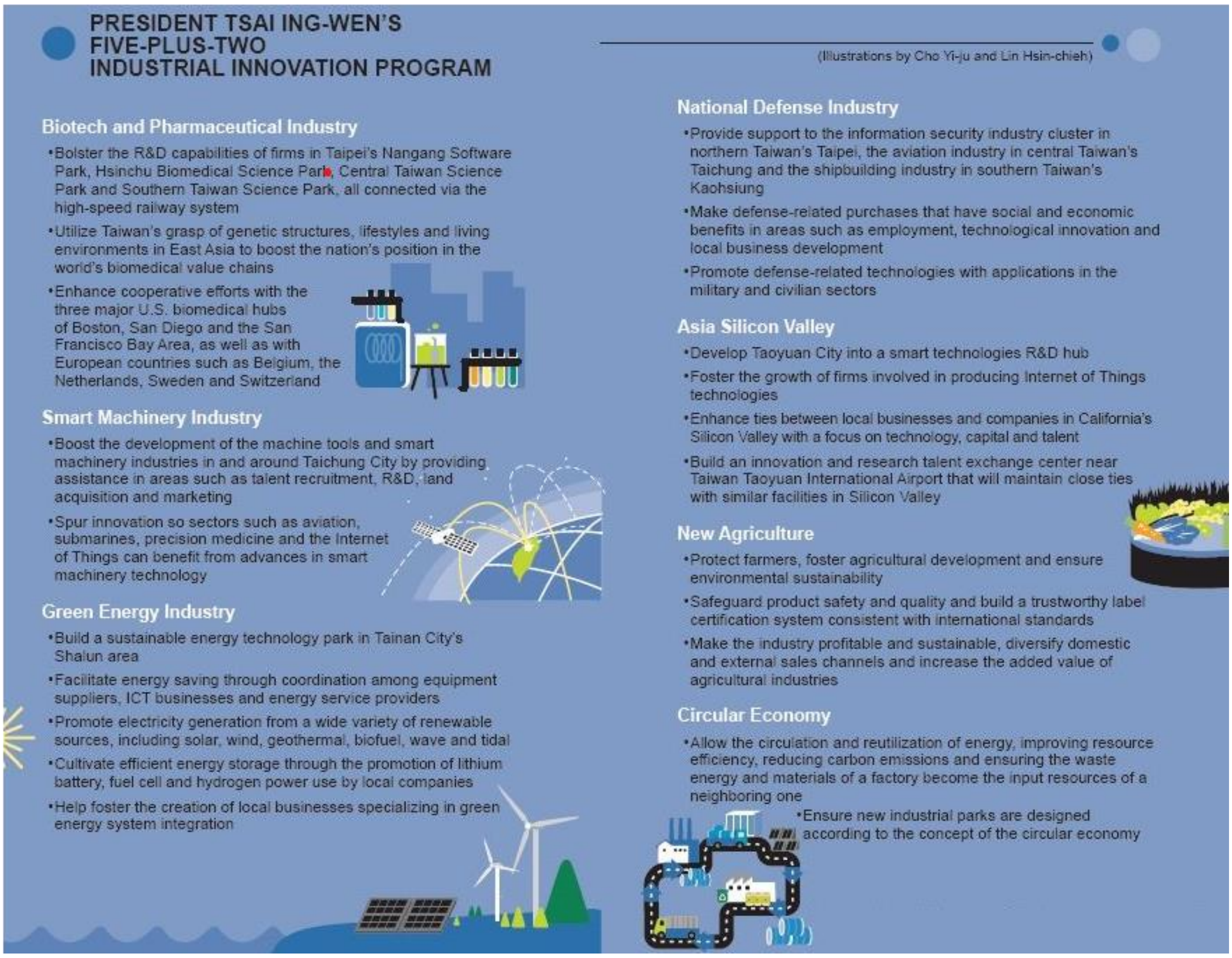
194 https://www.most.gov.tw/most/attachments/71f29c3f-0532-41c3-a088-c90a3f84600a.

the evaluation process. Recently, guidelines have increased the emphasis on the important independent evaluations and the use of independent industry experts, including from overseas.[195]

At system level, the national conferences and BOST strategic meetings have shown to be robust mechanisms to evaluate Taiwan's innovation system performance. Based on the information presented in reports from national science and technology development plans and the white paper, these fora are highly critical and provide abundant comparative evidence of the performance of other national and sectoral innovation systems.

Additionally, looking at the academic literature[196] assessing the role of public policy supporting the Taiwan innovation system, it can be concluded that the government has done a job learning from past experience and adapting to global changes. It also has deepened the use of STI as a critical tool to maintain international competitiveness.

Figure App.10: Industrial Innovation Strategy



195 https://www.most.gov.tw/most/attachments/8b9357a1-04f8-4043-834a-323b96302733 p.

196 Amsden & Chu, 2003.

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