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Abstract: This paper analyses science, technology, and innovation (STI) policy making in Iran between 1990 and 2022 using the network governance approach. Four phases of STI policy are identified: human resources and publication boom, agencification era, comprehensiveness quest, and innovation turn. The analysis shows a low degree of decentralisation, good coordination,

and successful interdisciplinary collaboration. However, challenges such as the pipeline model of innovation, performance measurement politics, and controversial government and university roles hinder policy reform. To create a national innovation system, a normative turn toward a broader societal definition of innovation is recommended, and the government should shift its role to facilitator rather than interventionist.

Keywords: STI policy; governance framework; network governance; historical perspective; evolutionary analysis; Iran' STI landscape; Iran.

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1 Introduction

Iran has made marked improvement in science, technology and innovation since 1990 and has move toward knowledge-and innovation-based economy (UNCTAD, 2016, p.ix) "in spite of abnormal obstacles in the path of the country's development" (Soofi et al., 2013, p.xi). According to the World Intellectual Property data in 2011 (Iran's first year of

presence in the index), the country's rank was 95 among 125 countries. Since then, Iran has improved to rank 67th among 132 countries in 2020 (Dutta et al., 2020, p.17). This has happened because science, technology and innovation (STI) policy has gone through major technological transformation since the establishment of the republic. Nonetheless, despite strong presence of Iran in development indicators and noticeable achievements in stem cells, defence industry, biomedicine, nanotechnology and nuclear industry, Iran suffers from Swedish paradox i.e., "weak performance in innovation and economic performance" in spite of "extraordinary focus on science and technology" (HamidiMotlagh et al., 2020). "Prometheus remains bound" and innovation paradox is prevalent (Cirera and Maloney, 2017).

For almost two decades, science and technology (S&T) policymaking in Iran has been the subject of several studies (Ghazinoory et al., 2009; Salami and Soltanzadeh, 2012; Soofi et al., 2013; Soofi, 2017; Soofi and Ghazinoory, 2011; UNCTAD, 2005, 2016). The primary motivation for the study of STI policymaking in Iran has been to remedy the deficiencies and overcome challenges in the governance structure of STI policymaking institutions. A couple of context-specific features make STI policy governance in Iran totally unique: direct and indirect government interventions, plentiful natural resources, persistent double-digit inflation and "tight international sanctions" (UNCTAD, 2016, p.x).

STI policy governance includes a wide range of tasks and activities focusing on complex interactions among various actors. Making timely decisions, determining priorities, (re)defining roles and optimal functions for various actors, all, fall within the scope of STI policy governance (Laranja, 2012). In addition, creation of a holistic perspective about future, continuous cooperation by actors, prioritisation, and preparation of innovation agendas (Gassler et al., 2008), analysis of obstacles to the progress of STI policies, and embedding policy learning in the policy process are important as well.

In recent years, numerous studies have focused on improving and promoting the governance of innovation policies. The emphasis has been on the necessity of enhanced policy coordination and involving a wider range of stakeholders in the innovation process. Moreover, there has been a growing recognition of the limitations of previous hierarchical governance mechanisms that were primarily confined within specific departments (Bauer et al., 2012; Edler et al., 2003). The increasing complexities of innovation policy, which now extends beyond the realms of science and technology to areas such as health, agriculture, and industry, require a multi-level and multi-faceted approach to design and implementation. Given the ineffectiveness of traditional governance mechanisms, there is a need to explore the advantages of network governance in addressing the fundamental requirements of innovation policy (Bauer et al., 2012; Borrás, 2007; Edler et al., 2003; Braun, 2008). Among the emerging approaches that effectively respond to the demands of the innovation landscape is the network and multicenter approach to governance.

In this paper, we will first develop a historical evolutionary perspective of various phases STI policy in Iran resulting in a roadmap of milestone events since 1994. Next, we will use network governance lens to evaluate different dimensions of policy evolution during this period. Finally, we will contextualise our findings in the literature to make some policy recommendations. This paper is structured as follows: in Section 2, some definitions and preliminary remarks of theoretical foundations are reviewed. Then in Section 3, the research method is elaborated. Section 4 provides a historical analysis of

STI policy governance in Iran through four periods. In Section 4, findings are discussed and finally, conclusion is provided in Section 5.

2 Theoretical foundations: some definitions and preliminary remarks

In this section we will glean some definitions and theoretical assumptions from the relevant literature. Kim and Dahlman (1992, p.437) define science and technology policy as "a set of instruments the government uses in promoting and managing the process and direction of acquiring such capabilities". But, Innovation, is application of those capabilities to the economic process (Metcalfe, 2003). "While S&T defines the accumulation and exploitation of knowledge to solve a given problem, innovation connects it to the market" (p.97). In the literature one way to connect S&T policy to innovation policy is through establishment of National Innovation System (NIS). NIS italicises the significance of interdependencies between various components of the system (Nelson and Rosenberg, 1993) and thus "offers a holistic view of rather than focusing on isolated aspects of the process" (Schrempf et al., 2013). According to the literature (Lundvall, 2016), internal organisation of firms, inter-firm relationships, public sector, specifications of finical sector, R&D intensity and R&D organisations are the main elements of NIS.

The next relevant concept in this paper is governance for which there are many definitions. However, this paper is based on the definition by Lynn et al. (2000): "The means for achieving direction, control, and coordination of wholly or partially autonomous individuals or organisations on behalf of interests to which they jointly contribute". Jones et al. (1997) define network governance as follows:

> "Network governance involves a select, persistent, and structured set of autonomous firms (as well as nonprofit agencies) engaged in creating products or services based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinate and safeguard exchanges" (Jones et al., 1997, p.914).

In the scope of STI policy, the term "governance" is quite new and has been developed through gradual development of NISs by policymakers (Laranja, 2012). These networks involve the civil society in the process of decision making (Rhodes, 1996). Salazar and Holbrook have referred to the basic nature of network governance as coordination based on cooperation, unanimity, and multilateralism (Salazar and Holbrook, 2007). The main advantages of network governance approach to governance are: Avoiding or minimising overlaps, minimising political and bureaucratic conflicts, facilitating consensus on priorities, avoiding political contradictions (Braun, 2008), creating horizontal coordination (Damgaard, 2006; Mayntz, 1993), increasing hierarchical (vertical) coordination, and adopting a comprehensive and "whole government" perspective (Braun, 2008). Moreover, network governance tends to eliminate horizontal and vertical communication obstacles leading to higher trust and increased cooperation among the actors (Goldsmith and Eggers, 2005; Rhodes, 1996). In order to facilitate cooperation, STI policy needs bodies which put "participation and dialogue itself into practice" (Dutrénit et al., 2018, p.305). This may improve the quality of policy-making and could remove many frictions on the way of innovation development. Furthermore, it could properly respond to the policy requirements by reducing the time of certain activities as

well as by considering the requirements of end-users of innovation. In particular, inter-disciplinary and multi-disciplinary interactions result in qualitative and quantitative improvement in policy learning (Cunningham and Ramlogan, 2012) which, in turn, reinforce collective learning processes (Cunningham and Ramlogan, 2012; Newig et al., 2010) through the expansion and complexity of communications (Stefan Kuhlmann, 2002; S Kuhlmann et al., 1999; Laranja, 2012; Tübke et al., 2001). Finally, the policy could be implemented both by supporting various actors involved in the policy implementation (Conteh, 2009; O'Toole and Meier, 2004; Rickne et al., 2012) and by making entities involved in innovation policies more accountable (Arnold et al., 2002; Laranja, 2012). In the literature of STI policy governance, improved accountability and evaluation are considered as requirements for pluricentric governance (Arnold et al., 2002; Cunningham and Karakasidou, 2009; Laranja, 2012). However, the literature of network governance shows that the improvement in accountability and evaluation faces multiple ambiguities due to multiplicity and lack of clear understanding of the responsibility of each actor in the implementation processes (Esmark, 2007; Keast et al., 2006; Yang, 2007). STI governance involves aligning actors with roles and responsibilities to achieve common objectives and create value. The active participation of actors who collaborate, build trust, share knowledge and information, and generate innovations and solutions is crucial (Hoffmann et al., 2022). Here the type of governance should help address challenges related to integration, collaboration, collective learning, and coordination, especially in contexts where diverse actors and horizontal relationships are necessary but can lead to conflicts and confusion (Foguesatto et al., 2021).

Innovation policy includes wider dimensions compared to science and technology policy and challenges the traditional borders and power communications among policy areas (Pelkonen, 2006). Meanwhile, the increasing trend of being horizontal has increased the importance of public acceptance, which sets the grounds for the development of new more cooperative governance (Todt, 2011). This, in turn, highlights the government's mediating and empowering role (Borrás, 2009; Pelkonen, 2006). Boekholt et al. (2002) consider the method to achieve coherent STI policy as one of the most important governance issues. They consider coherence and integration in three key dimensions. First, integration of knowledge creation (mainly fundamental research) and commercial application of knowledge. Second, coordinating various social and economic goals of research, while integrating STI policies among various sectoral departments. Third, combining knowledge from various fields of science in order to meet the needs of inter-disciplinary research. In addition, cases such as the way research organisations and funding entities should be held accountable, national and regional coordination, and governance of multi-disciplinary areas, such as nanotechnology and genomics, – particularly when new fund should be injected to these areas – are considered to be of paramount importance for STI governance (Arnold et al., 2002). In developing countries, accountability concern becomes even more important because of lack of enough government commitment to publicly funding these areas (Niosi, 2010). According to several authors, a network approach to governance promotes learning, trust-building, and voluntary contributions (Gifford et al., 2021; Könnölä et al., 2021; Autio, 2021). It also encourages participation, information exchange, and collective problem-solving (Oliveira-Duarte et al., 2021). Through coordination, actions are directed towards common goals (Könnölä et al., 2021).

More recently, "transformative innovation policy" has been suggested which accentuates the political nature of paradigm shift and calls for "broader conceptualisation

of transformative innovation" (Diercks et al., 2019, p.1), and … "a socio-technical understanding of innovation" (p.13). Also, Responsible Research and Innovation emphasises that "knowledge and solutions should be co-produced by diverse actors working in synergy, including civil society and citizens" (Deserti et al., 2020). These co-produced and co-created solutions call for a fundamental change in essence of STI policy. Foguesatto et al. (2021) suggest that understanding governance and different forms of governance in various innovation ecosystems is an important area for research. Wegner and Verschoore (2021) also note that despite progress in network governance modes for policies, there are still gaps that need to be addressed. Table 1 shows the dimensions of network governance in STI policy collected from the literature:

Table 1 Dimensions of network governance in STI policy

Dimensions	*Definition and manifistations*
Vertical Coordination	Coordinating governance of STI policies in various levels (vertical) (Cunningham and Karakasidou, 2009)
Policy Coherence	Coordinating policy mix and integratioon of policies (Cunningham and Karakasidou, 2009)
	Coordinating agendas and innovation priorities (Laranja, 2012)
Horizontal and Inter-Sectoral Coordination	Governance in systemic, horizontal and coordinated manner (Edler et al., 2003)
	Considering levels of governance other than innovation governance in policy mix (Cunningham and Karakasidou, 2009; Foguesatto et al., 2021)
	Integrating STI policies among different departments (Arnold et al., 2002; Cunningham and Karakasidou, 2009)
Political Coordination	Integrating three sub-systems of the society including the political, scientific and economic systems (Bauer et al., 2012; Foguesatto et al., 2021)
	Co-evolution of the political system and the innovation system (Stefan Kuhlmann, 2001; Hoffmann et al., 2022)
Coordination in Innovation Chain	Integration of science policies and innovation policies (Arnold et al., 2002; Laranja, 2012)
	Converging the areas of science and technology, research and development, and industrial policy (Cunningham and Karakasidou, 2009; Laranja, 2012)
Improving Policy and Learning Intelligence	Distributed Policy intelligence (knowledge and responsibilities) in innovation policy (Kuhlmann, 2002; Kuhlmann et al., 1999; Foguesatto et al., 2021)
	Determining reflecting overall social, scientific and technological trends (Laranja, 2012)
	Improving existing resources of policy intelligence (Tübke et al., 2001; Foguesatto et al., 2021)
Improving Communications, Creating Trust, and Increasing Stakeholders involvement	Active involvement of stakeholders in the policy cycle (Cunningham and Karakasidou, 2009; Laranja, 2012; Hoffmann et al., 2022)
	More negotiatory structure of governance (Pelkonen, 2006)
	More cooperative structure of governance due to increase in the importance of public reception (Pelkonen, 2006)

Table 1 Dimensions of network governance in STI policy (continued)

Dimensions	*Definition and manifistations*
Multi-Disciplinary and Inter-Disciplinary Interactions	Necessary interactions in governance of inter-disciplinary areas (Arnold et al., 2002; Laranja, 2012)
	Necessary interactions in governance of multi-disciplinary areas (Arnold et al., 2002; Kuhlmann et al., 1999; Hoffmann et al., 2022)
	Necessary interactions in areas relating to pervasive social issues (Arnold et al., 2002; Könnölä et al., 2021)
Better evaluation and Accountability	Improving the evaluation system of STI policy (Cunningham and Karakasidou, 2009; Laranja, 2012)
	Increasing the quality of accountability by research organisations and funding entities (Arnold et al., 2002; Laranja, 2012)
Facilitation of Policy Implementation	Creating strong allies in the political system to facilitate the policy Implementation (Rickne et al., 2012; Gifford et al., 2021; Könnölä et al., 2021; Autio, 2021)

3 Research method

The research method in this study followed these steps:

I Firstly, researchers analysed all published governmental documents related to STI policy between 1990 and 2022. All academic documents including 40 papers and 5 books (in Persian and English) were studied, too. Similar to (Gershman et al., 2018; Gokhberg and Sokolov, 2017), our aim was to create a historical analysis of the evolution of STI policy in Iran. An inductive approach was used and a roadmap of milestone events was created.

II Semi-structured interviews were conducted with 3 experts from Vice Presidency for Science and Technology (VPST) with 10 years of first-hand experience in design and implementation of STI policy in Iran to check out historical analysis and roadmap.

III Snowball sampling was used to select 12 experts to hold a focus group. Selected experts consisted of practitioners and academicians involved in designing and implementation of the Iranian STI policy (~50% public managers, ~15% public advisors, ~35% academicians).

IV A focus group was conducted to check the historical evolutionary analysis and accommodate suggestions to improve it. Four phases of STI policy in Iran between 1990 and 2022 were identified. Then, experts were asked to use the collected network governance dimensions (Table 1) to analyse four phases of STI policy in Iran.

It is noteworthy to mention that based on classification of (Börzel, 1997, Appendix, p.1 Figure 2), we used network governance as an analytical tool – and not as a theoretical lens – to appraise the evolution of STI policy in Iran to recognise its strengths and weaknesses, to investigate "structural relationships, interdependencies and dynamics between actors in politics and policy making". The literature suggests "under conditions

of environmental uncertainty and international, sectoral and functional overlap of social subsystems" (Börzel, 1997, p.7), "the network governance form has advantages over both hierarchy and market solutions" (Jones et al., 1997, p.911). The high penetration of internet and the rise of network society in Iran has increased the complexity and size of stakeholder participation thereby affecting the essence of the public discourse around policy and the relationship between "government" and "the public". We do believe that evaluation of evolution of STI policy in the light of network governance can firstly clarify the strength of weaknesses of STI policy and secondly help us re-evaluate the policy paradigm of STI policy in Iran.

4 STI policy governance in Iran: a historical evolution

Iran's approach to STI policy have evolved since its inception. This evolution has been affected by the economic environment, the country's institutional structure, Islamic Revolution, Iraq-Iran war, political climate and sanctions. Although the history of Iran's industrial development dates back to at least 1900, we have restricted this study to the time after the end of the war. In the remainder of this paper, we will first describe four phases of evolution of STI policy in Iran. Subsequently, we will analyse this evolution from a network governance lens and will contextualise our findings in the relevant literature.

4.1 The first period (1994–2004): human resource and publication boom

In this period, a remarkable expansion in higher education took place. Establishment of Payam-e-Noor University with nationwide branches and rapid growth of branches of Islamic Azad University indicates that growing the size of human resources was the leading strategy of this phase. As a result, tertiary enrolment skyrocketed reaching around 21% at the end of this period from the initial 4%. Also a result of emphasis on "science production" at the highest political levels, paper publication soared exponentially. This policy was the direct result of Figures 1–3 (World Bank, 2017) show 3 key performance indicators of this phase. During this period, the STI policy was centralised in the "Ministry of Culture and Higher Education" (MCHE). The "Higher Education Development Council" (HEDC) was the leading authority and its secretariat was based in the MCHE. In 2004, the structure of the HEDC and the "Iranian Scientific Research Council" (ISRC) was renovated and their key policymaking position was determined. ISRC was responsible for the following affairs: drawing up research policies, coordinating nationwide research programs, identifying priorities of launching new research centers, and planning research funds. The members of this council included Vice President, Minister of Culture and Higher Education, Minister of Health and Medical Education, President's Research Advisor, Head of Plan and Budget Organization of Iran, Head of the Commission of Higher Education of the Iranian Parliament, Deputy Head of Research of the MCHE, Head of Iran's Scientific and Industrial Research Organization, a relevant minister invited by the Head of the Council, 5–10 Iranian researchers in various fields familiar with research planning affairs and three individuals from top research centers. At a higher policymaking level, the Supreme Council of the Cultural Revolution (SCCR) monitored MCHE, HEDC and ISRC and set the overarching guidelines.

Figure 1 Iran's rank in the number of citations (see online version for colours)

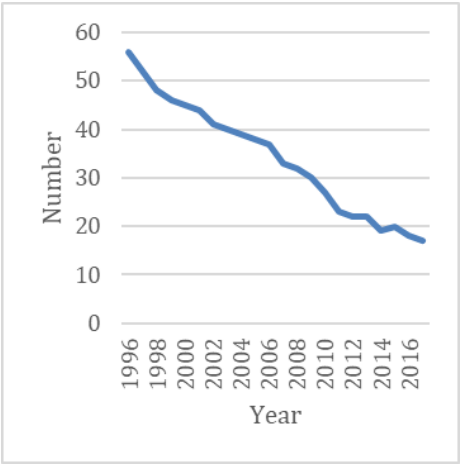


Figure 2 Tertiary enrolment, % gross (see online version for colours)

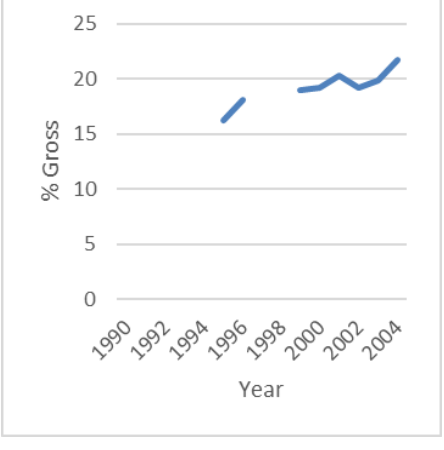
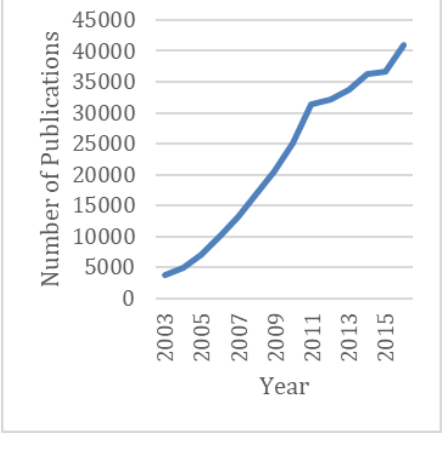


Figure 3 Number of papers in scientific journals (see online version for colours)



Another key player was "The National Research Institute for Science Policy" (NRISP). Established in 1980 as a think tank which studied STI polices. They identified research priorities, provided scientific and technological services and coordinated scientific relationships between local and international research centers. In addition, the Iranian Research Organization for Science and Technology (IROST) – also established in 1980 – acted as a governmental research center in various areas. They orchestrated research institutes and cooperated with Iranian industrial and economic centers. It also provided research infrastructure services through a number of provincial branches.[1]

Concerning industrial policy, there was no designated structural authority in Iranian ministries for it. Research in various industrial ministries was independently conducted in their affiliated research centers. Since this period was before the privatisation wave, most large industries were fully controlled and managed by the government, and research and development (R&D) was virtually absent in both governmental and private sector. Nonetheless, the Industrial Development and Renovation Organization of Iran and the Iranian Mining Industries Development and Renovation (both established in 1967) launched and developed some large industries by focusing on priorities which were autonomously chosen by themselves.

4.2 The second period (2004–2008): agencification era

Since 2004, a new period can be identified which starts moving away from fragment policymaking. It begins with some sweeping legislation to establish "Ministry of Science Research and Technology" (MSRT) with the following missions: coherent policy formation and execution in science, research and technology systems as well as comprehensive management of universities and tertiary education institutes. This was the most important decision to coordinate various institutes engaged in STI policy.

Under this major piece of legislation, Supreme Council of Science, Research and Technology (SCSRT) was established, too. Two significant previously-unheard-of changes were embedded in the structure of this council. First, the permanent commission – chaired by the president of Iran – pursued horizontal coordination, political coordination, and involvement of key stakeholders. Second, the technical commissions[2] sought to enhance the level of inter-disciplinary interactions. The council pursued not only coordination, coherence, and integration of STI policies but also inter-sectoral coordination as a fundamental goal. Another important decision was founding research and technology departments in various ministries which resulted in directing research towards technology development to a certain degree. Nonetheless, these S&T pursuits focused on resolving problems of the day without paying attention to emerging technologies or being led by an upstream technology foresight. Another significant characteristic of this period was that policymakers paid attention to the development of infrastructures for technology development. An illustrative example was development of science and technology parks and technology development centers (Figure 5).

As for the emerging technologies, the Supreme Council of Information and Communication Technology (SCICT) was established to focus on strategic technologies and was given the responsibility to develop ICT infrastructures and plan mid-term and long-term programs for theoretical and applied ICT research. The activities of the council reached its climax when "Development and Application of Information and Communications Technology" (DACT) bill was passed which resulted in a dramatic development in Iran's ICT infrastructures. DACT was one of the first comprehensive

plans for emerging technology development in Iran which was considerably successful in achieving its goals and set a pragmatic pattern for future endeavours. It was similar to the National ICT agenda which was designed and implemented in Malaysia and Philippines.

In 2000, another ambitious step was executed: formation of nanotechnology council under the direct supervision of the president. Nanotechnology council was instrumental in the auspicious development of nanotechnology in Iran initially reflected in the big jump of Iran's global ranking in publication of nanotechnology papers (Ghazinoory et al., 2009) and national technology patents (Figure 4). In 2000, Iran ranked 60th with only nine published nanotechnology papers. In 2019 it ranked 4th – ahead of many pioneers of the field (StatNanao, 2019).

Figure 4 Number national nanotechnology patents (see online version for colours)

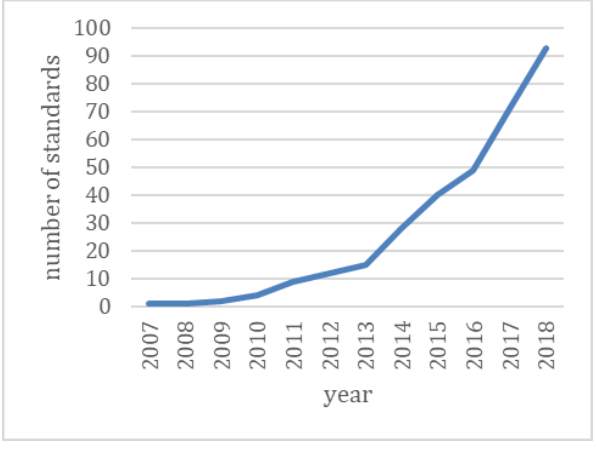
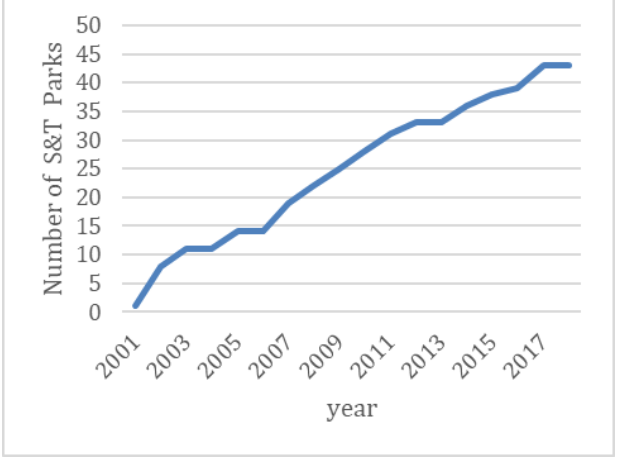


Figure 5 Number of S&T parks (see online version for colours)



ICT and nanotechnology initiatives provided impetus for biotechnology as well. In 2004, the "Green Iran Document" was drafted and passed. This was the first comprehensive plan designed through an inter-ministerial and inter-sectoral collaboration of MSRT, Ministry of Agriculture, Ministry of Health and Medical Education (MHME), Ministry of

Defense, Ministry of Industries and Mines, Ministry of Economic Affairs and Finance, Ministry of Commerce, various governmental and non-governmental organisations, such as Department of Environment, National Institute of Genetic Engineering and biotechnology, Razi Vaccine and Serum Research Institute, Pasteur Institute of Iran, Agriculture Biotechnology Research Institute of Iran, Iranian Biotechnology Society, Iranian Genetics Society, President's Office for Innovation and Technology Cooperation, as well as a number of experts and representatives of the private sector.

Enactment of Privatization Directive in 2005 was a historical decision. Before this directive the privatisation organisation had been founded in 2001. In Iran, since the inception of privatisation in 1991 it had experienced a very slow administrative process. There is ample theoretical and empirical evidence in literature about advantages of privatisation. Encouraging private sector innovative activities is an irreducible element of STI policy. The intended and unintended consequences of Iran's privatisation plan is out of the scope of this paper but one empirical study suggests that results of Iran's privatisation policy has been disappointing probably because other conditions such as "market openness, the modest and short-term bureaucratic control after privatisation, and corporate health prior to privatisation" were not present (Alipour, 2013, p.300). The partial transfer or even the mere transfer of state-owned-enterprises to private sector is not privatisation.

In 2004, the number of technology councils reached 13 in various technological areas. Among them, the nanotechnology council and the biotechnology council have been exceptionally triumphant (Ghazinoory et al., 2009). These are exemplars where a good-quality STI policy was formed and executed, interdisciplinary links were forged and the route from knowledge, to technology to market was successfully passed through.

4.3 Third period (2008–2012): toward integration and comprehensiveness

In this period, agencification continued and Vice Presidency Deputy for Science and Technology (VPST) was founded in 2008 after the Supreme Leader's emphasis on technological development of Iran. Its mission clearly states that STI policy should be directed toward commercialisation and wealth creation. Nanotechnology and biotechnology councils were integrated into VPST and multiple other councils were formed as well. Among them, one can refer to the Cognitive Science and Technologies' Council, ICT Council, and Aviation Technologies' Councils. Agencification aimed at coordinating the innovation chain i.e., science-technology-innovation and building inter-ministerial policy coherence beside inter-sectoral multi-disciplinary interactions. The budget of technology development experienced a huge rise (Figure 7).

In 2010, after three years of researching and drafting with participation of various stakeholders and 20 joint meetings, Iran's "Comprehensive Science Plan" was approved. This document was the first of its kind for upstream integration of S&T priorities. The document went beyond mere priority-setting and offered solutions for various aspects of STI policy including institutional dimensions. Other striking characteristics of the proposed STI policy in this document were: "supply-and-demand-oriented combination", "synthesis of national and international approaches", and "coalescence of formal education with research, and skill". In addition, it developed some STI indicators for Iran for the first time to move toward retrospective analysis and evidence-based STI policy. The indicators were more complex than simple indicators of phase one and included: R&D expenditure of the private sector, S&T induced annual growth in GDP and the rate

of employment in S&T. Furthermore, for the first time, continuous and organised scientific and technological collaboration with foreign countries was taken into consideration. The collaboration, though, was pursued by focusing on the science aspect and the main strategy was creating joint efforts between domestic and international universities without much attention to implicit knowledge. Another shortcoming was technology transfer efforts which were limited to a narrow definition of purchasing technological capabilities.

In Chapter 5 of this document – "Institutional Framework for STI" – a governance system was proposed for STI policy development: establishment of strategic councils under the supervision of SCCR. Since then, the councils have been the STI policy arm of SCCR for the implementation of the plan. Like pervious councils, inter-ministerial cooperation was aimed and encouraged by inclusion of various members of different ministries in strategic councils. At this phase, as a synergetic result the number of registered patents started to increase (Figure 6).

Figure 6 Number of patents registered in USPTO and EPO (see online version for colours)

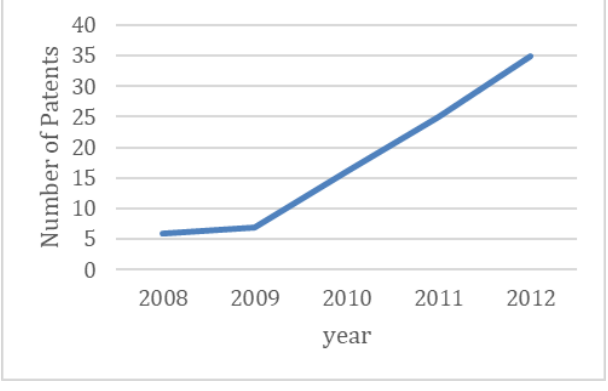
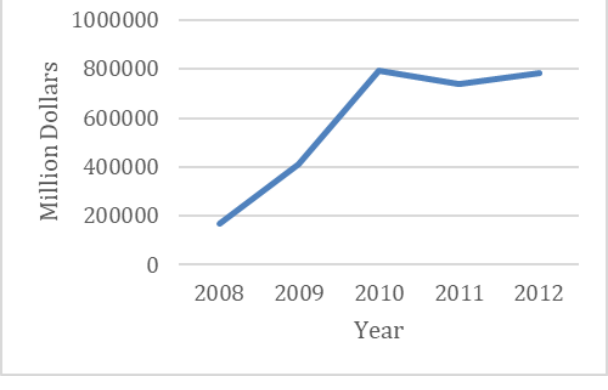


Figure 7 Budget of technology development councils (Million dollars) (see online version for colours)



During this period, development of technological capabilities was placed on the top of STI agenda via designing national mega-projects. They were designed and implemented in strategic areas with a problem-centered approach. They tried to form a link between

industry and university and benefit from research capabilities throughout the country by joint involvement of VPST and SCSRT. Later, diffusion of technology in existing industries was gradually taken into consideration, too.

Finally, another designed mechanism with the aim of simultaneous attention to supply and demand side of technology was inauguration of "Research Information Management System". In this system, the priorities of technological capabilities of all ministries were collected and approved for budget allocation by SCSRT. This also resulted in some multi-disciplinary interactions via this newly-developed network necessary for enhancement of the STI systems in Iran. Three main players during this era were: SCSRT, the Strategic Councils of Iran's Comprehensive Science Plan, and VPST. The seeds of knowledge-economy turn were planted at the end of this phase.

4.4 Fourth period (2012–2022): innovation-first policymaking

As knowledge-based economy gained salience, and based on directives of the top political leaders of Iran to move toward knowledge-based economy, policy planners felt an urgency to go for another turn in STI policy.

A quite comprehensive piece of legislation – "development and support of knowledge-based companies" – was ratified by the Parliament. It included a set of financial and technical incentives for knowledge-and-innovation-based firms: a wide range of financial assistance options, tax incentives, custom duty relief and exemptions and insurance for high-tech products. After it was passed in 2010, because of certain obstacles in the STI environment of Iran, its implementation was postponed until 2012. It was the first policy which completely targeted innovation. It was initially formulated with aim of supporting university-based companies and then all NTBFs were supported. Subsequently, "Innovation and Prosperity Fund" was launched to encourage and accelerate development of NTBFs. The fund provided various forms of financial incentives, investment services and venture capitals, supported export of knowledge-intensive goods and services, and finally facilitated technology transfer to eligible NTBFs. In addition, the committee for evaluation and identification of knowledge-based firms was established to determine those qualified to benefit from the supports provided by the law. The structure of the committee consists of VPST at the head with other key public and private actors.[3] The establishment of this committee was a step toward network form of governance particularly in such dimensions as horizontal coordination, policy coherence, and policy learning and intelligence.

In this period, not only did the STI system gradually evolve from emphasising science and education to a system that concentrated on innovation but also policymakers promot cooperation among various actors. Furthermore, VPST paid special attention to the agenda of enhancing policy intelligence and therefore implemented two projects: "National innovation survey" and "National technology foresight project" (2017–2019). In the National innovation survey, an in-depth and comprehensive report was written concerning Iran's innovation status at the national level by collecting nationwide data.

Another turning point in the evolution of governance in Iran's STI policy system was membership of VPST in the Supreme Council for Economic Coordination (SCEC) in 2017. This body is the highest authority to make decisions concerning implementation of major national projects. All industry-related ministries are the members of the council. Adding VPST – which is primarily concerned with the technological development of the country – to this council was a major step towards placing technological development

and innovation in the front and center of policymaking and manage the innovation chain i.e., science-technology-innovation route in a way that it will lead to wealth creation. It also provided VPST with a much better status in terms of political power.

In 2013, as a result of sanctions, "the Council for Resilient Economy" came into existence focusing on formation of indigenous technological, industrial, economic capabilities. Additionally, VPST launched "entrepreneurship ecosystem support program". It offers a systematic extensive support for the establishment of infrastructures necessary for the formation of innovation centers, accelerators, venture capitals (VCs) and corporate VCs. With design and implementation of the two above-mentioned national projects between 2015 and 2018, coordination of innovation chain, vertical coordination, stakeholders' involvement, and policy intelligence and learning were incorporated into STI policy formulation and execution in a more systemic and organised fashion. The focus on innovation development at national level and across different sectors has garnered significant attention, and a pivotal moment arrived with the approval of the "The Law of Knowledge-Based Production Leap" by parliament in April 2022. This legislation clearly highlights several aspects of the network approach to governance. In this law, the role of both general and sectoral networks has become highly prominent. Additionally, the law has established legal status for newer innovation policy tools that previously faced administrative complexities in Iran. One of the most significant tools introduced is the provision of research and development tax credits for all companies engaged in research and development activities, which initially encountered challenges upon its approval. Furthermore, the law establishes the Steering Council of Knowledge-Based Productions, with its secretariat located within the Vice Presidency for Science and Technology, which has been renamed the Vice Presidency for Science, Technology, and Knowledge-Based Economy. This council serves as a crucial mechanism for governance in innovation within the country. It holds responsibility for policy-making and operational implementation of a significant portion of innovation policies, along with its secretariat and sub-groups. At the departmental level, the law requires all ministries to develop annual programs for the advancement of knowledge-based production, adopting an inter-ministerial approach within their respective departments. Proposed programs must be approved within three months by the government delegation, and the council's secretariat continuously monitors their implementation with the involvement of all stakeholders. These measures demonstrate Iran's strong commitment to adopting a network approach in innovation policies, emphasising the growth and outputs of innovation rather than solely focusing on non-economic inputs within the system. The diffusion of technology into important economic sectors and the resultant wealth creation are reflected in indexes such as "the level of high-tech exports (current US$)" and "the percentage of medium-tech and high-tech exports to total amount of exports" (Figures 8 and 9). Figure 10 presents a roadmap of milestone events in STI policymaking of Iran. Table 2 shows the results of applying network governance – as an analytical tool in the focus group – to investigate presence of absence of different dimensions of it in the evolution of STI policy in Iran. To do this analysis, a focus group was conducted to check the historical evolutionary analysis and accommodate suggestions to improve it. Four phases of STI policy in Iran between 1990 and 2022 were identified. Then, experts were asked to use the collected network governance dimensions (Table 1) to analyse four phases of STI policy in Iran.

Figure 8 Percentage of medium-and high-tech exports in total exports of products (see online version for colours)

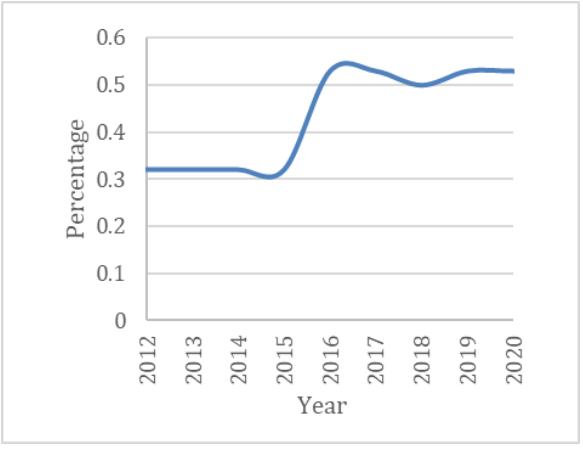


Figure 9 High-tech exports (Million US$) (see online version for colours)

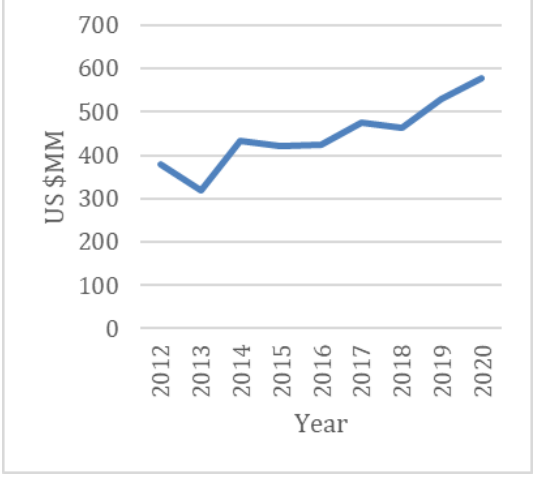


Figure 10 Roadmap of milestone events related to STI policy in Iran (see online version for colours)

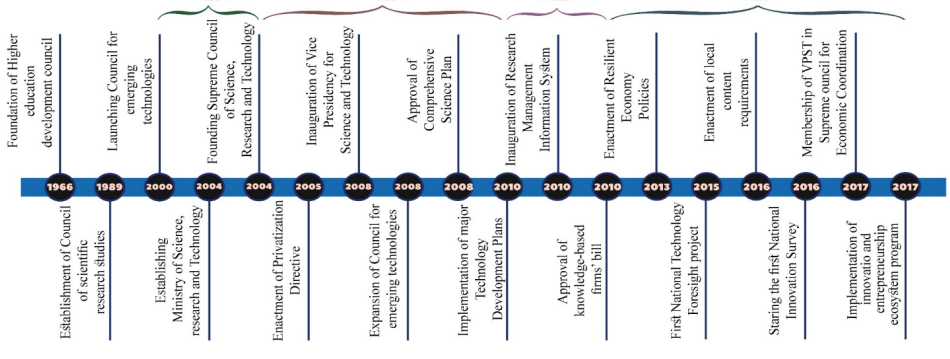


Table 2 Evaluation of evolution of STI policy in Iran by using network governance as an analytical tool

	Network governance dimensions							
			Enhancing coordination, coherence and integrity					
Mechanisms	*Horizontal coordination*	*Coordination in innovation chain*	*Policy coherence*	*Vertical coordination*	*Political coordination*	*Stakeholder involvement*	*Inter-disciplinary Cooperation*	*Policy Learning and Intelligence*
1st Period	✓	–	–	–	–	✓	–	–
2nd Period	✓✓	✓	✓	✓	✓	✓	✓✓	–
3rd Period	✓✓✓	✓✓	✓✓	✓✓	✓	✓	✓	✓
4th Period	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓	✓✓

5 Discussion

In this section, firstly, we will highlight our contribution to the literature and then we will discuss the strengths and weaknesses of STI policy using the historical analysis and the results of the focus group. We will try to re-evaluate the policy paradigm of STI policy in Iran and make some policy recommendations for future.

This paper stands out from other sources as it provides a comprehensive framework that systematically summarises and classifies the literature on network governance in the field of innovation policy. Unlike previous sources that have examined specific requirements of innovation policy in isolation for example political coordination (Braun, 2008), cooperation (Deserti et al., 2020), stakeholders engagement (Dutrénit et al., 2018), learning (Lundvall, 2016) and horizontal coordination (Edler et al., 2003), this paper brings together various dimensions such as Enhancing Coordination, Coherence and Integrity, Stakeholder involvement, Inter-disciplinary Cooperation, Policy Learning and Intelligence within a comprehensive framework.

While some sources (Arnold et al., 2002; Bauer et al., 2012; Cunningham and Karakasidou, 2002; Kuhlmann, 2002) have recognised the benefits of network approaches in innovation policy, they have not proposed a complete conceptualisation of these benefits. Additionally, these sources have discussed the necessities of innovation governance without effectively linking them to poly-centric and network governance approaches. Notably, sources such as (Laranja, 2012) and (Hoffmann et al., 2022) have provided more comprehensive insights, but they have not fully established the connection between the requirements of innovation policies and benefits of governance approaches, as this paper has done.

Although Laranja (2012) has discussed the benefits of network approaches in governance for innovation policy, it does not delve into dimensions such as inter-disciplinary Cooperation, which is the focus of this paper. Additionally, Laranja (2012) solely examines one main mechanism of network governance in Portugal (the national innovation plan called TP), whereas our study comprehensively analyses all mechanisms in the Iranian STI system, with a particular emphasis on experts' opinions. Thus, the novelty and knowledge-enhancing contribution of our research lies in providing an integrated framework that connects the requirements of innovation policy with network governance capabilities. Furthermore, our framework extensively examines Iran's experience, which is a valuable contribution, especially considering its status as a developing country striving to align its scientific progress with technological, innovative, and economic achievements. We have gone beyond the conceptualisation and necessity and importance of these sources and while classifying the network governance mechanisms specific to ST policymaking, we have used them to examine the situation of a country and have been able to use the reviewed experience to suggest the future pathways for Iran. We will elaborate this contribution in the rest of the discussion section. Although the first phase contributed to an impressive human resource repertoire (UNCTAD, 2016, p.ix), uncontrolled and even delirious proliferation of Azad and Payam-e-Noor University and exponential growth in number of publications were politically heralded, at the time and later, as a tremendous achievement. But a critical question was ignored and has been ignored so far: "who decides what should be measured, why and how? (Lewis, 2015, p.1)" The politics of performance measures has intricate problems, paradoxes and consequences (p.6). In Iran, it led to "output distortion" (p.7) and "over-interpretation" (Bird et al., 2005, p.2) in case of academicians and governments alike. They focused on what was being measured – on the carrot just in front instead of the fields of vegetables beyond (Mintzberg, 1989, p.166) – even if they might have been aware of more effective alternatives. In case of universities, it has resulted in an unwritten ordinance, "Leave the problem: be a machine for paper production" (HamidiMotlagh et al., 2020, p.400):

> "In other words, under the pressure of macro-institutional rules, the center which has been established to solve society's problems, has been forced to become a machine of article production … and has lost its capability to solve the problems facing the society." (Personal communication cited in HamidiMotlagh et al., 2020, p.401)

The initial attempts to achieve "coherence along the innovation chain" in Iran were made in 2004 with the establishment of the MSRT. Even though this was an essential step, it predominately focused on the science as the main driver of STI policy. Research prioritisation and agenda-setting (Gassler et al., 2008) for universities and evaluating them based on quantitative indicators such as number of publications was the result of deeply-held belief: the route from science accumulation to technology development to innovation is a linear deterministic progression. The subsequent wave of agencification (Establishment of VPST, SCSRT, and councils of emerging technologies), was an attempt to add coherence and integration to STI policy. Many of these mainly structural alterations were married to the so-called pipe-line model of innovation, (Brooks, 1994) though. Unlike others, councils of emerging technologies managed to follow an innovation-first policy. The success of nanotechnology council is the epitome of this approach. Iran's strategically timely entrance – as a choice and not necessity (Yazdi and

Zarj, 2013, p.134) – and emphasis on indigenous innovation (p.135) not only led to creation of technological capabilities but also high-tech product export. It was, nonetheless, unsuccessful, in diffusion of this innovation into other industries. The other reason for inability of STI policy to translate scientific progress into economic prosperity has been lukewarm commitment to endogenous development of industries and markets both within and beyond the country (Soofi et al., 2013, p.10). The percentage of Iran's mid-and-high-tech export to its total export – Figure 8 – clearly indicates that this market expansion will take time and policy alterations to happen. The low rate of knowledge-based employment in the national economy is another evidence for this problem (Heshmati and Dibaji, 2019).

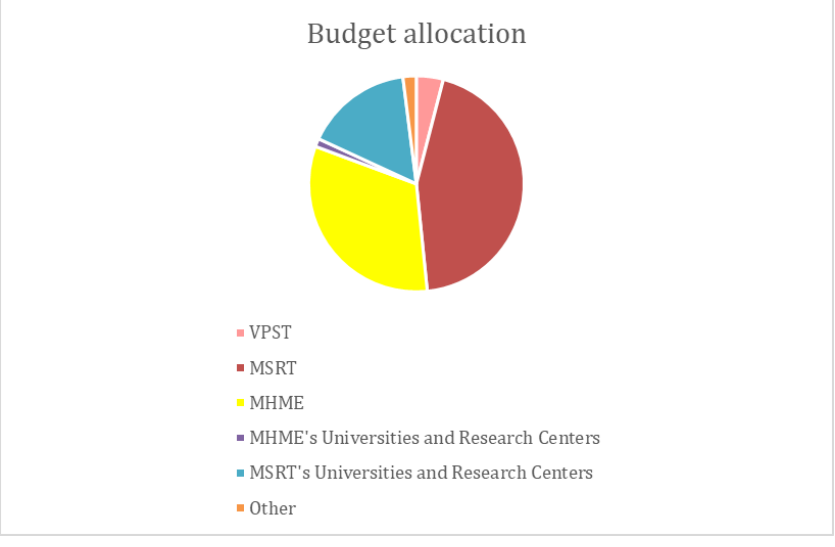
Even after 30 years of evolution of STI policy in Iran, this mechanistic linear and quantitative policy paradigm is still shaping STI policy. Despite agencification (phase 2), integration (phase 3) and innovation (phase 4) turn in STI policymaking, the "inertial residue" of the dominant paradigm in the first phase still reverberates through policymaking chambers and affects "not only the goals of policy and the kind of instruments that can be used to attain them, but also the very nature of the problems they are meant to be addressing" (Hall, 1993, p.279).

At the juncture of politics of "performance measurement" and pipeline model of innovation, take these controversial indicators into consideration: According to Global Innovation Index (Dutta et al., 2020) among 131 listed countries, Iran is the 3rd one in graduates in science and engineering, 1st in Trademarks by origin/bn PPP$ GDP, 7th in tertiary education, 25th in knowledge creation, and 21st in scientific and technical papers/bn PPP$ GDP (all accumulated result of phase 1 & 2 policies and their inertial residue). In a startling contrast, Iran ranks 128th in ease of starting a business, 125th in business environment, 117th in university/industry research collaboration, 129th in applied tariff rate. The asymmetry between these indices graphically illustrate that we have cherry-picked performance indicators due to either explicit/implicit politics of policymaking or a mechanistic and narrow conceptualisation of STI policy. The dismal condition of university/industry research collaboration – despite being the central motto of policy making for decades – is indicative of bottlenecks in innovation chain. Considering Iran's condition in business environment, ease of starting a business, regulatory quality and the controversial privatisation policy, it is no wonder that social/participatory dimensions of network governance (improving communications, creating trust, and increasing stakeholder's involvement) have not been considered as achievements of STI policy in Iran by focus group experts.

Based on our analysis, the structure of STI governance in Iran has principally followed a centralised under-representative closed corporatist model (Laranja, 2012) with vertical path dependencies and divisions between science, technology and innovation policy. Coordinating STI policy at various levels needs efficient semi-formal and informal interaction systems (Cunningham and Karakasidou, 2009). As the results of the focus group evidently demonstrate the current state of the vertical coordination of STI policymaking is far from desirable. In recent years, "Innovation and Entrepreneurship Ecosystem Program, the National Technology Foresight, and the National Innovation Survey have been launched to enhance vertical integration. A relatively low degree of decentralisation, public-private partnerships, stakeholder involvement, and public participation have been achieved. Despite rare emergence of semi-formal mechanism in the STI governance (nanotechnology councils), informal mechanism have been completely absent, policy silos, fragmented interventions and formal enforcement

mechanisms have been abundant. At the absence of dialogue, negotiation and collective deliberation (Laranja, 2012), the top level of STI governance has unquestionably set the overarching guidelines and priorities. Of the quartet of academic, business, government and civil society (Dutrénit et al., 2018), during the four phases, government has been behind the steering wheel of policy vehicle, academics have been sitting on rear seats, business sector have marginally been involved and the civil society has been basically ignored. Budget allocation among governmental bodies – Figure 11 (Islamic Parliament Research Center as cited in Heshmati and Dibaji, 2019) – shows that the policy mantra is still the following: "fund universities and innovation will naturally follow".

Figure 11 Share of each governmental body out of research, technology, and higher education annual budget in 2017 (see online version for colours)



In terms of stakeholder involvement, a comparative look at STI public dialogues in Latin America shows why a lot has to be done in Iran to create a genuine STI conversation. Brazil-STI Carnival, Cuba-Innovation, and Dominican R-STI Policy host 51, 98, and more than 200 various actors, respectively, with an emphasis on business sector and civil society (Dutrénit et al., 2018). In Iran, most members of almost all the councils – usually 10–15 – on Figure 10 are selected from various ministries, academicians and very rarely from business sector; power relations are almost always asymmetrical.

Involvement of various stakeholders is a key characteristic of network governance. The technical commissions of the SCSRT, technology development councils, and national mega-projects took steps to engage various stakeholder. But, no sufficient measures have been adopted to increase relationship between innovation and society (Pelkonen, 2006). People should have an active participation in designing policy tools, their implementation and achieving targeted goals (Cunningham and Karakasidou, 2009; Laranja, 2012).

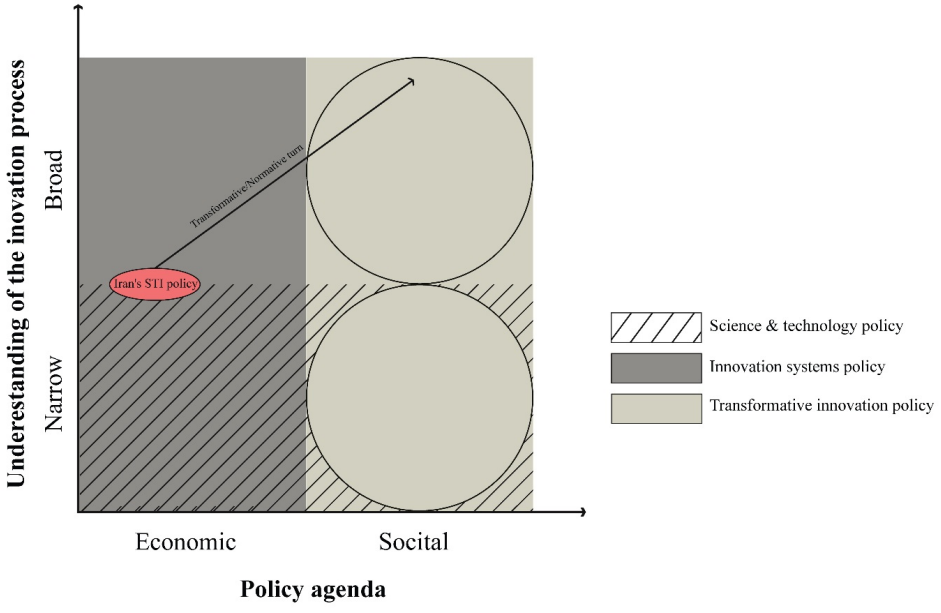
"Inter-disciplinary coordination and horizontal coordination" were relatively achieved by establishment of councils for the development of emerging technologies at VPST. However, these councils mainly concentrated on supporting NTBFs and were unable to support the formation and development of technological mega-projects which could lead

to building indigenous technological capabilities. Then, the mega-projects program in VPST and HCSRT took the responsibility of inter-disciplinary coordination which was moderately effective.

Since the beginning of phase 4, VPST has paid special attention to policy intelligence. The National Technology Foresight project was an effort to create a bottom-up distributed platform for policy learning and intelligence (Wang and Li, 2019). One major shortcoming is that there are no continuous mechanisms for enhancing policy learning by receiving feedback from policy implementation in order to move toward evidence-based policy. The distributed and cooperative mechanisms of policy intelligence are not sufficiently used to the extent needed by the system.

Based on all our discussion so far and by using the transformative innovation model of Diercks et al. (2018) – Figure 12 – the current position of Iran and a recommended directions which can be taken are presented (Diercks et al., 2019). Iran's STI policy needs to move toward transformative innovation policy i.e., of "pluricentric forms of governance" (Kersbergen and Waarden, 2004). This policy radically departs from pipeline interpretation of innovation toward a systemic and network-based conceptualising stressing the importance of demand-side of innovation, doing, using and interacting (DUI), tacit knowledge, stakeholder involvement, bottom-up mechanisms and social innovation (Diercks et al., 2019). This strategic shift calls for riding the emerging wave of STI policy rather than retrospective imitation of frameworks which are virtually obsolete or on the verge becoming obsolete.

Figure 12 Current position of Iran in STI policy and the recommended turn direction (see online version for colours)



Finally, what can other countries similar to Iran learn from this analysis? As has been mentioned in the paper, STI policy governance in Iran stands out due to several distinctive factors: direct and indirect government interventions, abundant natural

resources, ongoing high inflation rates, and the impact of stringent international sanctions. As a result, Iran has always better performance in innovation input indicators and science and education ones rather than innovation output and economic indicators. These specifications can distinguish Iran from many other countries even developing ones but also Findings of this paper has some implications for other similar countries.

Countries that have abundant resources and are therefore exposed to extensive government interventions in the science, technology, and innovation (STI) system can well afford to spend on innovation inputs, and the high level of government involvement in these systems in those countries makes medium- and long-term returns on investment in their economies less of a concern. Thus, as mentioned in the paper, the first period effects have been preserved to this day. It seems that network approaches, especially with the serious participation of private sector stakeholders, can help move them forward. Also, economic sanctions, due to the elimination of technological cooperation opportunities and the use of foreign investments and markets, emphasise the need for domestic market development and innovation-supporting policies by leveraging the domestic market, especially given the size of the government, which creates a larger market on its own. Iran has also tried to replace this large market with lost foreign markets by mechanisms such as the membership of the VPST in the Supreme Council for Economic Coordination (SCEC), which is responsible for approving large national projects.

To summarise, adopting a network approach in governance with a focus on leveraging government resources and markets towards innovation can accelerate the transition from a science and education-oriented approach to an innovation and economy-oriented approach in such countries. This market-making can be achieved through the creation of new councils, the approval of laws and regulations that require various government organisations to collaborate with each other to promote innovation and optimal use of limited domestic resources, and a focus on strengthening the private sector and involving it in the process.

6 Conclusion

This paper identified four main periods of STI policy governance in Iran. In the first period, human resource and publication boom erupted. The second phase created various policy bodies at an arm length form the government. Integration and comprehensiveness was sough in the next phase. At the final phase symptoms of moving toward innovation-first policy emerged.

The inertial residue of the first two phases beside a narrow pipeline model of innovation has resulted in unbalanced STI indicators. Government has set the priorities. Universities have been considered as engines of innovation. STI policies has largely been reduced to science policy. Performance indicators have been cherry-picked. Add path dependency to this picture and you will realise why Iran's STI policy should push the envelope and seek out-of-the-box solutions.

Politics of policy making should be considered. Performance measurements should be problematised and serious attention should be given to by whom, why and how STI policy impact is being measured. The role of the government should be debunked. The idea of interventionist government, in phase 1 and 2, can be defended but as Iran climbed

on the ladder of STI achievements and approached frontiers, political and economic decentralisation becomes absolutely necessary (Mahmood and Rufin, 2005, p.339). The government should let go of the steering wheel and create specific conditions for a national innovation system to be born. Trust institutions, increase the regularity quality, improve business environment, enhance political and operational stability, stimulate "Creative Insecurity" (Taylor, 2016, p.13), follow a genuine privatisation policy, and above all else accept a broader definition of innovation. If you set the right conditions, innovation will bubble up in a bottom-up fashion.

Iran's national innovation system is at its infancy and is in need of "transformative/normative turn". Arguably, the most successful example of Iran's STI policy has been the nanotechnology initiative where Iran entered this filed at its inception phase. Lee (2019) makes a suggestion about technological catch-up of developing countries which can be instrumental in STI policy as well: "one cannot catch up if s/he continues to work on catching up". Instead, he recommends one should master the art of "taking detours and flying a balloon" (Cobby, 2020). We did fly a balloon in case of nanotechnology by riding and emerging wave of technology when there was room for indigenous innovation and interpretative flexibility. Both in theoretical and pragmatic policy decisions, this non-imitative local approach of riding an emerging wave can be a source of long-term benefit.

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Notes

[1]In the second period, these provincial branches were converted into science and technology parks.

[2]Some technical commissions were energy, transportation, Information and Communication Technology; agriculture, water and natural resources, and basic sciences.

[3]Ministry of Defense, MSRT, Ministry of Agriculture, Iran Chamber of Commerce, etc.