# Evolution of NIS in a developing context: historical study of the role of institutions in Iran1

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Abstract:

The central issue of applying national innovation system as an analytical tool in the context of developing countries has been scrutinized. A mixed framework has been developed to study the institutional roots of Iran's falling further behind in a historical perspective. Four possible ways of hindering institutional adaptions were highlighted and tested in this specific context since two centuries ago. It has also showed how the institutional set-ups of the country could not respond properly to the requirements of technological changes differently in each period of time. Although the main literature of NIS concentrated on rules and regulations, this study shows how the cognitive institutions played a determining role in hampering technological catch-up of the country. Some theoretical and policy related remarks are presented at the end.

Keywords: National Innovation System, Institutions, catching-up, Technological Revolutions

[1] The author extremely thanks Prof. Ove Granstrand for his very useful comments and Prof. Adam Szirmai and Slavo Radosevic for their hints on improving this draft

## Introduction

The field of research into innovation systems has been classified as one of the three main areas of research in the general field of innovation, connecting the literature of the economics of research and development and the organization of innovation (Fagerberg et al. 2012). Among the varieties of innovation systems, National Innovation Systems (NIS) could be seen as the most important branch, and the works of Nelson (1993), Lundvall (1992) and Freeman (1987) on the systemic nature of innovation at the national level have been the most-cited (Fagerberg et al. 2012 p. 1141).

Although NIS has been widely used both as an analytical framework (Patel and Pavitt 1994, Metcalfe 1995, Freeman 1995, Edquist 1997, Lundvall et al.2002, Niosi 2002) and as an approach for policy-making (Edquist 2011, Lundvall and Borass 2005), there are still more ambiguities and disparities regarding the concept including issues around its academic or policy roots, its flexibility, the extent of its application, and its connection with other fields, such as neoclassical economics, triple helix, and linear models of innovation (Sharif 2006).

The main focus of this article is the application of the concept in the context of developing countries as an analytical tool with the specific aim of explaining the institutional roots behind failure of Iran in catching-up, or falling further behind. Figure 1 shows the growth of GDP per capita for Iran in comparison to 5 other countries including Iraq and Saudi Arabia as two neighbor and oil depended countries, Malaysia and South Korea as two East Asian countries passing Iran from early 1980s and Brazil as a Latin American country that although passed Iran in the same time, it could not create a substantial gap like the two East Asian ones. The figure clearly shows that Iran could not exploit the historical opportunity of catching-up after WWII (Abramovitz 1986).

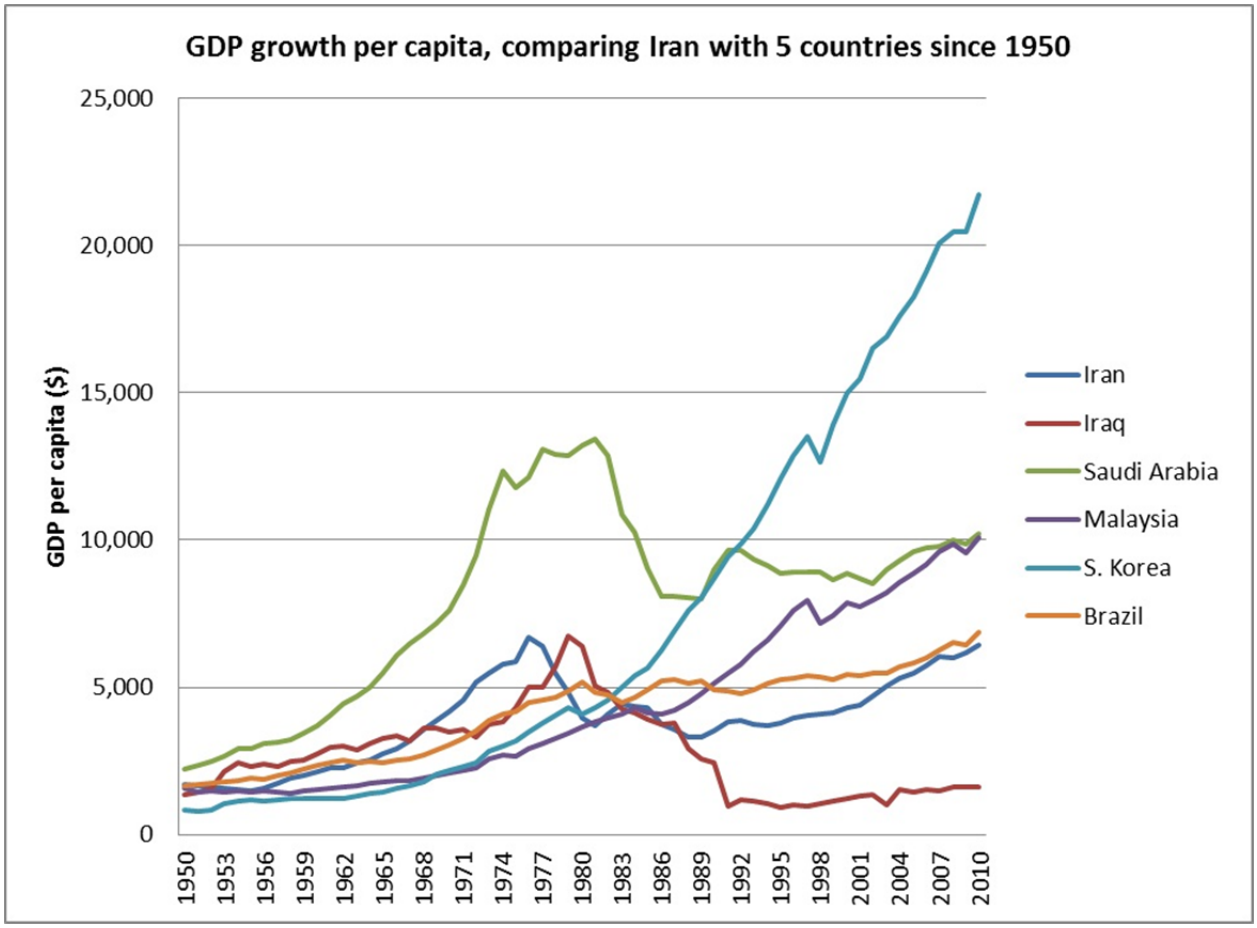


Figure 1: comparing Iran's GDP growth with 5 other countries since 1950s (source: Author's Calculation from Maddison (2013))

Maddison's calculations show no substantial differences between those countries since industrial revolution up to WWII, except for South (Maddison 2013). Therefore, Iran shows a natural case of falling further behind, while the historical records show that the country paid much attention to industrial development and technology transfer since 1925 (as will be discussed later).

For this purpose, a short discussion on the variety of approaches to NIS will be presented, following by scrutinizing viewpoints about the applicability of innovation system as a framework for the context of developing countries. After highlighting some voids in the current research, a framework based on will be developed that is deemed useful in the context of developing world. In the next part, this framework will be applied to the context of Iran in a historical

perspective that in turn reveals the institutional bottlenecks led to falling further behind, particularly during the past century. The empirical and theoretical considerations will be discussed in the final section.

## Approaches to NIS

It is common to classify NIS in two different ways (Edquist 1997, Lundvall et al. 2002, Niosi 2011): the narrower version proposed by Nelson (1993), and the broader version popularized by Lundvall (1992). Nelson puts the research and development (R&D) system of a country at the centre of analysis (Nelson 1993); makes a distinction between public and private knowledge production to discuss the institutions supporting corporate R&D in the context of United States (Nelson 1988). Lundvall criticises neo-classical economics, its views on knowledge production and its difficulty in explaining product innovations that necessarily need a great amount of producer-user interaction (Lundvall 1988). Interactions between different actors in the wider system, therefore, are the main determinants of innovation (Lundvall 1992). Other scholars also echoed this view, arguing that different types of interactions are needed to allow the transfer of knowledge in the wider national systems (Niosi et al. 1993, David and Foray 1995). As another approach, Edquist suggests putting activities (functions) at the centre of analysis (instead of components and their interactions) because they determine the development and diffusion of innovations (Edquist 1997, 2005). This approach is argued to be more instrumental for policy makers (Edquist 2011).

However, none of those approaches developed for explaining development and catch-up. It was Freeman who stressed the importance of institutions in innovation systems that could lead to catching up: "when Germany and the United States overtook Britain in the latter part of the nineteenth century and in the twentieth century, their success was also related to major institutional changes in the national systems of innovation" (Freeman 1988, p 330).

The trend of linking innovation system research with the theory of economic development and catching up has been intensified since 2000s (Muchie et al 2003, Johnson and Lundvall 2003, Cassiolato et al 2003, 2014, Dutrenit et al 2013, Lee 2013), considerable parts of them being reflected in GLOBELICS community (global network of economics of learning, innovation and competence building systems) (Muchie and Baskaran 2009, Cassiolato et al

2012). DUI versus STI mode of learning and innovation is an example tries to highlight which one may lead to catch-up (Jensen et al 2007).

Freeman and Louca (2001) provided a comprehensive historical and institutional analysis of the techno-economic paradigms (TEP), the notion formerly developed by Perez (1983). Each TEP is marked by a technical revolution carried out by cluster of industries, a collection of innovations (technological and non-technological) and related low-cost inputs and new infrastructures that together shape the forces of economic development and catching-up (Perez 2010). Freeman (2002) extended the idea to clarify the links between innovation systems and economic development by discussing the complementarities of institutions between five subsystems of society (i.e. policy, economy, culture, science and technology) and to explain experience of Britain's catch-up in the age of industrialization, the subsequent catch-up of the United States in the late nineteenth and early twentieth century, and the emergence of new economies in the past decades.

Linking innovation systems to catching-up is not limited to national systems, as other scholars have tried to make a similar connection at the sectoral level (Lee and Lim 2001, Malerba 2004, Park and Lee 2006, Nelson 2008, Jung and Lee 2010, Malerba and Nelson 2011, Almudi et al 2012), at the technological level (Park and Lee 2006) or at the corporate level (Granstrand 2000, Duysters et al 2009). Granstrand argued that catch-up could not have happened without large corporations benefiting from a proper corporate innovation system composes of actors, activities, resources and institutions supporting their innovative performance (Granstrand 2000). However, it is still debating to what extent NIS could be used for studying the context of developing countries in order to explain the reasons for their further falling behind; the topic to be scrutinized further in the next section.

## Research on NIS in developing countries

Although the concept of NIS was applied in the context of developing countries by some authors at early 1990s (e.g. Hou and Gee 1993, Kim 1993, Dahlman and Frischtak 1993, Katz and Bercovice 1993; discussing the experiences of Taiwan, Korea, Brazil and Argentina respectively in Nelson 1993), the issues surrounding the applicability of the framework for developing countries had not been discussed since late 1990s.

Gu tried to identify the gaps which may impede applications of NIS as a policy tool for the context of developing countries because of different concerns about: *Knowledge globalization and technological Opportunities, Latecomer firm and enhanced learning, Co-evolution between technology and institutions,* and *Adaptive policy process and the management of historical transition* (Gu 1999). Arocena and Sutz (2000) emphasized the same issue by discussing how the approach should be complemented by the Latin American perspective, which might be worried about its *ex-post character, normative weights, relational aspect* and *policy orientation.*

In addition to the applicability of the concept, some other researchers tried to use the modified version of NIS for analyzing the innovation systems of specific countries. Cimoli (2000) distinguished the role of institutions in the Mexician innovation system from top to down, namely: *interaction with production systems, functional role of institutions* and *institutional matrix.* However, institutions for her resemble organizations such as higher education, research and technological development organizations, industrial research laboratories and so on. Thailand, as a case of less successful country has been analysed in terms of actors and their interactions, which shows a very fragmented innovation system to emphasize the very problem of interaction within this country (Intarakumnerd et al 2002). Wong (2002) highlights the phases of development in the Singapore's innovation system by developing a framework suitable for newly industrialized economies (NIEs) composed of three actors: 1- entreprise sector, 2- public s&t institutions and 3- manpower development sector; the interaction of which leads to development of useful stock of scientific and technological resources that in turn being deployed by innovation actors. Those early works did not concern about either institutional changes or catching-up experiences.

Viotti points to the differences between the innovation systems of advanced and developing countries, stating that the latter is characterised by technological learning rather than by innovation (Viotti 2002). Technological learning is the absorption and improvement of existing techniques that could be passive or active: passive learning refers to technological absorption following pathways of minimal technological effort and incremental innovation that is almost automatic and costless, while active learning is accompanied by efforts to master assimilated technology by considerable investments. Although he paved the way for understanding the experience of catch-up, he did not discuss the role of institutional changes in this way.

The handbook on innovation system in developing countries is a reflection of the more recent efforts (Lundvall et al 2009). Lundvall suggests a conditional 'yes' to the usefulness of the concept in the south, emphasizing the importance of grounding innovation system research within a well-established theory of innovation, based upon facts and rooted in an evolutionary perspective (Lundvall 2009). He portrays innovation system as an open, evolving and complex system that not only considers linkages between organizations, but also institutions and socio-economic structures that determine the rate and direction of innovation and competence building while he admits that this view corresponds to the original works of Freeman (1987 and 1988).

His remark on the broadness of this definition and the need for developing a focusing device reveals that "the aim of using this device is to find-out which alternative institutional set-ups support strong dynamic performance of a (national/regional) economy or a sector" (Lundvall 2009). However, there is just one case study in that handbook which discusses a NIS, giving particular attention to the role of government in facilitating the transition of China's innovation system (Liu 2009) far from elaborating its institutional set-ups. Case studies in the edition by Muchie and Baskaran (2012) about different African countries or Cassiolato et al (2013) regarding Brazil's innovation system also did not serve this purpose.

The prominent work of Lee (2013) on NIS catch-up of Korea and Taiwan is very illuminating in a sense that it demonstrates the necessities of concentrating on short cycle technologies as a way to stay competitive with the advanced countries. Although it points to some important elements of knowledge and technology regimes of those successful countries, it tends to stay far from institutional analysis of those countries and their important roles in promoting or hindering technological progress.

Iran's innovation system has not been scrutinized with an exception of a paper used SWOT method to find its strengths and weaknesses not in a historical perspective (Ghazinoory and Ghazinoori 2006). In short, the corpus of literature on innovation system in developing countries are very illuminating; they seem not developed in order to analyse the catching up, or falling behind (except for Viotti 2002) of a developing nation like Iran; nor do they considered the important roles of institutions in this matter. In the next session, a framework will be developed to serve this purpose.

## Developing a framework

The framework has four main elements; the notion of technological paradigms (Freeman and Perez 1988, Freeman and Louca 2001), the dynamic of interactions between political and economic institutions (Acemoglu and Robinson 2012), classification of institutions as regulative, cognitive and normative (Scott 2014) and their final impact on the success of companies in technology, acquisition, exploitation and upgrading (Granstrand 2000, Lee and Lim 2001).

It is argued that Freeman's work is the only research being able to connect institutional analysis with technological change (Nelson 2008); however it lacks sufficient characterizations of institutions. Moreover, the dynamic of interactions between them is lacking in his analysis. Acemoglu portrays the dynamic interactions of institutions (either extractive or inclusive) but it is not connected to the technological change and simply admits the Schumpeterian creative destruction. Hence, his characterization of institutions does not help in connecting them to technological change. Scott (2014) provides a very interesting classification of different types of institutions, though his framework is originally designated for organizational purpose.

I posit that all three types of institutions reside either in the political or economic system. At the turning of each technological revolution, their cognitive institutions have to understand the importance of new coming technological paradigm. The first hypothesis here is that:

1- *The falling further behind for Iran is rooted in its in-appropriate understanding of technological revolutions.*

If they appreciate it properly, it needs to also pass the filters of normative institutions. Good interpretation would send the signals to the political and economic system in order to provide an appropriate regulatory response. Sometimes, it might take a long time for changing the values of the system that might postpone the process. The second hypothesis is therefore:

2- *The falling further behind for Iran is because of its normative institutions opposing the acceptance of technological revolutions.*

However, the next difficult stage is providing appropriate policy response. If one of them has enough control over another, or if they become both in the same direction, the responses could be devised easier. Otherwise, there will be a tension between political and economic system to reach a proper regulatory reaction. In the former (harmony between economic and political systems), then the main issue is to what extent do their responses are appropriate in order to reshape the institutions and enable the acquisition, exploitation and upgrading of technology within the firms. Good answers will lead to catching-up while inappropriate answers might lead to some levels of progress, but not catching-up. Therefore the country would fall further behind. The third hypothesis could be formulated as:

3- *The falling further behind for Iran is because of its inappropriate regulatory responses.*

Nevertheless, the latter situation is plausible in which there will be no harmony within the system to draft a proper policy response. As the main body of studies on innovation system of developing countries devoted to the former in order to find out to what extent do they provide appropriate responses; they normally failed to recognize the difficulty of finding such a regulative solution within the system because of inconsistencies between political and economic systems. In this instance, regulations will change frequently and the country does not move along a long term direction. Thus, the fourth hypothesis is:

4- *The falling further behind for Iran is because of inconsistencies between its political and economic system that prohibit finding long run regulatory responses.*

The main argument is that this framework could elaborate the changes of innovation systems throughout the time. The problem of many countries in falling further behind might not lie in their inappropriate regulatory responses, as they are hypothesized above. Therefore, it expands the literature by adding new dimensions to the institutional changes necessary for catching-up, while at the same time they could contribute to the falling further behind of the country.

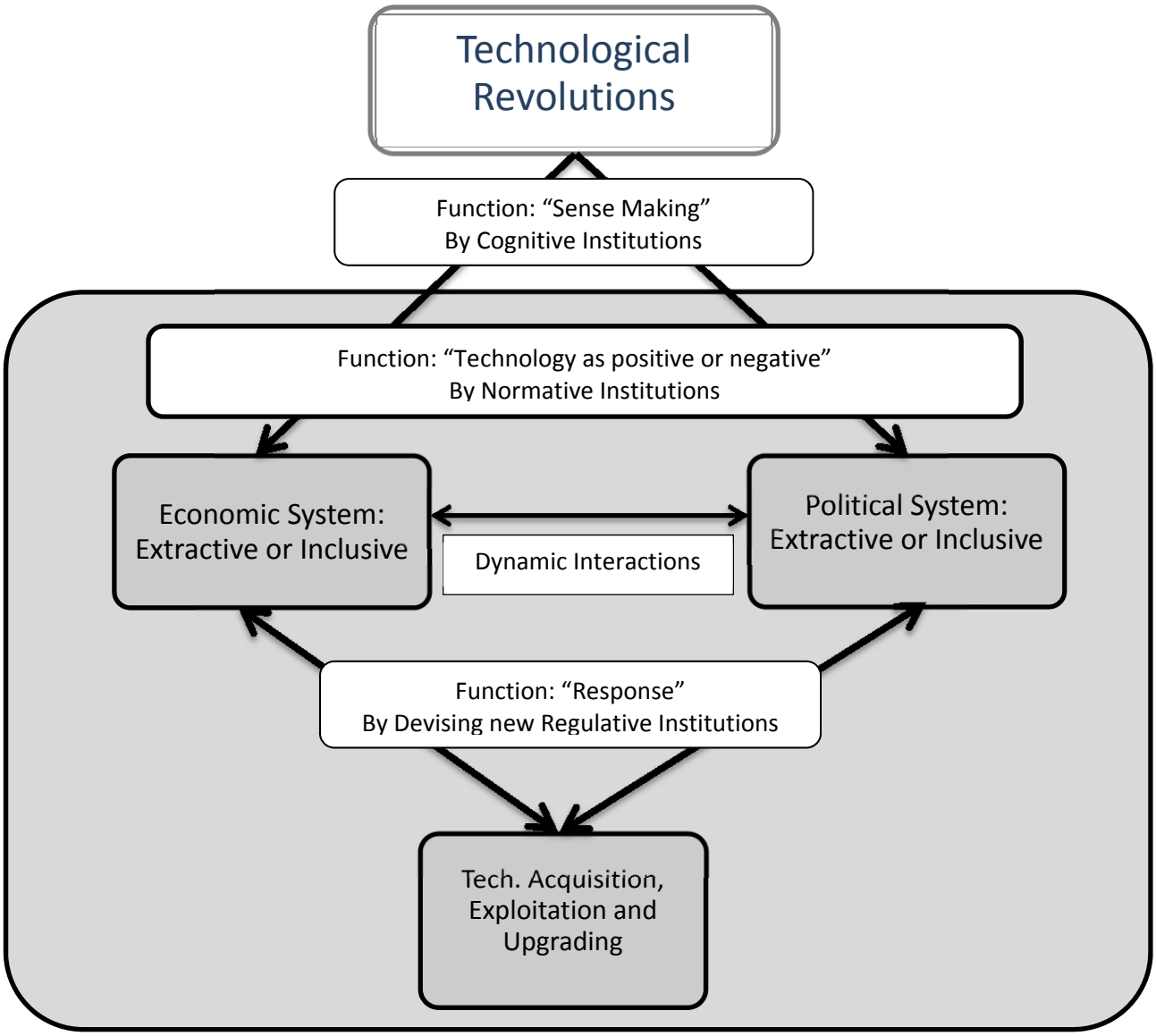


Figure 2. a model for analyzing NIS in the context of developing countries

*Method of analysis*

The analysis begins with matching the history of Iran with technological revolutions started from the early industrial revolution since 1770s. As a country with a long history that dates back 7000 years ago, Iran has always been a centre of evolutions and revolutions. Different dynasties, kingdoms and empires ruled the country from the early Median to the great Achamaenian, until when Islam diffused within the country following that Arabs conquered the Sassanid Empire in 651 (Elton 2000, Gershevitch 1985). Many other dynasties thereafter came to power and were deposed by wars, either internal or external. Table I shows the five technological revolutions and their

correspondence to the political systems in Iran. The Qajar dynasty faced the first three technological revolutions, while the Pahlavi dynasty mainly dealt with the fourth technological wave, and the Islamic republic was mainly in the era of the IT revolution. In the following sections, the analysis will be divided into 3 main periods each of which considers one political regime and will discuss the role of each element depicted in the framework.

Table 1: Technological Revolutions and evolution of Iran's political system

| | 1770 | 1830 | 1880 | 1930 | 1980 |
|---|---|---|---|---|---|
| | 1st Tech. Rev. | 2nd Tech. Rev. | 3rd Tech. Rev. | 4th tech. Rev. | 5th Tech. Rev. |
| Qajar | | 1791-1925 | | | |
| Pahlavi | | | | 1925-1979 | |
| Islamic Republic | | | | | 1979-Current |

Note: the dates of technological revolutions are taken from Freeman and Perez 1988

Each technological revolution will be analyzed in order to find out the reasons behind falling the country further behind, according to the 4 main hypotheses described above.

## Technological Revolutions and institutional responses in Iran

### *Qajar Dynasty: First, Second and Third Technological Revolution*

The first technological revolution, which took place between 1770 and 1830, was the age of early mechanisation, when some technical improvements to the processes of iron production and cotton mules led to a substantial increase in the effectiveness of iron and cotton production followed by the second revolution of steam power and railroads and the third revolution which was the age of the steel, electricity and chemical industries and the time when the US and Germany started catching up and even moving ahead of the UK (Freeman and Perez 1988).

The Qajar dynasty founded by in 1791 and lasted until 1925. The economic system at the time was mainly based on agriculture; some craft-based industries such as cotton and textiles, leather, carpet, silk and other local handicrafts that in no way could compete with their external counterparts (Jamalzadeh 1983). Although there were ample mineral resources in the country, the lack of adequate technical knowledge prevented Iran from extracting and using these resources (Kerzen 1983).

The dynasty's revenue obtained mainly from taxation of agricultural products, which ranged from 10 to 30 percent (Lambton 1953). Almost all of the members of the dynasty were accustomed to enjoy their life mostly through travelling to Europe; the required money for which could be obtained from either increasing taxation or from contracting with Europe to exploit from the land and other mineral resources (Shamim 1963). The traditional culture of the society was far away from technology and the education system was based on in house-schools. Therefore, the political system was absolutely extractive and the economic system was extractive feudalism with minimum awareness and reliance on technology.

As Iran's armies were then facing significant defeats in wars with former Russia, the attentions turned toward technology and mainly focused on learning how to build guns and organize troops. This is the first instance of making sense of importance of foreign technologies, although the military ones and not the technological paradigms of the time (i.e. textile machines and steam engines). Abbas-Mirza,[2] one of the most powerful figures in the country, supported the establishment of related military industries in Iran (Lockhart 2007) with the underlying belief that Iran must produce everything it needed (Mahboobi 1991). He also initiated sending of some Iranian people to the West to learn about the new science and technology, almost without substantial returns (Clawson and Rubin 2005). In this period, the political system realized the importance of some technologies and responded by its own, almost independent of the economic system.

The very short period when Amir-Kabir (meaning 'great ruler') took the position of prime minister in 1848 could be marked as an exception. His initiatives ranged from substantial political reforms and decreasing the power of courtiers (Amanat 1991) to supporting national production and even encouraging domestic manufactures to use steam engine (Adamiat 2006) to establishing a new technical school by employing foreign scholars in the fields of medicine, engineering, science and particularly military techniques (Mahboobi 1991). Unfortunately, he was killed due to a plot by unhappy dynasty members in 1852 and the changes did not continue (Amanat 1991). This short period is marked with realizing the importance of technological paradigms (by emphasis on steam engines and other new technical fields), trying to provide proper responses within the economic system.

[2]"Abbas Mirza". *Encyclopædia Britannica*. I: A-Ak - Bayes (15th ed.). Chicago, IL: Encyclopædia Britannica, Inc. 2010.

Hence, the Qajar dynasty returned to borrow money from other countries at the expense of giving them valuable contracts. For instance, a license to exploit oil in the south of Iran was contracted to a famous British trader named William D'Arcy to provide the money required for their expensive life (Cleveland 2004). As a result, this long period is best characterized by ignorance of technological revolutions, except few instances mentioned above, an absolutism political system and agricultural extractive economic system. In 1925, there were just 20 manufacturing factories employing about total 500 people within which there were just one factory having more than 100 employees (i.e. a textile manufacturing) (Barier 1984).

*Pahlavi dynasty: Fourth Technological Revolution*

The fourth technological revolution was the age of automobiles, oil and mass production started in the 1920s after the successful invention of the internal combustion engine based on oil as its new output (Freeman and Perez 1988). This technological revolution coincided emergence of Pahlavi dynasty with two kings.

Reza-Shah

Reza-Shah, a former officer who led a coup in the army, turned to the central power after regime change in 1925 and played a unique role in institutional reforms in Iran; chief among them was establishing a very strong government benefiting from the oil revenues (Katouzian 2006). Although the new Constitution was supposed to give strong powers to the parliament (constitutional monarchy (Acemoglu et al 2010), Reza-Shah continually tried to restrict the power of this institution through different means, such as creating political parties to win parliamentary elections (Cronin 2003). Therefore the political system continued to rule the economic system.

He took a very aggressive attitude to transform the country into what he called 'Modernism' with several elements from political to economic and cultural reforms. He put strong emphasis on the Iranian identity; the one that was portrayed something in contrast to the traditional culture. Several programmes initiated to enhance and purify the Persian language, to change the role of women in society, to educate the lay public and so on (Abrahamian 1982). A central education system based on the Persian language and with unified course materials was a major institutional reform to reshape the culture and the workforce required for the country. Some other programmes to educate civil

servants and tribes' people were also initiated, while traditional religious schools were restricted and forced to work under the control of the central education system (Cronin 2003). In this sense, the central necessary power for serving public people (as it is deemed necessary by Acemoglu and Robinson 2012) was in place and he could reshape the required institutions for this purpose.

The number of students sent to the West increased, among which 417 came back to Iran between 1921 and 1938 (Khalili-Khoo 1994). The first Iranian university, to be called University of Tehran, established in 1934 with departments of medicine, law, engineering, political and economic sciences, science and philosophy[3]. Founding the university was also part of modernization programme, yet it heavily based on teaching of the scientific materials that had already been developed elsewhere, putting research as a matter of personal interest (Farasatkhah 2009).

The agricultural system of the country remained unchanged and the most important industry of the country, oil, was controlled by the British Oil Company so that Iran was not involved in oil exploration and exploitation (Bamberg 2000). The government's strategy for other industries was development of consumption goods producers. Therefore, the system was mainly ignorant about its current technological revolution and its carrier industry (mass production in car industry).

It is estimated that about 210 laws about industry enacted from 1925 to 1941 (Sadeghi 2009). The law for commerce[4] and the law of industrial and commercial marks[5] enacted in 1925; the former then modified in 1932[6]. A law enacted in 1924 according to which industrial and agricultural machines exempted from custom tariffs for 10 years[7], while minimal effort was given to technological upgrading. Development of carrier industries of three former technological revolutions, i.e. textile and railroad as well as light generation, speeded up in this period.

The main approach towards technology and industry during that period was turnkey technology transfer, which was apparent in several industries especially the textile manufacturing (ibid). At the end of this period, there were about 300 manufacturing firms, most of them in consumer production industries with less than 10 factories in heavy

[3] The history of university is available in its website: http://www.ut.ac.ir/en/contents/Overview/UT-at-a-Glance-EN/UT.at.a.Glance.html
[4] The Persian text is available here: http://rc.majlis.ir/fa/law/show/91011
[5] The Persian text is available here: http://rc.majlis.ir/fa/law/show/91049
[6] The Persian text is available here: http://rc.majlis.ir/fa/law/show/92349
[7] The Persian text is available here: http://rc.majlis.ir/fa/law/show/91043

industries, all to be controlled by the government (Khamei 1996). Some estimates that less than 30 of those manufactures employed more than 500 (Farasatkhah 2009) indicating a positive trend towards enhancing the manufacturing sector.

Thus, this modernization period could be characterized by a mix of ignorance of its current technological revolution, while paying much attention to the former revolutions as well as providing regulatory responses promoting manufacturing development rather than technological catching-up within industries.

Muhammad-Reza-Shah

The next king took the throne in 1941, but it took some years until he could control the political disruptions within the country. As a very important event, the oil industry was nationalized by the efforts of one of the prime ministers in 1951; through the time when the king did not have a strong control over the country[8]. Instability of political and economic system continued up to 1963 when the king gradually gained control over the country. He persisted in spending a great amount of money on modernising the army to become the most powerful military power in the Middle East (Alikhani 2014)[9], although with less attention towards technology upgrading.

The major economic reform referred to as the White Revolution, started in 1963 with the aim of transforming Iran into a global economic and industrial power. The programme for such reform constituted from 19 elements to be carried out over a period of 15 years. Some of the most important elements of which were (Abrahamian 2008):

1: A Land reform programme that aimed to abolish feudalism.

2: Privatisation of government-owned enterprises.

3. Profit-sharing, so that industrial workers in the private sector were to hold 20 percent of the net benefits of the companies for which they worked.

4. Price stabilisation: a campaign was initiated against factory- and store-owners making extra profits.

[8] The Persian text for the law of which is available here: http://rc.majlis.ir/fa/law/show/94219

[9] This text is one of the original memorandums written by Alam, the minister of court. He has written his daily memorandums and his daily interactions with Mohammad-Reza-Shah

Some commentators stated, the White Revolution was not successful in its economic and industrial reforms (Dorman and Farhang 1987). It not only weakened the productivity of the agricultural sector of the country by dividing large farms into small family-based farms, but also imposed some restrictions on private companies by stabilising prices and enforcing that workers should benefit from the profits of factories. The reforms were both communistic and capitalistic, as on the one hand it enforced the privatisation of industries, while on the other hand it restricted the motivations of private sector. It is argued that the fear of the diffusion of socialism was a driving factor behind some set of these policies (Rahnema and Behdad 1996). As a result, although the program was initially intended to transfer the economic system into an inclusive one, it was not successful at this aim.

After the failure of that programme, Muhammad-Reza-Shah decided to found a new institution named the Industrial Development and Renewal Organisation (IDRO) of Iran in 1967, to imitate the Italy's Industrial Renovation Institute. The main idea behind this initiative was that the government owns its shares, but it operates under the rules and laws of the private sector[10]. The main roles of this organisation were to be[11]:

1. To invest in heavy industries that could not be established in the private sector.
2. To rejuvenate non-productive industries.
3. To cooperate with foreign investors to developing the industries and mines of the country.

The main strategy of this organisation was 'import substitution', which focuses on the necessity of building those industries from which the country has been importing large amounts of goods and products. The development of many large petrochemical plants, machine building and aluminum production were among the results of this strategy. From 1971 to 1977, IDRO contributed largely in establishing a variety of industries within the country either on its own, by cooperating with other investors or just by buying the shares of companies and trying to renovate them (Saeedi 2015). The last decade of Muhammad-Reza-Shah' reign therefore witnessed substantial increase in the number of manufactures initiated by IDRO, from 18 in 1971 to 111 in 1976 (IDRO 2007) [12]. IDRO played a

[10] The law of founding IDRO available here in Persian: http://rc.majlis.ir/fa/law/show/96103
[11] From IDRO's official website: http://www.idro.org/enidro/About%20Idro/History.aspx
[12] There are some biographical histories recently published in Persian according to interviews with prominent figures within that time such as the minister of economy and its deputies. They confirmed the view that the industrial policy was to produce the goods Iran were importing (e.g. Lajevardi 2010, Dehbashi 2014)

unique role in developing industrial basis of the country in several fields that Iran was importing goods mainly through buying machine tools in the form of turnkey technology transfer with less attention to other forms of technology acquisition, exploitation and upgrading; thanks to oil shocks in 1973. This regulative response played also important roles in pushing the economic system into more extractive ones being dominated by the government.

The car industry in the country established in 1962 when the "Iran National Company" was founded by the private investments, means that making sense of the current technological revolution happened within economic system. It continued assembling "Arrow-Hunter" since 1967 until Islamic Revolution in 1979, when the company was nationalized.[13] This company did not move along the path of active technological learning in terms of technology acquisition, exploitation or upgrading while the institutions of the country also did not encourage it to change its direction. Intriguingly, Arrow-Hunter remained its only product till late 1990s.

The hallmark of this period therefore could be making sense of mass production in car industry by the economic system; although the regulatory responses did not lead to satisfactory regulatory changes to promote technological upgrading within industries.

*Islamic Republic: fifth technological revolution*

ICT shaped the fifth technological revolution (Freeman and Louca 2001). During this global transformation, Iran observed another political revolution with the introduction of the new Islamic Republic system to transform the political system into an inclusive system. At this time, the country was benefiting from oil revenues; it had several industrial capacities as a result of earlier industrial developments.

According to the new Constitution enacted in 1980, Act 44 explicated that "The state sector is to include all large-scale and mother industries, foreign trade, major minerals, banking, insurance, power generation, dams and large-scale irrigation networks, radio and television, post, telegraph and telephone services, aviation, shipping, roads, railroads and the like; all these will be publicly owned and administered by the State"; while the private sector would normally

[13] http://www.ikco.com/En/Intro.aspx

play a complementary role to that of the government.[14]As a result, large industrial companies were nationalised at the beginning of the new system; some of which captured by the government and mainly by IDRO, some other merged to shape the "Oppressed People Institute[15]" and others formed another institute under control of the supreme leader which is called "Setad[16]"; they are large corporations in diversity of businesses. Thus, the economic system became even more extractive in comparison to the earlier period.

The first decade after the revolution was about a war with Iraq, which lasted until 1989. The main development programmes started in 1990s aimed at fundamental economic reforms. The major priority was to rebuild the infrastructures and industries that had been destroyed in the war, following the structural adjustment programmes to enable the country to get loans from the IMF and the World Bank at a time when the price of oil was at its lowest level. The main suggestions of such policies reflected in the 1st development program (1989-1993) aimed to liberalise trade, prices and currency, reducing the role of the government in the economy and increasing the efficiency of the manufacturing sector[17]. Industrial policy was still import substitution and IDRO continued its former role with less attention given to exploitation and upgrading technology.

ICT remained in the fringe until 2002 when a major 3 years programme called TAKFA[18] aimed at development of ICT applications launched, under which the government forced all departments to spend 1% of their revenue on developing ICT applications. As it was mainly focused on expanding its applications, rather than its carrier industries, this programme failed to bring about technology acquisition, exploitation or upgrading or even shaping large corporations in this sector[19]. ICT has not been considered as a high agenda in the next state governments.

Some trend of changes

In 2000 the scientific system experienced a radical change. According to the Third National Development Plan, the name of the Ministry of Higher Education was changed to the Ministry of Science, research and Technology,

[14]Author's own translation. The full text of the constitutional law can be found here: http://www.servat.unibe.ch/icl/ir00000.html
[15] More information about this institute is available here: http://www.irmf.ir/en/default.aspx
[16] Reuters published a report about this institute recently, however its estimation of its assets is debating: http://www.reuters.com/article/2013/11/11/us-iran-setad-news-idUSBRE9AA0CY20131111#xPwMO4p53Jrp2xZU.97
[17] The full text of this 5 years program is available in Persian in this link: http://www.parliran.ir/uploads/ghanoon%201_6357.pdf
[18] In Persian, it is the abbreviation of this phrase: practical development of information technology
[19] Details of the programme is available in Persian here: http://www.shci.ir/Portal/View/Page.aspx?PageId=f5e3374f-01e8-48b3-8847-d51d02baa9ba&ObjectId=8f1d008b-1921-466b-a3ae-05c4d3fbe67c&WebpartId=1f388f8a-164b-4192-8f63-530a2ee59eae

stressing the important role of science and technology[20]. During this period, the government provided substantial rewards for research and publications within universities, which led to radical changes in the number of international publications. The ministry also put development of "science and technology parks" close to universities as its main agenda. Along with those movements, the Supreme Leader continuously called for scientific and technological progress. For this purpose, in 2003 he envisaged that the country should become the first economic, scientific and technological power in South-West Asia by 2025.[21]

As a major reform in economic institutions, the Supreme Leader announced new privatisation reforms for the country by changing Act 44 of the Constitution in 2005. According to the new changes, the private sector could and should participate in basic economic activities, which were formerly forbidden to take part[22]. A year later, a new amendment was added to this declaration, stressing that most (about 80%) of governmental companies should be privatised with great emphasis on the necessity of capacity building within the private sector[23] for which the parliament enacted a particular law[24]. Although it is soon to judge the success of this significant economic reform, it seems that privatization programme transformed many of the former state owned corporations into publicly owned ones[25], set aside the private sector[26].

The government enjoying the high price of oil established a new "Vice Presidency of Science and Technology" in February 2007 aimed at supporting technological development. However, the initial years of this organization's work were depleted by supporting universities and research centres, based on a view of a linear model of innovation with less attention given to the role of firms as the main driver of technological development[27]. The Higher Council of the Cultural Revolution enacted the "Comprehensive Science and Technology Plan" of Iran in January 2011 to set the

[20] A Persian text of the law is available here: http://parliran.ir/uploads/ghanoon%203_6359.pdf?siteid=1&siteid=1&pageid=224
[21] An English translation of this vision is available here: http://www.vision1404.ir/fa/News48.aspx
[22] The text of this new amendment is available here in Persian: http://farsi.khamenei.ir/news-content?id=165
[23] The text of this new amendment is available here in Persian: http://farsi.khamenei.ir/news-content?id=1400
[24] The text of the law is available here in Persian: http://www.mcls.gov.ir/fa/law/260
[25] Such as the public institutes established after the revolution and mentioned before
[26] The head of Privatization organization who is in charge of privatizing state owned firms announced that in the past 12 years, just 12.7% of privatizations was really to private sectors: http://www.mehrnews.com/news/2191106/%D9%86%D8%A7%D9%85%D9%87-%D9%88%D8%B2%D8%B1%D8%A7%DB%8C-%D8%AF%D9%88%D9%84%D8%AA-%D8%AF%D9%87%D9%85-%D8%A8%D8%B1%D8%A7%DB%8C-%D8%A7%D8%A8%D8%B7%D8%A7%D9%84-%D8%AE%D8%B5%D9%88%D8%B5%DB%8C-%D8%B3%D8%A7%D8%B2%DB%8C-12-7-%D8%AF%D8%B1%D8%B5%D8%AF-%D9%88%D8%A7%DA%AF%D8%B0%D8%A7%D8%B1%DB%8C-%D9%87%D8%A7
[27] A list of activities of this organization in its 2 early years are summarized in the following link (in Persian), all were about funding universities, research centres and individual scholars: http://sub.isti.ir/index.php?option=com_content&view=article&id=97:2009-07-11-08-51-18&catid=42:2009-06-24-10-39-36&Itemid=180

priorities and strategies of the country with respect to science and technology[28]. Meanwhile, the Higher Council of Science, Research and Technology, the secretariat of which is located in the Ministry of Science, Research and Technology, started several major technological programmes mainly to be carried out within universities. "Vice Presidency of Science and Technology' also founded different technological councils to support implementation of CSTP in technological fields. The role of private sectors or even industries in formulating those plans or even taking active role in those programmes was very limited.

A very recent policy change in the country is enacting a law to support what is known locally as knowledge based firms[29], which are defined very close to the new technology based firms (NTBFs)[30] (Granstrand 1998). It has been implemented since 2013 in the vice presidency of science and technology, according to which, the government provides financial supports, tax and customs tariff exemption for those firms. Until know, about 3000 firms are recognized as knowledge based firms[31]. The law is criticized for not being linked to industrial or innovation policies.

As a result of overall efforts since the Islamic Revolution, some infrastructural industries benefited from technical change. The case of electricity generation is interesting in a way that a body of experts established MAPNA and FARAB as two state owned corporation in the ministry of power generation with substantial success in technological learning (the details of their success is elaborated in Kiamehr 2017 and Kiamehr et al 2013, 2015). Other sectors such as Defense went through the same success story as it could achieve variety of technologies in missile, satellite and other military equipment (although was not much successful in others such as big airplanes)[32]. The nuclear development was another case in which Iran could achieve substantial technological knowledge[33] as it was true in the case of nanotechnology (Ghazinoory et al 2009) and modern biotechnology enjoying rapid development of some high-tech results in research centres or in very few pharmaceutical firms (Mahboudi et al 2012). However, the key

[28] The text of which is available here in Persian: http://nj.farhangoelm.ir/%D9%85%D8%AA%D9%86-%D9%86%D9%82%D8%B4%D9%87
[29] The text of the law is available here in Persian: http://daneshbonyan.isti.ir/index.aspx?siteid=2&pageid=146
[30] The criteria for being recognized as a knowledge base firm is defined here, the most important are to produce high or high-medium tech products plus internalizing the technical knowledge: http://daneshbonyan.isti.ir/index.aspx?siteid=2&fkeyid=&siteid=2&pageid=149
[31] The complete list of those firms are available here: http://daneshbonyan.isti.ir/index.aspx?siteid=2&fkeyid=&siteid=2&pageid=6833
[32] There is no an integrated report describing the technological capability of the country in the military section. However, it is apparent from its outputs that there are lots of technical progresses there.
[33] This report on CNN describes the some facts and capabilities of Iran in nuclear sector: http://edition.cnn.com/2013/11/07/world/meast/irans-nuclear-capabilities-fast-facts/

success factor for them is that they are all based on government demands with few interactions to real economic system that is still far from technological learning (Mirimoghadam and Ghazinoory 2017).

Table 2 shows the number of factories in 2013 having more than 50 employees, including oil and gas production. According to the national statistics, these sectors constitute about 30% of the GDP while other 54% is in the service sector and the remaining 16% is produced in agriculture and construction[34]. The 6 industries detailed in the table accounts for 42% of the number of manufactures, 64% of the job creation, 84% of total value added, 90% of the sales and 96% of the exports in the manufacturing sector[35]. 3 among them are natural resources producing more than 40% of value added, more than 60% of sale and about 45% shares in exports. Chemical sector which is heavily based on petrochemical industries has about 27% of value added rooted in its cheap energy input, 16% of sales and 45% of exports. Food and beverages show less than 10% share in value added, less than 7% in sales and less than 6% in exports and finally the vehicle industry as a more technologically advanced sector just produces 6.3% of value added, about 3% of sales and negligible shares in exports (0.12%).

Table 2- Major manufacturing sectors of Iran[36]

| | Chemical products | Basic metals | Oil Refinery and coke | Food and beverages | Vehicle | Non-metal minerals | 6 industries | Total factories |
|---|---|---|---|---|---|---|---|---|
| # of factories | 413 | 327 | 43 | 882 | 313 | 14 | 1992 (42.2%) | 4724 |
| employees | 116494 | 121923 | 28637 | 168971 | 122722 | 120114 | 678861 (64.7%) | 1049542 |
| value added (billion $)* | 9.98 (27.7%) | 6.73 (18.7%) | 5.08 (14.1%) | 3.3 (9.15%) | 2.27 (6.3%) | 2.99 (8.3%) | 30.35 (84.2%) | 36.04 |
| Sales (billion $)* | 25.5 (16.43%) | 23.47 (15.12%) | 66.8 (43.04%) | 10.62 (6.84%) | 8.77 (5.65%) | 4.9 (3.16%) | 140.06 (90%) | 155.2 |
| Exports** (billion $) | 9.7 (44.99%) | 2 (9.27%) | 6.54 (30.33%) | 1.2 (5.56%) | .12 (0.5%) | 1.19 (5.52%) | 20.75 (96%) | 21.56 |

* Data transformed into $ by the author
** Data for exports was originally published in $

It shows that there are few successful sectors in new technological fields such as Nano, Bio, Turbine or Defense that are almost weakly linked to the economic system. Parts of those developments could be attributed to the growth of scientific activities; yet the scientific system suffers from lack of research capability to could help the demands of

[34] The data for which is available in central bank of Iran at: http://cbi.ir/simplelist/2054.aspx
[35] Iran is a main oil and then natural resource exporter. The data for exports are available in: http://atlas.media.mit.edu/en/visualize/tree_map/hs92/export/irn/all/show/2013/
[36] The data is published online and available here in Persian: http://www.amar.org.ir/Portals/0/Files/fulltext/1392/n_50nafar_92.pdf

corporations. The political system now pays more attention to technological learning, but it is almost in a linear paradigm and its technology policies could not connect to corporations. CISs in the main industries of the country are still undeveloped in terms of technology exploitation and upgrading while at the same time institutional changes and technological investments are not directed towards ICT development, nor upgrading the current manufacturing sectors such as the vehicle or oil industry as the main industries of the recent technological revolutions.

This area could be characterised as making sense of ICT paradigm in a short period of time by the political system while its main feature is an inclusive political system having control over the economic system and so many changes in its long run directions as a result of changing states every 8 years.

## Conclusion

The overall changes within Iran throughout the past 2 centuries are summarized in table 3. There are 6 major periods with different dynamics, interactions and results.

Table 3. Characteristics of evolution of Iran's NIS within 6 different periods

| | Qajar dynasty | Reza-Shah | Mohammad Reza Shah 1 | Mohammad Reza Shah 2 | Islamic Revolution 1 | Islamic Revolution 2 |
|---|---|---|---|---|---|---|
| **Time Period** | 1771-1925 | 1925-1941 | 1941-1963 | 1967-1979 | 1979-2000 | 2000-now |
| **Values and norms** | Traditional but not negative | Semi traditional but not negative | Neutral | Neutral and somehow positive | Neutral and somehow positive | positive |
| **Economic system** | Extractive Feudalism | -Transition into Industrialisation -Extractive | Extractive | Extractive | Very extractive | Extractive |
| **Political system** | Absolutism | Constitutional monarchy | Constitutional Monarchy | Constitutional Monarchy | Almost Inclusive and changing frequently | Almost Inclusive and changing frequently |
| **Dynamic interaction** | Almost Separated | Political System Dominated | Political System Dominated | Political System Dominated | Political System Dominated | Political System Dominated |
| **Making sense of technological Revolutions** | No sense, except few instances by political people | Not making sense of 4th Revolution, but the former ones | Not making sense | Making sense by economic system | making sense of 5th revolution by political system | making sense of 5th revolution mainly by economic system |
| **Regulative responses** | Sending few people abroad, establishing one technical school | Support for textile manufacturing perceiving technology as embodied in machines | No regulatory response because of conflicts within the system | Heavy development of industries based on IDRO perceiving technology as embodied in machines | Support for ICT perceiving technology as embodied in machines | Linear science push model for technology upgrading |
| **Confirmed Hypotheses** | H1: inappropriate | H1: inappropriate understanding of | H4: weakness in providing long | H3: inappropriate | H3: inappropriate | H3: inappropriate |

| | | | | | | |
|---|---|---|---|---|---|---|
| | understanding of technological revolutions | technological revolutions<br>H3: inappropriate regulatory responses (technology embodied in devices) | run regulatory response because of internal tensions | regulatory responses (technology embodied in devices) [recognition by economic system] | regulatory responses (technology embodied in devices)<br>H4: weakness in providing long run regulatory response because of frequent changes within the system [recognition by political system] | regulatory responses (linear response)<br>H4: weakness in providing long run regulatory response because of frequent changes within the system |

Four hypotheses vis-a-vis reasons of falling further behind for Iran have been tested. It showed that not catching-up could originate not only from inappropriate regulatory responses of the country, but also because of problems in cognitive institutions, normative ones or even the dynamic interaction between political and economic systems. The results of hypothesis testing are shown in last row of table 3. Hypothesis 2 has not been confirmed as the normative values of the society have always been in support of new science and technology. Moreover, it shows that more than one cause might restrict the innovation system of a country as it was in some periods of time in Iran.

However, there are 6 periods of time, with different underlying factors hindering technological catching-up of the country. The first three technological revolutions of the Qajar dynasty have been ignored by the system with an exception in the short period of Amir-Kabir. Although the 4$^{th}$ revolution has not been recognized in the second period, the regulatory responses of the system were not also appropriate for technological catching-up with the former technological revolutions. The third period was the age of internal tensions with no long run regulatory response followed by the next dominant political system with regulatory responses inappropriate for catching-up and sense-making of its current technological revolution by actors within the economic system. Finally, the Islamic revolution with an inclusive political system dominated the economic one could not reach a long run agreement about proper regulatory responses for technological catching-up, mainly because of frequent changes within the government. The short term responses was similar in its first half to the earlier times, while the second half was also acted based on a linear science push model for technological changes.

## Implications

The idea of linking innovation system to economic development has been empowered through analyzing institutional set-ups as focusing devices (Lundvall et al 2009) in the context of developing countries. It is argued that the concept of NIS as an analytical tool could be useful in the context of countries fell further behind; if it broadens its view towards institutions, their functions and the dynamic interactions of political and economic systems.

Classification of institutions as regulative, cognitional and normative by Scott (2014) suggested promising ways for further development of NIS by considering their different functions. Rather than failing to involve a discussion about usefulness of functionalistic views (proposed by Edquist 2005), it provided a new framework to classify institutions and their distinctive functions. Cognitional institutions, either in political or economic system, are extremely important in making sense of technological changes (that in the context of developing countries are exogenous) and also devising proper regulatory responses that will be appeared in the form of regulative institutions. Their success, to a large extent, also depends on norms and values of the society regarding new technologies. Therefore, cognitional institutions within each country are paramount in terms of their role in understanding the reality of technological changes as well as providing appropriate regulatory responses. The case of Qajar dynasty shows a good example of a country with very weak cognitions with respect to technological changes.

However, the dynamic of interactions between economic and political system is also very important in shaping the proper policy responses (Acemoglu and Robinson 2012). Inconsistencies between these two institutions might hinder adequate institutional changes within a country while frequent changes in their dynamic interactions would also bear inverse effects on finding a long term strategy for technological catching up (in comparison to e.g. South Korea (Lee 2013) or Japan (Freeman 1987)).

The NIS literature is mainly focused on the responses of the system to technological changes in order to promote innovations within corporations, paying less attention to the earlier stages that largely contribute to the experiences of falling further behind. The current framework was a step ahead in this respect. Evolution of NIS also could be captured by this framework as it is portrayed for the context of Iran. This framework could be useful for the context of other developing countries, especially for understanding the dynamic change of the system. Further analyses could

bring more resolution to this picture, while more case studies could also lead to improvement of the proposed framework.

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