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Iran's innovation system: historical account of institutional roots of falling behind

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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 discussed in this paper. A framework rooted in state of the art research on this issue and the theoretical insights of Freeman has been developed to study the institutional roots of Iran's innovation system in a historical perspective that may contribute in explaining the factors underlying its falling behind from of those technologically advanced nations. It has not only been showed how the institutional set-ups of the country could not respond properly to the necessities of technological paradigms from the beginning of industrial revolution; but also it is delineated how the Islamic revolution could not also be successful in changing some of those institutions. Some theoretical and policy related remarks are presented at the end.

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Keywords: National Innovation System, Development, Technological Revolutions, Institutions

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 publications in the field of innovation system research (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 2001, Lundvall and Borass 2004), 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.

For this purpose, a short discussion on the variety of approaches to NIS will be presented, following by viewpoints about the possibility of applying innovation system as a framework for studying economic development in the context of developing countries. After highlighting some voids in the current research, a framework based on Freeman's ideas about innovation system in less successful countries (Freeman 2002) will be developed that is deemed useful in analyzing the economic development in the 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 of the country in economic development. 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). In his book comparing the NIS of different countries (Nelson 1993), Nelson puts the research and development (R&D) system of a country at the centre of analysis, pointing to the importance of technical changes, the increasing role of science in technology and the central role of research in the process of scientific and technical development. Nelson makes a distinction between public and private knowledge production, identified by their R&D performers, and argues that the division of labour between these two complementary roles and the institutions supporting corporate R&D could provide an explanations of the differences of the national innovation systems in capitalist economies (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. In this sense, Lundvall defines NIS as "the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state" (Lundvall 1992). Other scholars also echoed this view, arguing that different types of interactions are needed to allow the transfer of science, technology and knowledge in the wider national systems (Niosi et al. 1993, David and Foray 1995).

Summarizing Japan's innovation system in a chapter of a book edited by Dosi et al. (1988), Freeman stated: "[W]hen Britain opened up a major 'technological gap' in the first industrial revolution, this was related not simply to an increase in invention and scientific activities, and a cluster of innovations in the textile, iron and engineering industries, but to novel ways of organizing production, investment and marketing and novel ways of combining invention with entrepreneurship… Similarly, 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). His main approach was to link institutional changes as a main determinant of technological catch up and economic development (Nelson 2008).

As another approach to NIS, 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 2005). He defines systems of innovation as "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist 1997, p. 14). He contends that this approach provides a dynamic perspective on what happens within the system and the process of change, while at the same time it can illustrate why a certain system performs badly with regard to certain kinds of innovation and at the same time it could be more instrumental for either policy design or for theory building (Edquist 2011).

The trend of linking innovation system research with the theory of economic development and catching up (Freeman and Perez 1988, Muchie et al 2003, Johnson and Lundvall 2003, Cassiolato et al 2003, 2014, Dutrenit et al 2013) is intensified since 2000s, considerable parts of them being reflected in GLOBELICS (global network of economics of learning, innovation and competence building systems) (Muchie and Baskaran 2009, Cassiolato et al 2012). Lundvall developed the idea of interaction through making a distinction between two types of learning and innovation: 'STI and DUI mode' (Jensen et al. 2007). The former reduces innovation to scientific and technological activities, while the later places learning by doing, using and interacting at the core of economic activities. The authors argue that

the DUI mode could lead to economic development and catching-up, while the STI mode is far from being fit for this purpose (Lunvall et al 2009).

Linking innovation systems to catching-up is not limited to national systems, as other scholars, such as Nelson and Malerba, have tried to make a similar connection at the sectoral level of innovation systems (Malerba and Nelson 2011). They also suggest that the answer to the question of the uneven development of sectors is partly rooted in the differences of the NIS of each country, in that the characteristics of the national systems favor the development of some sectors while obstructing the necessary development conditions of others, either with regard to their actors, institutions or knowledge bases (Malerba 2002, 2004).

The research on linking system of innovation research to the economic development is still young. The particular interest of this research is to understand the institutional barriers of innovation system in the context of a developing country; while for achieving this goal there is a need to follow a twofold purpose. On the one hand, application of the NIS to the context of developing countries should be considered carefully (Lundvall et all 2009) and on the other hand, linking institutions to the catching-up is not an easy work as Nelson (2008) argued that the study of Freeman is the only exception in this regard (i.e. Freeman and Perez 1988 and Freeman and Louca 2001). The following sections are discussing these two issues respectively.

Research on NIS in developing countries

Although the concept of NIS has been developed in the studies vis-à-vis the technologically advanced countries (e.g. Japan and USA); there has been several efforts to adapt it to the context of developing countries (e.g. Hou and Gee 1993, Kim 1993, Dahlman and Frischtak 1993, Katz and Bercovice 1993; all are chapters in Nelson 1993 discussing the experiences of Taiwan, Korea, Brazil and Argentina respectively). However, the issues surrounding the applicability of the framework for developing countries have not been taken into account seriously in those earlier works.

Some other contributions emerged at the late 1990s and early 2000s. Gu tried to identify the gaps which may impede applications of NIS as a policy tool for the context of developing countries (Gu 1999). He pointed to differences between NIS in those two contexts and accordingly suggested that the analysis of NIS in developing countries should have 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.* Arocena and Sutz (2000) emphasized the same issue by discussing how the approach should be complemented by a southern perspective, particularly the Latin American one, which might be worried about four aspects of NIS including its *ex-post character, normative weights*, *relational aspect* and *policy orientation.* 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. Technological learning can 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 in technology is accompanied by efforts to master assimilated technology by considerable investments.

In addition to the applicability of the concept to the context of developing countries, 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, as *interaction with production systems*, *functional role of institutions* and *institutional matrix*. Institutions refer to different types of organizations such as higher education, research and

technological development organizations, industrial research laboratories and so on. Wong (2002) highlights the phases of development in the Singapor'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 those actors leads to the development of useful stock of scientific and technological resources that in turn being deployed by innovation actors. 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 (Intarakumnerd et al 2002). The authors suggested making distinctions even between the less successful countries and the NIEs. Cassiolato et al (2013) analysed Brazilian innovation system via a framework composed of 1- policy dimension, 2- S&T infrastructure, 3- production structure and 4- the social dimension as an extra aspect to could consider the social inclusion.

The handbook on innovation system in developing countries is a reflection of the recent efforts (Lundvall et al 2009). They suggested 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, while admitting that it corresponds to the original works of Freeman (1982, 1987 and 1988). Lundvall proposed 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 rooted in the processes of science-based and experience-bases learning (Lundvall et al 2009). 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" (Ibid p. 7). However, there is just one case in the handbook discussing the national innovation system of China, giving particular attention to the role of government in facilitating the transition of its innovation system (Liu 2009) far from discussing the institutional set-ups or being rooted in a well-established theory of innovation or development. Case studies in the edition by Muchie and Baskaran (2012) about different African countries also did not serve this purpose.

That is a problem which is apparent also in the aforementioned studies about national innovation systems of developing countries as they are not either based on a well-established theory nor analyzing the institutional set-ups of those countries in more detail. The next section will propose a framework based on Freeman's approach (Freeman 2002) that might pave the way for enriching the innovation system research in the context of developing countries.

Developing a framework

Freeman and Perez (1988) popularized the idea of techno-economic paradigms (long waves or technological revolutions) in their seminal work stating that cluster of innovations in the economy were the result of new technological revolution that in turn led to catching-up and economic development. The theory of long waves is one category of evolutionary theorizing in economic development (Verspagen 2004) rooted in Condriatev waves and Schumpeterian business cycles (Perez 2010). Hence, it provides a theoretical root for innovation system research. Although Freeman did not develop a framework to link techno-economic paradigms with innovation systems in his early works on NIS (e.g. Freeman 1987, 1988), he briefly discusses the possible role of the new ICT revolution at the end of his article discussing the innovation system of Japan. He puts forward the argument that the advantages of Japan's innovation system would become more importance if they are seen in the light of the new IT paradigm that has changed the structure of the world economy.

However, in 2001 Freeman developed an integrative framework with Louca in their comprehensive analysis of the technological revolutions since the beginning of the industrial revolution, accompanied by multiple institutional changes (Freeman and Louca 2001). The foreword to this book written by Nelson suggests that their work combines two approaches, one arguing in favour of using history as a test for theory, and one with a more institutionally-oriented historical perspective, stressing the importance of understanding the complexity of the factors that drive economic development.

Freeman and Louca explore the economic development of different eras, each of which is marked by a technological 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. This process is characterised by substantial institutional changes in five subsystems of society, including *technology, science, economy, policy and culture*. Those countries that can better adapt the institutional arrangements of their subsystems to respond to the requirements of the new paradigm take over leadership of the world economy.

This approach forms the basis of Freeman's last paper on NIS (Freeman 2002). In this paper, Freeman tries to clarify the links between innovation systems and economic development by discussing the complementarities between five subsystems of society through historical, institutional and techno-sectoral analysis of the experience of Britain in the age of industrialization (for which he argues the full national system of innovation emerged within that time), the subsequent catching-up of the United States in the late nineteenth and early twentieth century, and the emergence of new economies in the twentieth century. At the end of this paper, Freeman points that "some of the most promising lines of future research on national systems would appear to be in the study of catch-up failure and falling behind in economic growth" (Freeman 2002 p. 208) for which he suggests using the congruent theory between subsystems of the society might be a useful explanation. This approach also adds a type of historical analysis that in turn enriches the analysis of economic development.

For the purpose of this study, the congruent theory will shape the central theoretical framework upon which I would try to delineate the historical evolutions of institutions within subsystems of the society. Nevertheless, the congruent theory should be modified in the context of developing countries. For the leaders of the world, technological paradigms could be seen as an internal factor that in turn calls for further changes in other subsystems. For instance, the UK's innovation system in the first and second technological revolutions was a context for those radical technical changes that in turn shaped the UK's innovation system. However, for other countries that are not the main drivers of technological revolutions, technological revolutions could not be seen as an endogenous system, but rather as an exogenous driving force that impacts other subsystems of society from the outside. This point is in line with observations of other scholars concerned with innovation systems in the context of developing countries (e.g. Gu 1999, Arocena and sutz 2000, Viotti 2002).

To analyse the innovation system of a developing country at any specific era, therefore, we need to see how that institutions of subsystems of a country have responded and evolved to the requirements of the external technological paradigm within that period of time. Therefore, the congruent theory reshapes here to discuss the congruency between and external technological paradigm and institutional responses of the internal economic, political, cultural and scientific systems (that is to say, technology is not considered as a separate system because it is considered as an exogenous factor).

Matching the history of Iran with technological revolutions

As a country with a long history that dates back 7000 years ago, Iran has always been a centre of evolution. Different dynasties, kingdoms and empires ruled the country from the early Median to the great Achamaenian, until when Islam diffused within the country after the Arab conquest of 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. After industrialization, Iran suffered heavy defeats in various wars during the time of the Qajar dynasty (Avery et al. 1991). Table 1 shows the five technological revolutions and their correspondence to the political systems in Iran. As it shows, 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.

Table 1: Technological Revolutions and Iran's evolution

Year	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

Technological Revolutions and institutional responses in Iran

In this part, the characteristics of each technological revolution will be briefly presented, and the institutional responses of each subsystem of the country, including policy, culture, economy and science, will be discussed to find out the extent to which Iran has responded adequately to the requirements of the long-waves, or whether it could not adapt properly that in turn leads it to fall behind.

First Technological Revolution

According to Freeman and Perez (1988), 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. Cheap coal and iron as a new input to the economy led to developments in broad areas of the economy, including iron wheels that were used as instruments for harnessing water power. In parallel to the cotton and iron industries, the building and construction industry also saw rapid progress because of the active role of the government in developing transport infrastructure, including turnpikes and canals. Entrepreneurship was also heavily supported by the government's strong IP system, which maintains the willing of change among entrepreneurs (Freeman and Louca 2001).

During this period, the Qajar dynasty had two kings, Agha-Muhammad-Khan from 1791 to 1796, and Fath-Ali-Shah[1] from 1796 to 1834. Most of the first technological revolution therefore corresponded with the reign of the later king, which is known as one of the worst periods in Iran's history, marked by substantial military defeats and breakdowns in all subsystem of society. The economic system at the time was mainly based on agriculture, some craft-based industries also existed, such as cotton and textiles, leather, carpet, silk and other local handicrafts. Although there were ample mineral resources in the country, the lack of adequate technical knowledge prevented Iran from extracting and using these resources, and most of the iron was imported from India. In short, the craft-based industries of the country could not compete with its external counterparts, which gradually led to the decline of local factories. Some ad-hoc efforts were made by Agha-Muhammad-Khan to support internal industry, but no considerable achievements were observed, particularly due to his short reign.

At this time, the dynasty's revenue came from taxation of agricultural products, which ranged from ten to 30 percent. However, there was substantial corruption in the political system. Almost all of the members of the dynasty were accustomed only to spending money and enjoying their lives, fulfilling their desires particularly through visiting more

[1] "Shah" means king in Persian.

advanced countries in Europe. This huge amount of spending required more money, which could in turn be obtained either from increasing taxation or from selling land or mineral resources through contracts with European countries (Shamim 1963). During that time, there was competition between Western countries to offer better entertainment opportunities and get more profitable contracts. The diffusion of this attitude within the political system of Iran hindered it from playing its primary role, which was to provide the security necessary for the people to freely start new business activities. On the contrary, the political system even denied the right to own property, in that it could easily take over people's properties.[2]

As Iran's armies were then facing significant defeats in wars with Russia, the majority of the attention towards technology was focused on learning how to build guns and learning techniques for organizing troops. Abbas-Mirza,[3] one of the most powerful people in the country, supported the establishment of related industries in Iran (Lockhart 2007). He also initiated the sending of some Iranian people to the West to learn about the new science and technology. Seven students were sent to Europe by Abbas-Mirza to learn modern medicine, chemical science, engineering, military techniques and English literature (Clawson and Rubin 2005). On their return to Iran, however, they were not able to generate substantial impacts on the science or technology of the Iran, except Mirza-Saleh, who was successful in setting up a publishing industry to Iran. As the modern worldview that emphasises liberty in different aspects of life was not diffused and accepted within Iran at the time, the culture was still based on traditional norms and values, with very few changes. The education system was based on traditional house-schools, and the family system remained unchanged.

Second technological revolution

The second technological revolution was the age of steam power and railroads (Freeman and Perez 1988). Steam power replaced water power, which needed to be close to rivers, and thus provided much more mobility through the invention of locomotives. Iron and coal remained cheap inputs during this period, while new infrastructures needed the construction of railroads, which in turn could lead to new jobs, new markets, and especially new industries. Engineers emerged as a new division of labour with the skills needed to build different steam engines based on precision tools and techniques that paved the way for the development of the machine tools industry. So many small and medium-sized firms worked together on a contractual basis that the law made it possible for companies to have separate legal identities and limited liability (Freeman and Louca 2001).

During this period, the Qajar dynasty had two kings: Muhammad-Shah from 1834 to 1848, ruling for about 14 years, and Naser-al-Din-Shah from 1848 to 1896, for nearly half a century. The attitude of the regime remained unchanged at this time, as the willingness of family members to buy the best goods from European countries and to travel expensively, as well as the substantial corruption of that court hindered any active or even passive technological learning. Muhammad-Shah continued the ideas of his predecessors in sending some people to the West to learn more military techniques.

However, there was a turning point during that era: a very short period when Amir-Kabir (meaning 'great ruler') took the position of prime minister in 1848 and established several initiatives. Although from the beginning there were substantial disagreements within the dynasty about his activities, Amir-Kabir started his work by changing almost all the people in official positions with the aim of fighting corruption (Amanat 1991). He banned the courtiers to get revenue from the taxation earnings, and instead tried to put money into rebuilding the country.

[2] Many scholars such as John Locke, Adam Smith and John Stewart Mill observed the crucial role of this principle.

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

His major policy with regard to the economic system was supporting the national production capacity via different means, chief among them by providing admirable security for manufactures and traders. Moreover, he started to reduce imports from the West by imposing strict rules on the freedom of imports, while at the same time motivating the public to use their capital to establish new factories. Among the industries that were supported, cube and sugar, crystals, paper, cast iron, lead, samovars, carriages, silk and a variety of textiles are worth mentioning. He also tried to bring order to the financial system by integrating a mintage mechanism (Adamiat 2006a).

In his support of local industries, Amir-Kabir recognised the crucial role of steam engines as the main provider of energy sources, and therefore motivated manufacturers to use steam engines as the prime source of their energy. However, those initiatives did not lead to the emergence of an engineering or machine tools industry within Iran. He also sent several people to European countries in 1850 to 1851 to learn a variety of techniques in several fields. Recognising that the traditional education system of the country, based on local education in house-schools and the ad-hoc transfer of some people to the West was useless, Amir-Kabir decided to build a technical academy within the country named Dar-ol-Fonoon (meaning 'the house of techniques'). For this purpose, he decided to employ scholars from the European countries, especially from those that had less political conflict with Iran, such as Austria. The education program covers several fields of science and technology, ranging from medicine to engineering, and from science to the military (Mahboobi 1991). Unfortunately, he was killed due to a plot by unhappy dynasty members in 1852, before the formal opening of this school (Amanat 1991). However, Dar-ol-Fonoon continued to operate and train people more or less in the way that Amir-Kabirhad desired, and thus it became one of the main drivers of later developments in the country (Ekhtiar 2001).

Regarding Iran's culture, Amir-Kabir had an aggressive attitude towards informing the public through allowing the publication of various newsletters, books and monographs that provided basic historical or scientific information. He even forced some from the rich social classes to subscribe to the newsletters. His modern views towards the education system were another factor in changing the traditional and mostly closed culture of the people and bringing about more open perspectives towards the recent evolutions of the world.

Third technological revolution

The third technological revolution was the age of the steel, electricity and chemical industries (Freeman and Perez 1988) and the time when the US and Germany started catching up and even moving ahead of the UK. The invention of electro-motors provided a new source of power for industry and called for new infrastructure for the generation and transmission of electricity, which in turn led to the further development of the electricity industry. Steel and copper was the new and cheap inputs of the time. Based on new scientific discoveries, industries started to create R&D laboratories that in turn changed their organisation methods. Therefore, the main driver of technological change shifted from entrepreneurs and SMEs to larger firms in the third technological revolution. This is what reflected in changing the view of Schumpeter to Capitalism from being driven by entrepreneurship to the large firms (Schumpeter 1942).

While the world was changing very fast, the Qajar dynasty was at the final stage of its power. During this time, three kings came to power: Mozafar-al-Din-Shah from 1896 to 1906, Muhammad-Ali-Shah from 1906 to 1909 and Ahmad-Shah from 1909 to 1925. Mozafar-al-Din-Shah devitalised the economic infrastructures of the country because of his endless desire to visit European countries. He continued to borrow money from Russia and other countries at the expense of giving them valuable contracts. On his first visit to Europe, he stayed seven months in France

without any political or economic benefits for Iran. Coming back from Europe, he gave a license to exploit oil in the south of Iran to a famous British trader named William D'Arcy to provide the money required for his expensive life (Cleveland 2004).

The economic system of the country, including its agriculture and industry, was in its worst situation to date. Farmers had to work for their landlords, and were required to pay a total of about 40 percent of their revenue either as taxes to the monarchy or as benefits to the landlords. Iranian industry could only produce primitive goods, and there was no advanced industry, especially in electricity, chemicals and steel. A famous trader at that time brought the first electricity generator to Iran, which could only provide light for the castle and the buildings near it. Other industries such as silk could not continue to compete with their European counterparts and eventually shut down. During this period, and after a considerable delay in comparison to the rest of the world, Iran started to build railroads by Russian and British companies, while there remained no infrastructure for electricity generation and transmission. However, in terms of education and science, the initiatives of Amir-Kabir continued during this period, and new schools in different cities of the country were opened to train young students. There was also no corresponding scientific community within the country, let alone a modern university.

The culture was changing slowly in the light of newsletters. In addition, a wave of persons who had been educated in Europe were now returning to Iran; they started to impose changes on different parts of society, particularly in terms of the culture and values of the people. They entirely changed the views of public towards the Qajar dynasty and led them to the conclusion that the main problem with Iran was the dynasty itself. These developments finally led to a major change called the Constitutional Revolution, signed by Mozafar-al-Din-Shah in his last year at 1906, according to which an elected assembly was convened and drew up a Constitution that provided for strict limitations on royal power, an elected parliament to represent the people and a government with a cabinet subject to confirmation by the Parliament (Adamiat 1991). However, Mozafar-al-Din-Shah's son, Muhammad-Shah, was strongly resistant to this constitutional reform, and over the next three years after he took the throne, there was widespread political instability within Iran. Eventually people deposed Muhammad-Shah and replaced him with his 12-year-old son, Ahmad-Shah at 1909. He was supposed to be the king under the new Constitution (Adamiat 2006b).

Fourth Technological Revolution

The fourth technological revolution was the age of automobiles, oil and mass production, which started in the 1920s after the successful invention of the internal combustion engine, which could provide a new source of mobility (Freeman and Perez 1988). Oil was the new input into industry, very large corporations were the drivers of change and roads were the new infrastructure; all of which contributed to the new technological paradigm that in turn led to many other economic, social and even cultural changes (the mass culture, Freeman and Louca 2001). The US, based on Ford's mass production system, was the leader of this age, while Europe and later Japan were able to catch-up with the US after some decades.

The fourth technological revolution corresponded with substantial changes in the political system: in 1925, Reza-Shah deposed the Qajar dynasty and founded the Pahlavi dynasty. He remained in the power until 1941, when his son, Muhammad-Reza, took the throne until the Islamic Revolution in 1979.

Reza-Shah

It is clear to see that Reza-Shah, a former officer who led a coup in the army, played a unique role in institutional reforms in Iran; chief among them was establishing a very strong government (Katouzian 2006). The government, with its centralised power and ample financial resources coming from oil revenues was therefore the major source of changes

during the reign of Reza-Shah. Indeed, he created the oil-driven economy within that time. Although the new Constitution was supposed to give strong powers to the parliament, Reza-Shah continually tried to restrict the power of this political institution through different means, such as by creating political parties and winning parliamentary elections. Another element in empowering the government was making a strong army (Cronin 2003).

Regarding Iranian culture, Reza-Shah took a very aggressive attitude to transform it into what he called 'Modernism', which was portrayed as a culture that fit the requirements of the new world outside Iran. For this purpose, he put strong emphasis on the Iranian identity, which he portrayed in contrast to Islamic ideology. He initiated several programmes to enhance and purify the Persian language, which had been widely influenced by the Arabic language. Another important cultural development was changing the role of women in society by enforcing a law that they should not wear Islamic head-coverings (Hijab). Many programmes to change the position of women and to educate the lay public were started during that time to show that a modern woman is not the one who stayed at home, but one who should enter society and play a social and even an economic role. Over a decade, Reza-Shah gradually revolutionised family law in a way that gave more power to women, even in terms of selecting their husbands or having some rights to divorce (Abrahamian 1982).

Reza-Shah tried to establish new public institutions in contrast to traditional institutions, and to do so, he asked those who had been educated in the West to take a greater part in shaping these institutions. Another important institutional transformation was constructing a modern justice system that restricted the traditional role and power of Mullahs in resolving conflicts between people. One of Reza-Shah's major reforms was building a central education system based on the Persian language and with unified course materials. The underlying belief behind these changes was the promotion of nationalism and modernism, and the belief in the necessity of a central and powerful government (Cronin 2003). This in turn led to an increase in the literacy rate among the Iranian people. 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.

Iran's scientific system witnessed two substantial changes. The first was an increase in the number of students sent to the West, among which 417 came back to Iran between 1921 and 1938 (Khalili-Khoo 1994). The second was the establishment of the first Iranian university, Tehran University, in 1934, with departments of medicine, law, engineering, political and economic sciences, science and philosophy. That university was heavily based on teaching the scientific findings that had already been made elsewhere, leaving research as a matter of personal interest.

Putting the government as the main economic actor was his most important institutional reform. In 1925, a law enacted according to which all imports and exports of important commodities such as mineral resources, wheat, and even some industrial commodities should be controlled by the government. Ample financial resources and the establishment of a strong army provided much better security for undertaking economic activities. Reza-Shah envisaged the main role of the government as building necessary infrastructures, such as roads, railroads, electricity generators and transformers, and so on. The first Iranian bank, based on the army's financial resources, was created in 1928. However, the agricultural system of the country remained unchanged, while the most important industry of the country, the oil industry, was controlled by the British Oil Company so that Iran was not involved in oil exploration and exploitation, but only benefited from its revenues (Bamberg 2000). The government's strategy for other industries was development of industries producing consumption goods. In this sense, importing machines used in those manufactures was seen as a sign of technological development and modernisation, while minimal effort was given to technological

learning. The main approach towards technology and industry during that period was turnkey technology transfer. Another area of technology transfer was in the defense industry, on which the government spent large amounts of resources to buy advanced weapons from the West, again without any considerable attention given towards technological learning.

Muhammad-Reza-Shah

Muhammad-Reza-Shah came to power after his father abdicated in his favour in September 1941 (Kapuscinski 2006). Gradually, he became the dominant power in the country and after 1948; the king continued many of his father's programmes, including rapid modernization emphasising the ancient Iranian history as well as the necessity of changing the culture of Iranian society, particularly with respect to women. Cultural programmes and the scientific trend towards establishing governmental universities in different cities focusing on translating and disseminating scientific material from outside Iran, with less attention given to research, also continued. Moreover, Muhammad-Reza-Shah persisted in spending a great amount of money on modernising the army, to become the most powerful country in the Middle East. The political system was composed of a prime minister (to be appointed by the king), a cabinet (to be appointed by the prime minister) and the parliament (to be elected by the people), but Muhammad-Reza-Shah had a unique power to do whatever he wanted.

The major social and economic reforms of Muhammad-Reza-Shah are referred to as the White Revolution, which started in 1963 with the aim of transforming Iran into a global economic and industrial power. The revolution was constituted from 19 elements to be carried out over a period of 15 years, the first six to be started immediately. Some of the most important economic and industrial elements of the reforms were (Abrahamian 2008):

1: A Land reform programme that aimed to abolish feudalism, which led to substantial changes in the lives of peasant families. However, once they owned their land, many peasants could not continue their agricultural work and migrated to the big cities.

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, and they were fined if they sold their products at a price higher than that which had been set by the government.

This programme 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 they enforced the privatisation of industries, while on the other hand they restricted the private sector to a large extent yielding no space for capability building within them. As some commentators stated, the White Revolution was not successful in its economic and industrial reforms (Dorman and Farhang 1987). Others argued that the fear of the diffusion of socialism was a driving factor behind these policies emphasizing the lower classes of society (Rahnema and Behdad 1996).

To modernise industry and its technological bases, Muhammad-Reza-Shah founded a new organiation named the Industrial Development and Renewal Organisation (IDRO) of Iran in 1967, after travelling to Italy and becoming familiar with Italy's Industrial Renovation Institute (IRI). The main idea behind this initiative was that the government owned its shares, but it operated under the rules and laws of the private sector. The main roles of this organisation were to be:[4]

[4] From IDRO's official website: http://www.idro.org/enidro/About%20Idro/History.aspx

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 focusses 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 reform them. The last decade of Muhammad-Reza-Shah' reign therefore witnessed substantial developments within Industry, but based on a governmental institution that operates under business attitude. However, there is the lack of attitude towards technological learning; instead, IDRO tended to invest in industries that were making an economic profit, especially in the short-term. As a result, the technological development of the country remained at the level of merely buying some plants and machines, with ad-hoc learning and improvement aimed at running profitable industrial businesses.

The automotive industry in the country established in 1962 when the Iran National Company was founded by the private investments. However, it also continued assembling foreign cars until Islamic Revolution in 1979, when the company was nationalized.[5]

Hence, having in mind a very specific economic reform, it did not yield successful results, particularly in paving the way for technological catch-up. The basic idea behind economic development was increasing the production capacity via establishing different industries according to import-substitution policy.

Fifth technological revolution

The important roles of universities and the US defense system gradually paved the way for the new information technology revolution, subsequently to be driven by the new software and hardware industries (Freeman and Louca 2001). The engine of this era was the strong and small data processor based on the new cheap input of transistors, while the new information infrastructure consisted of the internet, and other communication lines that were developed very quickly. The US continued to be the world leader during this era, followed by Japan and other countries.

During this global technological revolution, Iran observed another political revolution with the introduction of the new Islamic Republic to replace the former monarchy in 1979. At this time, the country was benefiting from oil revenues; it had several industrial capacities and a university system based primarily on teaching, a culture that mixed modernism and traditionalism and a new political structure that was based on republican philosophy, to be controlled by Islamic ideas under the provision of a Supreme Leader. The modernization programmes of the Pahlavi dynasty that stressed the ancient Iranian culture were replaced by an Islamic ideology.

According to the new Constitution enacted after the revolution, 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 play a complementary role to that of the government.[6] As a result, large industrial

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

[6] The full text of the constitutional law can be found here: http://www.servat.unibe.ch/icl/ir00000.html

companies were nationalised at the beginning of the revolution.

However, the first decade after the revolution focused on managing the war with Iraq, which lasted until 1989.The number of universities in the country was not enough to respond to the demands for higher education, and for that reason a new Islamic Open university was established shortly after the revolution in 1982 to be financed by tuition fees, in contrast with the existing free public university system. However, the main mission of both types of university was still education rather than research.

The main development programmes of the country started in 1990, when the new President, Ali-Akbar-Rafsanjani came to power. From the outset, it was clear that reforming the economy was the main agenda of the new government, with less attention given to other areas such as culture, politics or even science and technology. The political system of Iran had reached a position of stability with a new Supreme Leader, the former President, Ayatollah Ali-Khamenei. The major priority of the government was to rebuild the infrastructures and industries of the country that had been destroyed in the war, based on 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 were to liberalise trade, prices and currency, reducing the role of the government in the economy and increasing the efficiency of the manufacturing sector.

In this way, the government tried to construct many infrastructural industries in the country, according to Act 44 of the Constitution and the active role of IDRO, primarily continuing its earlier import substitution policy, with less attention given to active technological learning. During this period, no considerable attention was given to the requirements of the ICT revolution, but instead most attention was given to rebuilding the existing industries. However, the structure of the economy remained oil-driven, with many industries remaining government-owned, and much less success in privatization programmes.

Muhammad-Khatami, the next President of Iran, changed the mandate of the government and underlined the importance of political development. He tried to increase the level of public understanding of modern concepts such as freedom and democracy by liberalising and supporting the media and newsletters. On this basis, his government was called 'the government of reform', and the party supporting it was called the Reformists. Moreover, enhancing the level of political activity within universities was one of his other priorities. In 2000, and according to the Third National Development Plan of Iran, the name of the Ministry of Higher Education was changed to the Ministry of Science, research and Technology, stressing the important role of science and technology in the country.[7] During this period, the government provided substantial rewards for research and publications within the universities, which led to radical changes in the number of publications within the country. Nevertheless, the state of technology did not change, while those policies reflected a type of linear STI model, with the view of the government being that technology would develop when there was enough scientific output. As a result, there were no significant changes in the economic and industrial policies of the country: the attitude towards technological learning remained passive within industry. A major programme called Takfa began in 2002, aimed at developing IT applications in Iran (rather than the IT industry), under which the government forced all governmental organisations to spend one percent of their revenue on developing IT. However, this programme also failed to bring about active technological learning, as it was mainly focused on expanding IT applications.

President Ahmadi-Nejad came to power in 2005 with many ambitious programmes in mind, especially programmes to influence the international political

[7] A Persian text of the law is available here: http://parliran.ir/uploads/ghanoon%203_6359.pdf?siteid=1&siteid=1&pageid=224

system. A few months before he came to office, the Supreme Leader announced new privatisation reforms for the country by changing Act 44 of the Constitution. According to the new changes, the private sector could and should participate in fundamental economic activities, which were formerly supposed to be carried out by the government. A year later, a new amendment was added to this declaration, stressing that most governmental industries should be privatised with great emphasis on the necessity of capacity building within the private sector. Although it is soon to judge the success of this significant economic reform, it seems that there is a wide gap between the reforms that were planned and what is being done.

At the same time as these reforms were taking place, 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.[8] The President enjoying the high price of oil established a new deputy of science and technology in February 2007 with the major aim of supporting technological development. However, the initial years of this deputy'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 industry and the private sector as the main driver of technological learning and development. That in turn has led to serious clashes between this deputy and the Ministry of Science and Technology since the end of Ahmadi-Nejad's government; both institutions considered themselves as the main body responsible for scientific and technological development. The result of these activities and, partly, these conflicts was the development of a severe attitude throughout the country that science and technology are the main drivers of progress, and thus many public media programmes were established to show the importance of technology and science from this perspective. The Higher Council of the Cultural Revolution enacted the comprehensive scientific plan of Iran in January 2011 to set the priorities and strategies of the country with respect to science and technology. Meanwhile, the Higher Council of Science, Research and Technology, of which the Ministry of Science and Technology is its secretariat, started several major national programmes for technology development, mainly to be carried out within universities. The Deputy of Science and Technology also established some offices to support national technological development plans in various technological fields. In short, it is obvious that there is a type of STI view of the innovation system in the mind of most of the policy-makers within Iran, while the privatization programmes of the country are suffering from substantial shortcomings and problems.

Conclusion

In this paper, the idea of Freeman (2002) on applying innovation system to study the experiences of falling behind has been reconsidered. Linking innovation system to economic development by analyzing institutional set-ups as focusing devices (Lundvall et al 2009) has been empowered by the congruent theory of Freeman stressing the incongruence between institutions of the four sub-systems of a country might lead to not catching-up and falling behind. However, the framework was modified in a way that incongruence was tested between exogenous technological revolutions and endogenous institutional changes within economic, political, scientific and cultural systems.

Table 2 summarises some essential features coming out from this analysis. As the table shows, the first three global technological revolutions corresponded with the Qajar dynasty, which remained almost ignorant of those changes, far from encouraging either active or passive technological learning. The efforts of some individuals like Abbas-Mirza in absorbing foreign military techniques or Amir-Kabir in supporting the national production and education system were not successful on a large scale because of

[8] An English translation of this vision is available here: http://www.vision1404.ir/fa/News48.aspx

substantial internal disagreements and problems within the Qajar court.

The creation of many large and infrastructural industries, including consumption goods industries, started during the fourth technological revolution, when Reza-Shah established a powerful central government to be supported by oil revenues. However, the main drivers of the technological paradigm of that era, i.e. the oil and automobile industries, were not transferred to the country, in that Iran did not contribute to the oil industry and did not take considerable steps towards developing an automobile industry during that time. The main policy was trade substitution in the consumption goods industries and turnkey technology transfer. Muhammad-Reza, the next king of the Pahlavi dynasty, created some negative impacts on capability building within domestic enterprises because of his White Revolution programme. He subsequently tried to speed up the development and renewal of industries by founding IDRO and giving it unprecedented authority trying to develop heavy and large industries based on import-substitution policy and passive and piecemeal technological learning.

The Islamic Revolution in 1979 has brought substantial changes to the country; however, it has had less success in changing the structure of the economy, not to change the oil driven economy mainly run by the government; but enforcing this system via Act 44 of the constitution. The years since the Islamic Revolution can be divided into two different periods. The first period runs from the end of the war until the middle of Khatami's administration, in which technological learning and development was not the main priority of the country and most industrial policies concentrated on the renewal and development of existing or new large and heavy industries. In the second period, i.e. 2000 afterwards, a great emphasis on the necessity of scientific and technological progress within the country has led to spending a huge amount of money on scientific and technological progress, but as was discussed earlier, these initiatives have been based on an STI view of innovation system.

Table 3 summarises the changes in the subsystems of the society, and also indicates which institutions are rooted in the times before the Islamic Revolution and which ones are the product of the revolution that will need to change if the country wants to benefit from the opportunities of technological revolutions. Changes in the colour of cells indicate institutional changes have been happened. The white cells are those that are now moving in a good direction, while the grey areas are those that need to be changed further.

Table 2- the overall features of Iran's innovation system in each period

	1st	2nd	3rd	4th	5th	
Qajar	Ignorant View, Ad-hoc changes in culture and science started from 1848					
Pahlavi				Infrastructural industries, trade substitution, Turnkey tech. transfer; passive technological learning		
Islamic Republic					Many Similarities to the 4th tech. revolution →	Active view in policy, but based on STI mode of innovation system.

As the Table shows, the view of science is changing gradually to call more for research and less to teaching. This indicates a positive institutional shift. The economic system has continued to be oil-driven, still envisaging technology as something embodied in machines. Now, it seems that things have started to shift gradually, but not at a reasonable pace, and this needs to be considered as an urgent priority for the country. The policy of Iran in the time of the Qajar Dynasty was almost entirely ignorant about technical changes, while the policy of the Pahlavi Dynasty was mainly focused on governmental industrial development without paying much attention to technological learning and capability-building within firms and finally the Islamic Revolution has shown changes in policy in recent decade to support scientific and technological progress according to an STI view. This view of the policy system should also be modified urgently. The traditional culture of the Qajar dynasty has been gradually altered by a type of modernism culture, placing more emphasis on technology usage, but less on learning. The Islamic Revolution could make some changes in order to establish a sense that Iran is also able to develop technology.

At present, the country is changing its scientific system to integrate teaching and research, and this trend is in line with the necessities of technological revolutions. Regarding the economic system, it is evident that an oil-driven economy from the past was made worse by nationalising so many infrastructural and heavy industries at the beginning of revolution, however some trends of changes are emerging. The fourth point is about the policy system, which has shifted towards a linear model in recent decades, and this also requires extra changes. Finally, a good and open culture towards technology has been created in recent years, which needs to be promoted even further.

The table shows that incongruence between the necessities of technological revolution of each era were at the place as none of them were denoted by the white colour (white means there is a congruence while dark gray points to the extreme incongruence), except of science and culture in the recent decades. Those mismatches in turn would explain the institutional roots of what the country left behind of those advanced innovation systems. The darker colours denote more contrasts and therefore more distances from the requirements of technological paradigms; thus it also helps illustrating some recent advances in the country resulting from institutional changes. If the country likes to enjoy the experiences of catching-up, it should take serious actions to modify its incongruent institutions.

Table 3- Institutional changes of Iran's Innovation system

	Qajar	Pahlavi	Islamic Revolution	
Science	Traditional System	Teaching Universities	Moving Towards Research Universities	
Economy	Traditional Agricultural System, technology is something embodied in humans, not technological learning	Oil-Driven, Government based, Towards modest Industrialisation, technology embodies in machines, ad hoc technological learning	Same to Pahlavi	Some trends of changes (+ and -) emerging
Policy	Central, Corrupted, no policies for technological development except the 1848-1851	Central Industrial development stressing development of consumption good industries or import substitution policies, less concerned to technological learning	Same to Pahlavi	Stressing the importance of scientific and technological learning, but based on a linear view of Science and Technology (STI)
Culture	Traditional	Modernisation, more open to technology	More open, eager for new technologies	

Implications for further research

This study represents historical analysis of Iran's institutional changes. It represents a qualitative scheme of congruence theory. However, it brings some new insights to developing research on innovation systems in the context of developing countries.

Firstly, it was recognized that research on innovation systems should be based on established theories of innovation and development based on evolutionary economics. The idea of using technological revolutions would pave the way for this purpose as it is a type of informal evolutionary theorizing on the process of development (verspagen 2004). Hence, rather than concentrating on micro level of analysis, it offers a type of macro view to the evolution and the process of development within each country.

We may classify studies of innovation systems into two broad categories: those that take a macro approach to study the evolution of institutions; and those micro studies that focus more on the micro behaviours of agents and companies, shaped by their institutional environments. While the former could contribute to explanations of economic development, the later is deemed far away from this purpose. Nevertheless, as it is a type of macro analysis of institutional set-ups within a country, it should be modified in a way to can explain the capability building within domestic industries.

Secondly, it provides a focusing device that is being stressed as the necessity for making the concept more rigors (Edquist 2004, Lundvall et al 2009). Through dividing the society into four subsystems, institutional changes of each subsystem and their congruence with the requirements of technological paradigms, it leads to such a necessary focus. However, there is a shortcoming in defining the institutions within each subsystem that needed to be considered. More generalization on the type of institutions that are important in the process of economic development is required to can pave the way for further theorizing.

Thirdly, it adds a historical perspective to the analysis that in turn provides a more dynamic picture of the evolutions of innovation systems. As mentioned earlier; historical analyses could be used both for the test of theory and for developing some theoretical insights. The present study served both, as in the one hand tried to test the congruence theory, though with minor modifications, and on the other hand tried to explore the type of institutions that are deemed important in the process of economic development; although it is not possible to generate a category or generalize from the findings of this single case study.

As it is the first effort to apply Freeman's idea about applying the concept of innovation system for explaining the experiences of falling behind (2002), nevertheless, it might be modified in two ways: first by studying the experience of other countries using a similar framework with the aim of trying to find patterns similar to those of Iran, to pave the way for further theorisation of institutional development; and second, by extending the study with more detailed information about each period and about each type of institution, which may in turn lead to better empirical evidence for conceptualising the pattern of institutional changes within the country.

But there is another line of research that is evident in all researches about innovation system which is the necessity of bringing more quantitative tools to the analysis. Therefore, the theory of incongruence also needs to take this issue more seriously by elaborating the institutional necessities of each technological paradigm in more detail and also suggest better tools for measuring the institutional set-ups in each era. In this way, more rigorous analytical tools could be developed to test the congruences or mismatches.

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