Analysis of the Effects of Socioeconomic, Political and Institutional Determinants on Technological Innovation in the Maghreb

By

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ABSTRACT

This study focuses on three major Maghreb states (Algeria, Morocco and Tunisia) with distinct institutional, political and socioeconomic patterns. It essentially tackles the issue of technological development particularly investments, trade, human capital and patents in a socially and politically sensitive environment.

The researcher assumes that government stability, law and order, GDP growth and ICT usage are related to technological innovation in the Maghreb. The stated hypotheses indicate that these political, institutional and socioeconomic factors have significant effect on technological innovation in the Maghreb. Based on a two equations' empirical model, our researcher attempts to test these effects and explore the interactions between the different dependent and independent variables through a set of hypotheses. Data analysis covers three countries from 1996 to 2010.

The study identifies significant effects of key covariates on technological innovation in the Maghreb. Although not every predictor effect is consistent, the results indicate that they matter for technological innovation in the Maghreb. Empirical findings might constitute essential evidence for technology and innovation policies in this Middle East and North African region.

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Chapter 1

Introduction

Major Maghreb Countries (Algeria, Morocco and Tunisia) are in different stages of development and underwent socioeconomic, institutional and political transitions at different degrees. Due to unprecedented economic crisis during 80s and 90s, Maghreb countries knew slightly strong social vibrancy and political changes. The authorities attempted to implement institutional policies and political reforms to bring about sustainable development and prosperity. Even though these measures helped to achieve some degrees of stability, the growth in GDP per capita and technology production systems were fragile compared to other emerging markets (Tahari, Brenner et al., 2007). Therefore, major political and socioeconomic changes didn't significantly improve the development outcomes and the capacity of these countries to innovate.

Developed nations are usually politically stable countries with strong institutional support for technology production and innovation systems (Freeman, 1987). In countries with strong government stability, the level of industrial productivity and technology development is generally higher than unstable nations. In the latter, promoting an ecology of innovation seems to be linked to the institutional environment. Therefore, technological innovation policies might be insignificant when the institutions supporting them are weak. "Successful technological catch-up requires reforms that change government legislation so that it better supports an institutional and organizational environment that is conducive to innovation in a modern market economy" (Allard, Martinez et al., 2012).

In developing nations like the Maghreb, development strategies are unsuccessful to design and implement appropriate innovation policies that drive change and technology promotion. We focus our analysis on three major Maghreb states that already have some relevant experiences in innovation activities and technology development. Our research endeavors to determine the interactions between institutional, political and socioeconomic factors and technological innovation predictors in the Maghreb. Based on data analysis from the last two decades, we need to determine to which extent these predictors are relevant to technological innovation attributes in this region. This constitutes an opportunity to find out the role that governments, legal institutions and socioeconomic determinants play either to boost technology and innovation or hinder efforts to reach the technology frontier. Such investigation will draw conclusions that might potentially recommend reviewing technology policies towards more focus on driving technology production systems and establishing an innovation based development process.

The structure of this study is as follows. Chapter 1 provides a general background, explores the purpose and the objectives of the study, problem statement and significance. Chapter 2 explores the literature review about innovation and technology development policies in the Maghreb. It also provides a theoretical framework and assumptions regarding the effects of socioeconomic, political and institutional attributes on technological development outcomes that drive innovation. In Chapter 3 we describe our variables, determine hypotheses, and specify the quantitative analysis techniques and methods we use. In chapter 4, we

explore our summary statistics and highlight findings and relevant results. In chapter 5 we discuss the main conclusions based on our research findings.

General Background

Overview of the Political and Institutional Context of the Major Maghreb Countries

Algeria, Morocco and Tunisia share a myriad of patterns but at the same time have had distinguished institutional and political paradigms. They share authoritarianism and human right abuses records and present interesting cases of political development within the Middle East and North Africa (MENA) region. All the three countries lived under power states with apparent stability and deficient economic sustainability (Colombo, 2010). They represent an interesting sample of authoritarian governments which experienced significant political transitions.

Compared to other Arab countries, Tunisia achieved important economic development during the last decades (World Bank, 2010). However, this didn't prevent dissatisfaction of the existing system, human right abuse, unemployment, corruption and nepotism. The Tunisian regime was known to exert a quasi total control over political activities and liberties as the former president party (Constitutional Democratic Rally - CDR) had power over the parliament, state and local authorities. Tunisia has some particular attributes in the region like its ethnic homogeneity, a small territory, educated people and significant liberties for women. Some scholars believe that such attributes help the country to undergo successful political and institutional changes (Arieff, 2011). However, the kleptocracy of the ruling cronies, the daily oppression and a dramatic increase of

unemployment brought about an economic and political malaise for the country (World Bank, 2010).

Morocco shares social, cultural and economic attributes with Tunisia. Both countries, being former protectorates of France, managed to diversify their economies despite being non-oil nations. However, this Maghreb country is the only monarchy in the region with unique political and institutional experiences and outcomes. In Morocco, the political landscape was established as a pluralist system. Yet, it was designed to make the royal institution as the keystone of the political process and limit political participation (Sater, 2009). After decades of authoritarian rule, media repression and human rights abuses, the system experimented an era of 'alternance' in mid 1990s. Sater argues that no serious political reforms were implemented. He pointed out that the pluralist processes initiated by Arab authoritarian rulers make a step towards democratic change in order to forestall them (Sater, 2009). In other words, it only gives a perception of change but not a real transition. In fact, several reforms were implemented like a new family code, the strengthening of the women's and minority rights and the establishment of a council to investigate the human rights abuses committed before the king's accession to power. However, despite political stability brought about by the monarchy system during the last two decades, the reforms of the new era were not significant since political cronies remain the major political and institutional players.

Concerning Algeria, this former protectorate of France for more than 130 years considerably depends on oil revenues that constitute the backbone of its economic

growth. The oil generated wealth didn't help the country prosper as much as it created a 'natural resource curse' (Entelis, 2011). During eighties, the regime attempted to implement constitutional modifications, approved by referendum in 1989, to abandon the established ideological revolutionary socialism and dispose of the state single party (Zoubir & Fernandez, 2008). However, the implementation of multiparty polity and the liberalization of political life were a short life experience. By the end of the 1990s, the efforts of democratization and restoration of an institutional process were not significant. The regime, controlled by apparatchik cronies, benefited from increases in oil prices and attempted to dominate the political landscape and defeat or co-opt the forces of opposition (Lowi, 2011). The army junta was highly favored and privileged when other social categories were marginalized in case they couldn't be co-opted. This didn't happen without stimulating a political instability, weak institutions and social exclusiveness.

Overall, these Maghreb states policies didn't realize significant political and institutional development. This is chiefly due to the weak institutions and governance. Institutional quality plays a critical role in implementing successful policies. It's argued that "Interactions between institutions and economic reform may contribute to the success or failure of such reform depending on the level of institutional quality" (Baliamoune-Lutz & Adison, 2006).

Socioeconomic Development Indicators of the Maghreb

The three major Maghreb nations are positioned in an African affluent though arid region. They have around 78 million people and around one third of Africa's total GDP (ADBG, 2011). Being closed to Europe and a part of the MENA region, they are in a geostrategic situation for both international security and political and economic stability in the Middle East. The African Development Bank reports that the region is "the fastest growing region in the continent" by an annual growth rate of around 5 percent for the last decade.

Country	Population	GDP (Millions of US $)	Percentage % of the total GDP	GDP per Capita (US$)
Algeria	35,468,208	159,425,577,394	54.05	4,495
Morocco	31,951,412	91,196,031,840	30.92	2,808
Tunisia	10,549,100	44,290,655,120	15.01	4,199
Total	77,968,720	294,912,264,354	100%	
MENA	331,263,900	1,068,480,880,067		3281

Table 1: Gross Domestic Products 2010

Source: Adapted from the World Bank Data[1]

The three Maghreb countries are classified as middle income countries according to the World Bank Atlas Method based on the Gross National Income (GNI). This indicator is considered to be the "best single indicator for economic capacity and progress" (Nielsen, 2011). Hence, according to the Atlas method, the table below

[1] Retrieved from data.worldbank.org

categorizes Algeria as an oil producing and upper middle income country within this group of countries. Tunisia and Morocco are non-oil producing states that have diversified economies and classified in the category of lower middle income countries.

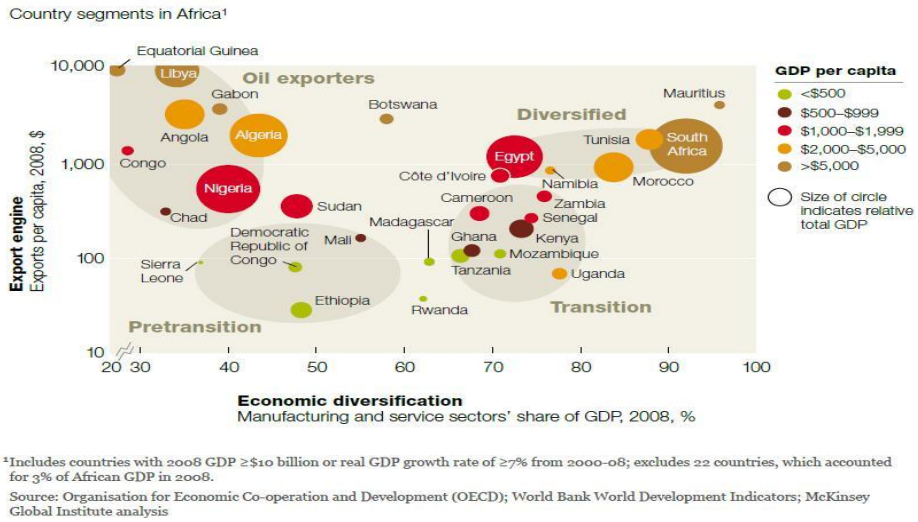
Upper middle income GNI per capita $3976 - $12,275	Lower middle income GNI per capita $1,006 - $3975
Algeria	Morocco, Tunisia

Table 2: Income categories in the Maghreb countries according to the World Bank Atlas Method

The Global Competitiveness Report 2011-2012 (Schwab, 2010), which highlights the issues of global economic growth and sustainable competitiveness, categorizes the Maghreb depending on the stage of development. The report uses the Global Competitiveness Index (GCI) to measure the microeconomic and macroeconomic underpinnings of the level of productivity and competitiveness of nations. According to the authors, the instability in the North African region had negative effects on competitiveness and caused a stagnation of the economies. This global report considers Algeria in a transition from stage 1 to stage 2. Both Morocco and Tunisia are classified within the stage 2 as efficiency economies (Sala-i-Martin, 2010). Morocco was classified in a stage of development of transition from stage 1 to stage 2 for 2010-2011 but improved the next year to an efficient economy.

McKinsey Global Institute regards Tunisia and Morocco, alongside Egypt and South Africa, as the continent's most advanced and diversified economies

(McKinsey, 2009). Over the past decade, Tunisia and Morocco knew an expansion of domestic services such as banking, tourism, information technology and telecommunications. They also built a comparative advantage through bolstering infrastructure and urbanization projects, which helped significantly reducing unemployment rates in these countries. On the other hand, Algeria benefited from the rise of oil prices and succeeded to lift their revenues during the last decade. But they didn't sharply take the advantage of their gas and oil resources to diversify their economies (McKinsey, 2010). Because of the natural resource curse, the manufacturing and services sectors count for less than one third of Algerian GDP. Natural resources seem to support economic growth but it's not sufficient. Henri Ghesquiere argues that there is a positive relationship between natural resources and economic growth but it's sometimes statistically insignificant. In fact, the availability of oil and gas can impede economic growth because of the negative effects of economic rent on political systems (state control, corruption) (Ghesquiere, 2007).



¹Includes countries with 2008 GDP ≥$10 billion or real GDP growth rate of ≥7% from 2000-08; excludes 22 countries, which accounted for 3% of African GDP in 2008.

Source: Organisation for Economic Co-operation and Development (OECD); World Bank World Development Indicators; McKinsey Global Institute analysis

Figure 1: Economic diversification of the Maghreb and other Africa states

Source: McKinsey

Despite the positive development of socioeconomic indicators and the improvement of GDP per capita in the major Maghreb states, they are not able to attain a technological take-off similar to the one reached by East Asian nations. This is chiefly due, among other factors, to the weak reforms and deficiency of innovation policies.

Purpose of the Study

The purpose of the current thesis is to determine the effect of socioeconomic, political and institutional predictors on technological innovation capabilities of the major Maghreb states (Algeria, Morocco and Tunisia). We aim to explore how these Maghreb countries can move forward their innovation rates by analyzing the effect of three category predictors. In other words, when socioeconomic, political and institutional issues eventually represent constraints to technological innovation, they require being analyzed and diagnosed. Such diagnosis will identify which variables are relevant to technological innovation and therefore economic development. Therefore, analyzing key determinants within institutional, political and socioeconomic categories seems to be an important step towards identifying policy measures and innovation constraints in the Maghreb; mainly for technological Research & Development (R&D), Foreign Direct Investment (FDI) and technology transfer, human capital development and technology export.

Objectives

- Determine socioeconomic, political and institutional conditions of the main Maghreb countries and their contribution to technological development.
- Identify the impact of key political, institutional and socioeconomic predictors conducive to the promotion of technological innovation in the Maghreb.
- Make conclusions about technological innovation outcomes in the Maghreb region.

Statement and Significance

Like most of the Arab states, Maghreb countries have sustained heavily stagnant and statist economies (Dede, 2011). State owned enterprises were inefficient and tried to provide employment to win political support and social stability (Noland & Pack, 2007). These countries' development models controlled by the state impeded political reforms for decades. They failed to develop economies of scale through the emergence of a class of entrepreneurs and innovation clusters independent from the state. Regardless the impressive liberalization of some countries in this region (Morocco, Tunisia), a large part of the population remains impoverished and unemployed (Heydarian, 2011). Besides, Maghreb countries remain less integrated in the global economy despite the recent improvement in trade integration (World Bank, 2006). For decades, and through top down approaches, the Maghreb kept implementing a myriad of unsuccessful policies which didn't significantly help to shift towards innovation and knowledge economies that could resolve demanding development issues.

Maghreb governments are strongly involved in economic activities but scarcely focus on boosting economic growth through technology and innovation. They are part of the lagging behind nations in terms of technology production and innovation. Therefore, the role of the state should be highlighted to tackle technology development barriers and stimulate innovation and technology assimilation (Huq, 1996). A shift towards development policies based on innovation and technology is required to initiate sustainable growth and inclusive development (Oukil, 2011). Maghreb states have competencies and talents, but

they neglect efficiency and adequate management of the human capital factor. This is one of the main reasons why they lag behind other developing countries regarding science and technology (S&T) input and output indicators. Moreover, the share of Research and Development (R&D) expenditures in Algeria, Morocco and Tunisia is lower than the R&D inputs and outputs in other leading developing nations. This reflects the weak performance of their innovation systems which remain unable to promote substantial technological capabilities to reach the technology frontier (Satti, 2005).

According to the United Nations Development Program (UNDP), the Arab countries lag behind most of the other regions based on the Innovation System Index. This entails a low level of readiness for the knowledge economy in the Arab world (UNDP, Arab Knowledge Report, 2009). Further, while some Maghreb countries are classified to be dynamic adopters of technology, they are still in lower positions according to the Technology Achievement Index (Sati, 2005). Despite focusing on major technology sectors like Information and Communication Technologies (ICTs) and Foreign Direct Investment (FDI), the achieved growth in the Maghreb didn't translate into productive employment of an increasing youth population (Hakimian, 2011). As far as FDI is concerned, the investments realized failed to successfully benefit a large disadvantaged population. Maghreb countries still face stagnant development, social unrest and illegal immigration because of inadequate technological innovation strategies. This caused a marginalization of R&D, waste of talents and an increasing youthful unemployed population (Oukil, 2011). Oukil stressed on the

development of new ideas and technological values that bring about a culture of technological innovation which the Arab world critically lacks.

Accordingly, technological innovation is reported to be the true indicator of driving production capabilities and social conditions for the Maghreb and other Arab states to catch up with advanced economies (UNDP, Arab Knowledge Report, 2009). To enhance competitiveness and production systems, Maghreb countries need to shift the role of government and institutions towards more focus on innovation and knowledge based economies. Advanced economies were capable to catch up by relying on technology and not on tariffs (Germany, Japan, and South Korea). Moreover, institutional innovation was a decisive factor in this process of "catching up and overtaking the established leading country, which suffered from institutional rigidity and inertia" (Freeman, 1989). The challenge is not to which extent technology is globally available for these states, but it's essentially their ability to implement the mechanisms to use it (Huq, 1996). This demonstrates not only the involvement of technical factors in technological innovation but a noteworthy role of the state and its political and institutional paradigms.

Efficient technological development process involves various factors that include "the role of institutions, education, the quality of governance, of public administration, the presence of economic opportunities, and the increasingly crucial role of technology and innovation." (Lopez-Carlo & Mata, 2011). The ability of developing countries, such as Maghreb states, to assimilate technology and bring about a successful process of innovation capabilities seems to have

political, institutional and socioeconomic aspects. Such aspects and constraints require being diagnosed and analyzed. This would help to determine factors conducive of technological innovation in the region and the relevance of these predictors to innovation activities. Besides, the current research is significant since, few researches were done to determine the relationship between technological innovation and socioeconomic, political and institutional effects in Maghreb countries.

Thus, our current research attempts to determine how innovation activities inputs and outputs are influenced by political, institutional and socioeconomic predictors. Our diagnosis endeavors to understand how changes of key determinants predictors during the last two decades affect technological development of the Maghreb region. The key determinants of innovation are emphasized in literature including the different editions of "The Arab World Competitiveness Report". They are considered essential components of growth engines in the Arab World. We group technological innovation components into four elements: technology research and development (patent applications), investment and technology transfer (Foreign Direct Investment), human capital and education (enrollment in tertiary education) and export and trade capabilities (high technology export). Literature also focuses on specific socioeconomic, institutional and political predictors necessary to lay down policies and development scenarios to boost economic development and innovation particularly in the Arab region (IMF, 2004; Schwab, 2010; Waguespack, Birnir et al. 2005; Makdisi, Fattah et al. 2003; Veganzones and Aysan, 2008). Therefore, in

our study, we use three categories as predictors of technological innovation: socioeconomic (GDP growth and ICT usage), political (government stability) and institutional (law and order) predictors.

Our analysis of the interactions between these two sets of variables will potentially help to identify policy measures and innovation picture in the Maghreb. It will also provide insights from previous inappropriate development policies to establish new technological progress frameworks that emphasize the enhancement of an innovation curve in this region.

In the next chapter, we review the literature of S&T, provide definitions of concepts and discuss types of innovation and models of technological innovation. We also provide conceptual frameworks and discuss the theory.

Chapter 2

1. Literature Review

Innovation Framework and Definitions of Concepts

Innovation is emphasized to be the major force for economic growth and social development in the modern society (Rosenberg, 2004). Nobel Prize-winning economist Robert Solow, developed a principle called the Growth Theory which considers technological progress and innovation "as the greatest engine of economic growth" (Mehta & Mokashi-Punekar, 2008). In a globalized world and persistently characterized by profound economic, political and social change, innovation is playing a critical role in shaping the process of adaptation to these changes (Gopalakrishnan, 2001).

Innovation concept is approached in different ways. Innovation couldn't be done without tackling science and technology (S&T). S&T constitute a set of activities that lead to innovation in a specific nation. This includes: scientific and technological research, experimental development, scientific and technological services, innovation and diffusion (Adeniyi & Oyewale, 2002). In an environment increasingly becoming global, enhancing S&T endeavors is a real challenge for all nation-states. It's reported that S&T is "the raw materials of the future for advancing beyond abject poverty, social justice and political subordination" (Tiyambe & Kakoma, 2004). Therefore, to advance their societies, developing nations need to mobilize S&T efforts and innovate in implementing successful policies of innovation and entrepreneurship. It's also argued that even in developed countries, people tend to stimulate change and courses of action when

they face harsh economic conditions and turmoil. This is how they could develop new opportunities and consolidate socioeconomic development (Oukil, 2011). In a policy response to the current economic crisis, the Organization for Economic Cooperation and Development (OECD) stressed on promoting innovation to expedite the shift towards stronger and sustainable economic growth. Such strategic policy aims at stabilizing the financial system and sustaining the economic recovery. The goals are to foster innovation, invest in smart infrastructure and promote green investment and R&D (OECD, 2009).

Innovation has many dimensions such as being a value driver, a process, an invention or a conduit of change. In an attempt to consolidate the cross-disciplinary concept of innovation, Ram and Cui (2010) define it as "a process through which an idea, object, practice, technology, process is created, reinvented, developed, diffused, adopted and used – having been created internally or acquired / sourced from external agencies, and that is new or significantly improved with the potential of creating or adding value to the adopting unit."

It's hard to give a complete definition to the innovation concept since it differs depending on the context. Some scholars focus on the newness of ideas and their practicability while others highlight the outcomes a propos the value creation or the improvement of services through technological innovation systems (Quazi & Talukder. 2009). Essentially, innovation constitutes a process that comprises different stages or activities: "idea generation, screening of ideas, research and development, business analytics, prototype development, test marketing and commercialization"(Adeniyi, 2007). But such innovation stages require

technological innovation capabilities (TICs), which imply the improvement of the existing technologies and the creation of new processes and techniques. Technology here refers to the body of techniques and knowledge used by a society to convert inputs (like natural resources) into outputs (services, goods) required by individuals and groups. It represents "the scientific and empirical knowledge relating to industrial activities, material and energy resources, modes of transportation and communication, and other similar fields that are directly applicable to the production and improvement of goods and services." (Adeniyi & Oyewale, 2002).

By the same token, the literature also discerns other S&T inputs and outputs. The European Report on Science and Technology Indicators distinguishes various inputs and outputs for S&T development. The report identifies financial and human resources as inputs. This also regards the intensity of R&D expenditure (R&D percentage of GDP) and human resources necessary for technological innovation activities and economic development. Output indicators are economic, technological and scientific performance. The measurement of performance includes the increases of productivity and technology exports, an accumulation of knowledge and learning experience and patents and research productivity (Satti, 2005). The following table summarizes these S&T inputs and outputs:

Definition of S&T input and output indicators	
Types	S&T Indicators/Variables
S&T Input: Financial and Human Resources	1. Financial resources: percentage of R&D expenditure to GDP or expenditure per capita, R&D area of performance, and origin of funding. change in public spending on education in relation to GDP 2. Human resources: HRST – the human capital engaged in science and R&D including the number of scientists and engineers employed in R&D. Total population size and proportion of young people, which represent the human resources potential of each country. educational attainment of the labor force and graduation rates, which show the rate at which newly educated graduates are available at the country level to enter the labor force, particularly the scientific and technological qualifications and doctorate levels, including R&D staff numbers, particularly in S&T fields
S&T Output: Economic, Technological and Scientific Performance	1. Economic indicators: growth in productivity/economic outputs as a major result of technological investment percentage of high-technology exports in total exports 2. Technological indicators: number of patents and patent applications 3. Scientific performance direct research output number of publications produced over a certain period of time

Table 3: Definition of S&T input and output indicators

Source: (OECD, 2005)

Types of Innovation

Literature elucidated that innovation can undergo a radical or an incremental process. Radical innovations "embody a new technology that results in a new market infrastructure… If a new industry results from a radical innovation (World Wide Web), new firms and new customers also emerge for that innovation". On the other hand, incremental innovations are "products that provide new features, benefits, or improvements to the existing technology in the existing market".

(Garcia & Calantone, 2001). This implies the adaptation, modification and improvement of the existing products (Song & Montoya-Weiss, 1998). Innovation types depend on the product life cycle. It's radical at the early periods of the product development and incremental during the advanced stages of development and diffusion. Joseph Schumpeter, who considers innovation and entrepreneurship as decisive dimensions of economic change, believes that "radical innovations shape big changes in the world, whereas incremental innovations fill in the process of change continuously." (OECD, 2005). While some scholars add other classifications for innovation activities, it was suggested that 10% of new innovations belong to the category of radical innovation while incremental innovations constitute 90% of the remaining cases (Garcia & Calantone, 2001). It's argued that continuous improvements and cumulative efficiency of products are considerably greater than radical and infrequent developments (Bessant, Pavitt, et al., 2001). The authors mention the example of Japanese manufacturing which significantly sustained the productivity and quality of industrial processes through incremental change. Besides, the potential significance of incremental innovation is emphasized through its effect on society and market. "In the case of electric light bulbs, the original Edison design remained almost unchanged in concept, but incremental product and process improvement over the sixteen years from 1880 to 1896 led to a fall in price of the light bulb of around 80%, thus ensuring its widespread use" (Tidd, 2006).

Models of Technological Innovation

Governments consider technological innovation as an undeniable path to guarantee the sustainability of their economies. Innovations are significantly shaped by governments' policies. They are also influenced by local and global political, economic and institutional conditions that impact innovation models and policy measures (Jianing, 2008). According to the OECD, scientific and technological innovation is "considered as the transformation of an idea into a new or improved product introduced on the market, into a new or improved operational process used in industry and commerce, or into a new approach to a social service." (OECD, 2005). In other words, technological innovation is a process that includes all the steps starting from a decision to perform a research enterprise through the identification of the potential possibilities that such research will bring about a contribution to the knowledge body in society. This ends by the diffusion or commercialization of a product or an application (Libcap & Thursby, 2008).

Technological innovation has been understood basically through a 'linear model of innovation'. This model is widely used among academia, policy makers and firm. It suggests that innovation begins with basic research before instituting applied research and development and ends with production and finally diffusion (Godin, 2005).

This model was first supported in the United States in Vannevar Bush's document "Science the Endless Frontier, a Report to the President". This document, written in 1945, proposes the mechanisms that should be implemented to shape the American S&T policy and boost scientific progress (Bush, 1945). The model constitutes a framework to measure technological innovation and define science policy agendas (Godin, 2005). Bush chiefly emphasized the socioeconomic benefits of S&T: "Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live the deadening drudgery which has been the burden of the common man for past ages. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited resources, and will assure means of defense against aggression" (Godin, 2005). It has been argued that the linear technology push model is an oversimplification of the innovation process. In fact, if basic scientific research gives rise to new technology, the latter has also given rise to new scientific work (Mahdjoubi, 1997). Landau and Rosenberg (1986) talk about the 'add-on' or beta concept and argue that innovations must go through many 'add-on' phases to achieve an economic impact and these beta stages don't necessarily involve scientific research.

Scholars highlighted the limits of this model because of the complexities and interactions that an innovation process entails. Hence, one of the most referred to as a non-linear model is 'Chain-Linked Model' or 'Stephen Kline's Chain-Linked Model' in reference to Dr. Stephen Kline, a professor Emeritus of Mechanical

Engineering, Stanford University. The model essentially stresses on the complex system of industry and technology and their socio-technical quality.

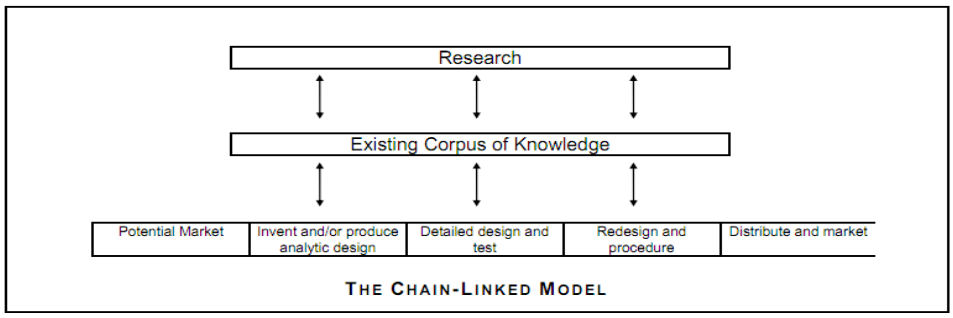


Figure 2: Elements of Chain-Linked Model

Source: Landau and Rosenberg (1986)

This model is different from the linear model as it presents many paths from which innovation might start with diverse interactions and feedbacks (Mahjoubi, 1997). "Contrary to much common wisdom, the initiating step in most innovations is not research, but rather design" (Kline, 1986) Instead of being the initiating step of innovation, research is a part of different stages of the process. The sources of innovation come from a corpus of knowledge that feeds all the steps of the technological innovation process (Kline, 1991).

Due to the increasing complexity of the innovation process, Rothwell (2006) also suggested the development of the linear model to an interactive one. He proposes 'fifth generation innovation' concept as a model based on multi action process and integrating intra and inter-firm levels.

Generation	Key features
First and second	The linear models – need pull and technology push
Third	Interaction between different elements and feedback loops between them – the coupling model
Fourth	The parallel lines model, integration within the firm, upstream with key suppliers and downstream with demanding and active customers, emphasis on linkages and alliances
Fifth	Systems integration and extensive networking, flexible and customized response, continuous innovation

Table 4: Rothwell's five generations of innovation models

Source: Adapted from Tidd, Bessant and Pavitt, 2005.

This process model, which benefits from information and communication technology (ICT) networks, highlights the issues of partial views of innovation. Tidd (2006) views the challenges of the linear model to be limited because it would fail to meet users' needs or respond to the market requirements if we only focus on high R&D capacities. An emphasis on breakthroughs would neglect incremental innovations required to sustain radical changes in firms and society. Moreover, the focus on internal or external ideas will reject innovations from outside or disregard internal development of technological innovations. The author also interestingly evokes the new opportunities and interactions that might trigger a dramatic shift of innovation conditions. Some of these triggers are economic and politico-institutional conditions. For example, the demise of the communism brought about alternative models to businesses and rules of many state-owned firms.

The State of Technological Innovation Policies in the Maghreb

Technological innovation policies in the Maghreb are essentially based on 'Catching-up of industry programs ('Mise à niveau' in French) as measures supported by the European Union to promote technology in firms. They also focus on specific programs and institutions devoted to innovation as clustering and technoparks to boost investment and entrepreneurship (Arvanitis, 2007). But states commitment to develop institutional frameworks for technology policies was not successful to strengthen the development process. Innovation policies were fragile because "national scientific research centers have been distanced from their responsibility to develop a national innovation vision and have left the creation of their strategic work plans to the political leaders of their countries" (UNDP, 2009). Moreover, the construction of innovation systems in the Maghreb "takes place in a very specific environment characterized by privatization of public concerns, the rise of a strong SMEs sector but with very little experience in the fields of technology R&D and innovation, and a relatively weak industrial sector in terms of industrial performances, suffering high obsolescence both in terms of human resources and equipment." (Djeflat & Zawdie, 2008). That's why the liberalization measures didn't significantly help in spurring innovation and entrepreneurship in the Maghreb. For example, Morocco concluded trade association with the EU and a free trade agreement with the US, but the local industries will hardly compete with advanced economies in terms of technological capabilities and human capital productivity.

Accordingly, governments remain the principal actor in R&D and innovation policies. More than 80% of R&D is supplied by the public sector. Universities contribute around 13% while the private sector contributes 6% of R&D. Therefore, it seems that private investment share of R&D activities in the Maghreb is very modest and insignificant compared to other advanced and industrialized countries where most of innovation activities are supported by the private sector (Satti, 2005). It's reported that "all of Algeria's and Tunisia's R&D personnel were employed in the public sector and in higher education. By contrast, China and Ireland, two large recipients of FDI, had about 78% and 62% of their R&D personnel employed in business enterprises, respectively" (Onyeiwu, 2008).

Literature reports that the effects of such policies are reflected by the outcomes of sectoral specializations in the market. "The place of the Maghrebian countries in the international division of labor is in those sectors where the intensity of R&D is the weakest, such as textiles and farm produce" (Alcouffe, 1996). Besides, the weak linkage of research and innovation with private industries in the Maghreb has significant socioeconomic consequences. It principally made unemployment among university graduates to reach higher rates, increased brain drain and generated sizeable weight of a rapidly growing population of students (Arvanitis & Mhenni, 2008).

Country	1998	2001	2004
Algeria	0.16	0.27	0.21
Morocco	0.32	0.71	0.80
Tunisia	0.43	0.53	1.00

Table 5: Estimated Figures on Expenditures on R&D as a Percentage of GDP in the Maghreb (1998-2004)

Source: Adapted from Country Reports, ESTIME

Country	Ministry of Research and Higher Education	Coordination and Funding Agencies	Documents defining research policy	Types of governance of S&T	Budget R&D GDP-ca. 2006 (%)
Algeria	Yes	ANDRU ANDRS ANVREDET…etc.	National Plan (1998) - Law 98/11	Centralized	0,25
Morocco	Two general directions in the ministry of Education	CNRST CPIRSDT	Vision 2025 (2006)	Centralized	0,8
Tunisia	Yes	HCSRT	National Plans Law 96/2006 (1996) S&T Strategy 2010	Centralized	1,0

Table 6: Principal characteristics of national research systems in the Maghreb

Source: Adapted from ESTIME Project

Maghreb states attempt to reinforce the modernization process through giving more emphasis to research and innovation systems. The literature views the

Tunisian policies as an example for the region. The country's main economic sectors (textiles, agriculture, tourism, clothing, machinery) endure low labor productivity and a strong global competitiveness. Tunisia endeavor to sustain competitiveness and attract more FDI through investment in technology and innovation. The country raised R&D expenditure to more than 1% of GDP and focused on programs of technological development to boost industry initiatives and private businesses. But it does not have a formal body to coordinate innovation policies (Arvanitis & Mhenni, 2008).

Morocco has deployed systematic efforts to bolster innovation and technological development. The country has shown firm orientation to develop technology platforms and research programs focusing on socioeconomic goals ('Pôles de competences', research-technological networks, Intellectual property regulations). A 2025 vision for technological and scientific development was created. This vision proposes measures to strengthen scientific research, improve the quality of tertiary education and consolidate business competitiveness through innovation (Arvanitis, 2007). However, an analysis of ESTIME project reports that R&D activities in the private sector grow slowly and remain limited to large companies. Also, like Tunisia, there is a lack of coordination of research and innovation activities and an uncertainty regarding the institutionalization of research (Arvanitis, 2007).

Algeria, an oil based economy, has instituted research programs and a law framework to develop innovation (Arnanitas & Mhanni, 2008). There was a major focus on 'industrializing industries' model to acquire high technology since

eighties (Saad, 2000). Nevertheless, expenditure on R&D remains modest and insignificant compared to other countries. A report mapping innovation and technology systems in Algeria, indicates that the country does not have an innovation policy despite the endeavors of the "Agence de la Valorisation de la Recherche" to promote links between R&D actors and businesses (Esau, 2006).

In the next section we will lay down a theoretical framework and empirical background of this research enterprise.

3. Theory

The consolidation of socioeconomic conditions and stimulation of technical change, in both developed and emerging nations, are tackled through the creation of new opportunities and innovation endeavors. Innovation and technical investments measures constitute an incentive for development and prosperity. One of the strong theoretical arguments emphasizing this relationship is the work of Robert Solow (1957) in his analysis of technical progress and the aggregate production. Thanks to this prominent Nobel Prize winner that innovation was introduced into formal economic development models (Torun & Çiçekçi, 2007).

Solow considers technical change as responsible for the bulk of economic development of the United States. His serious study focused on the analysis of the US factor productivity between 1909 and 1949. While the prevailing economic theories attribute economic growth to the accumulation of capital, Solow determined that the majority of growth is attributable to technical change. He affirms that "Gross output per man per hour doubled over the interval, with 87.5 per cent of the increase attributable to technical change and the remaining 12.5 per cent to increased use of capital." (Solow, 1957). Therefore, development and innovation are inseparable as today's innovation "is the crucial source of effective competition, of economic development and the transformation of society" (Torun & Çiçekçi, 2007).

Theory is strongly linking innovation to economic development. Our stated interest is to determine how technological innovation inputs and outputs are influenced by political, institutional and socioeconomic key determinants. We

assume that economic growth is necessarily dependent on innovation activities and that there is a relationship between economic development and political, institutional and socioeconomic changes. Therefore, is there necessarily an impact of such changes on technological innovation?

As far as economic development is concerned, Alesina and Ozler (1996) studied a sample of 113 countries during the period 1950-1982 and found out that there is a strong relationship between government stability or instability and economic outcomes. They affirmed that economic growth tends to be lower when a government collapses. They also reported that economic outcomes are affected and "growth is significantly lower than otherwise". This happens not only when a government collapses, but it tends to be the case of governments that are inclined to crumple or those that knew a significant shift of their ideological direction. Alesina and Ozler (1996) report that when there is a possibility of government crumple, they prone to tax productive activities and capital. This leads to a "substitution of productive domestic investments in favor of consumption and capital flight, and thereby leads to a reduction of domestic production". Moreover, a government which is under threat of getting unstable tends to seek stability by responding to pressure groups via rent-seeking activities. This potentially weakens the government and obstructs development efforts.

Accordingly, governments play important roles in shaping innovation performance. In fact, their policies create what is called a "political aspect of innovation" framework (Courvisanos, 2009). Such framework helps evaluate technological innovation policies in a particular country or business. OECD

developed a set of indicators that determine the effectiveness of innovation in a specific country or a group of countries (Arab World). This includes indicators like government stability, rule of law, patent applications and productivity growth. Furthermore, OECD determines that innovation outcomes are impacted by "four major criteria of the national innovation system: (i) framework conditions for innovation arising out of the nation's regulations, customs and rules; (ii) governance of the innovation system through public planning, funding and cooperative linkages; (iii) competitive university-based research funding and training, and (iv) promotion of innovation within firms and across the business sector through supply-based competence measures and demand-based procurement measures" (OECD, 2006). Likewise, OECD (1992) links development of innovation to the environment and policy context. Innovation results from "national or local environments where organizational and institutional developments have produced conditions conducive to the growth of interactive mechanisms on which innovation and the diffusion of technology are based".

Political institutions shape technological innovation capabilities whatever the stage of development of a country. That's to say, government stability, quality of the legal system and laws are potential incentives to promote innovation. "Politically unstable countries generate layers of uncertainty and mistrust: in authority figures, in the integrity of rules and regulations, and in the future itself. When trust is low, it follows that individuals in these societies will lack confidence in university-government-business collaborations and that the formal

and informal institutions that foster innovative systems" (Allard, Martinez et al., 2012). In unstable situations, ecology of innovation cannot develop, knowledge creation is unlikely to happen, technology investment is likely to put off and cooperation between research and development and industry are inadequate.

A related issue regarding the institutional framework especially the rule of law and private property and their impact on economic development was conducted by Gerald W. Scully (1988). This empirical study was carried out on data concerning 115 countries through the period 1960-1980. It found that the choice of an institutional framework has a significant impact on economic efficiency and outcomes. The author concluded that "politically open societies, which bind themselves to the rule of law, to private property, and to the market allocation of resources, grow at three times (2.73 to 0.91 per-cent annually) the rate and are two and one-half times as efficient as societies in which these freedoms are circumscribed or proscribed."

As far as MENA region is concerned, an analysis of the region's determinants of economic growth reported that trade openness and capital are less beneficial to growth performance. This is due to the scarcity of major contributing variables particularly weak investment, lower quality of institutions, modest human capital and inefficient educational systems (Makdisi, Fattah et al., 2003). This study is based on regression analysis and has been applied to 13 individual MENA countries over the period 1970-1998. Another study focused on the interactions between political stability, investment and economic performance in the MENA region including Turkey (Tosun, Gran et al., 2008). The research covers the

period 1987-2003 and measured political stability using government stability ranking carried out by the International Country Risk Guide (ICRG) published by the PSR Group (a private firm that provides consulting services to decision makers and global investors). The methodology is based on the Malmquist productivity index that efficiently measures both technological and productivity changes. In analyzing the relationship between government stability and investment profile, the authors found that "the higher the political risk is, the lower the macroeconomic performance will be. Additionally, the lower the political risk of a country is, the higher is the macroeconomic performance."

In relationship with private investment profile, Veganzones and Aysan (2008) studied the relevant governance indicators for this variable in the MENA region. This study also used political independent variables from the ICRG and Freedom House (FH). They argue that these "data set can be a good proxy to measure the perceptions of the investors about the institutions." The author essentially uses a set of variables like political stability, law and order, political accountability and quality of bureaucracy. The empirical analysis shows that these factors have an impact on private investment with different levels of significance (1%, 5%, and 10%). It's reported that "all of the three indicators were proved to be significantly -although at different levels of significance and magnitudes of influence- important for private investment decisions".

In an International Monetary Fund paper, Chan (2004) reported similar results regarding FDI in the MENA region. He argues that the risk instability is a key determinant of discouraging FDI into this region during the period 1990-1999.

The author used political, economic and financial risk indices of the ICRG as independent variables. The empirical results indicate that the degree of instability is a critical determinant of foreign investment in the MENA region. Similarly, Waguespack, Birnir and Schroeder (2005) examined the impact of political stability on another technological innovation determinant which is patent application rates. This study concerns the Latin America region and covers the period 1973-1999. Regression results determined that inventors consider political stability in a country before getting involved in inventions or apply for patents. The authors emphasized that their "principal finding is that political stability matters to patenting". It means that there is a significant relationship between political institutions and technological innovation.

In recent literature, law is considered very well related to innovation. "The American Bar Association, for example, takes this relationship as a given (ABA 2007). Statistical analysis has shown that the better the rule of law, the richer the nation, and as Suyitno (2008) notes, radical legal changes required by Central European and Baltic countries to join the EU improved their economies as well as their judicial systems." (Earle, 2010). It's also argued that law, as an institutional indicator, and a "proxy for the quality of the judicial system and protection of property rights, has a positive effect on innovation" (Faria & Barbosa, 2011). Within this context, a cross country empirical study of the National Bureau of Economic Research (Barro, 1996) analyzed the determinants of economic growth, including the rule of law indicator. He reported that "greater maintenance of the rule of law is favorable to growth. Specifically, an improvement by one rank in

the underlying index (corresponding to a rise by 0.167 in the rule of law variable) is estimated to raise the growth rate on impact by 0.5 percentage points."

In a study of the interactions between institutions and trade, Bhattacharyya and Dowrick (2009) analyze the impact of high quality institutions on improving trade and consequently economic growth. A "measure of the rule of law dominates the influence of both trade and geography as the fundamental determinant of long-run economic development." Many other scholars reported the positive impact of 'law and order' on economy, investment and development outcomes (Garcia-Blanch, 2001; Bhattacharyya & Dowrick, 2009; Harvey et al., 2010; Rachdi & Saidi, 2011). Besides, literature indicates that empirical studies use the 'law and order' variable from PRS Group as a "measure of law enforcement and legal protection" (Çeliköz & Arslan, 2010). This ICRG measure assesses the strength, impartiality of the legal system and popular perception of the law (Harvey, Bekaert et al., 2011).

"The strength of the rule of law is one of the best predictor of a country's economic performance. On the other side, if there is deficiency in the rule of law, it will encourage high rates of corruption, with further destructive consequences on the confidence of economic actors which gives direction to economy. This causes a lack in investment, then slows economic growth. Consequently, it deprives the governments of resources to invest in education, social safety nets, and sound environmental management, all of which are critical for sustainable development." (Çeliköz & Arslan, 2010).

Most of the empirical models that focus on cross country studies analyze the impact on economic growth and use variables relevant to innovation measures and socioeconomic development. Regarding innovation variables, Anghel (2005) studied the potential effect of institutions on FDI and reported that weak institutions have a significant and negative impact on FDI inflows. The author made an empirical analysis and reported that less FDI is explained by a low "quality of regulation or a low protection of property rights." (He also used other variables such as political stability and control of corruption). Hsu (2011) studied the determinants of economic growth in autocracies by focusing on the role of institutions and politics on economic performance. The study includes our sample countries (Algeria, Morocco and Tunisia) in addition to others regarded as autocracies. Interactions between variables such as GDP per capita, law and order, schooling, trade and energy production found interesting correlations. It's reported that "certain factors, such as stronger law and order, lower government spending, and human capital measures such as schooling, have a positive effect given a starting level of GDP".

By the same token, socioeconomic indicators play a crucial role in technical innovation and development of nations. Hassan (2003) investigated the interactions between GDP growth and FDI in the MENA region (Egypt, Iran, Jordan, Saudi Arabia, Morocco, Tunisia, Turkey and Yemen) between 1980 and 2000. He focused on ICT and human capital as crucial variables to growth and productivity enhancement in every sector. An important finding of his regressions is that information technology has a positive impact on FDI. However, he found

no significant effect of GDP growth on FDI. Likewise, an investigation of whether financial deepening and information technology (IT) play a significant role on the emerging economy of Qatar, Darrat and Al-Sowaidi (2010) reported similar finding for IT contributions. They found that IT is "essential before financial deepening can have its simulative long-run effects."

Satti (2005) examined S&T development indicators in both the Gulf and other Arab Mediterranean countries. She reported that the performance of the Mediterranean states (Algeria, Morocco and Tunisia) is higher mostly for economic and human capital indicators. This specifically regards "the average share of high-technology exports, TFP[2] growth and GDP per capita growth, scientific publications and international cooperation". However, compared to other developing countries, the Arab region has the lowest average FDI/GDP ratio. Between 1995 and 2003, this average was 1.51%, compared to 2.8% in other developing countries (Onyeiwu, 2008).

Other empirical studies (Aghion, Meghir et al., 2004) support the hypothesis that tertiary education has a significant positive growth impact only in technologically advanced economies, in this case OECD countries. Besides, Aghion (2008) argues that "higher education investment should have a bigger effect on a country's ability to make leading-edge innovations, whereas primary and secondary education are more likely to make a difference in terms of the country's ability to implement existing (frontier) technologies".

[2] Total Factor Productivity (TFP): "the portion of output not explained by the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production." (Comin, 2006)

In the case of the MENA region, a study of education and innovation through ICT in the Gulf Cooperation Council countries (GCC) demonstrates that despite the high level of school enrollment and internet use, there is still a significant lack in innovation indicators. But, it's reported that expenditure on education "indicates that much less is spent per student in the GCC compared to the international mean" (Wiseman & Anderson, 2012). In fact, there are plentiful resources available in these GCC countries, but the output of research and innovation doesn't match such supply. This is explained, to some extent, by institutional contexts that hinder knowledge creation and innovation development.

Accordingly, few studies analyzed technical innovation in the Maghreb region. Literature investigated this issue on a global cross-country perspective (Anghel, 2005; Hsu, 2011; OECD, 2006). Scholars who focus mostly on the MENA region and in some cases on the Maghreb (Tosun, Gran et al., 2008; Hassan, 2003; Chan, 2004; Satti, 2005; Wiseman & Anderson, 2012) explore this issue both quantitatively and qualitatively. Then, they gave general recommendations about innovation policy in the region. Our study will especially add to the literature in a way that a determination of the effect of three major sets of variables (socioeconomic, institutional and political) on technological innovation will further help identify innovation determinants among these variables and shape policy decisions vis-a-vis technological innovation.

Our research distinguishes itself in many aspects. First, we focus our analysis on three major Maghreb states that already have some relevant experiences in innovation activities, technology development and research institutions. However,

not many studies tackle the issue of innovation in the region. This will give a clear insight about what requires to be tackled chiefly in light of the technological innovation components we explore. Second, we focus on three sets of variables: socioeconomic, institutional and political and their impact on four main innovation aspects: R&D technology, investment, human capital and technology export. This will help us to determine interactions between these factors and technological innovation in the region and whether there is an impact or not within the last two decades. Lastly, we see our study as vital in determining differences in terms of technological development and innovation across Maghreb states, subject of this study.

Accordingly, most of these empirical studies and scholarships correlate technological innovation indicators, namely FDI, patents output, tertiary training and technology export with political, institutional and socioeconomic predictors. These predictors can either hinder or enhance technological development attributes. We will attempt to quantitatively determine the interactions between these variables in the case of the Maghreb region. We look to determine whether technological innovation in this region is influenced by these sets of predictors or their role is in fact insignificant. Therefore, the next section concerns our study methodology. It will provide variables background and definitions, hypotheses to be tested, data sources and quantitative models and techniques.

Chapter 3

1. Description of Variables

Dependent variables

The key dependent variables regarding technological innovation are listed and explained below. They concern four chief aspects: R&D, human capital, investment and technology transfer and technology export.

Patents Applications	System Output	R&D Technology	WIPO, Industrial and intellectual property offices in Morocco, Algeria and Tunisia
Students in Tertiary Education (per 100k inhabitants)	System Input	Education and Human Capital	UNESCO Data
Foreign Direct Investment (FDI)	System Input	Investment/Technology Transfer	World Bank
High Technology Export	System Output	Export/ Trade Capabilities (other than natural resources)	World Bank

Table 7: Dependent Variables

Research & Development Technology: Patent Applications

On a macroeconomic level, patents reflect research and development productivity of a country. They are regarded as a metric for research productivity measured by the number of patents (de Rassenfosse & de La Potterie, 2009). Patents outputs are essentially influenced by "education, intellectual property (IP) and science and technologies (S&T) policies" in each country.

Between 1985 and 2004, the global number of patent applications increased from 884,400 to 1,599,000. "The average annual rate of increase in total patent filings since 1995 was 4.75%" (Yunwei, Zhiping et al., 2009). Patents present multiple

advantages as data to study technological innovation. “First, patents contain highly detailed information on the innovation itself, but also about the inventor, the originating technological area(s) and industry, etc. Second, there is both a very large “stock” and “flow” of patents, so there exists a wealth of data available for research. Lastly, patent count data reaches back at least 100 years, making available long time series of data.” (Knudsen, Florida et al., 2005). Besides, patents contribute to the creation of R&D spillovers and scholars tend to measure the innovation at this level through “either patenting activity or patent strength, and measures of innovation or innovative activity” (Arora, Cohen et al., 2008). In this study we use the number of patent applications indicator provided by both WIPO and Industrial and intellectual property offices in Morocco, Algeria and Tunisia.

Human Capital: Tertiary Education

Human capital is knowledge accumulation and specialized skills that people acquire via training and ‘schooling’ activities. The acquired knowledge leads to technology, which transforms resources into outputs (Kagoshi & Jolly, 2010). This specialized knowledge and technology production is essentially acquired via education attainment and investment in tertiary education. Thus, being critical to innovation and the construction of knowledge economies, the role of tertiary education becomes more powerful as a key determinant of enabling countries technology and innovation capabilities (Salmi, 2003). Therefore, human capital is “the key input to the research sector, which generates the new products or ideas

that underlie technological progress. Countries with greater initial stocks of human capital experience a more rapid rate of introduction of new goods and thereby tend to grow faster." (Barro, 1991).

As far as our study is concerned, this indicator regards the total enrollment in a tertiary education following secondary school leaving. Based on the UNESCO data, it's measured as the total enrollment per 100,000 inhabitants.

Investment and Technology Transfer: Foreign Direct Investment (FDI)

OECD (1999) defines FDI as the fact of "obtaining a lasting interest by a resident entity in one economy (direct investor) in an entity resident in an economy other than that of the investor (direct investment enterprise)". It's a major medium to transfer enhanced production techniques and one of the most stable elements of technology transfer and capital flows to the developing world (Bénassy-Quéré et al., 2007). FDI is considered as "a driver of employment, technological progress, productivity improvements, and ultimately economic growth. It plays the critical roles of filling the development, foreign exchange, investment, and tax revenue gaps in developing countries. In particular, it can play an important role in Africa's development efforts, including: supplementing domestic savings, employment generation and growth, integration into the global economy, transfer of modern technologies, enhancement of efficiency, and raising skills of local manpower" (Anyanwu, 2012).

The data used for FDI are collected from the World Bank indicators database. It measures FDI as "net inflows (new investment inflows less disinvestment) in the

reporting economy from foreign investors" (World Bank). It's measured as percentage of GDP.

Technology Trade Capabilities: High technology export

The Global Innovation Index considers High technology exports as an innovation output and technology-related commercial activity (Dutta, 2011). According to the Word Bank Development Indicators database (Srholec, 2007), high technology (HT) exports are "products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery". High-tech products are a strong rising segment of global trade. Statistics demonstrate that developing countries are progressively becoming exporters of this category of products. However, the share of Arab countries in high-tech export is small compared to other regions (Srholec, 2006). "The change in export pattern according to technology contents is not uniform across Arab counties. HT exports in 2006 are highest in Lebanon (10.26 %), followed by Jordan (7.97%), Morocco (7.05%), Tunisia (4.58%)" (Abdmoulah & Laabas, 2010).

In our research, we would use high technology export capacity of the sample countries as a metric of technological innovation. It's measured as a percentage of manufactured exports.

Independent variables

Below are illustrated the three sets of independent variables we use in our study:

Political variable		
Government Stability	Political stability	International Country Risk Guide (ICRG) PRS Group
Institutional variable		
Law and order	Law/legal system	International Country Risk Guide (ICRG) PRS Group
Socioeconomic variables		
GDP growth	Rate of economic growth	World Bank
Internet Usage	ICT dissemination/infrastructure	World Bank

Table 8: Independent variables

a- Political and institutional variables

Our study considers 'government stability' predictor from the International Country Risk Guide as a political variable. It measures government's ability to stay in office and carry out its declared programs. Our main interest through the use of this predictor is to measure to which extent the governing body commands programs and accomplishes the proclaimed policies. This helps to capture the impact on the milieu of business and innovation development that requires stable policies and strong governance.

Innovation activities like foreign and local investment, export and promotion of patent applications depend significantly on certainty about the future stability or instability of the country (Waguespack, Birnir et al., 2005; Courvisanos, 2009). Moreover, "Debate within the comparative political economy (CPE) field concerns the duration of governmental commitment to particular policy positions. Setting aside the question of which policies are conducive to technology

development or economic growth, a propensity to abruptly and/or randomly change policies can introduce destructive uncertainty into the economic decision-making of stakeholders" (Waguespack, Birnir et al., 2005). We don't aim from using this variable to include every aspect of political stability of a nation particularly the type of regimes whether they are authoritarian or democratic. The emphasis is rather to grasp the impact of government stability as it's defined above. This particularly helps us to avoid the democracy type bias involving democratic regimes having greater government stability than autocratic regimes. Therefore, we presume that government stability would impact technological innovation regardless of democracy factor.

On the other hand, we consider law and order predictor from the International Country Risk Guide as our main institutional variable. It assesses the strength, impartiality of the legal system and popular perception of the law (Harvey, Bekaert et al., 2011). Our principal objective from using this institutional predictor is to capture the strength of the legal system in our sample countries chiefly its interaction with innovation activities and technological development. Therefore, we don't aim at focusing on every aspect of regulatory and law procedures involved in an institutional context.

As far as the rule of law is concerned, the World Bank (2005) looks "to the presence or absence of specific, observable criteria of the law or the legal system. Common criteria include: a formally independent and impartial judiciary; laws that are public; the absence of laws that apply only to particular individuals or classes; the absence of retroactive laws; and provisions for judicial review of

government action." Our main interest is to determine to which extent law and order predictor facilitates or hinders technical development and innovation. Hence, we maintained a functional definition that focuses on the quality and strength of legal procedures, law and contract enforcement and the courts.

Accordingly, there are two main raisons that dictated the choice of our political and institutional predictors. First, global institutions as the World Bank, UNDP, Fraser Institute, OECD and Freedom House usually don't have complete data for our sample countries. With the exception of the data from PRS Group experts, the available data for these countries don't tackle the very specific political and institutional factors. It was just recently that few institutions started to provide data about most of the developing countries. For example, the World Bank project Doing Business started lately to collect data measuring global business regulations which include the Arab countries. Second, we try to choose a single and viable predictor particularly for our political and institutional sets of variables based on the literature and to avoid multicollinearity. Thus, we select a political variable representing the governing body (executive/government power) which chiefly perceives government stability of a country. We also decide to select an institutional predictor that measures the strength of the legal system in a specific country (judiciary system).

To our knowledge and a part from the stated measures, no other complete institutional metrics are available for our sample. We had to go through numerous academic researches and empirical studies that analyze the impact of law and legal systems on economic growth, investment and other innovation or social and

economic development indicators. The aim is to choose viable institutional predictors. Thus, we considered three indicators that most of the scholarship use: 'rule of law' as one of the governance indicators compiled by the World Bank, 'legal system and property rights' which is a component of the Index of Economic Freedom developed by Fraser Institute and 'law and order' from The International Country Risk Guide (ICRG) prepared by PRS Group for fee-paying. We decide to use 'law and order' predictor for the following reasons. First, the component legal system and property rights has 'rule of law' as a sub element among others like impartial courts and integrity of the legal system (Hu, 2012). This indicates that 'rule of law' is assessed as a component of the legal system and would constitute a more specific measure than the legal system and property rights. Second, 'rule of law' predictor integrates multiple indicators though many studies use it as an institutional predictor. Third, Law and order is considered a more specific predictor to measure the legal system in a country. Prominent scholars consider it as a viable measure of the rule of law (Çeliköz & Arslan, 2010).

b- Socioeconomic variables

GDP growth

The World Bank defines the Gross Domestic Product growth as the "annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2000 U.S. dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated

without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources." (Ernst & Young, 2011).

In many Arab countries, GDP growth didn't only slow down, but it principally collapsed. The region went through three growth periods since 60s: 1960–84, 1985–94, and 1995–2000. In the first period, the annual growth rate was 2.5% with a significant growth in oil states. The second period knew a collapse of oil prices and thus growth rate turned down to 1%. The third period knew growth volatility afterwards the Asian crisis of 1996 (Elbadawi, 2005).

As far as our sample is regarded, we assume that GDP growth, as a socioeconomic variable, impacts innovation inputs and outputs in the region. We use this factor as the annual percentage growth rate as measured by the World Bank.

ICT usage

Today, all sectors of the economy benefit from the large spectrum of ICT applications. ICT made communications, storage, information processing and business automation widely accessible via the worldwide web. Organizations and individuals invest significantly in information technologies thanks to the growing ICT applications and the falling prices of computers and services. Moreover, because of their adoption by most of industries, ICTs bring about a considerable potential for technological innovation (e-commerce, reengineering of industrial processes, enhancement of high tech capabilities) (Hempel, 2004).

Nevertheless, the degree of adoption and use of ICT varies between regions and countries. Despite the improvement of the telecommunication sector, there is still a global digital divide between developed and developing nations (Guillen & Suarez, 2005). In the Arab region, there are important developments regarding IT use benefit (e-commerce, education). However, there are still chief impediments for internet take-off due principally to monopoly, technical obstacles, privacy and consumer behaviors (Aladwani, 2003).

ICT usage in our study regards people with access to the worldwide internet network in a specific country. It's measured as internet users per 100 people.

2. Hypotheses

Our assumption is that institutional, political and socioeconomic factors play a critical role in developing or hindering technological innovation in the Maghreb region. Therefore, we are attempting to determine the effect of these explanatory predictors on various innovation aspects and explore the interactions between different variables through the following hypotheses:

Hypotheses concerning political effect on technological innovation in the Maghreb

H1- Foreign Direct Investment development is positively related to government stability in Maghreb countries.

H2- The more the government is stable the more patent applications inventors will make

H3- High technology exports mostly enhance in countries with stable governments

H4- Tertiary education is more likely to increase in a policy and politically stable Maghreb country

Hypotheses concerning institutional impact on technological innovation in the Maghreb

H5- The more law and order is stronger in a Maghreb country, the more FDI inflows it will get

H6- Patent applications are positively related to a strong law and order

H7- A strong legal system might constitute an explanatory predictor for the improvement of human capital in the Maghreb

H8- High technology export would increase when there is less legal risks in Maghreb states

Hypotheses regarding socioeconomic impact on technological innovation in the Maghreb

H9- GDP growth has a negative effect on R&D outputs in the Maghreb countries

H10- The volatility of GDP rates in the Maghreb impacts negatively tertiary education enrollment in the region

H11- Unpredictability of growth rates influence negatively FDI inflows to the Maghreb

H12- ICT dissemination encourages patent applications outputs by innovators in the Maghreb

H13- ICT usage has a positive impact on FDI inflows in the Maghreb

H14- The enhancement of tertiary education in the region is positively related to an increase of ICT usage.

3. Data Sources

This study is curried out using secondary data compiled and produced by reliable global institutions. Data compiled by these organizations are principally based on accuracy and validity from data sources. It's reported that they are based on national statistics as a starting point. In addition to being trustworthy, these data are sometimes incomplete when it regards developing countries. Therefore, we attempted to collect the remaining data through phone and email from local competent institutions in our sample countries. Following are the data sources we use in our study:

- The World Bank: this institution provides relevant science and technology and socioeconomic indicators. The World Bank's Development Indicators (WDI) compiles data covering more than 800 variables regarding various economic, social development and technology and innovation inputs and outputs. These datasets are widely used in scholarly work and policy circles. Our indicators from the WDI are the following: FDI inflows, high technology export, GDP growth and ICT usage.
- World Intellectual Property Organization (WIPO): this organization records a wide range of indicators covering global intellectual property. Data are collected from various national and regional offices (Lerner, 2002). Thus, WIPO provides us with statistical data regarding the total number of patent

applications recorded on an annual basis in our sample countries between 1996 and 2010. However, we found out that there are some missing data regarding patent applications in our sample. The incomplete data were collected from industrial and intellectual property offices in Morocco, Algeria and Tunisia.

- The United Nations Educational, Scientific and Cultural Organization (UNESCO): this is the main organization producing and distributing comparative education data about all countries via its division of statistics. Its indicators principally entail development policies and underline political decisions in education and R&D (Cusso, 2006). We use this source to collect data about human capital in the Maghreb region through the variable measuring students' enrollment in tertiary education.
- International Country Risk Guide (ICRG): the Political Risk Services (PRS) Group produces ICRG indicators on a monthly basis for more than 140 countries. Data coverage goes back to 1980s (Barro, 2000). Each variable "is measured on a points scale with higher points denoting better performance with respect to the variable concerned. The assessment is based on expert analysis from an international network and is subject to peer review" (Parker et al., 2006). ICRG indicators have been independently acclaimed by the Economist, IMF and the Wall Street Journal (PRS Group). Besides, "the willingness of customers to pay substantial fees for this information is perhaps some testament to their validity" (Barro, 1996). We use this data source for

our political and institutional predictors, namely: government stability and law and order.

The measurements of these data are based on a three years average for all dependent and independent variables. Therefore, we have collected data for the following years: 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009 and 2010.

4. Model

Variables are captured between 1996 and 2010 in three major Maghreb countries. Therefore, we have a year average for each of the variables as calculated by data sources. For political and institutional covariates from the ICRG, we make an average of 12 months prior to a year average since data are collected on a monthly basis. As a result, we have a 15 time point average for the following years: 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009 and 2010.

Indeed, technological innovation elements depend on a multitude of factors, but the scope of our study is to determine the effect of our selected factors and their correlations in three Maghreb countries (Algeria, Morocco, and Tunisia). We assume that we can test the effect of political, institutional and socioeconomic predictors on technological innovation in the Maghreb by using a general linear model (GLM).

A GLM allows an analysis of variance by conducting ANOVA and F-tests to see if there are significant differences between populations' means. The research proposes one equation for each of our dependent variables (FDI, patent

applications, Tertiary Education and HT export) and includes all of the independent variables (government stability, law and order, GDP, ICT usage). We consider analyzing our data for the three countries together. Besides, we use the year and the country as indicator variables to determine if there is a year or country effect on our dependent variables. These indicator variables would have values of 0 or 1.

The following general linear model is considered for our data:

$$\text{Outcome} = \beta_0 + \beta_1\ \text{country1} + \beta_2\ \text{country2} + \beta_3\ \text{year1} + \beta_4\ \text{year2} + \beta_5\ \text{year3} + \beta_6\ \text{year4} + \beta_7\ \text{year5} + \beta_8\ \text{year6} + \beta_9\ \text{year7} + \beta_{10}\ \text{year8} + \beta_{11}\ \text{year9} + \beta_{12}\ \text{year10} + \beta_{13}\ \text{year11} + \beta_{14}\ \text{year12} + \beta_{15}\ \text{year13} + \beta_{16}\ \text{year14} + \beta_{17}\ \text{Gov stability} + \beta_{18}\ \text{Law and order} + \beta_{19}\ \text{GDP growth} + \beta_{20}\ \text{ICT} + e \quad \textbf{(1)}$$

Outcome is one of the dependent variables: FDI, High Technology export, Patent applications or Tertiary education. Hence, four independent models are fit to our data, each for one of the dependent variable. e denotes the error term, B0 is the constant and $B_{1\text{-}k}$ is the slope of the regression line. Country1, country2, and year1-year14 are indicator variables as explained below:

country1 = 1 if country = Algeria;

0 otherwise

country2 = 1 if country = Morocco;

0 otherwise

year1 = 1 if year = 1996;

0 otherwise:

year2 = 1 if year = 1997;

0 otherwise:

year3 = 1 if year = 1998;

0 otherwise:

year4 = 1 if year = 1999;

0 otherwise:

year5 = 1 if year = 2000;

0 otherwise:

year6 = 1 if year = 2001;

0 otherwise:

year7 = 1 if year = 2002;

0 otherwise:

year8 = 1 if year = 2003;

0 otherwise:

year9 = 1 if year = 2004;

0 otherwise:

year10 = 1 if year = 2005;

0 otherwise:

year11 = 1 if year = 2006;

0 otherwise:

year12 = 1 if year = 2007;

0 otherwise:

year13 = 1 if year = 2008;

0 otherwise:

year14 = 1 if year = 2009;

0 otherwise:

We assume that our sampled populations are normally distributed and we use the F tests to investigate the effect of our covariates in this model. The effects of the independent variables, including the two indicator variables (country and year), are tested using the following null and alternative hypotheses:

For country effect: H0: $\beta 1 = \beta 2 = 0$,

Ha: at least one of them is not equal to zero.

For year effect: H0: $\beta 3 = \ldots = \beta 16 = 0$,

Ha: at least one of them is not equal to zero.

For Gov stability effect: H0: $\beta 17 = 0$,

Ha: $\beta 17 \neq 0$

For Law and order effect: H0: $\beta 18 = 0$,

Ha: $\beta 18 \neq 0$

For GDP growth effect: H0: $\beta 19 = 0$,

Ha: $\beta 19 \neq 0$

For ICT effect: H0: $\beta 20 = 0$,

Ha: $\beta 20 \neq 0$

In the case of statistical significance of the F test for country effect, we proceed to a pairwise comparison to determine where differences occur. These multiple comparisons are conducted using Tukey's method (Neter & Wasserman, 1996).

Our second GLM model is similar to the background model but it doesn't include the year indicator variable. Similarly, it will have four independent models that fit to the data. Below is the proposed model:

$$\text{Outcome} = \beta_0 + \beta_1\ \text{country1} + \beta_2\ \text{country2} + \beta_3\ \text{Gov stability} + \beta_4\ \text{Law and order} + \beta_5\ \text{GDP growth} + \beta_6\ \text{ICT} + e \quad (2)$$

Where:

e denotes the error term, B0 is the constant, $B_{1\text{-}k}$ is the slope of the regression line and country1, coutry2 are indicator variables.

Likewise, the F test is used to test the effects of the covariates and differences are determined via pairwise comparisons. The same null and alternative hypotheses are used to test each effect with the exception of the year indicator variable.

For country effect: H0: $\beta1 = \beta2 = 0$,

Ha: at least one of them is not equal to zero.

For Gov stability effect: H0: $\beta3 = 0$,

Ha: $\beta3 \neq 0$

For Law and order effect: H0: $\beta4 = 0$,

Ha: $\beta4 \neq 0$

For GDP growth effect: H0: $\beta5 = 0$,

Ha: $\beta5 \neq 0$

For ICT effect: H0: $\beta6 = 0$,

Ha: $\beta6 \neq 0$

For our GLM, we would need to check some main model assumptions like normality to see if the distributions of the residuals are normal in addition to determining whether the residuals have constant or equal variances. This should be determined via the examination of sample skewness, Kurtosis measures, goodness of fit (Kolmogorov-Smirnov test), and quantile plot (Q-Q plot). Skewness measures the tendency of the deviations to be larger in one direction than in the other. As normal distribution is symmetric, observations that are normally distributed should have skewness near zero (A negative skew is skewed to the left of the mean and a positive skew is skewed to the right) (Neter & Wasserman, 1996). Kurtosis measures regard the heaviness of the tail and observations that are normally distributed should have a kurtosis near zero.

Goodness of fit test (Kolmogorov-Smirnov test) concerns the normality of observations and investigates whether the values are randomly selected from a normal distribution. P-value less than 0.05 test leads to the rejection of the null hypothesis of normality. Besides, the Q-Q plot tests if our data distribution matches the normal distribution (theoretical distribution). Constant or equal variances should also be determined through residuals plot (residuals versus the fitted values and a distribution of points scattered randomly about 0). Additionally, a logarithmic transformation of the dependent variable is applied to the second model when the assumptions do not hold.

Chapter 4

In our study, yearly data (1996-2010) from three countries (Algeria, Morocco, and Tunisia) are explored and analyzed for the two sets of variables indicated earlier. For the independent variables, GDP growth and ICT usage represent the socioeconomic factors, government stability represents the political factor, and law and order is the institutional factor. Our objective is to investigate the relationships between each of the dependent variables and the four covariates.

1. Summary Statistics

Table 9: Summary statistics of the dependent and independent variables for the three countries. (N= sample size. SD= Standard deviation)

Variable	N	Mean	SD	Minimum	Maximum
FDI	45	2.0107	1.7596	0.0067	9.5129
HT export	45	4.5434	3.7110	0.3599	12.3308
Patent	45	468.4667	263.8044	103.0000	1034.0000
Tertiary	38	1980.4000	861.9732	932.4338	3537.7100
Gov stability	45	10.0380	0.9689	8.0800	11.0000
Law and order	45	4.3478	1.3494	2	6
GDP growth	45	4.3467	2.3692	-2.2277	12.2169
ICT	45	9.5921	12.4564	0.0017	49.0006

Table 10: Summary statistics of the dependent and independent variables, by country. (N= sample size. SD = Standard deviation)

Country	Variable	N	Mean	SD	Minimum	Maximum
Algeria	FDI	15	1.2047	0.5193	0.5112	2.0078
	HT export	15	1.4438	1.2643	0.3678	4.4424
	Patent	15	452.8667	255.9698	145.0000	849.0000
	Tertiary	11	2307.8800	662.1361	1236.0200	3357.9700
	Gov stability	15	9.3613	0.7800	8.0800	10.5000
	Law and order	15	2.5660	0.4906	2.0000	3.0000
	GDP growth	15	3.5533	1.5729	1.1000	6.9000
	ICT	15	4.4248	4.6270	0.0017	12.5001
Morocco	FDI	15	1.5879	1.5767	0.0067	4.6418
	HT export	15	8.3548	3.6383	0.3599	12.3308
	Patent	15	628.7333	273.9420	245.0000	1034.0000
	Tertiary	13	1147.9200	130.3112	932.4338	1350.7700
	Gov stability	15	9.9147	0.9397	8.1600	11.0000
	Law and order	15	5.4773	0.5076	5.0000	6.0000
	GDP growth	15	4.6148	3.4948	-2.2277	12.2169
	ICT	15	13.3001	16.4397	0.0057	49.0006
Tunisia	FDI	15	3.2396	2.1143	1.2168	9.5129
	HT export	15	3.8316	1.4303	1.6394	6.6808
	Patent	15	323.8000	167.1860	103.0000	621.0000
	Tertiary	14	2496.1200	831.6007	1267.8700	3537.7100
	Gov stability	15	10.8380	0.5162	9.0000	11.0000
	Law and order	15	5.0000	0.0000	5.0000	5.0000
	GDP growth	15	4.8721	1.3807	1.7004	7.1461
	ICT	15	11.0514	12.2619	0.0275	36.5626

Table 11: Pearson's correlation coefficients between the dependent variables and the independent variables, overall and by country. (Numbers in parentheses are the p-values. NA = not available.)

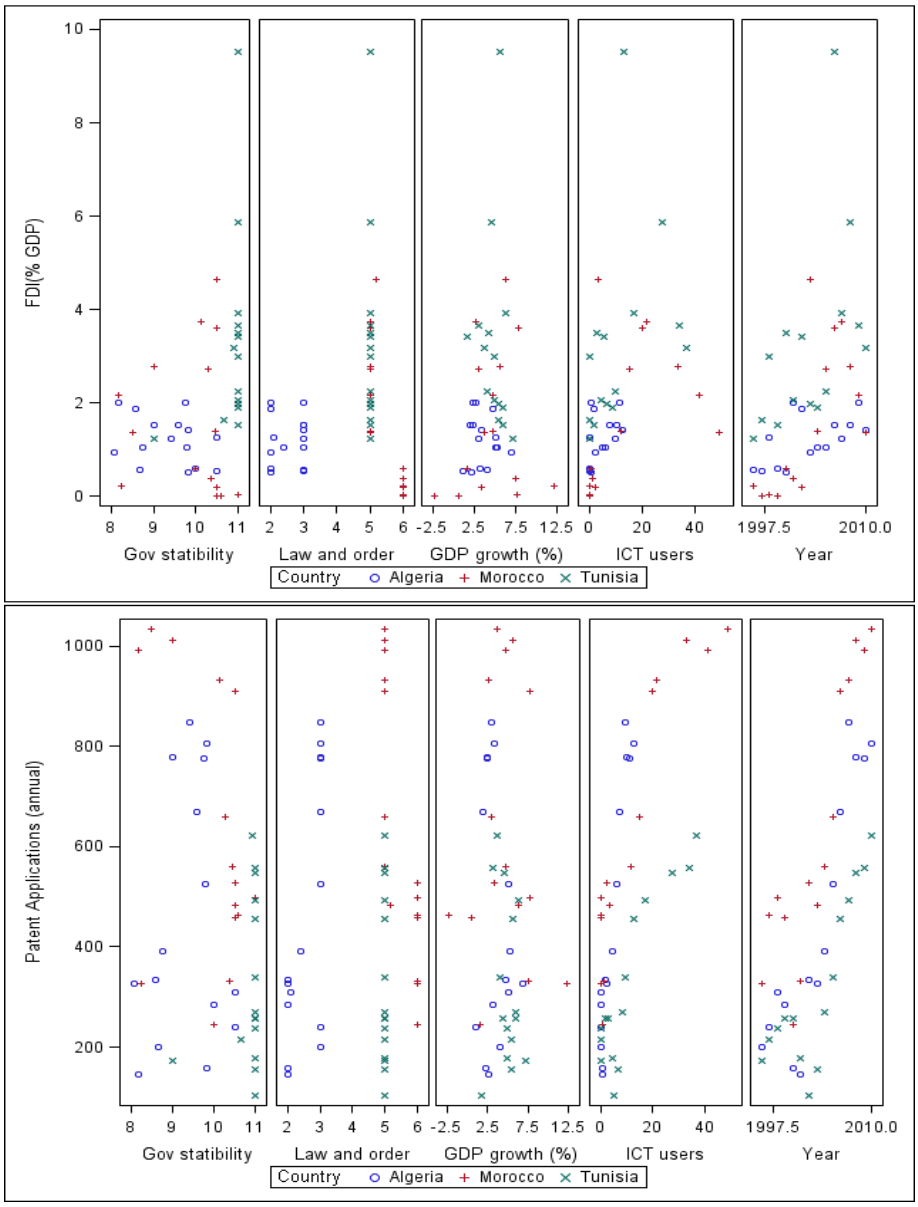
		FDI	HT export	Patent	Tertiary
Overall	Gov stability	0.34299(0.0211)	0.29745(0.0472)	-0.23315(0.1232)	0.18668(0.2618)
	Law and order	0.16614(0.2754)	0.60099(<0.0001)	0.08467(0.5803)	-0.31051(0.0578)
	GDP growth	*0.11919(0.4355)*	*0.04920(0.7483)*	*-0.07885(0.6067)*	*-0.00728(0.9654)*
	ICT	0.39395(0.0074)	0.24063(0.1113)	0.73780(<0.0001)	0.29871(0.0685)
Algeria	Gov stability	-0.29848(0.2799)	0.21827(0.4345)	0.16439(0.5582)	0.48376(0.1316)
	Law and order	0.04371(0.8771)	-0.53081(0.0418)	0.67384(0.0059)	0.52158(0.0999)
	GDP growth	-0.06571(0.8160)	-0.02599(0.9267)	-0.18351(0.5127)	-0.24541(0.4670)
	ICT	0.48093(0.0696)	-0.40884(0.1303)	0.96401(<0.0001)	0.95721(0.0001)
Morocco	Gov stability	-0.04264(0.8801)	0.48358(0.0678)	-0.42155(0.1176)	-0.65291(0.0155)
	Law and order	-0.82080(0.0002)	-0.13254(0.6377)	-0.80920(0.0003)	-0.83071(0.0004)
	GDP growth	0.13339(0.6356)	-0.12888(0.6471)	-0.02978(0.9161)	0.15612(0.6105)
	ICT	0.43285(0.1071)	-0.06543(0.8168)	0.91648(<0.0001)	0.86513(0.0001)
Tunisia	Gov stability	0.30095(0.2757)	0.48659(0.0659)	0.25812(0.3530)	0.49167(0.0742)
	Law and order	NA	NA	NA	NA
	GDP growth	-0.12850(0.6481)	-0.14124(0.6156)	-0.13144(0.6405)	-0.27366(0.3438)
	ICT	0.38802(0.1530)	0.57445(0.0251)	0.90420(<0.0001)	0.93483(0.0002)

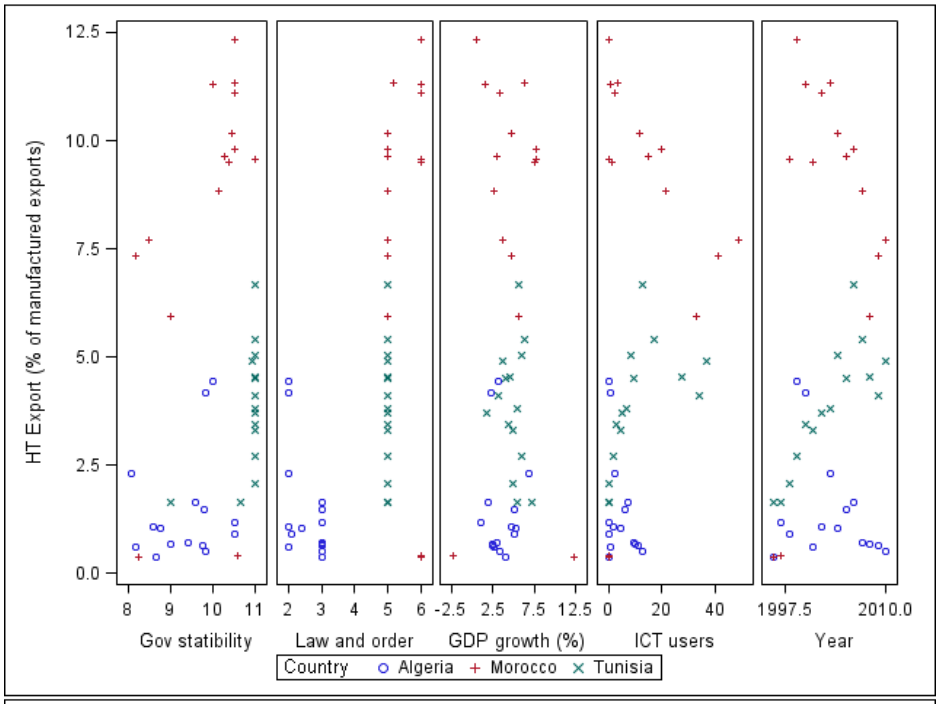
The table above displays the Pearson's correlation coefficients (overall and by country) and the p-value under the null hypothesis of zero correlation for each pair of dependent and independent variables.

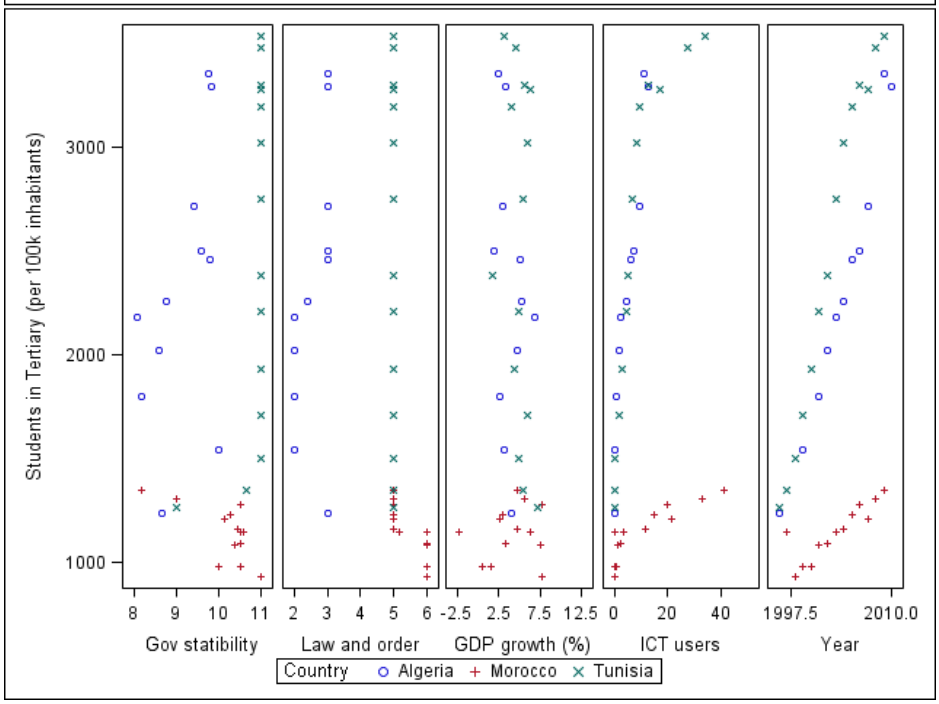
Table 12: Pearson's correlation coefficients between the independent variables. Numbers in parentheses are the p-values.

	Gov stability	Law and order	GDP growth	ICT
Gov stability	1	0.47252(0.0010)	-0.11696(0.4442)	-0.09314(0.5428)
Law and order		1	0.17959(0.2378)	0.19772(0.1929)
GDP growth			1	-0.02121(0.8900)
ICT				1

Figure 3: Scatter plots of each of the dependent variables against independent variables and year.




HT Export (% of manufactured exports)
12.5
10.0
7.5
5.0
2.5
0.0
8 9 10 11
2 3 4 5 6
-2.5 2.5 7.5 12.5
0 20 40
1997.5 2010.0
Gov stability
Law and order
GDP growth (%)
ICT users
Year
Country Algeria Morocco Tunisia


Students in Tertiary (per 100k inhabitants)
3000
2000
1000
8 9 10 11
2 3 4 5 6
-2.5 2.5 7.5 12.5
0 20 40
1997.5 2010.0
Gov stability
Law and order
GDP growth (%)
ICT users
Year
Country Algeria Morocco Tunisia

2. Data Analysis

a. Foreign Direct Investment (FDI) Variable

- **Analysis Based on Model (1)**

The table below shows the results of the F tests for each effect based on the data model (1). It tests the effect of the independent variables in addition to the country and year on FDI.

Table 13: F test results for FDI based on the Model (1). DF1 = the numerator degrees of freedom of the F test. DF2 = the denominator degrees of freedom of the F test. (Model (1) and dependent variable FDI)

Effect	DF1	DF2	F statistic	p-value
Country	2	24	5.81	0.0088
Year	14	24	1.80	0.0996
Gov stability	1	24	1.16	0.2919
Law and order	1	24	6.22	0.0199
GDP growth	1	24	0.08	0.7806
ICT	1	24	0.77	0.3887

The reported R squared for this model is R2=0.7319. This indicates that the model explains 73% of the variation in FDI in the Maghreb countries. It also explains that the country effect and the law and order effect are statistically significant at the significance level of 0.05. They have a p-value of 0.0088 and 0.0199 respectively.

The skewness and kurtosis of the residuals are 1.0685 and 3.6159, respectively. The goodness of fit test does not reject the null hypothesis of normality (p-value > 0.1500). Figure (4) (Appendix) shows the QQ plot and residual plot resulted from model (1) in the case of the FDI as a response variable. It suggests that data might not be from a normal distribution. The

plot also suggests that the variances are constant as the points are randomly scattered about 0. Then, we suggest a log transformation for the dependent variable FDI using model (2).

- **Analysis Based on Model (2) with Log Transformation for FDI**

The table below shows the results of the F tests for each effect on the dependent variable (Log)FDI based on data model (2).

Table 14: F test results for (log)FDI based on the Model (2). DF1 = the numerator degrees of freedom of the F test. DF2 = the denominator degrees of freedom of the F test.

Effect	DF1	DF2	F statistic	p-value
Country	2	38	7.06	0.0025
Gov stability	1	38	0.77	0.3868
Law and order	1	38	9.57	0.0037
GDP growth	1	38	4.09	0.0501
ICT	1	38	11.93	0.0014

The R square for this model is R^2= 0.6032. It indicates that the model explains 60% of the variation in Foreign Direct Investment in the three countries. The F test results above indicate that the country effect, the law and order effect, and the ICT effect are statistically significant at the significance level of 0.05.

The skewness and kurtosis measures of normality of the residuals are -0.4997 and 0.8305, respectively. QQ plot for the dependent variable (log)FDI in Figure (5) (Appendix) indicates that the residuals are from a normal

distribution. Residual plot suggests that the variances are constant as the points are randomly scattered about 0.

We assume that this model should be used to investigate the relationship between the dependent variable (FDI) and the independent variables: Government stability, Law and order, GDP growth, and ICT. The estimated equation is:

(Log)FDI= 3.9411 − 3.2115 country1 − 0.9861 country2 + 0.2006 Gov stability− 1.2681 Law and order + 0.1452 GDP growth + 0.0491 ICT.

- **Conclusion**

From both the table and the estimated equation above we can conclude that government stability effect is not statistically significant on (log)FDI (F=0.77, p-value=0.3868). Likewise, the GDP growth effect is not statistically significant on (log)FDI (F=4.09, p-value =0.0501). However, Law and order effect (F=9.57, p-value=0.0037), ICT effect (F = 11.93, p-value = 0.0014) and country effect (F=4.09, p-value=0.0501) are statistically significant on our response variable in Maghreb countries.

Holding other variables constant, for every one unit increase in Law and order, FDI decreases by 1.2681 (negative relationship). Holding other variables constant, for every one unit increase in ICT usage, FDI increases by 0.0491 (positive relationship).

The least squares means for each level of the country effect are: -1.6679 (Algeria), 0.5575 (Morocco) and 1.5436 (Tunisia). Least squares means are predicted population margins that estimate the marginal means over a

balanced population. For example, in the case of Algeria, we can compute the least squares mean of the country effect as:

$3.9411 - 3.2115 + 0.2006 \times 10.0380 - 1.2681 \times 4.3478 + 0.1452 \times 4.3467$

$+0.0491 \times 9.5921 = -1.6679$

The results of pairwise comparisons after adjustment for the p-values using Tukey's method indicate that there is no statistically significant difference between the least squares means of Algeria and Morocco (p-value = 0.2145) and Tunisia and Morocco (p-value = 0.1111). For the least squares means of Algeria and Tunisia, there is a statistically significant difference between the two (p-value = 0.0208).

From the four independent variables, the institutional variable, law and order, and the socioeconomic variable, ICT usage, seem to have significant effect on FDI. Besides, at least two countries least squares means are significantly different. This is the case of Tunisia and Algeria. Both Morocco and Algeria and Morocco and Tunisia don't have practical significant differences of their least squares means for the FDI outcome.

Therefore, our alternative hypothesis that holds true states that "ICT usage has a positive impact on FDI inflows in the Maghreb". For law and order effect on FDI, it's significant but suggests a negative relationship based on our data model (2).

b. High Technology Export Variable

- **Analysis Based on Model (1)**

The table below shows the results of the F tests for each effect using Model (1) for the dependent variable High Technology Export.

Table 15: Analysis results of F tests for each effect on HT export. DF1 = the numerator degrees of freedom of the F test. DF2 = the denominator degrees of freedom of the F test. (Model (1) and dependent variable HT export)

Effect	DF1	DF2	F statistic	p-value
Country	2	24	13.58	0.0001
Year	14	24	1.44	0.2098
Gov stability	1	24	5.32	0.0300
Law and order	1	24	0.01	0.9344
GDP growth	1	24	0.02	0.8862
ICT	1	24	1.01	0.3259

The R squared for this model is R2=0.8459 indicating that the model (1) explains 85% of the variation in High Technology export outcome. The country effect and the Government stability effect are statistically significant at the significance level of 0.05. As far as normality assumptions are concerned, the skewness and kurtosis measures of the residuals are -0.7499 and 1.0713, respectively. The goodness of fit test does not reject the null hypothesis of normality (p-value > 0.1500). Figure 6 (Appendix) shows the QQ plot and residual plot for residuals resulted from the model (1) for the dependent variable High Technology export. The plot indicates that the residuals are from a normal distribution and the variances are constant as the points are randomly scattered about 0. Our findings satisfy the assumptions of normality.

Since year effect is not statistically significant, we proceed to take it out from the model. Therefore, Equation (2) is used to model the relationship between High Technology export as a response variable and the explanatory variables.

- **Analysis Based on Model (2)**

The table below indicates the results of the F tests for each effect, using model (2) with dependent variable High Technology export.

Table 16: Analysis results of F tests for each effect on HT export. DF1=the numerator degrees of freedom of the F test. DF2=the denominator degrees of freedom of the F test. (Model (2) and dependent variable HT export)

Effect	DF1	DF2	F statistic	p-value
Country	2	38	22.54	< 0.0001
Gov stability	1	38	11.00	0.0020
Law and order	1	38	3.86	0.0567
GDP growth	1	38	0.03	0.8536
ICT	1	38	0.41	0.5261

The R square for this model is R2 = 0.7165. It indicates that the model explains 72% of the variation in HT export. The country effect and the Government stability effect are statistically significant at the significance level of 0.05. The skewness and kurtosis of the residuals are -1.1912 and 4.8651, respectively. The Kolmogorov-Smirnov test of goodness of fit rejects the null hypothesis of normality (p-value = 0.0217). Figure 7 (Appendix) shows the QQ plot and residual plot for residuals resulted from Model (2) when dependent variable is HT export. The QQ plot suggests that the residuals might not be from a normal distribution. The residual plot suggests

that the variances are constant as the points are randomly scattered about 0. Thus, we suggest a log transformation for the HT export outcome.

- **Analysis Based on Model (2) with Log Transformation for HT Export**

The table below shows the results of the F tests for each effect on the dependent variable Log(HT export) using model (2).

Table 17: Analysis results of F tests for each effect on Log(HT Export). DF1 = the numerator degrees of freedom of the F test. DF2 = the denominator degrees of freedom of the F test. (Model 2 used with dependent variable Log(HT export)).

Effect	DF1	DF2	F statistic	p-value
Country	2	38	12.56	< 0.0001
Gov stability	1	38	11.73	0.0015
Law and order	1	38	9.66	0.0036
GDP growth	1	38	0.15	0.7013
ICT	1	38	1.68	0.2027

The R squared for this model is R2=0.6490. It indicates that the model explains 65% of the variation in Log(HT export). The country effect, the law and order effect and the government stability effect are statistically significant at the significance level of 0.05. The skewness and kurtosis measures of the residuals are -1.0744 and 3.1902, respectively. The goodness of fit test (Kolmogorov-Smirnov) does not rejects the null hypothesis of normality (p-value = 0.0590). Figure 8 (Appendix) shows the QQ plot and residual plot for residuals resulted from the equation of model (2) when the response variable is (log)HT export. The QQ plot suggests that the residuals

may be from a normal distribution. The residual plot suggests that the variances are constant as the points are randomly scattered about 0.

Hence, this model equation can be used to investigate the relationship between High Technology export and the independent variables: Government stability, Law and order, GDP growth, and ICT. The estimated model is:

$$(Log)HT\ export = -0.4441 - 2.4082\ country1 + 1.4458\ country2 + 0.5426\ Gov\ stability - 0.8807\ Law\ and\ order + 0.0192\ GDP\ growth + 0.0127\ ICT$$

- **Conclusion**

From the table and the estimated model above, we conclude that both GDP growth effect (F=0.15, p-value=0.7013) and ICT usage effect (F=1.68, p-value=0.2027) are not statistically significant on Log(HT export). However, Government stability effect (F=11.73, p-value= 0.0015) Law and order effect (F=9.66, p-value=0.0036) and country effect (F=12.56, p-value =< 0.0001) are statistically significant on Log(HT export). Holding other variables constant, for every one unit increase in Government stability, HT export increases by 0.5426 (positive relationship). Holding other variables constant, for every one unit increase in Law and order, HT export decreases by 0.8807 (negative relationship).

The least squares means for each level of the country effect are: -1.0291 (Algeria), 2.8249 (Morocco), and 1.3791 (Tunisia). The results of pairwise comparisons after adjustment for the p-values using Tukey's method suggests that there is a statistically significant difference between the least squares

means of Algeria and Morocco (p-value = 0.0003), Algeria and Tunisia (p-value = 0.0114) and Tunisia and Morocco (p-value = 0.0003).

Both political variable (government stability) and institutional variable (law and order) have significant effects on HT export. However, data analysis doesn't suggest a significant impact of the socioeconomic set of variables (GDP growth and ICT usage) on this innovation output. Moreover, all three countries least squares means are significantly different in the case of HT export outcome. The least square means of Morocco, Algeria and Tunisia are different from other country's least square mean. The alternative hypothesis that holds true regards political effect on HT export outcome. It states that "High technology exports mostly enhance in countries with stable governments". Law and order effect is significant but suggests a negative relationship with HT export.

c. Patent Applications Response Variable

- **Analysis Based on Model (1)**

The table below shows the results of the F tests for each effect, using model (1) with the dependent variable patent applications.

Table 18: Analysis results of F tests for each effect on patent application. DF1=the numerator degrees of freedom of the F test. DF2=the denominator degrees of freedom of the F test. (Model (1) and dependent variable patent applications)

Effect	DF1	DF2	F statistic	p-value
Country	2	24	21.81	< 0.0001
Year	14	24	5.06	0.0003
Gov stability	1	24	1.11	0.3033
Law and order	1	24	0.10	0.7503
GDP growth	1	24	0.29	0.5942
ICT	1	24	0.15	0.6999

The R squared for this model is R2=0.9486, which indicates that the model explains 95% of the variation in patent applications outcome. The country effect and the year effect are statistically significant at the significance level of 0.05. The skewness and kurtosis measures of the residuals are 0.2732 and 1.1713, respectively and the goodness of fit test does not reject the null hypothesis of normality (p-value > 0.1500).

Figure 9 (Appendix) shows the QQ plot and residual plot for residuals resulted from model (1) regarding patent applications variable. The QQ plot suggests that the residuals are from a normal distribution and the residual plot indicates that the variances are constant as the points are randomly scattered about 0.

Model (1) shows that even though year effect is statistically significant, year and ICT seem to have the same relationship with patent applications. So, we will take the year effect out of the equation to determine the effect of ICT on patent and model the relationship with other explanatory variables.

- **Analysis Based on Model (2)**

The results of the F tests for each effect are shown in the table below, using the model (2) with dependent variable patent applications.

Table 19: Analysis results of F tests for each effect. DF1=the numerator degrees of freedom of the F test. DF2=the denominator degrees of freedom of the F test. (Model 2 with dependent variable patent applications)

Effect	DF1	DF2	F statistic	p-value
Country	2	38	20.20	< 0.0001
Gov stability	1	38	2.67	0.1092
Law and order	1	38	4.37	0.0434
GDP growth	1	38	0.98	0.3280
ICT	1	38	101.79	< 0.0001

The R squared for this model is R2=0.7970. It indicates that the model explains around 80% of the variation in patent applications. The country effect, the law and order effect, and the ICT effect are statistically significant at the significance level of 0.05. The skewness and kurtosis measures of the residuals are 0.0310 and -0.6896, respectively. Besides, the QQ plot, in figure 10 (Appendix), suggests that the residuals are from a normal distribution. The residual plot suggests that the variances are constant as the points are randomly scattered about 0.

Consequently, the relationship between patent applications and the independent variables should be investigated via the following equation:

$$Patent = -995.8327 + 601.6030\ country1 + 258.0010\ country2 + 48.2130\ Gov\ Stability + 109.8892\ Law\ and\ order + 9.1261\ GDP\ growth + 18.3859\ ICT.$$

- **Conclusion**

We conclude from both the F tests table and the equation above that the Government stability effect is not statistically significant on patent applications in Maghreb countries (F=2.67, p-value =0.1092). Also, the GDP growth effect is not statistically significant on patent applications (F=0.98, p-value =0.3280). However, the Law and order effect is statistically significant on patent (F = 4.37, p-value = 0.0434). Holding other variables constant, for every one unit increase in Law and order, patent increases by 109.8895 (positive relationship). Besides, the ICT effect is statistically significant on patent applications (F=101.79, p-value=<0.0001). Holding other variables constant, for every one unit increase in ICT, patent increases by 18.3859 (positive relationship). The country effect is statistically significant on patent applications (F=20.20, p-value=<0.0001).

The least squares means for each level of the country effect are: 783.5350 (Algeria), 439.9330 (Morocco), and 181.9320 (Tunisia). Pairwise comparisons after adjustment for the p-values using Tukey's method indicate that there is no statistically significant difference between the least squares means of Algeria and Morocco (p-value = 0.1122). Conversely, there is a statistically significant difference between the least squares means of Algeria and Tunisia (p-value = 0.0006) and Tunisia and Morocco (p-value = 0.0004).

Accordingly, two key determinants have significant effects on patent applications in the Maghreb states: the institutional covariate law and order and the socioeconomic variable ICT usage. They positively impact this innovation outcome. The difference of least square means is significant in the case of Tunisia

and Algeria and Tunisia and Morocco. Then, the alternative hypothesis that holds true regards law and order variable and states that "patent applications are positively related to a strong law and order system". The other one regards ICT usage and suggests that "ICT dissemination encourages patent applications outputs by innovators in the Maghreb".

d. Tertiary Education response variable

- **Analysis Based on Model (1)**

The table below shows the results of the F tests for each effect on the dependent variable Tertiary education using Model (1)

Table 20: Analysis results of F tests for each effect on tertiary education. DF1=the numerator degrees of freedom of the F test. DF2=the denominator degrees of freedom of the F test. (Model 1 with the dependent variable tertiary education)

Effect	DF1	DF2	F statistic	p-value
Country	2	24	29.86	< 0.0001
Year	14	24	2.84	0.0219
Gov stability	1	24	1.10	0.3088
Law and order	1	24	2.68	0.1199
GDP growth	1	24	1.31	0.2677
ICT	1	24	0.36	0.5575

The R squared for this model is R2=0.9465, indicating that the model explains 95% of the variation in tertiary. Both the country effect and the year effect are statistically significant at the significance level of 0.05. The skewness and kurtosis of the residuals are 0.1938 and -0.7055, respectively. The Kolmogorov-Smirnov test does not reject the null hypothesis of normality (p-value > 0.1500).

Figure 11 (Appendix) shows the QQ plot and residual plot for residuals resulted from Model 1 in case of Tertiary education as response variable. The plot suggests that the residuals are from a normal distribution and the variances are constant as the points are randomly scattered about 0.

Though year effect is statistically significant, but year and ICT seem to have the same relationship with tertiary. Hence, we proceed to take year out from the model to see what would be the effect of ICT and other explanatory variables.

- **Analysis Based on Model (2)**

The results of the F tests for each effect on the dependent variable Tertiary education using Model (2) are shown in the table below:

Table 21: Analysis results of F tests for each effect on tertiary education. DF1=the numerator degrees of freedom of the F test. DF2=the denominator degrees of freedom of the F test (Equation 2 with dependent variable tertiary education)

Effect	DF1	DF2	F statistic	p-value
Country	2	38	21.42	< 0.0001
Gov stability	1	38	11.61	0.0018
Law and order	1	38	2.56	0.1200
GDP growth	1	38	0.01	0.9201
ICT	1	38	46.66	< 0.0001

Based on model (2), R squared is R2=0.8213. It indicates that the model explains 82% of the variation in tertiary. For this model, the country effect, the Government stability, and the ICT effect are statistically significant at the significance level of 0.05. The skewness and kurtosis measures of the residuals are -0.2904 and -0.4345, respectively. The Kolmogorov-Smirnov test does not

reject the null hypothesis of normality (p-value > 0.1500). Figure 12 (Appendix) shows the QQ plot and residual plot for residuals resulted from model (2) when dependent variable is Tertiary education. The plots also suggest that the residuals are from a normal distribution and the variances are constant as the points are randomly scattered about 0. Therefore, our assumptions hold true. The following estimated model should be used to investigate the relationship between tertiary education and the explanatory variables, Government stability, Law and order, GDP growth, and ICT.

$$Tertiary = -3722.0913 + 1432.7854\ country1 - 1348.7926\ country2 + 387.6938\ Gov\ stability + 320.6167\ Law\ and\ order - 3.3969\ GDP\ growth + 48.8222\ ICT.$$

- **Conclusion**

From test results shown in table and equation above we conclude that Law and order effect is not statistically significant on tertiary education (F=2.56, p-value =0.1200). Also, GDP growth effect is not statistically significant on tertiary education (F=0.01, p-value =0.9201). However, Government stability effect is statistically significant on tertiary (F = 11.61, p-value = 0.0018). Holding other variables constant, for every one unit increase in government stability, tertiary education enrolment increases by 387.6938 (positive relationship). Likewise, The ICT effect is statistically significant on tertiary (F = 46.66, p-value = < 0.0001). Holding other variables constant, for every one unit increase in ICT, tertiary education increases by 46.8222 (positive relationship).

Besides, the country effect is statistically significant on tertiary (F = 21.42, p-value = < 0.0001).

The least squares means for each level of the country effect are: 3459.8638 (Algeria), 678.2858 (Morocco), and 2027.0784 (Tunisia).

The results of pairwise comparisons after adjustment for the p-values using Tukey's method indicate that there is a statistically significant difference between the least squares means of Algeria and Morocco (p-value = 0.0001), Algeria and Tunisia (p-value = 0.0210) and Tunisia and Morocco (p-value < 0.0001).

Both the political variable, law and order, and socioeconomic variable, ICT usage, seem to have a significant effect on tertiary education in the three Maghreb countries. The least square means of Morocco, Algeria and Tunisia are all different from other country's least squares mean. The alternative hypotheses that hold true regard one socioeconomic variable and political effect on tertiary education outcome. It states that "tertiary education is more likely to increase in a policy and politically stable Maghreb country". The other hypothesis claims that "the enhancement of tertiary education in the region is positively related to an increase of ICT usage".

Chapter 5

Conclusions

Based on a general linear model, two equations were designed to test the effects of political, institutional and socioeconomic determinants on four technological innovation outcomes in the major Maghreb countries. The results of our sets of modeling confirm that political, institutional and socioeconomic factors matter for technological development in the Maghreb. Even though not all of these factors are consistent with the reviewed theory, the findings and conclusions are supportive of our assumption that government stability, quality of the legal system and law and ICT dissemination are incentives to innovation in the Maghreb.

Theoretical assumptions suggest that the legal environment is critical to investment in the case of MENA region. Our empirical findings are consistent with those of Veganzones and Aysan (2008) who found that factors such as law and order influence important private investment decisions. Besides, an institutional indicator as law and order is vital for patent application and high technology export. This agrees with Faria and Barbosa (2011), Bhattacharyya and Dowrick (2009), Harvey, Bekaert et al., (2011), Rachdi and Saidi, (2011). Faria and Barbosa argue that the rule of law which is a "proxy for the quality of the judicial system and protection of property rights, has a positive effect on innovation". The significance of law and order makes it not only a determinant of technological innovation but it would also be a fundamental element for the

enhancement of trade in the Maghreb and a "determinant of long-run economic development" (Bhattacharyya & Dowrick, 2009).

These findings imply that the legal environment and law is of crucial significance for foreign investors, innovators and trade stakeholders in the Maghreb. Legal frameworks present a great deal of risk when flexible legal procedures are not implemented and where corruption and favoritism still prevail and constitute a threat to business activities. This should be one of the main technological development enterprises for politicians and decisions makers in the region.

The research suggests that political stability effect is significant on both high technology export and human capital outcomes. In fact, even though the three countries are regarded as autocracies, it seems that the stability of their political systems is vital for a thriving trade and human capital development. These two innovation elements are crucial to maintain economic growth and therefore the stability of the established political regimes. Thus, based on the recent social and political developments and from a policy perspective, more opportunities in access to tertiary education by youth in the Maghreb region would become a critical factor to improve social and economic equality and thus avoid political turmoil.

Furthermore, it's essential to mention that GDP growth, as a socioeconomic factor, doesn't seem to have a significant effect on our four innovation outcomes. This agrees with the findings of Hassan (2003) who investigated the interactions between GDP growth and FDI in the MENA region. He essentially found no significant impact of GDP growth on FDI. Besides, his empirical analysis of the

ICT role supports our assumptions and findings since our empirical results suggest a significant effect of ICT usage on most of our dependent variables. This indicates the fundamental role of ICT in technological development of the region especially in some emerging MENA countries such as Qatar (Darrat & Al-Sowaidi, 2010). In fact, a focus on this sector by building sound ICT policies should increase the Maghreb innovation potential and improve productivity and GDP per capita.

From comparisons between the three Maghreb countries, we cannot assume an evidence of significant dissimilarities in terms of technological innovation inputs and outputs. Findings concerning Algeria (an oil based economy) don't seem to be practically different from that of Morocco and Tunisia (two non-oil economies). No significant difference between the three countries implies that the policies implemented by these governments since mid 90s are not considerably distinct or efficient. It also suggests that other factors may explain the differences. Indeed, non-oil economies like Morocco and Tunisia are more advantageous in developing strong institutions and innovative policies. For instance, these countries are some of the continent's few advanced and diversified African economies (McKinsey, 2009) and dynamic adopters of information technology. Focusing on integrated policies that emphasize ICT, human capital and legal procedures should boost their innovation outcomes. Besides, in their sensitive political and institutional environment, development of a national and long run vision for innovation should reshape a framework for collaboration and performance.

Accordingly, results suggests that further investigations deserve to be made by including additional variables and other oil and non-oil economies in the MENA region to verify such differences. Likewise, future empirical studies could incorporate more countries in the region and study how major political disturbances as the 'Arab Spring' would influence technological innovation inputs and outputs. It would also be worth investigating technological innovation opportunities in the Maghreb region and how these countries could catch up and build strong institutions aftermath the current political tumult.

Despite the significance of variables modeled in the current study, our results are more carefully interpreted as demonstrating the relevance of socioeconomic, political and institutional variables on technological innovation in the Maghreb. We are indeed dealing with a complicated and evolving topic that implies dynamic interactions between various factors and attributes.

Furthermore, new social, technical and political developments seem to raise challenging issues for the Arab and Maghreb societies and their socioeconomic fabric. For instance, which social change do Maghreb societies aim amidst significant political developments and unprecedented global technological demands and economic challenges? And what would be the role of innovation endeavors within conservative social paradigms still controlled by a myriad of customs and bias concerning new technologies and products?

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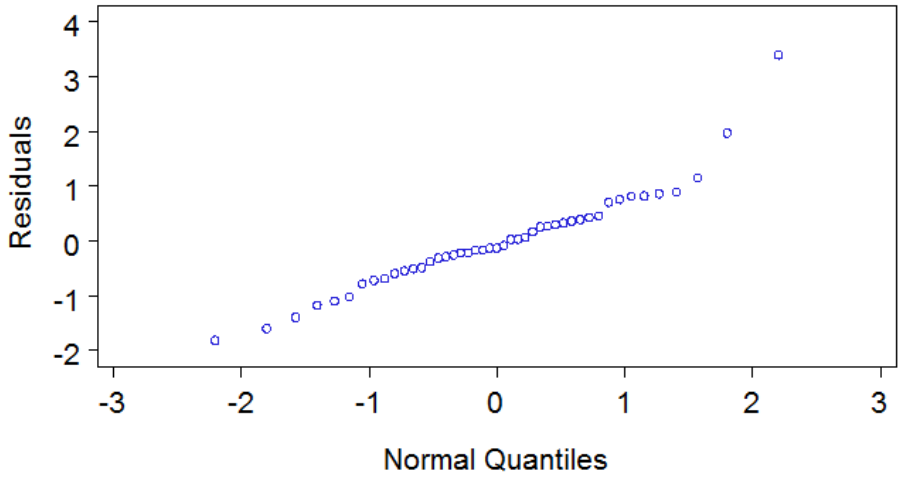
APPENDIX

Q-Q PLOTS AND RESIDUAL PLOTS FROM MODEL (1) AND (2)



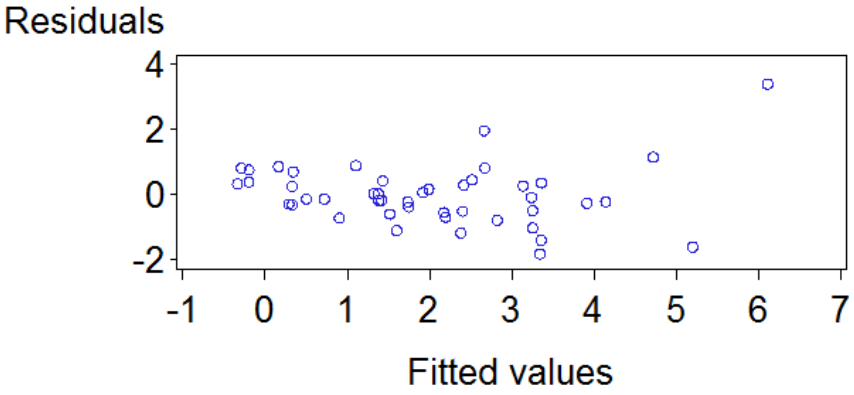


Figure 4: From top to bottom, QQ plot and residual plot for residuals resulted from Model (1) when dependent variable is FDI.

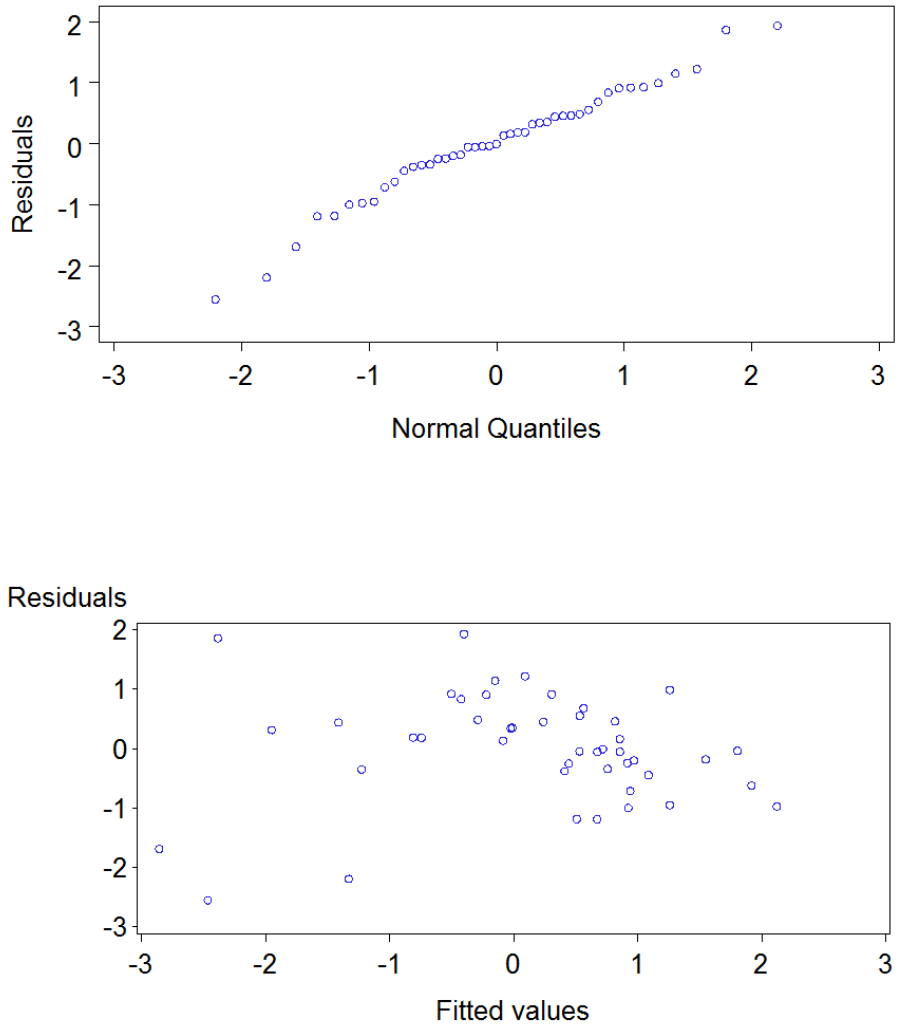


Figure 5: From top to bottom, QQ plot and residual plot for residuals resulted from Model (2) when dependent variable is (Log)FDI.

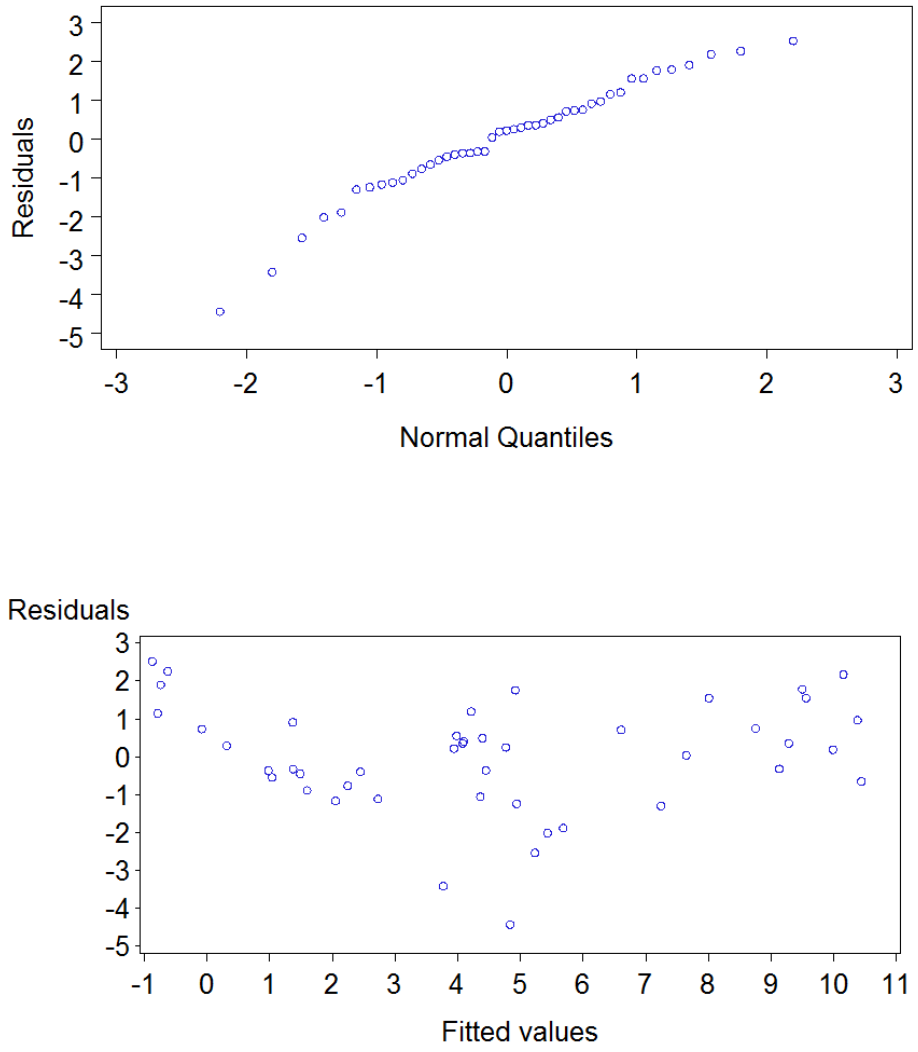


Figure 6: From top to bottom, QQ plot and residual plot for residuals resulted from Model (1) when dependent variable is HT export.

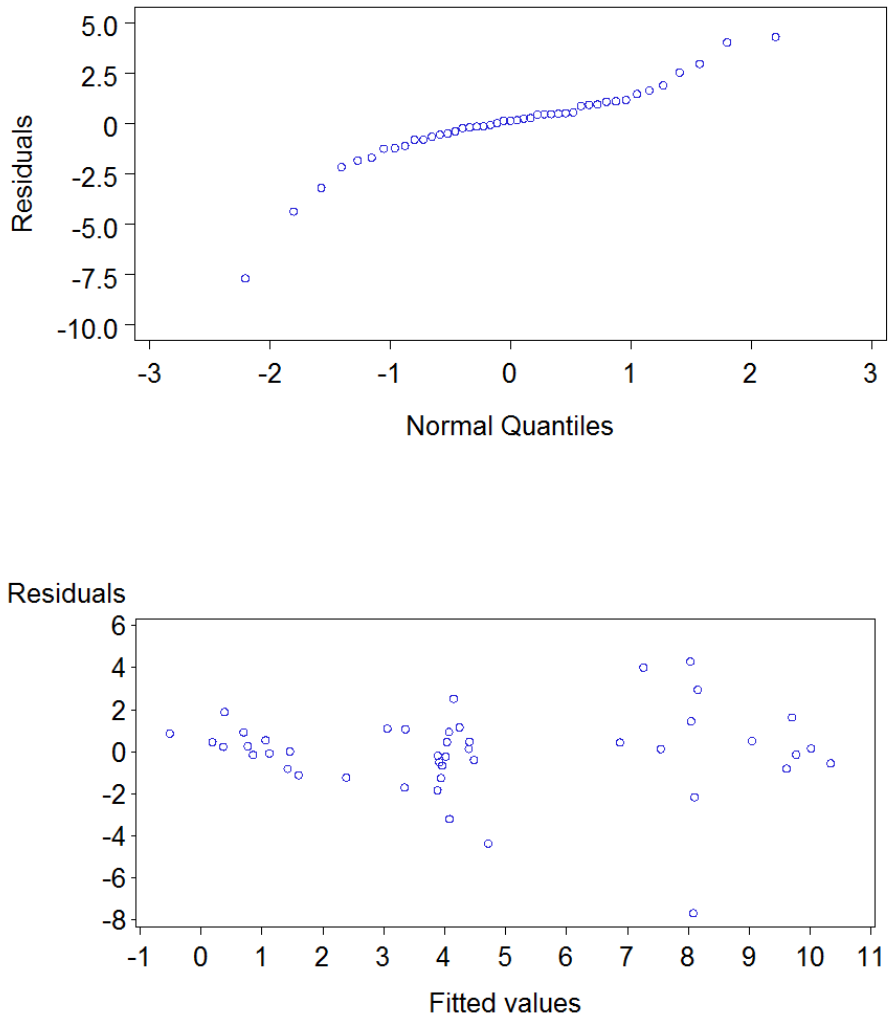


Figure 7: From top to bottom, QQ plot and residual plot for residuals resulted from Model (2) when dependent variable is HT export.

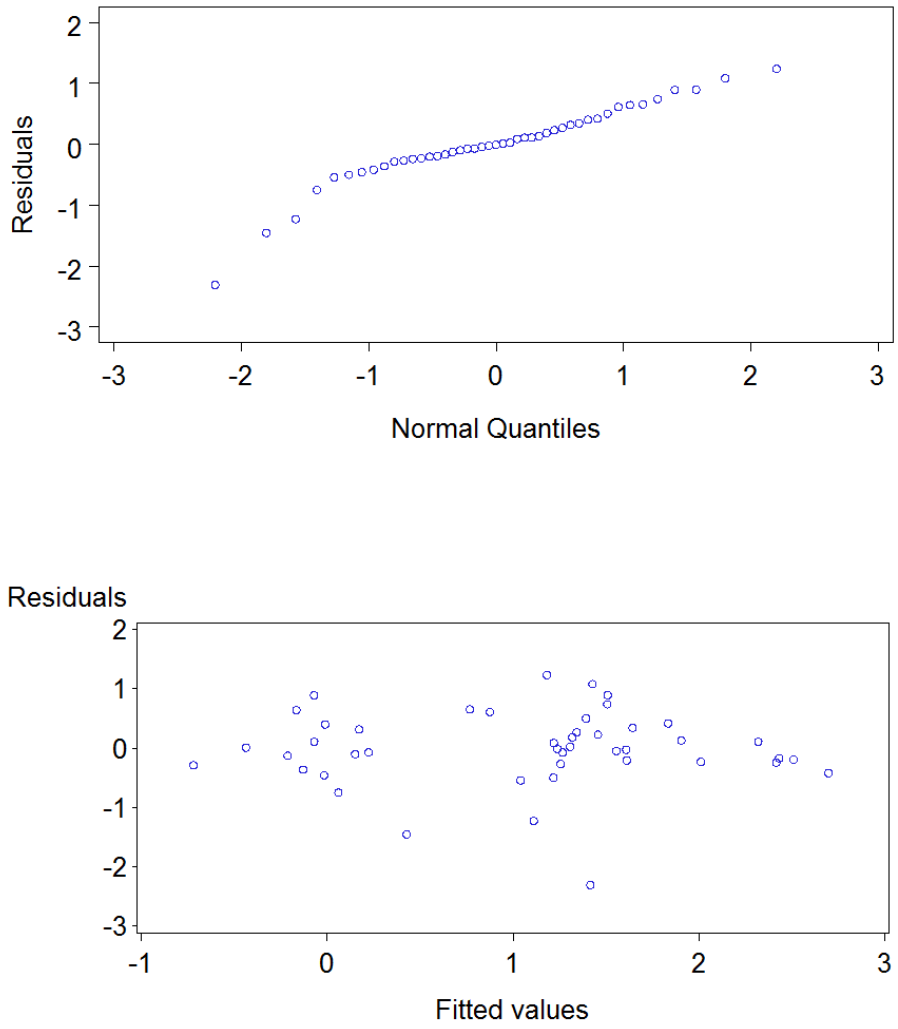


Figure 8: From top to bottom, QQ plot and residual plot for residuals resulted from Model (2) when dependent variable is (Log)HT export

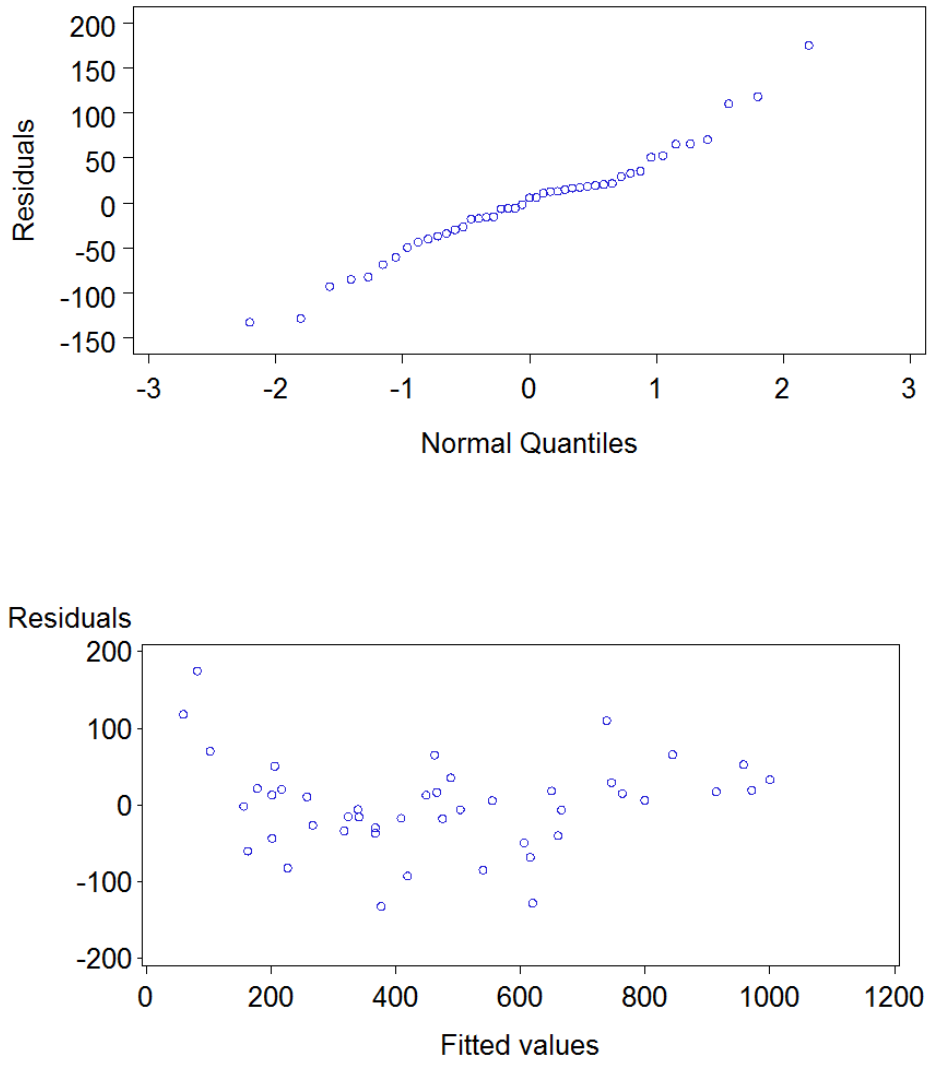


Figure 9: From top to bottom, QQ plot and residual plot for residuals resulted from Model (1) when dependent variable is Patent applications.

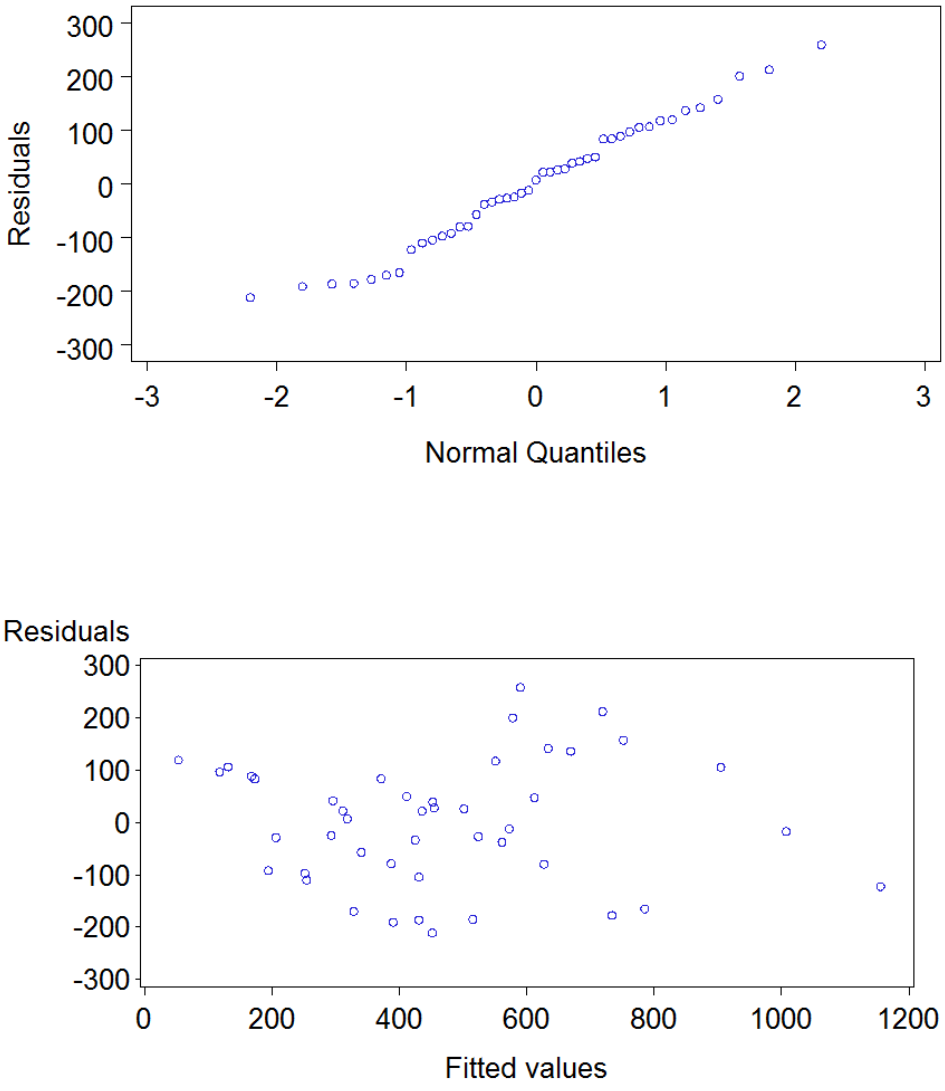
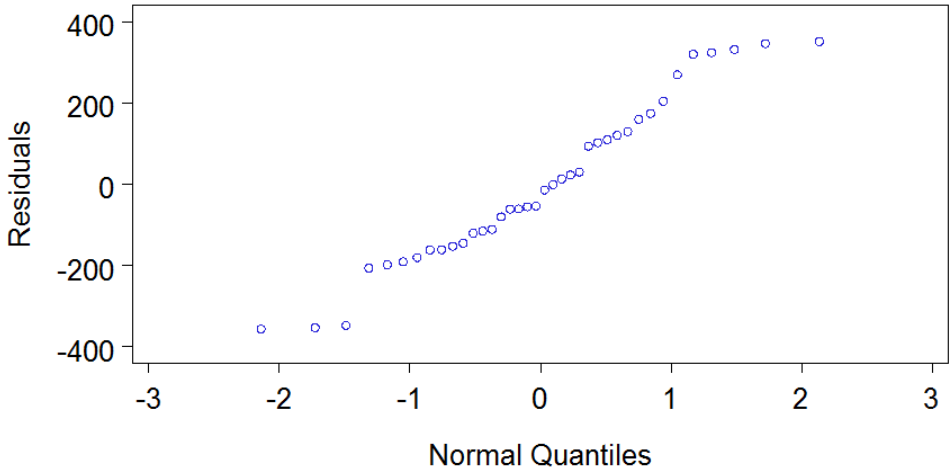


Figure 10: From top to bottom, QQ plot and residual plot for residuals resulted from Model (2) when dependent variable is Patent applications.



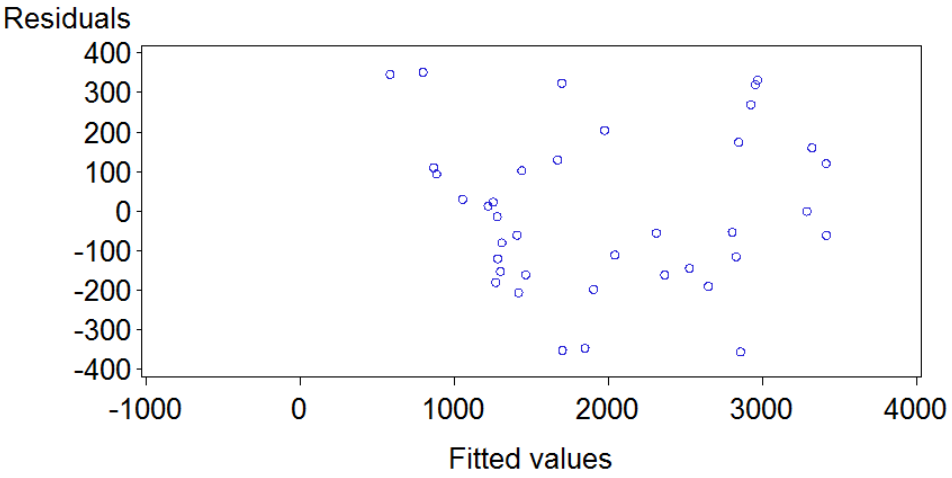
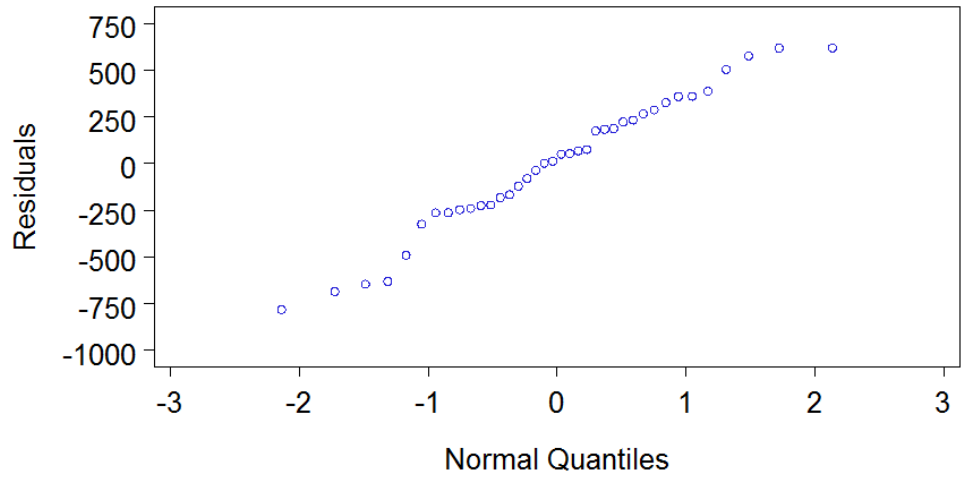


Figure 11: From top to bottom, QQ plot and residual plot for residuals resulted from Model (1) when dependent variable is Tertiary education.



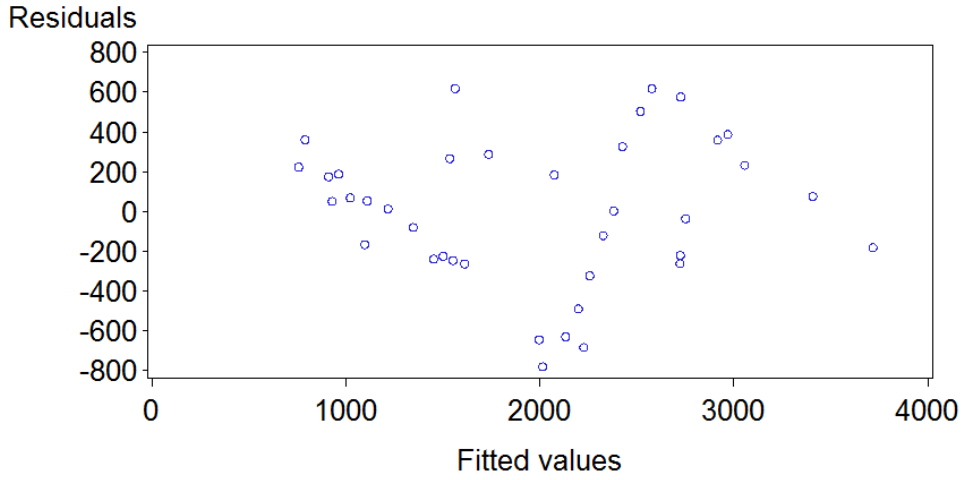


Figure 12: From top to bottom, QQ plot and residual plot for residuals resulted from Model (2) when dependent variable is Tertiary education.