# Innovation determinants and innovation as a determinant: evidence from developing countries

# Innovation Determinants and Innovation as a Determinant: Evidence from Developing Countries

Abdul Waheed

Production: Datawyse | Universitaire Pers Maastricht
ISBN xxxxxxxxxxxxxxx

# Innovation Determinants and Innovation as a Determinant: Evidence from Developing Countries

DISSERTATION

to obtain the degree of Doctor at Maastricht University,
on the authority of the Rector Magnificus, Prof. dr. L.L.G. Soete
in accordance with the decision of the Board of Deans,
to be defended in public
on Tuesday December 18th 2012 at 15: 45 hours

by

**Abdul Waheed**

Supervisor
Prof. Dr. Bart Verspagen

Assessment Committee
Prof. Dr. Pierre Mohnen (Chair)
Prof. Dr. Martin Carree
Dr. Gustavo Crespi (Inter-American Development Bank)

To my family

# Acknowledgements

The work on this dissertation was not possible without the help and support of many people, and I want to acknowledge and express thanks to all of them.

First of all, I am highly grateful to my supervisor Prof. Bart Verspagen for his guidance and valuable suggestions while I was working on this book. I am thankful to him for giving me the opportunity and guiding me to explore my area of interest with clarity and working on it with full flexibility. His comments and suggestions were always beneficial to shape my rudimentary ideas into a scientifically written manuscript. He guided me at each stage of my research, and I always found him ready while I need his help.

I am also very thankful to Prof. Pierre Mohnen, Prof. Martin Carree, and Dr. Gustavo Crespi for accepting my dissertation as the members of the dissertation committee and giving me suggestions. I benefitted a lot from these suggestions in order to improve my work.

I am deeply indebted to the Higher Education Commission of Pakistan for financial support and to the UNU-MERIT, the Netherlands, for providing me the work space and all other facilities needed for my research. I felt very convenient and comfortable working in the research-friendly environment of the UNU-MERIT. I am pleased to express my thanks to the colleagues and friends in the UNU-MERIT. I learned a lot from the discussion with them on various topics related to my research. The sweet memories of staying in the UNU-MERIT in particular and in Maastricht in general will always be with me throughout my life.

I am very thankful to my parents for their endless support at every moment of my life. This thesis so far is the final outcome of my academic career which was possible because of aspirations and then struggle of my parents. I still remember the days when I was in Tilburg University, the Netherlands for my MSc study, and how they took care of my wife and son in Pakistan, and provided me a relaxed mind to concentrate on my study.

Last but not least, I want to say thanks to my wife, Saghira, who was always with me during the long journey of writing this dissertation. Her emotional support was always a source of satisfaction and encouragement, with which I was always ready to work hard, even sometimes in very disappointing and dejected situations. She took care of our son (Talha) and daughter (Arma) and giving me full opportunity to focus on my research with mental ease and without emotional disturbance. I am also thankful to my kids (Talha and Arma) whose smiles always made me happy and relaxed. This happiness made me fresh and enthusiastic every morning to go further on the research trajectory.

# Table of Contents

# List of Tables

# List of Figure

# Chapter 1

## Introduction to the Thesis

The importance of technological innovation for economic growth (e.g. productivity increase) and for social welfare (e.g. employment generation) has long been a fascinating topic for economic historians and growth economists, especially since the advent of industrialization in the mid eighteenth century. The earlier accounts focused on societal changes as well as on human behaviors and attitudes towards technology in terms of mechanization. A further evolution led to the development of more sophisticated and narrower indicators of technology, i.e. innovation both in terms of input and of output.

As mentioned above, the initiation of the innovation-growth relationship is primarily linked to industrialization, and Arocena and Sutz (2005) argued that developing countries are those which lagged behind during the transition from agricultural to industrial societies. This might be one of the main reasons why innovation culture at the industrial level is not developed adequately in the developing world. Regarding innovation research in academia a significant dearth of analytical studies on smooth implementations of industrial innovation (and on operational problems) in developing countries can be constituted. Therefore, this thesis addresses this issue by investigating firm-level innovation phenomena in two developing regions: Latin America and South Asia.

Although the impact of innovation on economic development, especially after the pioneering work of Joseph Schumpeter, has been investigated by numerous researchers, extensive systematic econometric studies, even for developed countries, have only become feasible after the advent of innovation surveys. In the late 1950s, the first such survey was conducted by the Science and Industry Committee of the British Association for the Advancement of Science (Carter and Williams, 1958). The National Science Foundation (NSF) conducted innovation surveys for the USA in the 1960s. The survey conducted by Edwards and Gordon (1984) for the U.S. Small Business Administration was used to observe the innovation activities of U.S. companies in 1982. The Science and Policy Research Unit (SPRU) administered different waves of innovation surveys in the 1970s and in the early 1980s, in order to observe the successful commercialization of innovations in the UK between 1945 and 1983 (Robson and Townsend, 1984). Moreover, the Oslo Manual of 1992 (OECD 1992, updated in 1997) has laid the foundation of the harmonization of European countries in the form of the Community Innovation Surveys in the early 1990s.Nowadays many developing countries also conduct their own surveys, and the emergence of the World Bank's Investment Climate Survey (the source of data for the empirical analyses in chapters (3)-(5) of this thesis) also provides a framework for the scholar to assess innovation activities in developing countries, along with many other firm-specific characteristics.

Two distinctive features of the innovation studies are (1) which factors (environmental conditions) induce a firm to innovate and (2) what effects innovation can have on firm performance. We study innovation in both ways and aim to identify similarities/differences between our results and those obtained from the analyses of developed countries. Following an overview of innovation phenomena across developed and developing countries and a discussion of innovation problems of the latter in chapter (2), chapter (3) provides the empirical analysis of the innovation determinants for the Latin American firms.

Two complementary actors of a firm's operations are employer and employee. Depending on the particular context, both have similar and conflicting interests. On one hand there is a possibility that innovation stimulates productivity, on the other it may destroy jobs. The former is a positive outlook for employer, while the latter is an alarming phenomenon for employees. Therefore, we study the productivity and employment effects of innovation for Bangladesh and Pakistan in chapters (4) and (5) respectively, to have more substantiated evidence of the impact of innovation on firm performance. Chapter (6) concludes this thesis with a policy discussion.

More specifically, chapter (2) describes why innovation in developing countries is not as prevalent a societal and industrial notion as in developed countries. The success of innovation depends on the smooth and healthy interplay of different underlying actors (sources), which are intricately connected. As is argued in chapter (2), developing countries tend to have very low education levels and insufficient infrastructure; these are the countries where national innovation systems (Freeman, 1987; Lundvall, 1992) have many problems. We analyze different quantitative indicators which allow a comparison of innovation inputs and outputs across developing and developed counties. One of the important components, as Kim (1980) and Dahlman et al. (1987) argued, for innovation success are technological capabilities of a firm or of a country. Our empirical analysis of cross-country technological capabilities shows that most of the developing countries have very low technological capabilities compared to the developed world. Additionally, in terms of R&D commitment and scientific publications, developed countries are ahead of the developing world. A comparison based on the Global Innovation Index (GII) indicates the same.

In chapter (3) we analyze the determinants of innovation of fourteen Latin American countries. (Some of the) innovation determinants can affect innovation inputs and outputs differently. Therefore, we observe both innovation input (R&D) and output (product innovation) determinants separately. Our econometric analysis also investigates whether innovation (both R&D and product innovation) determinants behave differently in differently sized classes and in different product market competition environments. More specifically, we investigate two important innovation determinants (in the Schumpeterian sense), along with some potential control variables. The results of the analysis of the effects of firm size on innovation follow the pattern observed in developed countries: employment (size) increases the likelihood of both R&D and of product innovation; it also increases the R&D intensity but less than proportionately. The results of the competition-innovation relationship analysis do not follow the pattern of widely observed outcomes for the developed world: an inverted-U relationship. In particular, competition has a significantly positive impact on the probability of R&D occurrence and product innovation, and does not have any relationship with R&D intensity. The effects of both firm size and market competition on both R&D decision and intensity as well as the effect of firm size on product innovation do not differ between small and large firms. However, the effect of market competition on product innovation is more pronounced in larger firms. The determinants of both R&D intensity and product innovation result in different effects in small and large firms, with more significant difference for the former. In case of different competition environments, such difference is observed only for product innovation. Cross-country and cross-industry differences are observed to be important determinants of both innovation types.

Chapter (4) discusses impact on the (labor) productivity of both product and process innovation for Bangladesh and Pakistan. To achieve this, the CDM model (Crepon et al., 1998) is augmented by including process innovation and some additional control variables. In addition reduced (involving only two equations: the innovation and productivity equations) and full (having the R&D, innovation, and productivity equations) versions of the CDM are applied in order to observe whether there are different effects of innovation (both product and process) on productivity. Descriptive statistics show that Bangladeshi firms are more often innovators, whereas productivity output and traditional productivity inputs are larger in Pakistan. Both intermediate productivity input (raw material cost) and fixed capital input are observed to have strong influences on productivity outputs of both countries' firms. Moreover, the assumption of constant returns to scale is not rejected most of the time. Our comparison of the results of the full and reduced CDM applied to Bangladeshi firms reveals that someone could be indifferent between them, to observe the effect of innovation output on labor productivity (we do not have R&D information to analyze this phenomenon in Pakistan). One of the striking results is that both product and process innovation generally are important determinants of labor productivity as a whole (all firms taken together) and in separate analysis of Bangladesh and Pakistan, with some insignificance of product innovation in the former two cases.

Chapter (5) describes the empirical analysis of another important consequence of industrial innovation: the effect of both product and process innovation on employment growth. A further analysis of whether both innovations complement each other or which effect (displacement or compensation) of one particular innovation type dominates the other, to influence employment. This analysis is also carried out for Pakistan and Bangladesh. One of the striking findings is that both process and product innovation spur employment in this region as a whole. This positive effect is also obtained in separate analyses of low and high tech industries, for all firms taken together. The separate analyses of Pakistani and Bangladeshi firms also disclose that both innovation types are important determinants to stimulate employment of all Bangladeshi and of all Pakistani firms. However, our further industry-specific investigation reveals a clear contradiction: process and product innovations are an important catalyst for employment growth of only high-tech Bangladeshi firms and of only low-tech Pakistani firms. In addition, we witness a strong complementarity between both innovation types, suggesting that both product and process innovation should be carried out together to enhance employment generation. Another important finding is an insignificantly negative effect of wages on employment growth, contrary to its significantly negative impact in most of the developed countries' outcomes. The reason might be the availability of cheaper labor in this region compared with the developed world.

# Chapter 2

# Innovation in Developing and Developed Countries

## 2.1 Introduction

Innovation, for good reasons, is often conceptualized as one of the important determinants of micro-level productivity gains and macro level economic growth. Innovation commitment of a country and/or of a firm can broadly be investigated in terms of two major indicators: inputs into innovation processes and outputs gained by these particular inputs. On the national level, these innovation inputs and outputs are not the results of an individual's efforts but rely heavily on the links between different actors/sources (Freeman, 1987; Lundvall, 1992). Hence, innovation is not a straightforward goal to be achieved easily owing to many complexities involved at the stages of these links, for both innovation types.

One important issue in innovation studies is the appropriateness of the indicators used in order to gauge both innovation types. Despite the recognition of the importance of technological change for development a long time ago, systematic quantitative measurement has hardly been conducted before the notion of research and development (R&D). Moreover, the launch of innovation surveys in the relatively recent past enabled analysts to study the notion of innovation in a more extensive and intensive way. Regarding firm-level innovation inputs, researchers use expenditure on research and development (R&D), acquisition of technology from external sources (particularly important for developing countries), R&D personnel, etc. On the other hand, measures such as innovation counts, innovation sales, patents[1], process and product innovation status, etc. are considered innovation outputs.

[1] Patents are sometimes considered as an intermediate measure of innovation.

Macro- and micro-level innovation studies, using above mentioned measures, have been conducted extensively in the developed world compared with the developing one, but it is not appropriate to use the findings of the former to analyze the innovation behaviors of the latter, owing to their different economic circumstances and social needs. A highly sophisticated and complex innovation could be very important in a developed region of the world, but its significance may not be as vital in a developing country. The two main reasons for this insignificance in developing countries are (1) the consumers in the developing world may not be sufficiently educated and aware to understand the necessity for and the complexities of this innovation and (2) the manufacturers in this region may not have the required resources to conduct such complex innovation. On the other hand, a particular incremental innovation could be an important achievement in a developing country, despite its trivial influence in the developed world. These differences necessitate innovation studies with a particular focus on developing countries. So far, there is a lack of such studies.

The definition of developing countries is somewhat arbitrary. However, the generally acceptable definition is that developing countries are those which lag behind in the transition from agricultural to industrial societies, and their economies, compared with the developed world, are not primarily based on knowledge (creation and diffusion) and usage of science and technology (Arocena and Sutz, 2005). The standard of living, human development index (HDI), and per capita income is relatively low in these countries (Gaillard, 2010).

The main share of knowledge production (innovation) takes place in developed countries, and innovations in "the rest" heavily rely on radical developments of "the north". This does not undermine the importance of innovation (and studies analyzing its operations) in (on) developing countries; even if innovation in a developing country does not contribute substantially to the global knowledge frontier, its impact may still be very important for that particular country (Fagerberg et al., 2010), and it could contribute substantially to the economic development of that country. More importantly, it is essential for policy making to know why innovation culture does not prevail in developing countries. Which forces hinder technological advancements and knowledge creation in this region? How can the situation be improved to promote innovativeness at the individual, societal, and institutional level in developing countries?

Innovation in general terms involves abstraction of a new idea, its materialization in the form of a tangible object, its diffusion to society, and finally its commercial success to maximize the profit (especially for industrial innovation). These steps involve their specific determinants which induce them to participate successfully in this innovation mechanism. The combination of these determinants can broadly be translated into absorptive capacity (Cohen and Levinthal, 1989, 1990), social capability (Abramovitz, 1986), technological capability (Kim, 1980), and national innovation system (Lundvall, 1992; Edquist, 1997) which is a more systematic approach to link these concepts with additional innovation-conducive factors. The reason innovation is not as accepted in developing countries as it should be is the lack, partially or wholly, of these innovation determinants at a macro level, and characteristics of micro level sub-indicators which shape these macro level factors. These micro level characteristics may be the lack of education (technical in the case of industrial workers and general in the case of the whole society) and knowledge bases which hinder the assimilation of new knowledge, a lack of technological, telecommunication, and other public infrastructures, a preference for the status quo and an unwillingness to accept industrial, institutional, and individual changes, a plethora of laws and institutions governing the launch of a new product which may slow the pace of innovation, political instability, insecurity, a lack of links between industries and universities (research centers), etc.

The level of education is considered to be one of the most important determinants of innovation, but developing countries are often characterized by low levels of education. Universities and other research institutes often lack the research planning connecting them to their local environment because most of the scientists employed there have been trained in developed countries, and do not have a deep-rooted knowledge of the local technological problems and needs (Crane, 1977). Moreover, these research laboratories and institutions often face a scarcity of research funds, and may not be fully equipped with the latest instruments.

The migration of the few available highly educated and skilled workforce to developed countries[2] is one of the problems that hinder innovation activities in developing countries. As Aubert (2004) pointed out, this brain drain is a significant hurdle for developing countries in their struggle to establish local knowledge bases. He also argued that these emigrants could be a source of enhancing the knowledge bases of their own countries through teaching, transferring, and upgrading the technical skills in their countries of origin. The potential routes of knowledge enhancement, as he argued, could be returning back to home country, Foreign Direct Investment (FDI), their remittances, and their role as a broker between foreign and local partners.

A healthy infrastructure is an important driver of innovation. This infrastructure may comprise roads, energy, and telecommunications. Most of the developing countries face problems of insufficient infrastructures. The usage of mobile phones although has improved telecommunication in the developing world and enhanced the connectivity between actors which are necessary ingredients of innovation and economic development (i.e. suppliers, manufacturers, consumers, and analysts), the tele-density has so far been quite low, and developing countries are also behind in terms of internet use (Aubert, 2004). This insufficient infrastructure increases the risk of sub-optimal results of innovation efforts.

Consumers/users may also propel manufacturers to innovate (Von Hippel, 1986). As Lettl (2007) argued, a firm benefits more by involv-

---

[2] Many immigrants want to work in their own country and endeavor to exploit their potential and expertise for the advancement of their own country, but they are not able to acquire appropriate support from government institutions, and face a lack of well-embedded infrastructure required for research, development, and technological advancement. Therefore, they choose to migrate to a technologically well-equipped country to avoid atrophy of their talent.

ing the right users at the right time in the right form. In developing countries, the lack of consumer awareness decreases their involvement in innovation processes. A related concept is demand-pull innovation. In developing countries, demand for innovative products is lower because of the consumers' traits, their lower education level and less technological know-how. This passive role of demand side factors decreases manufacturers' motivation to innovate.

## 2.2 Innovation Indicators across Developing and Developed Countries

Intellectual property, knowledge base, technology prevalence, scientific strength, and innovation performance of a country can be observed in a number of ways. These indicators are different routes to observe the innovation capability of a country. Hence, in this section, we endeavor to compare some of these indicators across developing and developed countries in order to get an insight into their innovation capabilities.

### *2.2.1 Scientific Publications across Developing and Developed Countries*

One of the important ways to gauge the scientific strength of a country is its number of scientific publications (Gaillard, 2010). We can find many studies conducted bibliometric analyses using this measure (Schubert and Telcs, 1986; Galvez et al., 2000). In our particular analysis, we use the international scientific publications of journals that were selected by the Science and Engineering Indicators 2012 of the National Science Foundation (NSF), from the journals listed on the Science Citation Index (SCI) and the Social Sciences Citation Index (SCCI) of Thomson Reuters (NSF, 2012). Despite language, geographical, and other context-based biases (Galvez et al., 2000; van Leeuwen, 2006; Gaillard, 2010), these indices (SCI and SSCI) are the most reliable and the most widely used measure to observe the scientific strengths of countries.

Table (2.1) reports the world share of scientific publications and of population of developed and developing regions. The region OECD-32 includes countries which are currently members of the OECD, except Chile and Mexico. The European part of the OECD-32 comprises those European countries which are members of the OECD. The Latin American and Caribbean region includes 30 major countries of this region (details can be seen in Table (A2.4)). The South Asian region consists of the following countries: Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan, and Sri Lanka. Sub-Saharan Africa includes countries that are located south of Sahara (including Sudan) (for details, see Table (A2.1)). The country details for all regions included in Table (2.1), along with each country's scientific publications and population share, can be found in Tables (A2.1)-(A2.6).The population figures have been obtained from the United Nations, Department of Economic and Social Affairs, Population Division (United Nations, 2011). The primary reason to report population statistics, alongside scientific publications, is to get a deeper insight into these countries' scientific strengths by observing its science as well as its population share of the world's total scientific output and population. We report both indicators for the year 1999 and 2009 to observe the increase/decrease in the proportion of each region. The biggest share of the world's scientific publications in 1999 was that of the OECD-32 region, 86.3%. This dropped to 76.9%in 2009, but the figure still indicates that more than three quarters of the world's scientific output in 2009 was produced by the developed world (OECD-32). Moreover, the publication shares of the Western European part of the OECD[3] and the USA decreased, this effect was more pronounced for the USA. The world share of the former in 2009 was 30.9%, while the figure for the latter was 26.5% (while the population shares in the same year for both of them were 6.2% and 4.6% respectively). In both

[3] The Western European part of the OECD includes the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and Great Britain.

**Table 2.1 World share of scientific publications (articles) and population across developed and developing regions**

| Areas | World share (%) of | | | | Differences (2009-1999) | |
|---|---|---|---|---|---|---|
| | pop. | articles | pop. | articles | | |
| | 1999 | | 2009 | | pop. | articles |
| OECD-32[a] | 17.3 | 86.3 | 16.5 | 76.9 | -0.8 | -9.4 |
| European part of OECD-32 | 7.7 | 37.1 | 7.2 | 33.0 | -0.5 | -4.1 |
| Western European part of OECD-32 | 6.6 | 35.2 | 6.2 | 30.9 | -0.4 | -4.3 |
| Eastern European part of OECD-32 | 1.1 | 1.9 | 1.0 | 2.1 | -0.1 | 0.2 |
| USA | 4.7 | 30.8 | 4.6 | 26.5 | -0.1 | -4.3 |
| Others in OECD-32 | 4.9 | 18.4 | 4.7 | 17.5 | -0.2 | -0.9 |
| Latin America and Caribbean | 8.4 | 2.3 | 8.5 | 3.1 | 0.1 | 0.8 |
| South Asia | 23.6 | 1.9 | 24.4 | 3.5 | 0.8 | 1.6 |
| Sub-Saharan Africa | 10.7 | 0.7 | 12.1 | 0.6 | 1.4 | -0.1 |
| Other Africa and Middle East | 3.8 | 0.6 | 4.2 | 0.8 | 0.4 | 0.2 |
| CSTT[b] | 22.3 | 4.1 | 21.0 | 12.0 | -1.3 | 7.9 |

[a] OECD-32 excludes Mexico and Chile
[b] CSTT includes China, Singapore, Taiwan, and Thailand
Notes: "Articles classified by year of publication and assigned to region/country/economy on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. Detail may not add to total because of rounding" (NSF, 2012).
Sources: Our own calculations by using the following sources: (1) for the scientific publications data, those journals that were selected by the Science and Engineering Indicators 2012 of the National Science Foundation (NSF), from the journals listed on the Science Citation Index (SCI) and the Social Sciences Citation Index (SCCI) of Thomson Reuters; (2) for population data, United Nations, Department of Economic and Social Affairs, Population Division.

years, the publication share of the Eastern Europe part of the OECD[4] was quite low, albeit a slight increase (1.9% in 1999 vs. 2.1% in 2009). In addition, the statistics show that the publication share of developing countries is very small. In the year 2009, Latin America and Caribbean (LAC) and South Asia contributed 3.1% and 3.5% to the world's scientific publications respectively. However, we notice an increase, compared to the corresponding values of 1999 (2.3% for LAC and 1.9% for South Asia). A remarkable finding is the large increase from 4.1% in 1999 to 12% in 2009 of the publication share of CSTT (China, Singapore, Taiwan, and Thailand). The driver of this change was China, with only a 2.6% publication share in 1999 which jumps to 9.4% in 2009 (see Table (A2.6)). This means that China was the second largest contributor to the world's scientific output after the USA in 2009. If we compare scientific publications shares across countries for 1999, countries such as Canada, France, Germany, Italy, Japan, and the UK have greater world shares than China (see Tables

[4] The Eastern Europe part of the OECD includes the Czech Republic, Estonia, Hungary, Poland, Slovakia, and Slovenia.

(A2.2) and (A2.6)). But China's contribution a decade later is substantially higher than that of each of these countries, suggesting a strong commitment to catch-up and to become a scientifically advanced country. Finally, the data shows very small publication shares of Sub-Saharan Africa and "other Africa and the Middle East", with the fractions of 0.6% and 0.8% respectively. We can clearly notice large differences between developed and developing countries. More specifically, only 16.5% of the world's population of the OECD-32 produced 76.9% of the world's scientific literature in 2009. Despite accounting for 12.1% of the world's population in the same year, Sub-Saharan Africa's contribution was only 0.6%.

Country-specific shares of these statistics (population and scientific publications), as mentioned earlier, are reported in Tables (A1)-(A6). We have already mentioned some results in our discussion of China. We elaborate some other findings. The publication share of thirteen out of eighteen Western European and two out of six Eastern European countries decreased from the year 1999 to 2009, by a maximum of -1.88[5] for the UK. Japan's share also decreased, whereas the scientific shares of South Korea and Turkey increased. The share of some of the South Asian countries (India, Iran, Pakistan, and Sri Lanka) also increased, with the maximum value for India and a modest increase for Sri Lanka.

As briefly discussed in chapter (1), the empirical analyses in chapters (3)-(5) of this thesis are based on two developing regions: Latin America and South Asia. We report performances of the countries used in these empirical analyses measured by the share of scientific publications in 2009 in Table (A2.8) (details of these countries will be provided in subsequent chapters). In Latin America[6] the highest share of the world's scientific publications in 2009 was measured for Mexico with a percentage of 0.52, followed by Argentina with 0.46%. Some countries like El Salvador, Guatemala, Honduras, Nicaragua,

[5] These values are obtained by simply subtracting a country's world share in 2009 to the corresponding value for the year 1999.

[6] The reader should be borne in mind that empirical analyses in chapters (3)-(5) do not include Brazil and India.

and Paraguay have very low percentages. The South Asian countries analyzed in this thesis are Pakistan and Bangladesh. The global publication share of Pakistan was 0.13%, while the fraction of Bangladesh was 0.03%. According to values, the Latin American region analyzed in chapter (3) seems to perform better in terms of scientific output compared with the South Asian countries of chapters (4) and (5).
Having discussed scientific publication shares for different regions, we proceed with an analysis of the scientific strengths of developing and developed regions by measuring scientific publications per capita. The former describes a country's/region's share of scientific publications worldwide, while the latter is a measure of the ratio of the scientific literature of a country (region) to its population. The scientific publications per capita values for 2009 across the regions listed in Table (2.1) are reported in Table (2.2). Again, the highest value was measured for the world's most developed region (OECD-32). The table shows that this region produced 0.531 scientific publications per 1000 people in 2009. The values for Western Europe, Eastern Europe, and the USA were 0.569, 0.236, and 0.653 respectively. Recall that in Table (2.1), Western Europe's share of 33% of the world's scientific publications in 2009 was higher than the 26.5% achieved by the USA, but in terms of scientific publications per capita, the USA performed slightly better than Western Europe. Similar to the poor performance seen in Table (2.1), developing regions' inhabitants are less scientifically productive than their counterparts in the developed world. Again the poorest performing region is Sub-Saharan Africa with 0.006 scientific publications per 1000 people, while CSTT has the highest value with 0.065. LAC's value was 0.041, while the figures for South Asia and "Other Africa and Middle East" were 0.016 and 0.022 respectively. If we compare LAC and South Asia (this is important to note that these regions here are not confined to the countries which are included in the empirical analyses of chapters (3)-(5) of this thesis), the performance of the latter is better in terms of the world share of publications, whereas the former has higher value of the scientific publications per capita. Comparing the developing and developed regions

with respect to both scientific indicators, the dominant position of the latter is unequivocally established.

**Table 2.2 Scientific publications per 1000 people across developed and developing regions**

| Areas | Scientific publications per 1000 people |
|---|---|
| | 2009 |
| OECD-32[a] | 0.531 |
| European part of OECD-32 | 0.522 |
| Western European part of OECD-32 | 0.569 |
| Eastern European part of OECD-32 | 0.236 |
| USA | 0.653 |
| Others in OECD-32 | 0.423 |
| Latin America and Caribbean | 0.041 |
| South Asia | 0.016 |
| Sub-Saharan Africa | 0.006 |
| Other Africa and Middle East | 0.022 |
| CSTT[a] | 0.065 |

[a] OECD-32 excludes Mexico and Chile [b] CSTT includes China, Singapore, Taiwan, and Thailand
Notes and sources: same as Table (2.1).

In Table (A2.7) we report the country ranks, along with actual values, for both above discussed indicators for 2009. This facilitates easy comparisons of country performances with reference to both indicators. This table is helpful to understand how countries' positions change by considering one or the other indicator. We will not discuss these results in detail but focus on the key findings. The world's top 10 countries in terms of scientific publications per capita in 2009 were OECD members, with the exception of Singapore, which was ranked 9th. We can easily highlight the leading role of Western Europe by observing that top six countries are located in this region. According to scientific productivities these countries are ranked as follows: (1) Switzerland, (2) Sweden, (3) Denmark, (4) Finland, (5) Norway, and (6) the Netherlands. The ranks of Great Britain and the USA are thirteenth and fourteenth respectively. In terms of world share of scientific publications, nine of the top ten countries are OECD members. The only exception is China, as already discussed. Another point worth mentioning is that although China and India are ranked second and eleventh in terms of world share of scientific publications, with the percentages of 9.4 and 2.5 respectively, based on scientific publications per capita they only rank 46th and 64th respectively, with the corresponding values of 0.05 and 0.02 scientific publications per 1000 inhabitants. The obvious reason is their large population sizes; China is the most populous country of the world followed by India (United Nations, 2011). The world's third most populous country, the USA, is ranked fourteenth in terms of scientific publications per capita. Note that China's population is substantially higher than that of the remaining world, except India: the population size of China is more than four times that of the USA, the third largest country, and even more than ten times and so than many other countries (United Nations, 2011). This means that China's 0.05 scientific publications per 1000 inhabitants is still a significant figure to consider it as a growing scientific powerhouse.

### *2.2.2 Research and Development (R&D) across Developing and Developed Countries*

As mentioned earlier, innovation can be thought of under two different aspects: innovation inputs and innovation outputs. Research and development (R&D) is a widely used measure to observe the efforts of a country (and of a business unit) in terms of innovation input, and its commitment to technological efforts and to knowledge enhancement. The Frascati manual of 2002 (OECD, 2002) defined R&D as "Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." As Deeds (2001) argued, an increase in R&D intensity could result in an increase in the firm's internal discoveries and in a flow of new scientific information to the firm.

The positive effect of R&D efforts on innovation output has often been documented in the literature, and it is believed that a firm can produce more innovative products if it runs R&D activities in a systematic way. The study of Pakes and Griliches (1980) on patents applied by the medium and large United States companies from 1968 to 1975 found a positive effect of R&D expenditure for the year 1963-1975 on the propensity to apply for a patent. A significant effect of industry and university R&D on patent activities in the USA can also be found in Jaffe (1989). Mairesse and Mohnen (2005), by using the third wave of the community innovation survey (CIS3) for French manufacturing companies, found a significantly positive influence of R&D on different innovation output measures. They further observed the effect of R&D to be more important than the effect of firm size. The strong association between R&D and innovation outputs was also observed by Griffith et al.(2006) and by Hall et al. (2009). It is very hard to report all literature concerning the effect of R&D on innovation output, but we can generally conclude a positive effect of R&D on successful innovation outputs.

The role of technical change (and innovation) on economic growth has always fascinated economists (see, e.g. Abramovitz, 1956; Solow, 1957; Verspagen, 2004, among others), and most empirical studies have confirmed a significant impact of innovation on productivity (Geroski et al., 1993; Koellinger, 2008, among others). Moreover, innovation activities in terms of R&D also had a significant positive effect on productivity output (Verspagen, 1995; Griliches, 1998, chapter 4). More specifically, the study of Hall and Mairesse (1995) on French manufacturers showed a strong positive impact of R&D capital on labor productivity. By applying an econometric analysis to data of German manufacturing firms, Harhoff (1998) postulated a positive effect of R&D commitment on firms' productivity output.

One implication of the endogenous characteristics of technology for economic growth, as advanced by the endogenous growth theory (Romer, 1986, 1990; Lucas, 1988), is the necessity to increase R&D efforts to gain new knowledge and improve technological capabilities. Moreover, today's technological world changes quickly and requires more R&D efforts at indigenous level to compete in knowledge generation and to survive at the technological front. As Cohen and Levinthal (1989) argued, the dual role of R&D is the generation of new knowledge and the enhancement of firms' ability to assimilate and use existing knowledge; the latter is more important for developing countries given their existing knowledge bases. The contributions of R&D

to enhance firms' knowledge basis is well documented, yet the majority of expenditures on worldwide research and development activities are hitherto funded by the developed world as well as newly industrialized countries of the developing world. One of the main reasons of less common R&D efforts from developing countries is the direct purchase of technology from abroad (Dahlman et al., 1987), which can be used to produce new indigenous products by requiring lower technological efforts. One of the sources of R&D in developing countries is the current wave of R&D globalization. This R&D globalization involves FDI and the execution of R&D activities by multinational corporations (MNCs) in the host countries. As Reddy (2005) pointed out, the urge to get access to foreign science and technology resources and availability of trained manpower at lower wages relative to developed countries have motivated MNCs to carry out R&D projects in some developing countries since the mid-1980s. He further argued that developing countries could benefit more from these R&D activities by improving their frameworks and enhancing their capabilities. They should strive to assimilate existing knowledge and to create new knowledge from these R&D efforts of MNCs.

**Table 2.3 Share of world R&D expenditures by regions/countries in 2007**

| Region/Country | R&D share (%) | Region/Country | R&D share (%) |
|---|---|---|---|
| USA | 32.6 | Japan | 12.9 |
| European Union | 23.1 | China | 8.9 |
| Germany | 6.3 | NIE Asia | 6.3 |
| France | 3.7 | India | 2.2 |
| UK | 3.4 | Israel | 0.8 |
| CIS Europe | 2.4 | Other Asia | 1.1 |
| Russia | 2 | Oceania | 1.6 |
| LAC | 3 | Africa | 0.9 |
| Brazil | 1.8 | South Africa | 0.4 |
| Mexico | 0.5 | Arab States (Africa) | 0.3 |
| Argentina | 0.2 | Other Africa | 0.2 |
| Asia | 32.2 | | |

Source: UNESCO Institute for Statistics estimates, 2010
Notes: CIS Europe: Commonwealth of Independent States in Europe; LAC: Latin America and Caribbean; NIE Asia includes Hong Kong, Indonesia, Malaysia, Philippines, South Korea, and Singapore; Other Asia excludes Japan, China, NIE Asia, Israel, and India. Other Africa excludes South Africa and Arab States (Africa).

A quantitative measure helps to understand the R&D efforts of different regions in more depth. Hence, we discuss descriptive statistics on R&D performances of developing and developed countries to compare R&D commitments across these regions. Table (2.3) reports the shares different regions and selected countries hold of the world's R&D expenditure. The top ranked country was the USA with a share of 32.6%. The European Union's collective share of total R&D expenditure in 2007 was 23.1%. If we break this ratio down by countries, the percentages for Germany, France, and Great Britain were 6.3, 3.7, and 3.4 respectively. The Latin America and Caribbean share was 3%, with 1.8% for Brazil, 0.5% for Mexico, and 0.2% for Argentina. Asia contributed 32.2% of the world's total R&D spending in 2007.The majority of which, 87%, was invested by Japan, China, and NIE Asia[7], with percentages of 12.9, 8.9, and 6.3 respectively. The contribution of India and Israel was 2.2% and 0.8% respectively, while rest of the Asia's contribution was 1.1%. Similar to the findings on scientific publications, Africa was the least R&D active continent, holding only 0.9% of the world's R&D in 2007, with 0.4% for South Africa and 0.3% for the Arab States of Africa. According to these statistics, 55.7% of the world's R&D expenditure in 2007 was spent by the USA and the EU. If we combine Japan, China, and NIE Asia with the two above mentioned regions, the combined share was 83.8%. These results clearly illustrate the leading role of developed countries and newly industrialized Asian countries in R&D activities, with a more significant share for the former. Hence, similar to the scientific publications indicator, the performance of developing countries is substantially low in terms of R&D activities.

## 2.3 Technological Capability, Absorptive Capacity, and National Innovation System in Developing Countries

In this section, we discuss the performance of the developing world with respect to three important innovation-related notions which have been developed recently (in the 1980s and 1990s), and is gaining prominence nowadays for the successful implementation of innovation. We also try to compare developing and developed countries empirically with respect to these concepts where possible. The study of

[7] See Table (2.3) for the definition of NIE Asia.

these aggregate parameters is helpful to understand the innovation scenario in developing countries at a broader level, contrary to the individual innovation indicators discussed above.

### *2.3.1 Absorptive Capacity and Technological Capability*

The role of "absorptive capacity" is very important for successful innovations. The concept was defined as a firm's ability to recognize external knowledge, assimilate, and apply it commercially (Cohen and Levinthal, 1989, 1990). This absorptive capacity is often described as a significant determinant of innovation efforts (Nieto and Quevedo, 2005). Fabrizio (2009) argued that the concept of absorptive capacity focuses on the fact that a firm cannot absorb external knowledge without sufficient efforts and expertise. She further stated that a firm's efforts to build absorptive capacity by enhancing internal research and collaboration with universities increase its benefits in terms of superior innovation search. The study of Veugelers (1997) showed that a firm's search for external knowledge (in terms of R&D cooperation) has a significant influence on its internal R&D spending, only if it has sufficient absorptive capacity (R&D department and R&D personnel). This underlines the significant role of absorptive capacity in the complementarities between internal and external knowledge. This means that if a firm already has a sufficient internal knowledge base (absorptive capacity), it will try to enhance it to absorb external knowledge more efficiently. This is indirect evidence of the argument brought forward by Cohen and Levinthal (1990) that a firm's absorptive capacity is a function of its previous knowledge base. Most of the developing countries are unable to extend their absorptive capacity due to low levels of internal knowledge. Their knowledge base is insufficient to promote an understanding of the sophistications of advanced countries' imported technologies; thereby they cannot optimally utilize external knowledge according to their needs.

Access to external knowledge to enhance a firm's innovative capability depends heavily on the position of the firm in the knowledge space. The study by Tsai (2001) observed a positive relationship between firms' more central network positions and innovation. Devising R&D intensity as an investment to enhance a firm's absorptive capacity, he concluded that an increase in absorptive capacity results in an innovation increase. But the advantage of the above discussed "near-knowledge-spillover" is lower for developing countries due to a weaker intra-country knowledge base. As Girma and Görg (2005) argued, the domestic establishment's absorptive capacity determines whether sufficient benefits from FDI spillover are realized, developing countries cannot obtain optimal productivity increases until they have sufficient absorptive capacity to assimilate and utilize foreign (advanced) technologies.

Kim (1997) advanced the concept of "technological capabilities" as the ability to assimilate, exploit, adapt, and change existing knowledge/technologies, as well as the ability to develop new technologies. These capabilities are also considered to be important ingredient of economic growth (Archibugi and Coco, 2004). A country with a decent "amount" of these capabilities could run more smoothly on the technological trajectory than one which lacks them.

As has been argued, a lower knowledge base at the initial stage hinders the progress of most of the developing countries to enhance their capabilities. But they can improve their technological skills by implementing thoughtful technological policies, focusing on interactions with foreign, technologically advanced countries as a first step. More specifically, they can enhance their knowledge base through spillovers, joint ventures, sending their personnel to advanced countries for training, and hiring skilled management from abroad. Dahlman et al. (1987) described in detail how Usiminas (a steel producer in Brazil) started its work and took off by improving its technological capability. In the Beginning, Usiminas hired Japanese steel experts and worked with them in order to improve its local labor force's technological capabilities. Once it had acquired basic production capabilities, it tried to learn more to enhance its innovation capabilities. It also sent its personnel abroad to study and gain practical experience. As Dahlman et al. (1987) argued, the success story of Usiminas describes how one poor firm in a developing country can develop its technological capabilities through systematic long-term efforts. Kim (1980) described the stages of technological development of South Korea. He argued that the success of Korea from a poor country to one of the world's industrial leaders started with the import of foreign technology. Local firms, after accumulating production experience, exerted indigenous efforts to assimilate the imported knowledge, which increased their local capabilities. These local technological capabilities were sufficient for Korea to improve the foreign technologies. He continued that this pattern is not confined to Korea, but also applies to the history of manufacturing industries. Hence, although most of the developing countries lag behind the global technological frontier, they can catch-up by applying systematic innovation policies on a regular basis.

The definitions of Kim (1997) and Cohen and Levinthal (1989, 1990) discussed above share certain underlying characteristics. Both can be improved by an evolutionary process, depending primarily on the indigenous capabilities of a firm or a country. Since both concepts are combinations of qualitative number of characteristics of individuals, firms, and countries, it is difficult to quantify them in a single index. More specifically, there is no systematic measure that encompasses all aspects of absorptive capacity to capture this concept in a single quantitative indicator. Although R&D is not the only source of absorptive capacity (Flatten et al., 2011), it is frequently used as a proxy to measure it (Veugelers, 1997; Tsai, 2001, among others). On the other hand, we can find some success in gauging "technological capability" using suitable set of indicators. One of these empirical measures was constructed by Archibugi and Coco (2004)[8]. Another study of these authors (i.e. Archibugi and Coco, 2005) compared their own measure (ArCo) with other "technological capability" indicators[9]. All these indicators, with varying intensities and scopes, are the com-

---

[8] They named the measure they devised ArCo.

[9] They compared ArCo with the "technological capability" indicators constructed by the World Economic Forum (WEF), the UN Development Program (UNDP), the UN Industrial Development Organization (UNIDO), and the RAND Corporation.

binations of quantitative measures of innovation outputs, infrastructure, human capital, and competitiveness (see Table (1) in Archibugi and Coco, 2005, for details). ArCo is a combination of three main technological indicators: the creation of technology, the technological infrastructure, and the development of human skills. These indicators are measured by using eight sub-indicators. The "creation of technology" indicator is the average of two sub-indicators namely the number of patents and scientific articles. The second indicator (technological infrastructure) is a combination of (1) internet penetration (2) telephone penetration, and (3) electricity consumption. Finally, the "human skill" indicator is composed of the mean of tertiary science and engineering enrolment, mean years of schooling, and literacy rate (see Archibugi and Coco, 2004, for details of these indicators and sub-indicators).

The ArCo country ranks are presented in Table (2.4), a modified version of Table (1) in Archibugi and Coco (2004). The ArCo scores illustrate the leading role of developed countries and the poor performance of developing countries in terms of technological capabilities. We have already discussed some of the reasons for the low ranks of developing countries such as the lack of education, insufficient infrastructure, etc. In a cross-country comparison, Sweden is ranked first with an ArCo score of 0.9 while Somalia, a Sub-Saharan African country, holds the lowest rank (162th) with a value of 0.03. The top three ranks are held by European countries, with Finland and Switzerland in second and third place.

Similar to the scientific publications indicator, we report in Table (A2.9) ArCo scores (with ranks) for the countries used in our empirical analyses in chapters (3)-(5) (see footnote (6)). One of the important findings is that Guatemala, the lowest ranked Latin American country on rank 109 with an ArCo score of 0.234, is ranked above than the highest ranked South Asian country, Pakistan, which is on rank 120 with an ArCo score of 0.191. The highest ranked country in Latin America (and also in both regions) is Argentina, which is ranked

**Table 2.4 Technological capability indicator (ArCo) across countries, 1990-2000**

| Ranks | Country | ARCo | Ranks | Country | ARCo |
|---|---|---|---|---|---|
| 1 | Sweden | 0.867 | 57 | Lebanon | 0.37 |
| 2 | Finland | 0.831 | 58 | Malaysia | 0.369 |
| 3 | Switzerland | 0.799 | 59 | Venezuela | 0.369 |
| 4 | Israel | 0.751 | 60 | Costa Rica | 0.361 |
| 5 | United States | 0.747 | 61 | Malta | 0.361 |
| 6 | Canada | 0.742 | 62 | Yugoslavia | 0.358 |
| 7 | Norway | 0.724 | 63 | Mexico | 0.358 |
| 8 | Japan | 0.721 | 64 | Tajikistan | 0.356 |
| 9 | Denmark | 0.704 | 65 | Turkey | 0.347 |
| 10 | Australia | 0.684 | 66 | Jamaica | 0.346 |
| 11 | Netherlands | 0.683 | 67 | Peru | 0.345 |
| 12 | Germany | 0.682 | 68 | Thailand | 0.342 |
| 13 | United Kingdom | 0.673 | 69 | Jordan | 0.341 |
| 14 | Iceland | 0.666 | 70 | Azerbaijan | 0.337 |
| 15 | Taiwan | 0.665 | 71 | Colombia | 0.331 |
| 16 | New Zealand | 0.645 | 72 | Brazil | 0.33 |
| 17 | Belgium | 0.642 | 73 | Armenia | 0.326 |
| 18 | Austria | 0.619 | 74 | Puerto Rico | 0.326 |
| 19 | Korea, Rep. | 0.607 | 75 | Saudi Arabia | 0.326 |
| 20 | France | 0.604 | 76 | Paraguay | 0.323 |
| 21 | Singapore | 0.573 | 77 | Philippines | 0.322 |
| 22 | Hong Kong, China | 0.569 | 78 | Cuba | 0.322 |
| 23 | Ireland | 0.567 | 79 | Ecuador | 0.319 |
| 24 | Italy | 0.526 | 80 | Uzbekistan | 0.319 |
| 25 | Spain | 0.516 | 81 | Iran | 0.313 |
| 26 | Slovenia | 0.507 | 82 | Libya | 0.312 |
| 27 | Greece | 0.489 | 83 | El Salvador | 0.311 |
| 28 | Luxembourg | 0.486 | 84 | Dominican Republic | 0.308 |
| 29 | Slovak Republic | 0.481 | 85 | China | 0.306 |
| 30 | Russian Federation | 0.48 | 86 | Kyrgyz Republic | 0.306 |
| 31 | Czech Republic | 0.475 | 87 | Bolivia | 0.305 |
| 32 | Estonia | 0.472 | 88 | Fiji | 0.304 |
| 33 | Hungary | 0.469 | 89 | Oman | 0.3 |
| 34 | Poland | 0.465 | 90 | Macedonia, FYR | 0.3 |
| 35 | Portugal | 0.45 | 91 | Turkmenistan | 0.289 |
| 36 | Bulgaria | 0.449 | 92 | Tunisia | 0.288 |
| 37 | Cyprus | 0.44 | 93 | Mauritius | 0.285 |
| 38 | Latvia | 0.439 | 94 | Syrian Arab Republic | 0.282 |
| 39 | Belarus | 0.431 | 95 | Sri Lanka | 0.28 |
| 40 | Argentina | 0.426 | 96 | Zimbabwe | 0.279 |
| 41 | Chile | 0.424 | 97 | Algeria | 0.277 |
| 42 | Ukraine | 0.417 | 98 | Guyana | 0.271 |
| 43 | Uruguay | 0.417 | 99 | Egypt, Arab Rep. | 0.269 |
| 44 | Croatia | 0.414 | 100 | Indonesia | 0.265 |
| 45 | Bahrain | 0.41 | 101 | Suriname | 0.264 |
| 46 | Lithuania | 0.408 | 102 | Honduras | 0.258 |
| 47 | Kuwait | 0.405 | 103 | Botswana | 0.255 |
| 48 | Moldova | 0.395 | 104 | Albania | 0.251 |
| 49 | UAE | 0.394 | 105 | Iraq | 0.246 |
| 50 | Romania | 0.393 | 106 | Zambia | 0.24 |
| 51 | Panama | 0.382 | 107 | Vietnam | 0.239 |
| 52 | Kazakhstan | 0.381 | 108 | Nicaragua | 0.238 |
| 53 | Trinidad and Tobago | 0.38 | 109 | Guatemala | 0.234 |
| 54 | Qatar | 0.38 | 110 | Gabon | 0.231 |
| 55 | Georgia | 0.379 | 111 | India | 0.225 |
| 56 | South Africa | 0.372 | 112 | Swaziland | 0.222 |

(continued to next page)

**Table 2.4 (continued)**

| Ranks | Country | ARCo | Ranks | Country | ARCo |
|---|---|---|---|---|---|
| 113 | Morocco | 0.217 | 138 | Djibouti | 0.122 |
| 114 | Namibia | 0.217 | 139 | Nepal | 0.121 |
| 115 | Congo, Rep. | 0.207 | 140 | Madagascar | 0.116 |
| 116 | Kenya | 0.204 | 141 | Benin | 0.114 |
| 117 | Ghana | 0.203 | 142 | Rwanda | 0.113 |
| 118 | Mongolia | 0.197 | 143 | Mauritania | 0.111 |
| 119 | Cameroon | 0.192 | 144 | Central African Republic | 0.11 |
| 120 | Pakistan | 0.191 | 145 | Angola | 0.107 |
| 121 | Korea, Dem. Rep. | 0.187 | 146 | Bhutan | 0.103 |
| 122 | Myanmar | 0.179 | 147 | Lao PDR | 0.098 |
| 123 | Lesotho | 0.178 | 148 | Mozambique | 0.098 |
| 124 | Tanzania | 0.155 | 149 | Cambodia | 0.096 |
| 125 | Senegal | 0.151 | 150 | Liberia | 0.095 |
| 126 | Papua New Guinea | 0.146 | 151 | Eritrea | 0.093 |
| 127 | Togo | 0.145 | 152 | Guinea | 0.079 |
| 128 | Nigeria | 0.141 | 153 | Burundi | 0.078 |
| 129 | Sudan | 0.14 | 154 | Guinea-Bissau | 0.076 |
| 130 | Yemen, Rep. | 0.14 | 155 | Sierra Leone | 0.075 |
| 131 | Côte d'Ivoire | 0.136 | 156 | Chad | 0.071 |
| 132 | Malawi | 0.134 | 157 | Ethiopia | 0.067 |
| 133 | Uganda | 0.133 | 158 | Mali | 0.066 |
| 134 | Haiti | 0.129 | 159 | Afghanistan | 0.056 |
| 135 | Congo, Dem. Rep. | 0.125 | 160 | Burkina Faso | 0.05 |
| 136 | Gambia | 0.123 | 161 | Niger | 0.031 |
| 137 | Bangladesh | 0.123 | 162 | Somalia | 0.028 |

This table is a modified version of Table (1) of Archibugi and Coco (2004).

40th with an ArCo score of 0.426. The lowest ranked country in both regions is Bangladesh, with an ArCo value of 0.123 on rank 137.

### *2.3.2 National Innovation System*

In the previous subsection, we have discussed the importance of "technological capability" and "absorptive capacity" for successful innovation implementation. Since a firm cannot innovate in isolation, the "national innovation system" (NIS), a system-level approach, developed in the late 1980s (Freeman, 1987; Lundvall, 1992; Edquist, 1997), received considerable attention, and is now considered an important concept. It focuses on the innovation efforts of a country within its national boundaries. Since innovation is a complex phenomenon with different actors, this systemic concept demonstrates how smooth interconnections and regular interplays of all national actors can enhance the innovation capabilities of a firm as well as a country.

These national players can broadly be termed *organizations* and *institutions*. *Organizations* comprise universities, research institutes, private firms, and government institutes, while *institutions* are rules and laws which foster fair play in innovation, e.g. patent laws, etc., social norms which shape the relationships between universities and firms (Edquist, 2004) as well as other social norms and traditions (Carlsson et al., 2002). A healthy connection among these factors is necessary for successful innovation policy (Dahlman, 2007). Although the NIS was developed based on observations of industrialized countries, its application should not be confined to these countries (Arocena and Sutz, 2000). They further argued that globalization affects the overall innovation environment of a country and the underlying sources shaping this environment. Significant effects of national policies on a country's innovation commitment are still possible.

National innovation systems in developing countries commonly suffer from a number of micro- and macro-level problems, impeding a successful innovation environment in this region. As Intarakumnerd et al. (2002) stated, while the concept of national innovation system (NIS) is in its early stages generally, it lags even more in developing countries. They argued that innovation is a fashionable word in Thai policy making, and yet they have no well-defined innovation policy at the national level. Little consumer-producer interaction, low technological spillover from MNCs (unlike Singapore), a poor industry-university relationship, and a weak nexus between public research organizations and firms are some of the problems the Thai innovation system faces. The study of Alcorta and Peres (1998) on the Latin American and Caribbean NISs reveals that research institutes in this region do not function optimally, and that the research-business nexus is very poor, the effectiveness of public policies is in question. Dahlman (2007) stated that the NISs in South Asia are filled with many problems.

The NIS approach advocates systematic connections among different *organizations*, which are governed by *institutions* in a systematic way. Developing countries perform poorly on both fronts. They do have insufficient *organizational* inputs, and their political and social systems do not allow their *institutions* to optimally develop to have sound NISs.

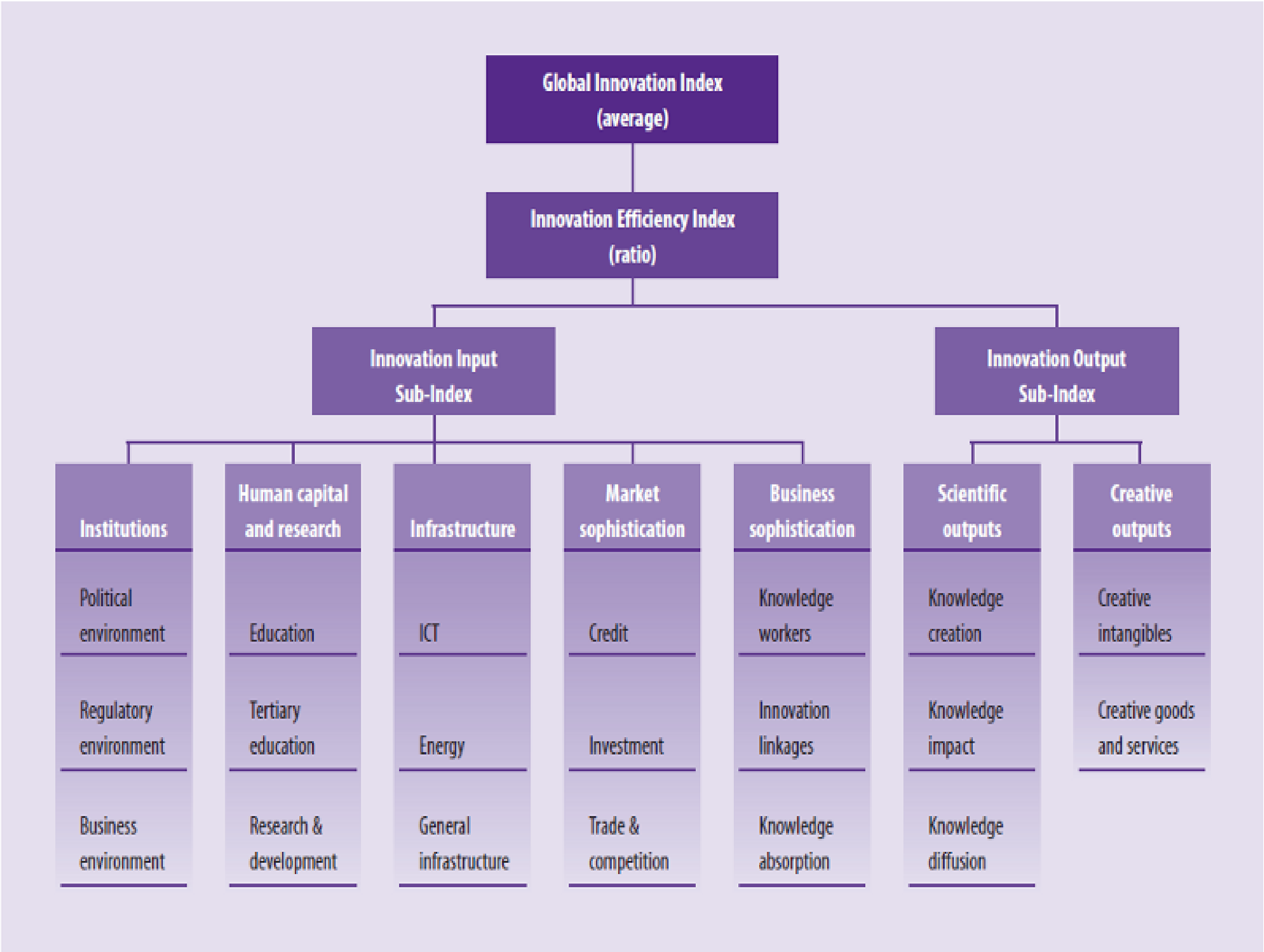
Although the NIS is an important concept to understand the innovation capabilities of a country, a clear-cut quantitative index does not yet exist to capture this notion empirically, and to compare countries' performances in terms of this particular aspect. Liu and White (2001) argued that while studying innovation systems, researchers commonly focus on particular factors in specific contexts, although all players of a system should not be considered as single entities, but should be observed systematically to assess the performance of a system (Carlsson et al., 2002). Analyzing the performance of different actors as singular entities would have a different scope than an analysis of these actors as components of a system. In a system, one particular actor could complement or substitute other actor(s), and it would be difficult to capture every minute detail in a single quantitative measure. Different countries have different *organizational* structures and different *institutional* frameworks which connect these *organizations*. Hence, a contentious issue is the question how can we device a single index which captures these differences at a national innovation policy level.

The study of Furman et al. (2002) tried to capture the innovation system concept by using proxies for innovation (patent and R&D), quality of innovation infrastructure, and quality of linkages. They did not provide an indicator to analyze innovation systems on a national level, and to empirically compare the NISs of different countries. Fagerberg and Srholec (2008) also calculated a measure of innovation system, but their measure lacked a lot of important information due to data unavailability and the construction mechanism. Their primary objective was not to construct an NIS measure, but they selected a set of variables and conducted a factor analysis to reduce the complexities attributable to the large number of indicators related to patents, scientific articles, internet penetration, etc. They constructed four major variables (factors) from these indicators; one of them is the "innovation system", as they call it. Although they attempted to measure innovation systems, their measure did not address the peculiarities and sophistications of the theoretical foundation of NIS. In a nutshell, to our knowledge, no systematic study at large scale is hitherto available which solely focuses on the construction of an index to empirically measure national innovation system.

## 2.4 The Global Innovation Index (GII) across Developing and Developed Countries

So far we have discussed innovation capacities across developing and developed countries in terms of a number of particular and aggregate indicators. Although these are informative quantitative indicators per se, they focus on innovation efforts of a country in specific directions. However, innovation capacity should not be confined to these particular definitions, and should be thought of in a broader context (INSEAD, 2011). Note that the first indicator was related to the number of scientific articles, while the second measured R&D spending across different regions. These two indicators help us to understand innovation capabilities across different regions, but only in terms of these specific concepts. We subsequently discussed countries' performances on a more aggregate level as quantitative measures which proxy technological capabilities, such as the ArCo which is a more general indicator, but lacks information compared to the Global Innovation Index (GII). More specifically, the ArCo focuses on technology and human skill related indicators (see subsection (2.3.1) and Archibugi and Coco, 2004). The GII adds depth to the ArCo and also comprises a large range of quantitative indicators to gauge institutional strengths and market and business sophistication (see below). Therefore, we postulate that the GII allows researchers to investigate the innovation environment of a country in a broader context than the ArCo.

**Figure 2.1 Framework of the Global Innovation Index (GII) 2011**




Source: This figure is Figure (1) of the chapter (1) of the Global Innovation Index 2011 report of INSEAD

To find an innovation index, we consider the Global Innovation Index 2011 (GII 2011) constructed by the European Institute of Business Administration (INSEAD) in 2011. As shown in Figure (1.1), the GII 2011 combines institutions, human capital and research, infrastructure, market and business sophistication, as well as scientific and creative output which are called pillars, as they name them. These pillars consist of corresponding sub-indicators, which are gauged through different quantitative measures. For example, the institutional pillar is a combined measure of the political, regulatory, and business environment. The political environment is measured by "political stability", "government effectiveness", and "press freedom" indices. The regulatory environment is assessed by "regulatory quality", "rules of law", and "rigidity of employment" indices. And the indicators used to rate the business environment are (1) time to start a business, (2) cost of starting a business, and (3) total tax rate. The human capital and research pillar is obtained by assessing a country's education- and R&D-related indicators.[10]

The GII 2011 scores and corresponding ranks across countries are listed in Table (2.5). Of 120 countries, the top ranked country, with a score of 63.82, is Switzerland, followed by Sweden with a GII 2011 score of 62.12. Six out of the top ten countries are European. The USA is ranked seventh with a score of 56.57, while Canada is on rank eighth. The third and fourth ranks of Singapore and Hong Kong, with respective scores of 59.64 and 58.8 are particularly noteworthy.

The previously witnessed differences between developing and developed countries are reaffirmed: most of the developed countries' rank considerably above the developing countries. The difference between the GII 2011 scores of top (mentioned above) and lowest ranked country (Burkina Faso, a Sub-Saharan African country) is large, namely 40.68.

[10] Further details of these pillars and their sub-indicators, including measurement proxies, can be found in INSEAD (2011).

**Table 2.5 Distribution of countries with respect to Global Innovation Index (GII) 2011**

| Rank | Country | Score | Rank | Country | Score |
|---|---|---|---|---|---|
| 1 | Switzerland | 63.82 | 57 | Oman | 35.51 |
| 2 | Sweden | 62.12 | 58 | Argentina | 35.36 |
| 3 | Singapore | 59.64 | 59 | South Africa | 35.22 |
| 4 | Hong Kong | 58.8 | 60 | Ukraine | 35.01 |
| 5 | Finland | 57.5 | 61 | Guyana | 34.83 |
| 6 | Denmark | 56.96 | 62 | India | 34.52 |
| 7 | USA | 56.57 | 63 | Greece | 34.18 |
| 8 | Canada | 56.33 | 64 | Uruguay | 34.18 |
| 9 | Netherlands | 56.31 | 65 | Turkey | 34.11 |
| 10 | UK | 55.96 | 66 | Tunisia | 33.89 |
| 11 | Iceland | 55.1 | 67 | Macedonia | 33.47 |
| 12 | Germany | 54.89 | 68 | Mongolia | 33.4 |
| 13 | Ireland | 54.1 | 69 | Armenia | 33 |
| 14 | Israel | 54.03 | 70 | Ghana | 32.48 |
| 15 | New Zealand | 53.79 | 71 | Colombia | 32.32 |
| 16 | South Korea | 53.68 | 72 | Trinidad and Tobago | 32.17 |
| 17 | Luxembourg | 52.65 | 73 | Georgia | 31.87 |
| 18 | Norway | 52.6 | 74 | Paraguay | 31.17 |
| 19 | Austria | 50.75 | 75 | Brunei Darussalam | 30.93 |
| 20 | Japan | 50.32 | 76 | Bosnia and Herzegovina | 30.84 |
| 21 | Australia | 49.85 | 77 | Panama | 30.77 |
| 22 | France | 49.25 | 78 | Namibia | 30.74 |
| 23 | Estonia | 49.18 | 79 | Botswana | 30.51 |
| 24 | Belgium | 49.05 | 80 | Albania | 30.45 |
| 25 | Hungary | 48.12 | 81 | Mexico | 30.45 |
| 26 | Qatar | 47.74 | 82 | Sri Lanka | 30.36 |
| 27 | Czech Republic | 47.3 | 83 | Peru | 30.34 |
| 28 | Cyprus | 46.45 | 84 | Kazakhstan | 30.32 |
| 29 | China | 46.43 | 85 | Kyrgyzstan | 29.79 |
| 30 | Slovenia | 45.07 | 86 | Guatemala | 29.33 |
| 31 | Malaysia | 44.05 | 87 | Egypt | 29.21 |
| 32 | Spain | 43.81 | 88 | Azerbaijan | 29.17 |
| 33 | Portugal | 42.4 | 89 | Kenya | 29.15 |
| 34 | UAE | 41.99 | 90 | El Salvador | 29.14 |
| 35 | Italy | 40.69 | 91 | Philippines | 28.98 |
| 36 | Latvia | 39.8 | 92 | Jamaica | 28.88 |
| 37 | Slovakia | 39.05 | 93 | Ecuador | 28.75 |
| 38 | Chile | 38.84 | 94 | Morocco | 28.73 |
| 39 | Moldova | 38.66 | 95 | Iran | 28.41 |
| 40 | Lithuania | 38.49 | 96 | Nigeria | 28.15 |
| 41 | Jordan | 38.43 | 97 | Bangladesh | 28.05 |
| 42 | Bulgaria | 38.42 | 98 | Honduras | 27.81 |
| 43 | Poland | 38.02 | 99 | Indonesia | 27.78 |
| 44 | Croatia | 37.98 | 100 | Senegal | 27.56 |
| 45 | Costa Rica | 37.91 | 101 | Swaziland | 27.52 |
| 46 | Bahrain | 37.8 | 102 | Venezuela | 27.41 |
| 47 | Brazil | 37.75 | 103 | Cameroon | 26.95 |
| 48 | Thailand | 37.63 | 104 | Tanzania | 26.88 |
| 49 | Lebanon | 37.11 | 105 | Pakistan | 26.75 |
| 50 | Romania | 36.83 | 106 | Uganda | 26.37 |
| 51 | Viet Nam | 36.71 | 107 | Mali | 26.35 |
| 52 | Kuwait | 36.64 | 108 | Malawi | 25.96 |
| 53 | Mauritius | 36.47 | 109 | Rwanda | 25.86 |
| 54 | Saudi Arabia | 36.44 | 110 | Nicaragua | 25.78 |
| 55 | Serbia | 36.31 | 111 | Cambodia | 25.46 |
| 56 | Russia | 35.85 | 112 | Bolivia | 25.44 |

(continued next page)

**Table 2.5 (continued)**

| Rank | Country | Score | Rank | Country | Score |
|---|---|---|---|---|---|
| 113 | Madagascar | 25.41 | 120 | Burkina Faso | 23.14 |
| 114 | Zambia | 25.27 | 121 | Ethiopia | 22.88 |
| 115 | Syria | 24.82 | 122 | Niger | 21.41 |
| 116 | Tajikistan | 24.5 | 123 | Yemen | 20.72 |
| 117 | Côte d'Ivoire | 24.08 | 124 | Sudan | 20.36 |
| 118 | Benin | 23.81 | 125 | Algeria | 19.79 |
| 119 | Zimbabwe | 23.54 | | | |

Source: INSEAD, 2011

Table (A2.10) shows the ranks of the Latin American and South Asian countries which are used in our empirical analyses in chapters (3)-(5). The comparison shows that most Latin American countries perform better than their South Asian counterparts (note that the analyses of the next three chapters do not include Brazil and India). The highest GII 2011 rank is held by Chile (with a GII 2011 score of 38.84), while Argentina ranks second with a GII 2011 score of 35.36, deviating from its first rank according to the ArCo measure, but similar to its second rank by global share of scientific publications (Tables (A2.8) and (A2.9)). The lowest rank in Latin America (as well as in both regions) is held by Bolivia, which ranked 112th. In South Asia Bangladesh ranked 97th, while Pakistan's rank is 105th. Hence, the dominance of Latin America in terms of technological capability (as measured by the ArCo) is not confirmed by the Global Innovation Index, or the scientific publications measure. (Recall that many Latin American countries produce lower shares of the world's scientific publications than the South Asian countries in Table A2.8). Focusing on the countries analyzed in chapters (3)-(5), the general impression is that the Latin American region is technologically more advanced than South Asia.

## 2.5 Conclusions

The role of technology in economic development has been studied extensively by economic historians and growth economists. The problem of quantifying technology was resolved to some extent by using research and development (R&D) measures. Further evolution led to the advent of innovation surveys through which innovation studies based on more sophisticated methods were possible. However, the contribution of developing countries to this evolution was not satisfactory, and the intensity of innovation studies is still very low in developing countries compared to developed ones. This thesis attempts to fill this gap by analyzing innovation determinants and innovation as a determinant of firm performance.

We argue that the low prevalence of innovation culture in developing countries is attributable to their low education levels (especially technical), to insufficient infrastructure (roads, telecommunications, and energy), to poor links between academia and industry, to name a few. The descriptive statistics of important innovation indicators (such as the scientific publications measure and R&D commitment) across developing and developed countries revealed that developed countries perform far better than the developing world. We observed that the developing world is also less well equipped with regards to technological capability and absorptive capacity. This inhibits optimal results of technological innovation efforts and knowledge enhancement. In addition, the national innovation systems in developing countries are plagued with a number of problems.

Despite sub-optimal innovation culture, developing countries can improve their innovation culture by learning innovation capabilities through hiring experts from advanced countries, by sending their local labor force abroad for training, through R&D joint ventures with developed countries, and with the help of FDI. They can also enhance their innovation skills by importing foreign technologies and subsequently learning by working with these technologies. Being accustomed to imported technologies, these countries can build up their own knowledge base and innovation capacities.

However, the success of all the above mentioned routes for technological advancement depends heavily on developing countries' commitments and honesty at an individual, societal, and institutional level. Developing a skilled labor force is not a matter of years but of decades and more. Therefore, only long term innovation policies without interrupted by bureaucratic hurdles will result in healthy innovation environments. Developing countries should have faith in their innovation commitments knowing that innovation based progress is achievable. The industrial advancements of newly industrialized Asian countries (especially South Korea and Taiwan), which gained technological success through the implementation of the above mentioned policies (with varying intensities and scopes) on a regular, long term basis have illustrated this.

# Chapter 3

## Size, Competition, and Innovative Activities: A Developing World Perspective


### Summary

The impact of firm size and product market competition on firm-level innovative activities have received considerable attention in developed countries, but the still lack focus in the developing world. This chapter is an attempt to contribute to this direction by including 14 Latin American countries using Enterprise Survey data of the World Bank. We considered both input and output innovation to analyze the influence of firm size and market concentration on innovative activities. We also investigated the differences between the impact of innovation determinants in different size classes and in different competition environments.

Our analysis reveals that firm size (employment) increases the likelihood of R&D and product innovation, and influence R&D expenditure positively but at a less than proportionate rate. We found that product market competition increases the probability of both positive R&D decisions and innovation output, but has no influence on R&D intensity. We found no relationship between R&D expenditure per employee and product innovation. Country and industry differences also contribute substantially to firm-level R&D activities and product innovation. Large or small firms do not tend to be advantageous for employment and competition to influence R&D activities; however, for product innovation, competition is a more significant stimulus for large firms. Our results suggest that firms' R&D productivity is independent of firm size and competition environments. The determinants of both R&D intensity and product innovation generally differ in small and large firms, more significantly so for R&D intensity. In case

of different competition environments, the difference is observed only for product innovation.

## 3.1 Introduction

Innovation is pervasive in every aspect of life, but its importance becomes more apparent when observed within the context of economic growth. It is considered an influential determinant of business growth (Rogers, 2004) and economic development (Fagerberg and Srholec, 2008). Innovative activities have been widely studied at the firm level, and a plethora of research is available investigating the factors which influence firms' decision regarding innovation (see, for example, Freitas et al., 2011; Evangelista and Mastrostefano, 2006, for developed countries; Ayyagari et al., 2007, for the developing world). Two factors contributing to innovative activities are firm size and market concentration. Whether Schumpeter's view regarding these two characteristics could be corroborated or not is still contentious. In the 1960s, scholars like Mansfield (1963), Hamberg (1964), Scherer (1965a, 1965b, 1967), and Comanor (1967), to name a few, started to investigate the so-called Schumpeter's hypothesis of industrial innovation, which can simply be explained as: (1) innovation and firm size are positively associated (and more strictly innovative activities increase more than proportionately with firm size); (2) innovation thrives in monopolistic markets.

One of the main issues of investigating these relationships is the measure of innovation[11].Researchers used R&D related measures (Lunn and Martin, 1986; Cohen et al., 1987), patents (Arvanitis, 1997), and the number of innovations (Acs and Audretsch, 1987; Pavitt et al., 1987)[12]. Broadly speaking, we can distinguish these meas-

[11] One reason for the use of different measures of innovation is the availability of the relevant information/data.

[12] A brief overview of the literature on the size-innovation and the competition-innovation relationships is discussed in Acs and Audretsch (1991a). A comprehensive review of the relationship of size and market structure with innovative activities is available in Kamien and Schwartz (1982) and, more recently, in Gilbert (2006).

ures into inputs to the innovation process and innovation outputs[13]. If we consider the stricter version of the Schumpeter's hypothesis on firm size, i.e. a more than proportionate firm size effect on innovative activities, the literature commonly championed a less than proportionate increase (Santarelli and Sterlacchini, 1990; Lee and Sung, 2005), with some strong opposite voices as well (Soete, 1979, for example). However, researchers generally seem to agree on the positive impact of the firm size on both innovation input and output. For innovation output, nevertheless, we can also find a negative firm size effect (Hansen, 1992; Stock et al., 2002). Regarding competition, the most-established phenomenon – for both input and output innovation – is the inverted-U relationship, implying that neither monopoly nor perfect competition is conducive to innovative activities, but the suitable market structure is the moderately competitive market (Scherer, 1967; Aghion et al., 2005).

One common parameter of the outcomes stated above is their provenance from the studies on developed countries. So far a minuscule amount of research has been carried out with particular reference to developing countries.[14] This chapter is an attempt to step forward to this direction, and to investigate potential differences of the effects of firm size and market concentration on innovation, when input and output proxies are considered. We compared the findings of studies of developing countries – particularly of Latin America – directly with those that are well-established from research on developed countries. The motivation is to observe whether any differences at the input and output stages of innovative activities exist, both within our dataset and for our data compared with developed countries' outcomes. Developing countries tend to have a less formalized R&D structure, a less knowledgeable workforce, and greater bureaucratic hurdles. These

[13] Patents are sometimes avoided as an output measure and are criticized for the following reasons: (1) Not all inventions are patented; (2) Not all Patents can be commercialized; (3) Industrial differences exist in patenting (some technologies have higher propensities to be patented than others).

[14] Possible reasons may be the non-availability of data and carelessness at institutional and individual levels to fully understand the need for innovation for productivity gains at a micro level and for economic growth at a macro level.

shortcomings inhibit optimal results of firms' R&D activities in these countries. We try to capture this phenomenon empirically by investigating the role of R&D as a determinant of product innovation. It might be the case that one particular firm size (large or small) is more conducive to some determinants to induce innovation activities (R&D and product innovation). Performance differences of innovation determinants may also emerge for different competition environments. Therefore, following Acs and Audretsch (1987, 1988), we analyzed whether the influences of determinants of innovation (input and output) differ in small and large firms, and extended this comparison for different competition environments. To our knowledge, size-innovation and competition-innovation studies have hardly been done for such a large number of countries. Our analysis includes 14 countries[15], which also gives us the opportunity to inquire whether country-specific factors contribute to input and output innovative activities, and how this contribution is affected by firm size and competition environment.

Our results regarding the size-innovation relationship are consistent with the outcomes that had been observed in developed countries. We observed that employment increases the likelihood of R&D performance and product innovation, and increases R&D intensity at a less than proportionate rate. Regarding competition, we refuted the Schumpeter hypothesis (and also found no indication of an inverted-U relationship), because our analysis reveals that product market competition increases the likelihood of both positive R&D decisions and product innovation, and we found no relationship between competition and R&D intensity. Our analysis produces a statistically insignificant coefficient of the relationship between product innovation and R&D expenditure per employee, interestingly suggesting that firms do not rely on their R&D activities to produce product innovation. We found country-and industry-specific characteristics to be significant for both input and output innovation. We noticed that the effects of headcount and competition on positive R&D decisions and expendi-

[15] Details will be in section (3.3).

ture do not differ significantly between small and large firms. The effect of large-and small-firm employment as a determinant of product innovation does not differ either; however, competition is a more important stimulus of product innovation for large firms than it is for small units.

The remainder of this chapter is organized as follows. Section (2) provides a short overview of studies analyzing the relationships of innovative activities and their potential determinants. The Enterprise Survey and summary statistics are discussed in section (3), and section (4) sets out the methodology and discusses the empirical results. Section (5) concludes the chapter.

## 3.2 Firm Size, Competition, and other Control Variables as Determinants of Innovative Activities

### *3.2.1 Firm Size and Innovative Activities*

The size-innovation relationship has been investigated to determine whether the Schumpeterian hypothesized advantage of large firms exists. The advantage of economies of scale in R&D activities is perhaps the most striking argument in favor of large-sized firms. Large research departments can provide an environment to engage with more colleagues, facilitate division of labor according to expertise and, as a consequence, improve the individual's productive performance. Large-sized firms have more opportunities to diversify their R&D activities to increase the probability of beneficial results (Kamien and Schwartz, 1982). It is further claimed that large firms have substantial funds to invest in innovation-related activities as well as opportunities to access to a wider range of knowledge. In large firms, R&D activities may be more productive due to the complementarities with non-manufacturing processes. Contrary arguments can also be found in the size-innovation association literature. Bureaucratic hurdles created by the innovation-hostile culture of the red tape are considered to be one of the drawbacks of large-sized firms. The rewards of innovative activities are less likely to reach the individuals responsible in large firms. Hence the motivation of these individuals may be lower in large firms than in small ones. Holmstrom (1989) argued that to protect their reputation, large firms are too risk-averse to embark on innovative activities, but that this concern is less pronounced in small firms. Audretsch and Vivarelli (1996) asserted that small firms are more capable of harvesting the benefits of R&D spillovers from outside the firm, in particular from universities.

On empirical grounds, the size-innovation relationship studies focus on the linear as well as non-linear (if possible) impact of firm size on innovative activities. In case of a non-linear increase, most studies advocate a less than proportionate increase (for example, Santarelli and Sterlacchini, 1990; Lee and Sung, 2005). We can also find strong voices in favor of a more than proportionate increase (for example, Soete, 1979). Generally there seems to be consent that firm size and innovative activities have a positive association. The studies rely on both input and output measures of innovation. Looking at innovation input, Hamberg (1964) analyzed large US firms on the fortune 500 index, and found a positive and significant correlation (.69) between R&D employment and employment, and a positive and significant correlation (.55) between R&D employment and assets. The general conclusion of Scherer (1965a) was that R&D employment increases with firm size up to a threshold of $500 million, and declining tendency sat in afterwards. He observed virtually the same findings for different industries, except chemicals, which showed an increasing R&D tendency regardless of sales volume. Bound et al. (1984) observed that the slope of the regression equation of the logarithm of R&D on the logarithm of sales is close to unity, implying a positive relationship between R&D activities and firm size. They went onto analyze non-linear relationships and concluded that both small and large firms are more R&D intensive than medium-sized firms.

Looking at developing countries, Kumar and Saqib (1996) concluded that the likelihood of R&D activities has an inverted-U relationship with firm size; however, R&D intensity and firm size have a linear, positive relationship. In the particular Latin American context, Braga and Willmore (1991) showed that Brazilian firms' size (measured by the average value-added of the firm for the fiscal year 1978-80) increases the odds of R&D activities, but that the effect is rather small, although significant. For Chile, Benavente (2006) concluded that firm size is a significant and positive determinant of the probability to engage in R&D activities; he did not find any link between firm size and the amount of R&D expenditure relative to employees.

Focusing on output measures, Scherer (1965b) concluded that patented inventions increase with firm sales at a less than proportionate rate. Santarelli and Sterlacchini (1990) came to the conclusion that innovation activities increase with firm size, albeit less than proportionally. Henderson and Cockburn (1996) showed empirically that large firms are better placed to produce patent outputs in the pharmaceutical industry. According to Acs and Audretsch (1987) large firms have an innovative advantage in capital-intensive and/or advertising-intensive industries and concentrated markets, whereas small firms are in an advantageous position in industries where a high share of skilled labor is required and which have a relatively high proportion of large firms. Some studies found innovation output is negatively related to firm size (Hansen, 1992; Stock et al., 2002), and it is also argued that R&D productivity decreases with firm size (Acs and Audretsch, 1991b). Looking at developing economies, the literature generally describes a positive relationship between firm size and innovation output (see, for example, de Mel et al., 2009, for Sri Lankan firms; Benavente, 2006, for a Latin American context, particularly Chilean firms).

### *3.2.2 Competition and Innovative Activities*

There is an ongoing debate whether innovation thrives in monopolies or not, and we can find both favorable and unfavorable accounts. A firm realizing extraordinary profits by exploiting a monopoly is in a better position to finance research internally to protect itself against the disclosure of its technological secrets, thereby hire more R&D personnel and strengthen its R&D department. It has also been argued that the introduction of a new product to the market, patents, and trademarks give firms an advantage over their rivals by creating a temporary monopoly. A monopolistic firm's reaction against innovation by a new entrant is nimble, and it endeavors to control the market again by improving its old product or by introducing new products. Although the industrial organization literature provides arguments in favor of increased market concentration, we can also find the opposite. If a monopolistic firm earns enough profits (especially through innovation), it may develop a sluggish attitude towards innovation, and may not be as eager to promote innovation as new entrants. This sluggishness decreases the chances of technological development especially if the monopolist firm is able to establish non-technological entry barriers (such as advertisement and capital, for example) to retain the status quo. If this situation persists the market will stagnate in a low technology equilibrium.

Similar to the size-innovation relationship, the impact of monopoly power on innovation has been studied empirically with the help of both input and output indicators. Analyzing innovation input Scherer (1967) found a positive relationship between innovative activities (measured by employment of scientists and engineers) and market power up to a concentration ratio of almost 55%, but he witnessed disadvantages of market power beyond this threshold, implying an inverted-U relationship. Levin et al. (1985) cast serious doubts on the notion that market concentration increases innovative inputs, after observing an inverted-U relationship between R&D intensity and a four-firm concentration ratio; however, this relationship became insignificant when they included other variables related to technological opportunity. Hamberg (1964) found a weak positive correlation between R&D and market concentration. Subodh (2002) concluded that market concentration has no influence on the decision to perform R&D and on R&D intensity in the pharmaceutical and electronics industries in India. Looking at output measures Acs and Audretsch (1988) used a more direct measure of innovative activity obtained from the data gathered by the U.S. Small Business Administration, and concluded that the number of innovations in 1982 decreased with the four-firm concentration ratio. However, Blundell et al. (1999) asserted that the number of innovations successfully commercialized by British firms between 1945 and 1983 (SPRU dataset from the Science and Technology Policy Research centre) are positively associated with competition. Tang (2006) found a positive relationship between competition and innovation. Similar to the findings of studies focusing on innovative inputs, an inverted-U relationship is found to be the general pattern between market competition and innovative outputs (Aghion et al., 2005 for example).

### *3.2.3 Other Control Variables*

To analyze firm size-innovation and competition-innovation relationships in more detail, and to obtain more robust results, we included several control variables in our regressions. The control variables used are export intensity, import intensity, foreign ownership (i.e. foreign owners owning more than 10% of the company's shares), the age of the firm, the share of unionized and skilled workers of the workforce, and the average education level of production workers.

The impact of a firm's trade orientation on its innovative performance has frequently been studied in the context of innovation determinants. Pla-Barber and Alegre (2007) found a positive relationship between innovation outcomes and export intensity for the French biotechnology industry. For developing countries, export is often considered conducive to innovative activities (Braga and Willmore, 1991; Subodh, 2002). Seker (2009) studied 43 developing countries and showed that firms' trade (both imports and exports) has a substantial effect on their innovativeness. using the Community Innovation Survey of five European countries Dachs et al. (2008) found that foreign ownership does not have a positive influence on the firm's decision to undertake innovation activities. They observed a negative relationship for two of these five countries, namely Austria and Norway. They were also unable to find a relationship between foreign ownership and innovation expenditure, except for Norway where they found a negative relationship. They found that foreign ownership increases firms' innovation output, except in the case of Austria. In developing countries (such as Brazil), Braga and Willmore (1991) showed a positive influence of (more than 10% of) foreign ownership on five different input and output innovation activities; however, the relationship was insignificant for R&D expenditure. Using a National Science Foundation (NSF) dataset Hansen (1992) revealed that firm age is inversely related to innovation, whereas Radas and Božić (2009) demonstrated that it has no influence on both product and process innovation of the Croatian firms. Leiponen (2005) asserted that a highly educated workforce has a significant positive impact on its innovative activities. Radas and Božić (2009) found a positive relationship between employees' education levels and radical product innovation; however, they were unable to find any relationship between education and process innovation. Acs and Audretsch (1988) found that innovation is negatively related to unionization, and that the relationship between skilled labor and innovation is positive.

## 3.3 Dataset Description and Summary Statistics

The dataset used in this chapter and in two subsequent chapters has been obtained from the Enterprise Survey (Investment Climate Survey) conducted by the World Bank. Before describing the summary statistics and empirical analysis, we discuss characteristics of this survey in particular and innovation surveys on developing countries in general in the following subsection.

### *3.3.1 Enterprise Surveys on Developing Countries*

The Enterprise Survey (ES) is the outcome of the World Bank's efforts to understand the business environment of the country and the obstacles hindering the firm performance.[16] Firm-level surveys on developing countries are not conducted extensively by their individual departments. Therefore, the ES provides us with the mechanism to understand the business conditions of these countries. Innovation sur-

[16] More detailed information on the Enterprise Survey can be found at http://www.enterprisesurveys.org.

veys on developing countries are even rarer and the ES is a remarkable source to fill this gap. This survey is also known as the Investment Climate Survey. To have a representative sample, the survey is conducted using the stratified random sampling based on three criteria: size, geographical location of the firm, and industrial sector (primarily classified on two-digits). The data is collected for both manufacturing and service sector, but our analysis in this thesis is restricted only to the former. In addition to have questions on the innovation characteristics of the firm, the ES includes many questions regarding firms' other characteristics such as trade orientation, employment, sales volume, product market competition, etc., which are far larger than the usual national innovation surveys. This richness of the survey allows researchers to investigate the innovation characteristics of the firm in a broader context.

One of the criticisms on the survey-based studies is the subjectivity of the respondents. In addition, the reader should understand what innovation in developing countries is perceived by the firms. Developing countries are usually not radical innovators, but the firm (and more specifically the interviewee) perceives an incremental change or even an imitation as an innovation. This perception may lead to the higher percentages of innovators in developing countries as compared to developed ones (Crespi and Zuniga, 2012). Almost all studies on developing countries share these limitations. Since our empirical analysis is based on the survey on developing countries, this study is also not an exception. But for that particular country it is still an innovation, and the reader should be aware of the concept of innovation perceived in developing countries, for interpreting and understanding our empirical findings.

As mentioned earlier, our empirical analysis in chapters (3)-(5) is based on fourteen Latin American and two South Asian countries. Despite having national innovation surveys on many Latin American countries, in addition to aforementioned advantages we used the ES for the following reasons. The ES is administered by using homogenous questionnaire on these fourteen countries. This homogeneity (of questionnaire) precludes us to combine rather different questions, sometimes may be in different context, to acquire identical information. This mismatch may lead to wrong or at least not precise information. Secondly, since we work on fourteen countries, it is very hard to acquire dataset for all these countries. For South Asian countries (Bangladesh and Pakistan), the ES is the only available survey with information of innovation administered at the national level.

### *3.3.2 Summary Statistics*

In this chapter we focused on manufacturing companies of fourteen Latin American countries[17] over eight two-digit (ISIC Rev. 3.1) industrial sectors[18]. The survey data needed to be cleaned from missing observations, outliers, and non-responses, after which we were left with the data of 6917 firms. The largest fraction was Mexican firms (16.78%), while Panama contributed the smallest share with a representation of only 0.03%. All pecuniary information in the survey was gathered in local currency. To achieve homogeneity, we converted these into USD using the corresponding annual average exchange rates. All monetary variables were measured for the fiscal year preceding the survey. Therefore, 2005 exchanged were used to calculate the exchange rates since the survey was conducted in 2006. We used both input and output measures of firms' innovative activities. Besides R&D-related activities, the survey includes information on whether a firm is a product innovator or not, which is extracted from the following question:

> *During the last three years, did this establishment introduce into the market any new or significantly improved products?*

Table (3.1) and (3.2) report the descriptive statistics of R&D activities and product innovation, for countries and industries respectively. According to Table (3.1), Bolivian firms are the most often product innovators with a value of 75.75%, followed by Argentina with a

[17] See Table (3.1) for country details.
[18] See Table (3.2) for industry details.

slightly lower proportion (75.27%); Mexico came last with 34.58% of firms reporting to be product innovators. With regards to R&D, Argentina is in first place with 49.77% of firms engaged in R&D activities, followed by Ecuador with a share of 49.30%. Again, Mexico has the lowest percentage of R&D performing companies. We also analyzed the average R&D expenditure for R&D performing firms to get more a rigorous picture of R&D activities in different countries. The statistics reveals that, among R&D performers, Colombian firms spend the highest annual average R&D amount with $142,980, and Paraguay ranked lowest with an amount of $24,510. According to the descriptive statistics presented in Table (3.1), both innovation input and output show considerable difference across countries. These

**Table 3.1 Cross country distribution of product innovation and R&D activities**

| Country | Product Innovation | | R&D | | |
|---|---|---|---|---|---|
| | No. of firms (reported Y/N) | % of innovators | No. of firms (reported Y/N) | % of R&D[a] performers | Av. R&D[b] Exp.(in $1000) |
| Argentina | 651 | 75.27 | 649 | 49.77 | 142.98 |
| Bolivia | 367 | 75.75 | 364 | 43.96 | 20.80 |
| Chile | 638 | 69.59 | 637 | 33.44 | 190.41 |
| Colombia | 632 | 68.99 | 631 | 44.37 | 200.79 |
| Ecuador | 359 | 73.82 | 359 | 49.30 | 66.37 |
| El Salvador | 433 | 65.36 | 430 | 33.49 | 30.28 |
| Guatemala | 312 | 67.95 | 311 | 34.41 | 39.84 |
| Honduras | 258 | 63.57 | 256 | 24.22 | 45.13 |
| Mexico | 1119 | 34.58 | 1107 | 20.23 | 119.24 |
| Nicaragua | 349 | 52.15 | 349 | 25.79 | 26.25 |
| Panama | 238 | 56.30 | 236 | 30.08 | 69.82 |
| Paraguay | 378 | 68.25 | 377 | 35.81 | 24.51 |
| Peru | 360 | 77.78 | 358 | 48.60 | 63.96 |
| Uruguay | 361 | 67.59 | 361 | 35.46 | 89.66 |
| Total | 6455 | 62.85 | 6425 | 35.61 | 101.39 |

[a] R&D performers are those firms which spend any amount on R&D activities within and/or outside the establishment during the fiscal year 2005.

[b] To calculate average annual R&D expenditure, those firms that reported at least 1 USD on R&D expenditure are included.

differences are consistent with the findings of Crespi and Zuniga (2012): they studied six Latin American countries (five of these are also included in our study; the only exception is Costa Rica). Regarding innovation activities across industries, Table (3.2) shows that the chemical industry achieves the highest share of product innovators and of R&D performers with 72.77% and 53.87% respectively, whereas the electronics industry is the least innovative industry with a share of 37.50% of product innovators and 18.75% of R&D performers[19]. Similar to the differences found between countries, disparities exist (attributable to the technological opportunities) across industries. We will investigate the inter-country and inter-industry differences more rigorously by including dummies for them in the regression analysis in the subsequent section.

**Table 3.2 Cross industry distribution of product innovation and R&D activities**

| Industry | Product Innovation | | R&D | | |
|---|---|---|---|---|---|
| | No of firms (reported Y/N) | % of Innovators | No. of firms (reported Y/N) | % of R&D[a] Performers | Av. R&D[b] Exp.(in $1000) (R&D performers only) |
| Food | 1635 | 62.14 | 1625 | 39.01 | 108.47 |
| Chemicals | 1021 | 72.77 | 1019 | 53.87 | 85.80 |
| Garments | 1122 | 63.28 | 1115 | 26.66 | 198.15 |
| Non-Metallic Minerals | 319 | 43.89 | 319 | 22.88 | 33.83 |
| Machinery and Equipment | 416 | 59.38 | 415 | 36.39 | 117.23 |
| Textiles | 674 | 59.94 | 668 | 32.33 | 28.32 |
| Electronics | 80 | 37.50 | 80 | 18.75 | 22.47 |
| Other Manufacturing | 1188 | 64.56 | 1184 | 29.81 | 81.9 |
| Total | 6455 | 62.85 | 6425 | 35.61 | 101.39 |

[a,b] same as Table (3.1)

Table (3.3) shows the summary statistics of product innovation and R&D activities by firm size and product market competition. It should be emphasized that we did not use traditional measures such as concentration ratio and Lerner index to measure market competition, but followed Tang (2006) and used firms' perception of market com-

[19] Since electronics is a high-tech industry by definition, these low percentages, especially for R&D, are somewhat surprising. One possible reason could be that we have a limited number of observations (approximately 1.25% of the total sample) for this sector to assess R&D and product innovation. If we had more data, the results might be different.

petition[20]. We observed innovative activities at firm level, so a firm's innovation efforts could be explained more precisely by measures directly related to a firm instead of its industry as a whole. We considered firms with more than 200 employees as large firms.[21] Table (3.3) reveals that large firms are more often product innovators than small firms. In terms of annual average R&D expenditure (for R&D performers only), large firms on average spend $434,790, which is significantly higher than the expenditure of small-sized establishments with an average of$35,020. This large difference between large and small firms illustrates the fact that large firms spend relatively large amounts on R&D activities. Large firms are also 19.55% more likely to be product innovators than small ones, and the difference is 34.24% for R&D performance. These findings conform with the notion established for developed countries: R&D as a proxy of innovation efforts underestimates the efforts of small firms (Archibugi et al., 1995), and we believe this effect to be more severe for developing countries because of less formalized R&D structures in these countries, especially

[20] Firms were asked for the number of competitors they face in their main market. See Table (3.4) for descriptions of the competition-related dummy variables we use in this chapter.

[21] Until now, no clear-cut threshold has been defined to mark the distinction between small and large firms, and most of the size-innovation relationship studies relied on arbitrary size classifications. We adopted a singular threshold of 200 employees per firm for all countries in our data set. Another possibility is to use a variable threshold for each country; we also tried this and determined the size classification as follows. We calculated that the size of 200 employees (our singular threshold) is at the 90.5$^{th}$ percentile for the whole sample. We applied the threshold of the 90.5$^{th}$ percentile to each country and found different employment values to denote small and large firms for different countries (see Table (A3.1) in appendix A3). The reason why we prefer the singular threshold is our understanding that it is not justified to pool a firm of a country with a very low threshold, for example, 90 employees in case of Nicaragua, with a firm of a country with a very high threshold, say, 340 employees for Argentina, and group them as large firms. It could be argued that a variable threshold is a plausible choice because each country has a different industrial structure, which may affect firm size towards one size or the other. This is a valid argument in its own right, but it does not mean that the behavior of a firm with, say, 400 employees in a pro-small firm country differs from a firm of the same size in a pro-large firm country despite countries' specific industrial structure. In a nutshell, it is hard to define an appropriate threshold; however, based on the argument set out above we used a singular threshold.

in small units. Firm facing medium competition environment (between 2 and 5 competitors) present the biggest share of product innovators, followed by firms facing high competition environment (more than 5 competitors). In monopolies and duopolies, the shares of innovators are below than those prevalent in medium and high competition environments. The share of innovators in monopolies and duopolies is similar, but marginally lower in duopolies. Medium competition environments produce the highest proportion of R&D performers, followed by high competition environments, while monopolies produce the lowest share of R&D activists. The statistics for R&D expenditure reveal that on average firms in highly competitive markets need to spend significantly more on R&D than those in any other competition

**Table 3.3 Percentages of product innovators and R&D performers, and average annual R&D expenditure (in $1000), for different size classifications and competition environments**

| Innovation activities | Firm size | | Competition environments | | | |
|---|---|---|---|---|---|---|
| | Small fims | Large firms | Monopoly | Duopoly | Medium competition | High competition |
| Product innovation (%) | 60.98 | 80.39 | 49.65 | 48.41 | 65.41 | 62.23 |
| R&D performers (%) | 32.55 | 66.20 | 27.56 | 28.11 | 38.81 | 32.97 |
| Av. R&D Exp.(in $1000) | 35.02 | 439.31 | 74.7 | 58.97 | 67.92 | 121.66 |

Note: To calculate average annual R&D expenditure, only R&D performing firms are considered.

environments. These descriptive statistics suggest that contrary to Schumpeter's assertion competition propels firms to carry out both R&D and product innovation. These findings are merely based on summary statistics; therefore, at this stage of the analysis, we cannot conclude with certainty. To fully comprehend these relationships, we explored these phenomena more extensively using regression analyses. The results are presented in next section.

## 3.4 Regression Analysis

Following the descriptive analysis, we analyzed the data using regressions. Table (3.4) provides the detailed information (labels and descriptions) of the variables used in our regression analysis.

**Table 3.4 Variables and their description**

| Variable | Description |
|---|---|
| LEMP | Logarithm of number of full- time employees. It includes both permanent and temporary employment. |
| LRDI | Log of Ratio of R&D expenditures to employment. |
| EXP | Ratio of export sales to total annual sales. |
| IMP | Ratio of imports in total annual purchase of material inputs and/or supplies. |
| AGE | Age of the firm in years |
| UNION | Ratio of unionized workforce to total workforce. |
| SKILL | Ratio of skilled production workers to total production workers |
| MONO | Dummy if a firm faces no competitor in the main market in which it sold its main product. |
| DUOP | Dummy if a firm faces one competitor in the main market in which it sold its main product. |
| MEDCOMP | Dummy if a firm faces between 2 to 5, inclusive, competitors in the main market in which it sold its main product. |
| HIGHCOMP | Dummy if a firm faces more than 5 competitors in the main market in which it sold its main product. |
| FOR | Dummy if the ownership of private foreign individuals and/or companies is more than 10%. |
| ASSET | Dummy if a firm purchases fixed assets (machinery, vehicles, equipment, land, or buildings). |
| EDU | Dummy if the average education of a typical production worker is 13 years and above. |
| LARGE | Dummy if a firm has more than 200 employees. |
| MODU | Dummy if product market is monopoly or duopoly. |
| PDINN | Dummy if a firm introduces into the market any new or significantly improved product. |
| RD | Dummy if a firm spends on R&D activities. |

Note: (1) Originally, all monetary variables are given in the currency units of respective countries. To achieve homogeneity, we convert them into USD using corresponding annual average exchange rates. The year 2005 is used to calculate exchange rates since the year of conduct of survey was 2006 (2) The variable Product innovation was asked for 2003-5, while Age, Union, Skill, Foreign ownership, and Education were asked to provide the information exactly at the time of conduct of survey. The rest of the variables are measured for 2005.

We have already viewed country- and industry-specific differences in Tables (3.1) and (3.2). To capture the heterogeneity attributable to these differences, we have included their respective intercepts in our regression models. The reference categories were Mexico and "other manufacturing" for countries and industries respectively. The introduction of dummies allows us to probe inter-country and inter-industry differences of R&D activities and product innovation. Our regression equations also include dummies for competition environments taking high competition environment as the reference category. In addition to that, the control variables discussed in the subsection (3.2.3) are also included to explore innovative phenomena more extensively. We use (log of) employment as a measure of firm size.

Table (3.2) shows that only 35.61% of all firms in our sample are R&D performers, implying that the R&D intensity variable is zero for the majority of firms in the sample, and we have continuous data for only 35.61% of firms. This means that the OLS regression of R&D intensity would provide misleading conclusions because it only takes firms with a positive amount of R&D expenditure into account, and ignores the majority of firms as incomplete samples. Subsequently it is unrealistic to extend the empirical finding of a selected portion of a sample to the whole population (selectivity bias). Hence, we used the Heckman selection[22] two-step procedure to avoid the erroneous conclusions attributable to a sample selection bias.

### *3.4.1 The Heckman Selection Model*

The Heckman selection model rectifies the selectivity bias by introducing two equations, which are commonly known as the selection equation and the outcome equation. Firstly, the selection equation estimates the relationship of a firm's R&D choice and its determinants by probit regression (due to the binary nature of the R&D decision variable). In the second step, the outcome equation describes the influences of the explanatory variables on R&D intensity, after incorporating the selectivity problem.

More specifically, suppose $RD_i^*$ is the unobserved utility difference between the $i^{th}$ firm's R&D and non-R&D, and x1i is a vector of determinants influencing the $i^{th}$ firm's R&D decision, then:

$$RD_i^* = x'_{1i}\beta_1 + \varepsilon_{1i} \tag{3.1}$$

[22] The other commonly used names for the Heckman selection model are tobit 2 model, sample selection model, and generalized tobit model.

All we know (i.e. 0 & 1 for R&D decision variable) follows the decision rule:

$$\begin{aligned} RD_i &= 1 \qquad\qquad if \quad RD_i^* > 0 \\ RD_i &= 0 \qquad\qquad if \quad RD_i^* \le 0 \end{aligned} \tag{3.2}$$

where $RD_i$ is (a dummy of) the R&D decision for the $i^{th}$ firm. Moreover,

$$RDI_i^* = x'_{2i}\beta_2 + \varepsilon_{2i} \tag{3.3}$$

where $RDI_i^*$ is the observed value of R&D intensity for the $i^{th}$ firm, which is a positive amount if the $i^{th}$ firm is a R&D performer, and zero otherwise, i.e.

$$\begin{aligned} RDI_i &= RDI_i^* \qquad\qquad if \quad RD_i = 1 \\ RDI_i &= 0\,(assumed) \qquad if \quad RD_i = 0 \end{aligned} \tag{3.4}$$

where $x_{2i}$ is a vector of all determinants that influence the $i^{th}$ firm's R&D intensity. Note that equations (3.1) and (3.3) also include random error terms, which jointly follow the distributional assumptions (where $\text{var}(\varepsilon_{2i}) = \sigma_2^2$, $\text{cov}(\varepsilon_{1i}, \varepsilon_{2i}) = \sigma_{12}$):

$$\begin{pmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \end{pmatrix} \overset{NID}{\sim} \left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{pmatrix} \right)$$

The Heckman selection model corrects the selectivity bias and estimates the conditional expectation of R&D intensity as:

$$E(RDI_i / RD_i = 1) = x'_{2i}\beta_2 + \sigma_{12}\lambda(x'_{2i}\beta_2) \tag{3.5}$$

Where $\lambda$, the inverse mills ratio, is obtained as $\phi(x'_{2i}\beta_2)/\Phi(x'_{2i}\beta_2)$, $\phi(.)$ and $\Phi(.)$ are the density function and the cumulative distribution function of a standard normal distribution respectively.

Recall that we considered both innovation input and output. Innovation output is presented as a binary response variable which calls for the probit model.

### 3.4.2 The Probit Model

Since the only observable information for product innovation is whether the firm innovates or not, we define the $i^{th}$ firm's unobserved utility difference of carrying out product innovation and of not carrying out it as:

$$PDINN_i^* = x_i'\beta + \varepsilon_i , \varepsilon_i \sim NID(0,1) \tag{3.6}$$

where $x_i$ is a vector of all predictors which can explain this utility difference. A firm carries out product innovation, if its utility difference exceeds a certain threshold, and we assume this threshold level is zero. Hence, the probit model can be written as:

$$\begin{aligned} PDINN_i &= 1(\textit{firm is a product innovator}) && \textit{if } PDINN_i^* > 0 \\ PDINN_i &= 0(\textit{firm is not a product innovator}) && \textit{if } PDINN_i^* \leq 0 \end{aligned} \tag{3.7}$$

### 3.4.3 Empirical Results

The results of the Heckman selection two-step procedure using LRDI as a dependent variable are depicted in Table (3.5). The variable selection for the vectors $x_{1i}$ and $x_{2i}$ is a critical aspect of the application of the Heckman selection model. One of the important assumptions of the Heckman selection model is that the vector $x_{2i}$ (the outcome equation) should exclude at least one variable of the vector $x_{1i}$ (the selection equation).[23] Our likely explanation to exclude ASSET from the outcome equation is that this variable shows the improvement of a firm's infrastructure (machinery, equipment, etc.), which is one of the basic necessities before a firm decides on R&D activities. Secondly, R&D in developing countries is not a firm's first priority, but often left until it perceives that it has sufficient infrastructure to start a R&D project successfully to ascertain optimal results. Hence, we anticipate

[23] In the literature, this is often called the exclusion restriction. This crucial restriction is also used to avoid the collinearity between the mills ratio and other explanatory variables used in the outcome equation (Wooldridge, 2009).

a positive influence of ASSET on positive R&D decisions, but it seems less likely to influence the R&D budget allocation.

**Table 3.5 Results of the Heckman selection model. Standard errors are in parentheses**

| Independent Variables/Tests | Dependent Variables | |
|---|---|---|
| | LRDI (outcome equation) | RD (selection equation) |
| Intercept | 7.462* | -2.338* |
| | (0.647) | (0.119) |
| LEMP | -0.364* | 0.304* |
| | (0.066) | (0.020) |
| MONO | 0.102 | -0.148 |
| | (0.199) | (0.099) |
| DUOP | 0.157 | -0.195† |
| | (0.201) | (0.103) |
| MEDCOMP | -0.011 | 0.055 |
| | (0.079) | (0.044) |
| EXP | 0.461† | 0.571* |
| | (0.279) | (0.151) |
| IMP | 0.279# | 0.226* |
| | (0.128) | (0.066) |
| AGE | 0.004† | 0.001 |
| | (0.002) | (0.001) |
| UNION | -0.114 | 0.072 |
| | (0.156) | (0.085) |
| SKILL | -0.060 | 0.081 |
| | (0.112) | (0.060) |
| FOR | 0.307# | 0.126 |
| | 0.124) | (0.080) |
| EDU | 0.169† | 0.206* |
| | (0.098) | (0.052) |
| ASSET | - | 0.426* |
| | | (0.044) |
| Country Dummies | yes | yes |
| Industry Dummies | yes | yes |
| Test-stat. to test | | |
| Significance of countries | 156.90* | 106.76* |
| Significance of industries | 30.51* | 116.52* |
| No. of obs. | 5102 | |
| censored obs. | 3510 | |
| $\lambda$ | -0.619#(0.265) | |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

In addition to control for selectivity problem, the Heckman selection model provides the framework to analyze the determinants of the

R&D decision (column (2) of Table (3.5)) and the influence of these determinants on the subsequent R&D expenditure (column (1) of Table (3.5)). The significance of $\lambda$ provides empirical support to the use of the Heckman selection model. Our results are in line with the well-established notion of R&D in developed countries: size has a significant, positive impact on firms' decision to perform R&D, and increases R&D expenditure but at a less than proportional rate. We find that firms' R&D expenditure per employee are not influenced by any form of product market competition (all competition-related dummies are insignificant). However, our results give the impression that competitive pressure has an influence on the firms' R&D decision (although the negative coefficient of DUOP is significant only at the 10% level, the coefficient of MONO, albeit insignificant, also has a negative sign). Hence, although we have the competition-related variables in discrete forms, our results hint the absence of an inverted-U relationship between R&D and competition, a well-established phenomenon in the developed world. Trade orientation (both exports and imports) increases both the likelihood of positive R&D decisions and the intensity of R&D expenditure, with the former being more important. Firm age has no influence on R&D decisions but has a significant, positive effect on R&D intensity, though significance is only achieved at the 10% level. Our results reveal that shares of unionized workers and skilled production workers have no influence on R&D-related variables. At first glance this could contend that skill has a positive influence on R&D activities, but the intuition on the insignificance of the coefficient is that in our dataset skill denotes production workers' professional skill level, which is quite different from the scientific and technological knowledge of workers. Of course, the advantage of professional skills is the ability to implement production processes efficiently, but it does not imply that the workforce is also sufficiently equipped with the technological expertise necessary for innovativeness. We observe that foreign ownership has no influence on firms' R&D decisions but increases R&D intensity, and that education increases the probability of and the expenditure on R&D activities; similar to trade orientation education is more vital for R&D decisions. Finally, firms that purchased fixed assets have a significantly higher likelihood to perform R&D. The Wald tests of the overall significance of the country and industry dummies show that country- and industry-specific characteristics are significant determinants to explain both types of R&D activities (R&D decisions and expenditure).

**Table 3.6 Results of the Probit regression. Standard errors (robust for column (1) and bootstrapped for column (2)) are in parentheses**

| Independent Variables/Tests | Dependent Variable: PDINN | |
|---|---|---|
| Intercept | -1.386 * | -0.271 |
| | (0.108) | (1.549) |
| LRDI | | -0.143 |
| | | (0.209) |
| LEMP | 0.234 * | 0.180 # |
| | (0.019) | (0.072) |
| EXP | 0.390 # | 0.460 # |
| | (0.175) | (0.185) |
| IMP | 0.391 * | 0.431 * |
| | (0.063) | (0.081) |
| MONO | -0.150 † | -0.137 |
| | (0.087) | (0.088) |
| DUOP | -0.315 * | -0.290 * |
| | (0.090) | (0.087) |
| MED COMP | 0.045 | 0.043 |
| | (0.041) | (0.042) |
| AGE | -0.001 | |
| | (0.001) | |
| UNION | 0.363 * | 0.347 * |
| | (0.080) | (0.083) |
| SKILL | 0.063 | |
| | (0.056) | |
| FOR | -0.016 | |
| | (0.082) | |
| EDU | 0.143 * | 0.173 * |
| | (0.051) | (0.060) |
| Country Dummies | yes | yes |
| Industry Dummies | yes | yes |
| Test -stat. to test | | |
| Significance of countries | 238.01 * | 244.39 * |
| Significance of industries | 33.67 * | 15.62 # |
| No. of obs. | 5420 | 5420 |
| McFadden $R^2$ | 0.127 | 0.127 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: For LRDI, the predicted values obtained in Table (3.5) are used.

Table (3.6) shows the results of the probit regression of product innovation. We ran two probit regressions: excluding and including LRDI as a determinant of PDINN, and the results are shown in column (1) and (2) respectively. The objective of including R&D intensity as an explanatory factor is to observe the effect of R&D on firms' innovation output. To control for the endogenous nature of R&D intensity in the PDINN equation, we used the instrumental variable for LRDI. To serve as an instrument, we used the predicted values of LRDI obtained from the Heckman selection model in Table (3.5)[24]. It is important to mention that because we used predicted values as explanatory variables, we have corrected our standard errors by bootstrapping (100 replications). Note that column (1) of Table (3.6) (PDINN equation without R&D intensity) is simply a reduced from equation for PDINN. Since we used predicted values of R&D intensity as one of the predictors in column (2), we dropped some explanatory variables in order to avoid the PDINN equation to be unidentified. Note that most of the results in column (1) and (2) are same. According to Table (3.6), firm size and product market competition increase the likelihood of product innovation. The comparison of the relationship between competition and innovation output with the relationship between competition and R&D intensity in Table (3.5) reveals that firms rely more on product innovation than the R&D expenditure, to succeed over product market competitors. The reason might be that the firms' perception of their competitors' control of the market (by competition we mean product market competition) demands a prompt response such as product innovation, which can be carried out with less R&D-intensive activities like the slight modification of an existing product or the imitation of an innovation available in developed countries. Our results reveal that R&D intensity does not influence product innovation. Similar to R&D, trade orientation (both exports and imports) increases the probability of innovation output. These findings are in line with the general concept that trade orientation induces firms to innovate. We show that firm age has no influence on the likelihood of product innovation. This means that while firms' maturity has a positive impact on their R&D intensity, it might be

[24] Note that by including the predicted values of LRDI, we are able to use substantially more observations than we could have done using the actual values of LRDI.

offset by higher innovative efforts (in the innovation output phase) of the younger firms which have to perform to withstand being driven

**Table 3.7 Results of the Heckman selection model including interaction terms of LARGE. Standard errors are in parentheses**

| Independent Variables | Dependent Variables | | | |
|---|---|---|---|---|
| | LRDI (outcome equation) | | RD (selection equation) | |
| Intercept | 7.756* | (0.708) | -2.316* | (0.130) |
| LEMP | -0.323* | (0.079) | 0.293* | (0.024) |
| MONO | 0.039 | (0.209) | -0.120 | (0.104) |
| DUOP | 0.145 | (0.215) | -0.203† | (0.109) |
| LOWCOMP | -0.045 | (0.083) | 0.058 | (0.045) |
| EXP | 0.279 | (0.306) | 0.507* | (0.160) |
| IMP | 0.232† | (0.133) | 0.233* | (0.068) |
| AGE | 0.003 | (0.002) | $4.24e^{-04}$ | (0.001) |
| UNION | 0.001 | (0.171) | 0.057 | (0.091) |
| SKILL | -0.193 | (0.119) | 0.070 | (0.063) |
| FOR | 0.171 | (0.148) | 0.164# | (0.089) |
| EDU | 0.169 | (0.106) | 0.219* | (0.055) |
| FIXED | | | 0.425* | (0.045) |
| Country Dummies | yes | | | |
| Industry Dummies | yes | | | |
| LARGE | -2.777* | (1.003) | -0.567 | (0.906) |
| LARGE × LEMP | 0.047 | (0.153) | 0.089 | (0.142) |
| LARGE × MONO | 0.331 | (0.583) | -0.495 | (0.362) |
| LARGE × DUOP | 0.488 | (0.565) | -0.060 | (0.407) |
| LARGE × LOWCOMP | 0.298 | (0.233) | 0.009 | (0.194) |
| LARGE × EXP | 1.392# | (0.702) | -0.340 | (0.543) |
| LARGE × IMP | 0.699† | (0.413) | -0.229 | (0.328) |
| LARGE × AGE | 0.004 | (0.005) | 0.002 | (0.004) |
| LARGE × UNION | -0.652 | (0.427) | -0.097 | (0.304) |
| LARGE × SKILL | 0.955* | (0.320) | 0.281 | (0.257) |
| LARGE × FOR | 0.254 | (0.275) | -0.172 | (0.223) |
| LARGE × EDU | 0.157 | (0.267) | -0.085 | (0.214) |
| LARGE × FIXED | | | 0.138 | (0.247) |
| LARGE × Country Dummies | yes | | yes | |
| LARGE × Industry Dummies | yes | | yes | |
| No. of obs. | 5102 | | | |
| censored obs. | 3510 | | | |
| $\lambda$ | -0.633#(0.276) | | | |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

out of the market by their mature rivals. Foreign ownership and workers' skill levels also have no effect on the likelihood of product innovation. As expected, education is a significant, positive determinant of firms' chances of product innovation. Our results show that the probability of product innovation increases with the share of unionized workers. Similar to R&D activities, the country and industry dummies have a significant impact on product innovation, implying that inter-country and inter-industry differences play important roles in firms' attitude to and aptitude for product innovation.

We further explored innovation phenomena in small and large firms, and used the interaction terms of the large firms dummy (LARGE) with all explanatory variables (including the country and industry intercepts) used previously; the results are reported in Table (3.7). Again, the significance of $\lambda$ corroborates our choice of the Heckman selection model. Since all variables are interacted with LARGE, the side effect is that the coefficients of the variables without interaction terms provide information on the effects of these variables in small firms only. We do not discuss these coefficients because the objective of using the interaction terms is to explore whether the effects of innovation determinants are the same in small and large firms or not[25]. The significant, negative coefficient of LARGE for R&D intensity indicates that small firms spend more on R&D per employee than large firms. Recall that the summary statistics in Table (3.3) revealed that large firms are more R&D intensive. The joint interpretation of these findings would be that although large firms spend more on R&D, their R&D expenditure per employee is lower than that of small firms. It is also a way to understand why we find that R&D expenditure increases with size but less than proportionally as shown in Table (3.5). The results in Table (3.7) reveal that R&D decisions are not influenced by size classification.[26] We observe that the effects of employment and competition do not differ in small and large firms, both for R&D intensity and decision. However, EXP, IMP and SKILL (although IMP is significant only at the 10 % level) are more important determinants of R&D intensity in large firms relative to small ones. All other control variables have no significantly different effect on R&D intensity in small and large firms. Similar to employment and competition, we cannot find any significant difference in small and

[25] Having said that, we still report these coefficients in Table (3.7) for interested readers.

[26] This result is based on the insignificance of LARGE as a determinant of R&D decisions. However, in Table (3.5), we show that employment itself is a significant, positive determinant of R&D choice.

large firms if we consider the influence of each control variable on R&D decisions.

**Table 3.8 Results of the probit model including interaction terms of LARGE. Standard errors (robust for column (2) and bootstrapped for column (4)) are in parentheses**

| Independent Variables | Dependent variable: PDINN | | | |
|---|---|---|---|---|
| Intercept | -1.453* | (0.115) | -0.456 | (1.636) |
| LRDI | | | -0.123 | (0.219) |
| LEMP | 0.234* | (0.022) | 0.187# | (0.077) |
| MONO | -0.116 | (0.090) | -0.105 | (0.107) |
| DUOP | -0.290* | (0.093) | -0.269* | (0.097) |
| MEDCOMP | 0.071† | (0.042) | 0.068 | (0.044) |
| EXP | 0.344† | (0.184) | 0.391# | (0.196) |
| IMP | 0.428* | (0.064) | 0.466* | (0.095) |
| AGE | -0.001 | (0.001) | | |
| UNION | 0.409* | (0.085) | 0.382* | (0.084) |
| SKILL | 0.087 | (0.058) | | |
| FOR | -0.002 | (0.090) | | |
| EDU | 0.147* | (0.052) | 0.178* | (0.066) |
| Country Dummies | yes | | yes | |
| Industry Dummies | yes | | yes | |
| LARGE | 0.788 | (0.930) | 0.003 | (1.462) |
| LARGE × LRDI | - | | 0.140 | (0.182) |
| LARGE × LEMP | 0.008 | (0.148) | -0.006 | (0.161) |
| LARGE × MONO | -0.740# | (0.357) | -0.596 | (0.390) |
| LARGE × DUOP | 0.318 | (0.409) | -0.460 | (0.388) |
| LARGE × MEDCOMP | -0.415# | (0.195) | -0.469# | (0.206) |
| LARGE × EXP | 0.982 | (0.598) | 0.835 | (0.585) |
| LARGE × IMP | 0.688# | (0.332) | -1.003* | (0.293) |
| LARGE × AGE | -0.002 | (0.004) | | |
| LARGE × UNION | -0.417 | (0.317) | -0.308 | (0.303) |
| LARGE × SKILL | 0.513† | (0.273) | | |
| LARGE × FOR | 0.035 | (0.229) | | |
| LARGE × EDU | 0.192 | (0.232) | -0.154 | (0.239) |
| LARGE × Country Dummies | yes | | | no |
| LARGE × Industry Dummies | yes | | | no |
| No. of obs. | | 5416 | | |
| McFadden $R^2$ | | 0.133 | | |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: For LRDI, the predicted values obtained in Table (3.5) are used.

We also examined whether product innovation determinants have different effects in small and large firms; the results are reported in

**Table 3.9 Results of the Heckman selection model including interaction terms of MODU. Standard errors are in parentheses**

| Independent Variables | Dependent Variables | | | |
|---|---|---|---|---|
| | LRDI (outcome equation) | | RD (selection equation) | |
| Intercept | 7.537* | (0.644) | -2.337* | (0.123) |
| LEMP | -0.373* | (0.067) | 0.316* | (0.021) |
| EXP | 0.408 | (0.295) | 0.423* | (0.161) |
| IMP | 0.331# | (0.133) | 0.238* | (0.070) |
| AGE | 0.003† | (0.002) | 0.001 | (0.001) |
| UNION | -0.108 | (0.161) | 0.032 | (0.091) |
| SKILL | -0.067 | (0.116) | 0.109† | (0.063) |
| FOR | 0.315# | (0.129) | 0.173# | (0.085) |
| EDU | 0.145 | (0.099) | 0.192* | (0.055) |
| FIXED | | | 0.425* | (0.046) |
| Country Dummies | yes | | yes | |
| Industry Dummies | yes | | yes | |
| MODU | -0.877 | (0.866) | 0.033 | (0.418) |
| MODU × LEMP | 0.148 | (0.131) | -0.069 | (0.073) |
| MODU × EXP | 0.263 | (0.828) | 0.385 | (0.508) |
| MODU × IMP | -0.647 | (0.501) | -0.0018 | (0.243) |
| MODU × AGE | -0.001 | (0.009) | -0.009# | (0.005) |
| MODU × UNION | 0.001 | (0.641) | 0.340 | (0.279) |
| MODU × SKILL | 0.052 | (0.470) | -0.324 | (0.222) |
| MODU × FOR | -0.332 | (0.541) | -0.580# | (0.281) |
| MODU × EDU | 0.190 | (0.389) | 0.071 | (0.194) |
| MODU × FIXED | | | -0.010 | (0.166) |
| MODU × Country Dummies | yes | | yes | |
| MODU × Industry Dummies | yes | | yes | |
| No. of obs. | 5102 | | | |
| censored obs. | 3510 | | | |
| $\lambda$ | -0.624# (0.264) | | | |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Table (3.8).[27] Table (3.8) reports the results of two regressions we ran with and without the predicted values of LRDI. The bootstrapped standard errors are calculated when the predicted values are used as

[27] Similar to Table (3.7) although we do not discuss the main effects in small firms only, we report them in Table (3.8) for interested readers.

predictors. Again both regressions provide virtually the same results. Contrary to the findings on R&D intensity, LARGE is not statistically significant, implying that there is no difference between large and small firms in explaining the likelihood of product innovation. Our results reveal that HIGHCOMP is a significantly more important stimulus for large firms than for small ones to induce product innovation, because the coefficients of the interaction terms of LARGE with MONO and with MEDCOMP are significant and negative. This result refutes Schumpeter's notion that a monopolistic environment increases innovation in large firms. In other words, in competitive markets large firms are a more important source of product innovation than small firms. We observe that the interaction of LARGE with LRDI produces insignificant results, implying that, contrary to Acs and Audretsch's (1991b) findings for developed countries, there is no indication of an increase or decrease of R&D productivity with firm size. We also notice that the importers' influence on the likelihood of product innovation is more significant in large firms than in small ones. We have already established in Table (3.6) that importers are a significant determinant of product innovation, but that large firms provide a better environment to utilize these imports towards product innovation. Another significant (and positive) interaction term is SKILL, implying that although the share of skillful workers is per se insignificant in explaining product innovation, its influence is more important in large firms compared to small establishments. All other interaction terms produce insignificant coefficients, suggesting that the behaviors of the other control variables are almost the same for both size classes.

One of the objectives of this chapter is to shed light on the disparities of explanatory factors of innovation, for different size classes and competition environments. Therefore, similar to the interactions with LARGE, we analyzed the interaction effects of different potential predictors of innovation by interacting with competition. We divided the competition variable into two categories: firms with one or fewer product market competitors and firms with more than one competitor.

**Table 3.10 Results of the probit model including interaction terms of MODU. Standard errors (robust for column 2 and bootstrapped for column 4) are in parentheses**

| Independent Variables | Dependent variable: PDINN | | | |
|---|---|---|---|---|
| Intercept | -1.398* | (0.113) | -0.889 | (1.548) |
| LRDI | | | -0.160 | (0.201) |
| LEMP | 0.252* | (0.020) | 0.193* | (0.068) |
| EXP | 0.467# | (0.189) | 0.548* | (0.212) |
| IMP | 0.359* | (0.066) | 0.411* | (0.083) |
| AGE | -0.001 | (0.001) | | |
| UNION | 0.326* | (0.086) | 0.296* | (0.091) |
| SKILL | 0.087 | (0.059) | | |
| FOR | 0.072 | (0.089) | | |
| EDU | 0.143* | (0.053) | 0.186* | (0.066) |
| Country Dummies | yes | | yes | |
| Industry Dummies | yes | | yes | |
| MODU | 0.134 | (0.363) | 1.092 | (0.921) |
| MODU × LRDI | | | -0.121 | (0.127) |
| MODU × LEMP | -0.146# | (0.060) | -0.216* | (0.071) |
| MODU × EXP | -0.568 | (0.528) | -0.565 | (0.565) |
| MODU × IMP | 0.337 | (0.223) | 0.375# | (0.189) |
| MODU × AGE | 0.001 | (0.004) | | |
| MODU × UNION | 0.225 | (0.236) | 0.362† | (0.195) |
| MODU × SKILL | -0.295 | (0.197) | | |
| MODU × FOR | -0.707* | (0.264) | | |
| MODU × EDU | 0.073 | (0.184) | -0.051 | (0.158) |
| MODU × Country Dummies | yes | | no | |
| MODU × Industry Dummies | yes | | no | |
| No. of obs. | 5420 | | | |
| McFadden $R^2$ | 0.134 | | | |

* Significance at 1% level # Significance at 5% level
† Significance at 10% level
Note: For LRDI, the predicted values obtained in Table (3.5) are used.

We call the former non-competition and denoted by MODU. The results of the Heckman selection model (for R&D) and the probit model (for product innovation) including interactions with MODU are depicted in Tables (3.9) and (3.10) respectively.[28] The $\lambda$ coefficient favors the Heckman selection model again. Surprisingly all interaction terms of LRDI are insignificant, meaning that competition does not provide a favorable (unfavorable) environment to any factors to influ-

[28] See footnotes (25) and (27) for discussions of the non-interacted coefficients.

ence R&D intensity positively (negatively). Most of the R&D decision interactions are insignificant again; however, we find two exceptions: AGE and FOR. Both of these variables provide significant, negative coefficients, suggesting that product competition is a noticeable stimulus for mature firms and for firms under foreign ownership to decide R&D. Equivalent to Tables (3.6) and (3.8) we ran both product innovation regressions.[29] The significant, negative coefficient of the interaction of MODU with LEMP indicates that employment is a more significant determinant of innovation in competitive markets than in monopoly or duopoly. The coefficient of interaction of MODU with LRDI reveals that the influence of firms' R&D expenditure (per employee) on product innovation is independent of the competition environments they are in. The coefficient of unionized workforce shows some indication of importance of this variable in non-competitive environment. Foreign ownership is more likely to induce product innovation in competitive environments than in non-competition. The remaining interaction terms produce insignificant coefficients.

### 3.4.4 The Joint Significance of Interaction Effects

So far we examined the significance of the interaction terms of each predictor separately, except for the country and industry dummies. We also analyzed the differences of innovation (both R&D and product innovation) determinants in small and large firms at an aggregate level.[30] Firstly, we observed an overall difference between innovation determinants in small and large firms by investigating the joint significance of the interactions of LARGE with LEMP, MONO, DUOP, MEDCOMP, all controls, country, and industry dummies, and tested the following hypothesis:

---

[29] We excluded the same set of controls as in Table (3.6) and (3.8); included LRDI as one of the determinants for the probit regression and calculated bootstrapped (100 replications) standard errors.

[30] We ran two probit regressions: excluding and including LRDI as a determinant of PDINN. To calculate the overall significance, we chose the former (i.e. the first column of Table (3.8)).

> *H0: There is no overall disparity between the innovation determinants in small and large firms.*

Secondly, we investigated the overall disparity in behaviors of determinants of innovation, apart from countries and industries, in small and large firms by observing the joint significance of the interactions of LARGE with LEMP, MONO, DUOP, LOWCOMP, and all controls. For this purpose, we tested the hypothesis:

> *H0: There is no overall disparity between the innovation determinants, other than that between countries and industries, in small and large firms.*

For RD, the interaction of LARGE with FIXED is also included in both above stated cases. Thirdly, we investigated the overall differences of the country dummies in small and large firms, and observed the joint significance of interactions of LARGE with the country dummies. Statistically, we investigated the following hypothesis:

> *H0: There is no overall disparity between countries in small and large firms.*

Finally, the interactions of LARGE with industry dummies were observed in a similar fashion, and the null hypothesis to be tested was:

> *H0: There is no overall disparity between industries in small and large firms.*

Table (3.11) provides the significance of the p-values of the Wald tests used to analyze the aforementioned null hypotheses, for both R&D (dummy and intensity) and product innovation. We have already noted in Table (3.7) that the effect of each predictor on R&D decision is the same for both size classes; the second column of Table (3.11) similarly indicates that the determinants of R&D decisions do not influence small and large firms differently, except for country effects. An entirely different picture emerged when we considered R&D intensity, as we obtained significant results in all rows of column (1), suggesting that all factors jointly (including countries and industries),

**Table 3.11 Significance of p-values of tests of joint impact of interactions of LARGE with different groups of explanatory variables**

| Null hypotheses | Heckman selection | | Probit |
|---|---|---|---|
| | Dependent Variable | | Dependent Variable |
| | LRDI | RD | PDINN |
| There is no overall disparity between the innovation determinants in small and large firms | * | insignificant | * |
| There is no overall disparity between the determinants, other than between countries and industries, of innovation in small and large firms | * | insignificant | # |
| There is no overall disparity between countries in small and large firms | # | # | insignificant |
| There is no overall disparity between industries in small and large firms | † | insignificant | insignificant |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

all predictors jointly (excluding countries and industries), all countries jointly, and all industries jointly have different influences in small and large firms, to increase R&D intensity. Country- and industry-specific differences do not have a different effect on product innovation in small-and large-sized firms. Moreover all determinants jointly (for both cases: including and excluding countries and industries) have significantly different influences in small and large firms. The general picture that emerges in Table (3.11) is that innovation determinants of bothR&D intensity and innovation output behave differently in small and large firms. For R&D-related activities, country-specific characteristics differ more in small and large firms than industry-specific characteristics.

To observe the significances of the interaction terms of MODU with each predictor (except for the country and industry dummies) separately, we examined the overall significance of these interactions as we did in the case of LARGE, again for all innovation variables.[31] We observed, similar to the interactions of LARGE, the joint significance of: (1) the interactions of MODU with LEMP, all control variables, the country, and industry dummies; (2) the interactions of MODU with LEMP and with all control variables; (3) the interactions of MODU with the country dummies; (4) the interactions of MODU with the industry dummies. For RD, the interaction of MODU with FIXED is also included in (1) and (2). Table (3.12) presents the significances of the p-values of the tests on the above stated interaction terms (and the corresponding hypotheses which are stated in the same line as LARGE).

**Table 3.12 Significance of p-values of tests of joint impact of interactions of MODU with different groups of explanatory variables**

| Null hypotheses | Heckman selection | | Probit |
|---|---|---|---|
| | Dependent Variable | | Dependent Variable |
| | LRDI | RD | PDINN |
| There is no overall disparity between the innovation determinants in different competition environments | insignificant | insignificant | * |
| There is no overall disparity between the determinants, other than between countries and industries, of innovation in different competition environments | insignificant | insignificant | * |
| There is no overall disparity between countries in different competition environments | insignificant | insignificant | insignificant |
| There is no overall disparity between industries in different competition environments | insignificant | insignificant | # |

* Significance at 1% level  # Significance at 5% level  † Significance at 10% level

For R&D-related variables, all results are insignificant, implying that all determinants jointly (including and excluding countries and industries), all countries jointly, and all industries jointly do not behave differently in competition and non- competition environments.

[31] See footnote (31), for the discussion on the regression which is used to observe the overall significance.

Recall that in Table (3.9) we find two significant interaction terms, namely the interactions terms of MODU with AGE and FOR in case of R&D decision, but the overall insignificance here indicates that the significance of these two interaction terms is crowded out by the insignificance of the other variables. We found significant p-values for product innovation but interactions with the country dummies. It means that all determinants jointly (both including and excluding country and industry dummies) and all industries jointly have significantly different influences on product innovation, when there is more than one competitor compared to a maximum of one competitor. These results suggest that innovation determinants do not effect R&D intensity differently in different competition environments, contrary to firm size; however, we observed different effects of innovation determinants on product innovation which are stronger than size.

## 3.5 Conclusions

The firm size-innovation and the market competition-innovation relationships have been studied intensively in developed countries, but the research body evaluating the developing world is still humble. This chapter contributed to this research field by analyzing both innovation input and output.

According to our analysis, the impact of firm size on innovation is similar to developed countries. We found that employment has a significant, positive impact on the likelihood of R&D and of product innovation, and employment increases R&D expenditure at a less than proportional rate. We observed that product market competition is a positive stimulus for product innovation, but has no influence on R&D expenditure per employee. The reason for these findings could be that the pressure from the competitors in the product market triggers an immediate response in terms of final products. Since R&D is a long term process, firms may prefer to fight competitive pressures through slight modification of existing products and/or the imitation of developed countries' innovations, which may be achieved quicker and without costly R&D expenditures. Country-specific and industry-specific characteristics were observed to be significant factors for both innovation input and output.

We failed to find a significant relationship between R&D intensity (R&D expenditure per employee) and the likelihood of product innovation. Our two interpretations of this finding are that firms, especially in developing countries, may not have a formal R&D structure and underestimate their actual expenditure, which in turn leads to an underestimation of the significance of their R&D expenditure. Secondly, developing countries are more prone to imitate (of developed countries products) than to engage in radical product innovation, which entails lower R&D expenditure. Moreover, we observed that the relationship between R&D intensity and product innovation is independent of size classes and of product market competition environments.

Our results show that firms' foreign links as importers and exporters contribute substantially to their pursuit of R&D activities and product innovation. Another important determinant of our innovation measures is education (of production workers), which shows a positive effect on R&D decisions, expenditure, and product innovation. We noticed that firm age has a significant, positive impact on R&D intensity, but has no influence on product innovation. Our interpretation of these results is that mature firms spend more on R&D per employee, since they are "old" players and have sufficient resources for R&D, to protect their market value and to benefit from their established infrastructures. However, this may be offset by product innovation by younger firms (the extreme case are new entrants), which are necessary for them to establish themselves in the market.

We observed that the effects of employment and competition on R&D activities, and the effect of employment on product innovation, are the same for large and small firms. However, competition is a more significant stimulus of product innovation for large firms compared to small ones. Hence, our results for developing countries contradict Schumpeter's view that monopolies benefit large firm innovation. Our analysis revealed that large firms' trade orientation (both import and export) has a more significant influence on R&D expenditure per employee than small firms' trade orientation. For product innovation, we found the same but only for imports. Although we did not find a significant influence of skillful workers on innovation (both input and output), our empirical findings suggest that, in a comparative analysis, workers' skill has a more significant effect for large firms than for small ones, for both R&D intensity and product innovation. There is no evidence of differences between small and large firms with regards to the effects of firm age, unionization, education of production workers, and (more than 10%) foreign ownership, on both types of innovation. We find that, for R&D activities, country-specific characteristics playa significantly more important role in small and large firms than industry-specific characteristics; however, these specific characteristics (both of countries and industries) do not effect product innovation significantly different in either size class , suggesting that large and small firms' strategy towards innovation output is not influenced by the geographical region they are situated in or by the specific product they manufacture. Neither inter-country nor inter-industry differences were observed to effect R&D activities substantially differently in competition and non-competition environments. However, for both competition environments industry-specific characteristics behave significantly different as the determinants of product innovation.

Our results suggest that the determinants of R&D as a whole have disparate effect on small and large firms, but they have the same impact while we consider them in competition and non-competition environments. It means that firm size is a more significant factor than market competition status, for these determinants behave differently to influence firm-level R&D activities. But the joint difference of influence of these determinants on innovation output is more significant for different competition environments than for different size classes, suggesting the opposite scenario (compared to R&D) for product innovation.

# Chapter 4

## Innovation and Firm-level Productivity: Econometric Evidence from Bangladesh and Pakistan


### Summary

The labor productivity impact on innovation of manufacturing firms in Bangladesh and Pakistan has been a neglected field of studies compared with the developed world. This topic is studied in this chapter using World Bank Enterprise Survey data from 2006.

We applied the Cobb-Douglas production function, augmented with innovation-related inputs (and other expected sources of productivity) in a simultaneous three-equation system – connecting R&D to its determinants, innovation output to R&D, and productivity to innovation output – and in a two-equation system – connecting innovation output to its determinants, and productivity to innovation output – after correction for the biases attributable to the selectivity bias of R&D and to the endogenous nature of both R&D and innovation output.

Our results reveal that Bangladeshi firms are more often innovators compared to Pakistani ones; however, the productivity output appears to be larger in Pakistan. We are not able to reject the constant returns to scale assumption. In addition, our econometric analysis shows a strong and positive influence of raw materials and of net book value on firm productivity. One of the striking results is that both product and process innovation have significant, positive effects on productivity for all firms. However, separate analyses for each country show mixed findings. Finally, we noticed that the traditional production inputs (material and capital) have more significant effects on productivity than non-traditional input factors (controls in our case).

## 4.1 Introduction

In chapter (3), we endeavored to understand innovation determinants using econometric models in which innovation indicators were the dependent variables. The purpose of this chapter is to explore innovation as an independent variable. More specifically, we analyze the effect of innovation on firm-level labor productivity.

The impact of innovation on labor productivity has been examined many times in the growing literature on the link between innovation and economic growth. The debate on this relationship can be split into two streams: the productivity effect of innovation input, especially R&D (see Griliches, 1998), and the influence of innovation output on firm performance (labor productivity, for example). More specifically, the emphasis in this last type of literature was on the effect of innovation input on innovation output, and in turn the productivity effect of innovation output, in line with the pioneering work of Crepon et al. (1998), henceforth CDM. In earlier works, one of the reasons to investigate R&D instead of innovation output as a determinant of firm productivity was the non-availability of the data on innovation output.[32] The general perception, nowadays, is that it is innovation output rather than input which contributes to productivity, and the existence of innovation surveys enables innovation scholars to investigate this relationship extensively. More specifically, the CDM model contributed to this field by investigating the effect of innovation input on productivity implicitly (through its impact on innovation output) and of innovation output explicitly by using a four-equation system of simultaneous equations in three steps: linking R&D to its determinants (involving two equations), observing the innovation output impact of R&D (the knowledge output phase), and connecting firm productivity to its innovation output (the productivity output stage). Our methodology in this chapter is partly based on the CDM model, we will use its full version (with all four equations), henceforth FCDM, and its re-

[32] The reason for this non-availability was the lack of innovation-related surveys, even in developed countries.

duced specification (involving the innovation output and productivity equations), henceforth RCDM.

Researchers in developing countries have studied the technological change and growth relationship extensively (see e.g. Hall and Mairesse, 1995; Verspagen, 1995; Harhoff, 1998; Griffith et al., 2006), but developing countries have not contributed much to this debate. Gu (1999) argued that the national innovation systems (NISs) of developing counties do not operate optimally, and that a lack of institutional sophistication, as well as a lack of links among organizations characterize their NISs. Growth in these countries depends more heavily on capital investment than knowledge and learning. Similar to other developing regions (see e.g. Alcorta and Peres, 1998, for Latin America and the Caribbean), the study of Dahlman (2007) asserted that innovation systems of South Asian countries are plagued by institutional and societal problems, and they are far behind the global technological frontier. He argued that South Asian countries' economies are not knowledge-based due to illiterate and unskilled societies, as well as the emigration of the skillful workforce. The region is also confronted by the problem of poor links between university and commercial, firm-based scientists. However, despite the above stated limitations, the region has generally witnessed economic growth since the 1980s (Collin, 2007). According to Collin we cannot ignore the role of capital accumulation and of efficient use of other factors for economic growth of this region, more investment in both physical and human capital is needed.

The purpose of this chapter is to investigate the links between firm performance (as proxied by labor productivity) and innovative activities for two developing South Asian countries: Bangladesh and Pakistan, a region so far hardly the subject of this type of studies. We enhanced the CDM model (1) by including process innovation alongside product innovation in the knowledge output phase to examine the influence of cost reductions and labor efficiency benefits on (labor) productivity, and (2) by using additional information acquired by the inclusion of more explanatory factors in the productivity output phase.

More specifically, we estimated the productivity output equation by using an innovation-augmented Cobb-Douglas production function in two ways: (1) by including traditional production inputs, i.e. labor, capital, and raw materials (we call this the basic model); (2) by extending the basic model to include additional inputs as potential determinants of labor productivity (we call this the extended model). In addition, we used two different systems of equations: (1) a four-equation system similar to the CDM, which we applied only to Bangladesh because we did not have any R&D investment information for Pakistani firms; (2) a two-equation system which estimates the link of innovation outputs with its determinants, without R&D, and measures the link between labor productivity and innovation output, which we applied to both Pakistan and Bangladesh. Hence, briefly speaking, our estimation models had the following four forms: (1) four-equation basic system (henceforth, FEBS); (2) four-equation extended system (henceforth, FEES); (3) two-equation basic system (henceforth, TEBS); (4) two-equation extended system (henceforth, TEES). Note that, FEBS and FEES will only be applied to the Bangladeshi firms, while TEBS and TEES will be applied to both Pakistan and Bangladesh, as well as to the all firms taken together. Alongside the richness of the model and the exploration of the dynamics of labor productivity more extensively, the extended version also serves as a robustness check for the basic model. It would be interesting to examine whether the effect of innovation output on productivity remains the same when R&D is included or excluded at the knowledge output stage for developing countries(i.e. whether we strictly need an FCDM or not).[33] We anticipate no difference in our case since innovations in developing countries are generally less connected to formal R&D activities (see e.g. Arocena and Sutz, 2000 and chapter (3) of this thesis). The esti-

[33] For French manufacturing firms, Mairesse et al.(2005) estimated and compared various versions of the CDM model. They estimated the complete CDM, the reduced CDM by estimating productivity semi-elasticities (elasticities) of R&D occurrence (intensity) and of (different definitions of) innovation occurrence (intensity) directly, with and without correcting for selectivity and endogeneity of the variables, as well as correcting only for selectivity and only for endogeneity.

mates of the four and two equations systems for Bangladesh will provide us with a mechanism to test this hypothesis empirically.

We find a substantial effect of firm size only for Bangladeshi firms' R&D and process innovation. Pakistani firms' trade orientation (both exports and imports) appears to be a significant factor explaining product innovation and only imports are important component of process innovation; however, the results for Bangladesh do not follow this pattern. Material and physical capital are observed to be conducive to productivity. The productivity effect of both process and product innovation is generally significant and positive in this region. We also show that one could be indifferent between the use of FCDM and RCDM based on the Bangladeshi data.

The chapter is organized as follows. Section (2) is devoted to the literature review, section (3) discusses the models theoretically that will be the basis of our empirical econometric analysis. Section (4) explains the dataset with descriptive statistics, while section (5) describes and discusses the empirical findings. Section (6) concludes the chapter.

## 4.2 Literature Review

The analysis of the effect of technical change on productivity (and economic growth, in general) at a macro and micro level is not a new topic. However, one of the main issues in this research area is how to measure technical change (the others are model specifications and estimation methodologies). The pioneering research in this field often relied on proxies which could not be measured directly and quantitatively. For instance, Solow (1957), one of the pioneers of the technology-productivity relationship literature, calculated the impact of technological progress as a residual. The obvious limitations of this approach led to a further evolution which progressed to the definition of an easier quantifiable measure: research and development (R&D). Although the use of R&D[34] as an indicator of technological change to

[34] The impact of R&D on productivity (levels or growth rates) has usually been estimated by including R&D as an additional input factor (in addition to traditional

explain productivity has also been questioned many times (see for example Griliches, 1978, 1998), it has been used extensively due to its quantifiability and, perhaps primarily, to the non-availability of innovation surveys which could quantify innovation activities in terms of more plausible determinants of productivity such as innovation outputs rather than its inputs (as in the case of R&D).

Empirically, the analysis of R&D activities in developed countries often confirmed their significant influence on productivity.[35] Griliches (1998, chapter 4) estimated a positive impact of R&D activities on firms' productivity in the USA – both in terms of value-added and of sales growth rates. A positive link between R&D and firm performance can also be found in Hall and Mairesse (1995) for French, and in Harhoff (1998) for German manufacturing firms. Verspagen (1995) used a translog production function to analyze data of 11 OECD countries also concluded that R&D is a significant determinant of productivity, particularly for high-tech industries.

As mentioned earlier, the adoption of R&D to investigate the productivity impact of technological change has always been considered questionable, and the thirst to employ more appropriate indicators which would be related to innovation outputs (instead of innovation inputs) has been quenched, to some extent, by the use of patent statistics, and by the advent of innovation surveys. To follow the CDM strategy, the innovation-productivity relationship analysis also observed the influence of innovation input on productivity indirectly via the innovation output impact of R&D (and/or alike inputs), and of innovation outputs directly, by building up a recursive simultaneous equations system which works in three phases: relating R&D to its determinants, innovation output to R&D, and in turn productivity to innovation output. The empirical findings for developed countries

inputs: labor and physical capital) in the production function.

[35] Mairesse and Sassenou (1991) provided a survey of the studies focused on the productivity effect of R&D, which is measured by the econometric analysis of production function. Another survey can be found in Griliches (1998).

generally showed a positive link between innovation and firm performance whether the CDM approach is used or not (see Geroski et al., 1993; Lööf and Heshmati, 2002, 2006; Koellinger, 2008, among others). In particular, Bogliacino and Pianta (2011) observed that the innovation inputs (R&D and new machinery expenditures) of eight major EU countries contributed significantly to labor productivity growth. They further replaced patent applications with R&D in science-based industries (Pavitt's taxonomy) and again found significant results (albeit machinery expenditure proved to be insignificant). Crespi and Pianta (2008) used both input and output indicators for innovation and concluded that both transform remarkably well into productivity increases for six European countries. Furthermore, Klomp and Van Leeuwen (2001) showed that Dutch firms that perform R&D on a permanent basis are largely innovators, and that innovative sales value contributes significantly to total turnover growth, and its effect is modestly negative on employment growth rates. They further showed that (a dummy of) process innovation increases both performance measures considerably. However, in another study, they (Van Leeuwen and Klomp, 2006) estimated impact of innovative sales on value-added per employee (sales per employment growth) to be insignificant (significant), and a negative influence of process innovation on sales growth rates (scaled by employment). The positive effect of innovation input on innovation output and of innovation output on firm performance (productivity levels and growth rates) can also be found in Lööf and Heshmati (2002) for Swedish firms. Griffith et al. (2006) asserted a substantial influence of R&D intensity on both product and process innovation using the third Community Innovation Survey (CIS3) for France, Germany, Spain, and Great Britain. They also found a significant relationship between product innovation and labor productivity except in Germany. For process innovation they observed a statistically significant estimate only for France. Another strong relationship between R&D and both innovation types (product and process) was found by Hall et al. (2009) who also postulated a significant influence of both innovation outputs on firm productivity.

However, the significance of process innovation collapsed when they introduced investment intensity as a proxy for physical capital. The study of Parisi et al. (2006) concluded that process innovation has a larger effect on productivity than product innovation. It is hard to encompass the innovation-productivity relationship literature comprehensively in one study, but we can argue that product innovation generally seems to have a more robust and remarkable influence on productivity (growth) than process innovation in developed economies.

In terms of empirical findings for developing countries Yang and Huang (2005) demonstrated the important role of R&D in employment growth of Taiwanese electronics firms. Benavente (2006) showed that Chilean firms' innovative sales do not depend on R&D intensity, and that innovation output does not enhance the productivity per worker. For six Latin American countries Crespi and Zuniga (2012) observed that investment in innovation activities resulted in a notable increase of the likelihood of product or process innovation in all countries, and that innovation expenditure had a considerable impact on labor productivity, except in Costa Rica. The productivity effect of innovation output also produced statistically significant outcomes, except for Cost Rica. In addition, Lee (2011) found both process and product innovation inconsequent for Malaysian firms' value addition. The work of Goedhuys and Veugelers (2011) on Brazilian manufacturing firms found product innovation to be a better explanatory factor of sales growth than process innovation. They also found the impact of combined process and product innovation to be significant.

## 4.3 Model Specification

Our econometric analysis can be divided into two systematic approaches: a three-step procedure (FCDM) for Bangladesh, and a two-step method (RCDM) for both Bangladesh and Pakistan. The steps of the three-step approach are: (1) the link of R&D activities to firm specific and external explanatory factors; (2) the relationship of knowledge output (measured by indicators of innovation output) with R&D

and other potential determinants; (3) the connection of productivity output with knowledge output and other traditional productivity inputs. The two-step procedure is limited to the second and third stages

**Table 4.1 Variables and their description**

| Variables | Descriptions |
|---|---|
| LEMP | Logarithm of number of full- time employees. It includes both permanent and temporary employment. |
| LSALE | Logarithm of total annual sales of a firm in 2005/06. |
| LRDI | Log of Ratio of R&D expenditures to sales. |
| EXP | Ratio of export sales to total annual sales in 2005/06. |
| IMP | Ratio of imports in total annual purchase of material inputs and/or supplies in 2005/06. |
| AGE | Age of the firm: 2006 (year of survey)-year of beginning of the operation of the firm |
| BONUS | Percentage of bonuses, allowances, and other benefits to sales in 2005/06. |
| LMATERIAL | Logarithm of total annual cost of raw material per employee in 2005/06. |
| LNETBOOK | Logarithm of net book value of firm assets (machinery, vehicles, equipments, land, and buildings) per employee at the end of 2005/06. |
| LPROD | Logarithm of labor productivity: sales/employment in 2005/06. |
| PRODIN | Ratio of permanent production workers in permanent employment |
| EXPER | Experience of top manager in years. |
| INDZONE | Dummy if a firm located in industrial zone (park). |
| UNION | Dummy if a worker union exists in the firm. |
| EDU | Dummy if the average education of a typical production worker is 7 years and above. |
| TRAIN | Dummy if the firm runs formal training program for its permanent employees in 2005/06. |
| WEB | Dummy if the firm uses website to communicate with its clients or suppliers. |
| MEMBER | Dummy if firm is a member of any business association (e.g. CoC etc.) |
| PDINN | Dummy if the firm introduces into the market any new or significantly improved product during the last three fiscal years. |
| PRINN | Dummy if the firm introduces into the market any new or significantly improved production process, including methods of supplying services and ways of delivering products, during the last three fiscal years. |
| RD | Dummy if the firm spends on R&D activities in 2005/06. |
| LICE | Dummy if the firm uses technology licensed from foreign-owned company. |
| DIV1 | Dummy if the firm has only one product |
| DIV2 | Dummy if the firm has two products |
| ACCESS | Dummy if the firm perceives that access to finance is the main obstacle affecting its operation. |
| PAK | Dummy if country is Pakistan. |

of the three-step approach, without using R&D as one of the determinants of knowledge output.

Table (4.1) provides the descriptions and labels of the variables used in the subsequent model discussion and econometric analysis.

### *4.3.1 The Research (R&D) Equation*

As discussed earlier, the first step is to relate firms' R&D efforts to their determinants. To do so, we relied on the Heckman selection model to resolve the selectivity
bias attributable to the large number of non-R&D performing (and/or reporting) firms. For the empirical estimation of the model we applied the Heckman two-step procedure.

In particular, we assumed that the $i^{th}$ firm's R&D decision is based on a latent selection criterion which has the following form:

$$rd_i^* = x_{0i}\beta_0 + \varepsilon_{0i} \tag{4.1}$$

where $x_{0i}$ is the vector of the determinants of the R&D decision, $\beta_0$ is the vector of the corresponding coefficients, and $\varepsilon_{0i}$ is an error term. We assumed that the firm will decide to initiate an R&D project if its latent variable exceeds industry threshold $c$. Hence, our binary R&D decision variable (the information which we actually have) would be:

$$\begin{aligned} rd_i &= 1 \qquad \text{if} \quad rd_i^* > c \\ rd_i &= 0 \qquad \text{if} \quad rd_i^* \leq c \end{aligned}$$

Moreover, we approximated the latent R&D intensity of the $i^{th}$ firm with the following equation:

$$rds_i^* = x_{1i}\beta_1 + \varepsilon_{1i} \tag{4.2}$$

where, similar to equation (4.1), $x_{1i}$ and $\beta_1$are the vectors of the R&D intensity determinants and the associated coefficients respectively, and $\varepsilon_{1i}$ is a disturbance term which captures all other sources of errors. The actual R&D intensity $rds_i$ is equal to the latent R&D intensity conditional on the R&D performance (i.e. if $rd_i = 1$) and zero otherwise (i.e. if $rd = 0$). In addition to assuming that ($\varepsilon_{0i}$,$\varepsilon_{1i}$) are independent of the covariates of equations (4.1) and (4.2), we had to rely on the following distributional assumptions to estimate the model econometrically. We assumed the distributions of error terms to be as follows:

$$\begin{pmatrix} \varepsilon_{0i} \\ \varepsilon_{1i} \end{pmatrix} \overset{NID}{\sim} \left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma^2_{\varepsilon_0} & \rho\sigma_{\varepsilon_0}\sigma_{\varepsilon_1} \\ \rho\sigma_{\varepsilon_0}\sigma_{\varepsilon_1} & \sigma^2_{\varepsilon_1} \end{pmatrix} \right)$$

Where $\rho$ is the correlation coefficient between both disturbances, and $\sigma^2_{\varepsilon_0}$ and $\sigma^2_{\varepsilon_1}$ are the respective variances. The model in equation (4.1) is in fact a probit model, which requires a normalization restriction that can be obtained by setting $\sigma^2_{\varepsilon_0} = 1$.

We used LRDI as the dependent variable in equation (4.2), for the approximation of research intensity. The explanatory variables used for both covariates vectors are:

$$x_{1i} = (LSALES, DIV1, DIV2, ACCESS, UNION, TRAIN, WEB, MEMBER)$$
$$x_{0i} = (x_1, EXPER)$$

Both sets of covariates also include industry intercepts to address sector-specific heterogeneity. Note that $x_{0i}$ includes $x_{1i}$ and one additional variable because a crucial assumption of the Heckman selection procedure is that at least one of the explanatory variables of the selection equation (equation (4.1)) should not be included in the outcome equation (equation (4.2)), to obtain a well-identified model. It is hard to determine the variables that could affect the R&D choice, but do not influence subsequent R&D expenditure conditional on the decision to perform R&D, since both phenomena are closely linked. However, our reason for excluding EXPER from the outcome equation is the following: The start of an R&D project involves a risk of failure or a risk of not achieving optimal results. Therefore, older managers may be against the initiation of an R&D project due to a higher risk-aversion compared to younger managers, and this reluctance may be more significant at the start of a new R&D project than during the allocation of budget to an already approved and/or ongoing R&D project. Therefore, we anticipate a negative influence of EXPER on the R&D decision, and we believe that EXPER is not strongly connected to R&D expenditure. We entered the variable LSALES as a traditional 'Schumpeterian' variable to control for firm size. To follow Crepon et al. (1998), we tried to capture product diversification by including two dummies DIV1 and DIV2. Our variables are not similar to Crepon et.al; they constructed the inverse of Herfindahl index, but we did not have detailed information in order to construct this index. The information we had is sales shares of firm's two main products, decomposed at the ISIC 4-didgit industrial sectors. We constructed DIV1 as a dummy taking the value 1 if the firm sales share is 100 for one and 0 for other product, i.e. the firm has only one product. DIV2takes the value 1 if the sales share of the two main products adds up to 100, i.e. the firm has two main products. The firm with more than two products, i.e. the firm for which sales share of the two main products is less than 100, is considered as a reference category. The financial condition of a firm may be one of the main factors for the firm's innovation investment decision and intensity. We entered the variable ACCESS both in R&D intensity and decision equations and assumed that if a firm's main obstacle is the access to finance, it is less likely that it will invest in innovation activities, especially in developing countries where innovation is not the first priority of the firms. We also included some other control variables to enrich our R&D equations. It is important to recall that the empirical results of the R&D equation have only been obtained for Bangladesh.

#### *4.3.2 The Knowledge (Innovation) Output Equation*

The second step is regress innovation output on R&D and other potential sources which contribute to its variability. Following Griffith et al. (2006) and Hall et al. (2009) we used both process and product innovation to measure innovation output. Hence, our model of knowledge output for the $i^{th}$ firm is the following:

$$
\begin{aligned}
pd_i &= 1 \qquad \text{if} \quad pd_i^* = rd_i\alpha + y_i\gamma + u_{1i} > c \\
pr_i &= 1 \qquad \text{if} \quad pr_i^* = rd_i\alpha + y_i\gamma + u_{2i} > c
\end{aligned}
\tag{4.3}
$$

where $rd_i$ here is the predicted value of the R&D intensity (LRDI) obtained from the Heckman selection model in step (1). We used the predicted values from equation (4.2) as an instrument of research intensity to avoid biases caused by the endogenous nature of the R&D variable in the knowledge output equation.[36] The dummies $pd_i$ and $pr_i$ denote product and process innovations (i.e. PDINN and PRINN) each assumes the value one if the corresponding latent variables ($pd_i^*$ and $pr_i^*$) are greater than threshold $c$. The vector $y_i$ is a vector of the covariates (other than research intensity) influencing both types of innovation outputs, and $\gamma$ is the corresponding coefficients' vector. Furthermore, $(u_{1i}, u_{2i})$ are the disturbance terms with $\text{cov}(u_{1i}, u_{2i}) = \rho$[37].

In addition to the sector dummies, the explanatory variables used in the covariates vector are:

$$
\begin{aligned}
y_i = (&LSALES, EXP, IMP, EDU, INDZONE, LICE, WEB \\
&MEMBER, AGE)
\end{aligned}
$$

We entered LSALES to control for the size specific characteristics of the firm. We also included other commonly used variables to measure the firm trade orientation, i.e. EXP and IMP. It is often argued in the literature that the firm's trade orientation has a significant impact on its propensity to innovate. Furthermore, we assumed that if a firm has an educated workforce, it has higher probabilities to innovate; the variable EDU was included to capture this information. The firm's social

[36] By using the expected values of R&D investment, we do not restrict our analysis to the R&D-reporting firms, but employ richer information by including all firms.

[37] We assume that $\rho \neq 0$ and avoid to use $\rho = 0$ directly due to the fact that both product and process innovation may be correlated, and that there may be a high risk of association among the unobserved characteristics (captured by $u_1$ and $u_2$) influencing both types of innovation activities. Nonetheless we empirically tested the null hypothesis of a zero correlation and found it refuted in all bivariate regressions (details can be found in the empirical section), implying the validity of the non-zero correlation assumption.

networking and a healthy infrastructure may be helpful to innovate. We anticipated that the firm situated in an industrial park may enjoy both more than the firm which is operating in isolation, and included the variable INDZONE to observe this empirically. We also assumed that the use of foreign licensed technology may have a strong influence on the firm propensity to innovate, especially in developing countries, and the variable LICE was included in the innovation equation to explore this phenomenon. We also included other control variables to investigate the firm's innovation propensity more accurately.

We further supposed that if the R&D data of Bangladeshi firms is unknown, and one has to rely on the RCDM. For this purpose, we defined another knowledge production function, which is a reduced form equation of innovation output:

$$\begin{aligned} pd_i &= 1 \qquad if \quad pd_i^* = y_{1i}\gamma_1 + u_{3i} > c \\ pr_i &= 1 \qquad if \quad pr_i^* = y_{1i}\gamma_1 + u_{4i} > c \end{aligned} \tag{4.4}$$

Where $(u_{3i}, u_{4i})$ are the error terms; the definitions of all variables are as defined earlier in the context of model (4.3), except for $y_{1i}$ with the associated coefficients vector $\gamma_1$, which is defined as:

$$y_{1i} = (y_i, DIV1, DIV2, ACCESS, UNION, TRAIN)$$

Note that the vector $y_{1i}$ includes the vector $y_i$ and additional variables (i.e. all exogenous variables of equation (4.2) and (4.3)), since equation (4.4) actually is a reduced form equation of innovation output. Equation (4.3) is the second equation of the FCDM, while equation (4.4) is the first equation of the RCDM, although equation (4.4) might be difficult to interpret economically since it is an auxiliary equation.

Due to the unavailability of R&D investment data for Pakistan, the equation above (4.3) cannot be used for Pakistan. One alternative would be to employ equation (4.4) to Pakistan as well. We cannot follow this route because we do not have the data of the variable MEMBER for Pakistan. We could drop the variable MEMBER for

Bangladesh and use model (4.4) for both Bangladesh and Pakistan, but we do not do that because we want to observe to which extent innovation commitment is on the agenda of firms' policy debates in a developing country. Therefore, we defined another model as:

$$\begin{aligned} pd_i &= 1 \quad if \quad pd_i^* = w_i\delta + \upsilon_{1i} > c \\ pr_i &= 0 \quad if \quad pr_i^* = w_i\delta + \upsilon_{2i} > c \end{aligned} \qquad (4.5)$$

The latent dependent variables are as defined earlier, and the error terms ($\upsilon_{1i},\upsilon_{2i}$) have the same distributional assumptions as ($u_{1i},u_{2i}$). Although we have already defined the knowledge output model for Bangladesh in equation (4.3) and (4.4), we use model (4.5) for all firms taken together and for Pakistan and Bangladesh separately. The reason to apply model (4.5) to Bangladesh as well is to obtain comparable results for both countries by using the same model specification. The covariates vector $w_i$ is defined as:

$$w_i = (LSALES, EXP, IMP, EDU, INDZONE, LICE, WEB, AGE)$$

In addition to include the Pakistan dummy (PAK) when applied to all firms to control for country-specific effects, the only difference between the vectors $y_i$ and $w_i$ is that the former includes the variable MEMBER but the latter does not.

### *4.3.3 The Productivity Output Equation*

The final equation for models (4.3), (4.4), and (4.5) is the productivity output equation. To formulate this equation, we employed the widely used Cobb-Douglas production function, augmented with product and process innovation terms. Following Griffith et al. (2006) and Hall et al. (2009) we used both innovation outputs in one equation, but they happened to be highly collinear (the details can be found in the empirical section of this chapter). To avoid a distortion of the estimation outcomes by the multicollinearity, we inserted process and product innovations into the production function separately. Hence, we defined two separate productivity equations for the $i^{th}$ firm as follows:

$$
\begin{aligned}
lp_i &= l_i\alpha_1 + m_i\alpha_2 + pd_i\lambda_1 + z_i\varsigma + \xi_{1i} \\
lp_i &= l_i\alpha_1 + m_i\alpha_2 + pr_i\lambda_2 + z_i\varsigma + \xi_{2i}
\end{aligned}
\tag{4.6}
$$

where $lp_i$ is productivity (logarithm of sales per employment), labeled LPROD, $l_i$ is (the log of) employment, i.e. LEMP, the (2×1) vector $m_i$ (scaled by employment) has two other traditional production inputs: raw material costs and the net book value (both in logarithmic form), we labeled them LMATERIAL and LNETBOOK respectively. This is necessary to emphasize that we did not assume constant returns to scale (henceforth, CRS) but endeavored to examine this empirically. For $pd_i$ and $pr_i$, we used the predicted values of PDINN and PRINN respectively, which were obtained from either equation (4.3), (4.4), or (4.5), depending on the context in which model (4.6) is used. The advantage of using the predicted values of innovation outputs is to control for the endogeneity of these variables in the productivity output equation. Moreover, all our production function estimations contain industry dummies and, wherever needed, a country dummy. We estimated model (4.6) in two different settings: a basic model with no additional controls (where $z_i$ is a null vector) and an extended model with control variables (where $z_i$ is not a null vector). When the FCDM model was used (i.e. when we applied R&D, innovation, and productivity equations), and when the RCDM model (innovation and productivity equations) was used only for Bangladesh, the controls, if used, were the following:

$$z_i = (EDU, WEB, BONUS, LICE, PRODIN)$$

We did not have BONUS data for Pakistan; therefore, when we applied the RCDM to all firms, Pakistan, and Bangladesh, the vector $z_i$ has the variables as:

$$z_i = (EDU, WEB, LICE, PRODIN)$$

Note that we calculated the RCDM twice for Bangladesh; the first to compare the results of the FCDM with its reduced version in a same variable setting, and the second to compare the results of the RCDM for both countries in a same model specification.

**Table 4.2 Summary statistics of continuous variables**

| Variables | Bangladesh | | | | Pakistan | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Median | $Q_1$ | $Q_3$ | Mean | Median | $Q_1$ | $Q_3$ |
| Employment | 293.40 | 90 | 22 | 320 | 114.11 | 15 | 7 | 50 |
| Sales (in mil.) | 2.23 | 0.29 | 0.05 | 1.73 | 5.03 | 0.09 | 0.03 | 0.67 |
| Export intensity (%) | 33.52 | 0 | 0 | 100 | 12.21 | 0 | 0 | 0 |
| Import intensity (%) | 34.97 | 10 | 0 | 80 | 11.69 | 0 | 0 | 10 |
| Age (in years) | 16.95 | 14 | 8 | 22 | 20.20 | 18 | 11 | 26 |
| Experience of top manger (in years) | 14.59 | 13 | 8 | 20 | 20.81 | 20 | 13.5 | 30 |
| R&D expenditures to sales (%) | 0.55 | 0 | 0 | 0.33 | | | | |
| R&D exp. to sales (performers) (%) | 1.28 | 0.16 | 0.43 | 1.13 | | | | |
| Production workers intensity[a] (%) | 82.75 | 86.67 | 77.78 | 93.13 | 77.26 | 80 | 70 | 85.71 |
| Ratio of bonuses to sales (%) | 1.67 | 0.98 | 0.24 | 2.2 | | | | |
| Sales per emp. (in thousands) | 7.56 | 3.15 | 1.43 | 6.85 | 23.77 | 6.02 | 2.67 | 13.92 |
| Material cost per emp.[c](in thousand) | 5.13 | 1.81 | 0.67 | 4.54 | 11.09 | 2.39 | 0.84 | 6.68 |
| Net book val. per emp. (in thousand.) | 5.93 | 1.69 | 0.43 | 4.94 | 28.93 | 4.48 | 1.73 | 11.13 |

[a] It is a ratio of permanent, full-time, production workers to total permanent, full-time employees.
[b] It is a ratio of permanent, full-time, skilled production workers to total permanent, full-time employees production employees.
[c] For material cost and net book value, only those firms that report non-zero monetary values are included.

## 4.4 Data and Descriptive Statistics

The empirical study in this chapter is based on the World Bank enterprise survey of two South Asian countries: Bangladesh and Pakistan, conducted in 2006-07 and covering the preceding three fiscal years (i.e. from 1st July 2003 to 30th June 2006)[38]. The sample was selected using stratified random sampling following the commonly used three criteria: size, sector, and geographical location.[39] Overall, the sample contains 2,085 manufacturing firms (784 in Pakistan and the others in

[38] The fiscal years of Pakistan and Bangladesh start on 1st July and end on 30th June. Some of our variables collect information for the last fiscal year and others for the last three fiscal years (see Table (4.1) for details).
[39] Further details of the survey can be found at https://www.enterprisesurveys.org.

Bangladesh) and over nine two-digit industrial classifications.[40] It contains only eleven non-metallic minerals firms, none of them in Bangladesh. Hence, for computational purposes, we merge these firms into a broader manufacturing sector category: other manufacturing.[41] We do not have complete data for all the variables of this study, and we also had to delete some outliers; therefore, our econometric analyses will not be based on all 2,085 observations, but will be based on the number of firms with the complete data for the particular model setting.

Tables (4.2) and (4.3) report the summary statistics of all variables used in the econometric analyses. In the survey the information of all monetary variables was gathered in the respective country's currency unit, which we converted into USD to obtain comparable figures. The first striking result is that although Pakistan has more SMEs than Bangladesh (the average firm's employment is 293.40 in Bangladesh compared with only 114.11 in Pakistan), the firms' average sales value is \$5.03 million, which is more than twice that of Bangladesh, i.e. \$2.23 million.[42] In addition, Bangladeshi firms are more often trade

[40] Our sample includes the following two-digit manufacturing sectors: Food, chemical, garments, non-metallic minerals, leather, textiles, machinery and equipments, electronics, and other manufacturing.

[41] This does not affect the econometric estimations of our main variables.

[42] These findings should be considered with caution because there might be some firms in Pakistan having very high sales relative to others. It could also be noted quantitatively by comparing very large average (mean) sales relative to the value of only \$0.09 million for median. We observed the possibility and found that two firms have high sales figures compared with the remaining pool. The average sales volume for Pakistan by excluding these two firms was \$2.72 million (quite near to the figure of Bangladesh). The immediate effect of large sales volumes of these two companies could be the sharp upward shift of the labor productivity because we measure it by sales/employment, but we noticed that it was not changed substantially: average labor productivity of Pakistan was \$23.77 thousand by including these two firms and was \$23.05 thousand by excluding them, implying that these large sales values were not the wrong entries due to the data gathering errors (because they also have large employment). Having said that, we were concerned about the distortions of our econometric results (will be discussed subsequently) owing to these large sales values. Therefore, in empirical part of this study, we also estimated all of our models by excluding these two firms (the results will not be reported with econometric estimation outputs in order to conserve space) and found no difference.

oriented and innovators (both product and process). More specifically, the average share of export sales of total sales is 33.5% for Bangladeshi firms and 12.21% for Pakistani firms. The figure for import intensity is 35% for the former and 11.7% for the latter. In terms of innovation, 33.1% of the Bangladeshi firms reported to be product and 45% to be process innovators, while the percentages for Pakistan are 12.3 and 9.6 respectively. Moreover, the point estimates reveal that workers in Bangladeshi firms are more often educated and have formal training programs. On the other hand, compared with Bangladesh, on average companies in Pakistan are older, have more experienced top managers, and are more often located in industrial parks. Regarding two important production function inputs: raw material costs and net book value of fixed asset[43] (both scaled by employment), Pakistani firms appear to have higher values than Bangladeshi ones, the difference is particularly large for the net book value of fixed assets (see the last two rows of Table (4.2)). Note that for both measures, we consider only firms that reported non-zero monetary values. In case of the net book value, 301 Pakistani firms (of the 647 firms which answered this particular survey question) reported zero net book value. The exclusion of these 301 firms compared to only 3 Bangladeshi firms (of the 1,293 firms who answered this question) could introduce a bias favoring the overestimation of the average net book value for Pakistan. Hence, we also estimated averages of the net book values (per employee) by including these zero-value reporting firms for both countries separately; the difference is still large ($15,410 for Pakistan, while the average value for Bangladesh is only $5,930), suggesting that Pakistani firms really own larger capital assets than those in Bangladesh. The point estimates also reveal that 32% Bangladeshi firms perceives that access to finance is the main obstacle to their effective operation. Moreover, 41% Bangladeshi firms manufacture only one product, while 28% companies have two manufacturing products. Another significant finding from these descriptive statistics is that labor productivity (sales per employee) is substantially higher in Pa-

[43] These fixed assets are machinery, vehicle, equipments, land, and buildings.

kistan than in Bangladesh. Two reasons for this difference of productivity between Pakistan and Bangladesh may be the relatively sizeable flow of raw materials to and a comparatively large stock of fixed assets in Pakistan. Moreover, the complementarities in the production process also play a significant role in the high productivity of Pakistan. In addition, we analyzed the relationships of these two production inputs with the productivity by sketching two scatter plots (see Figure (4.1) and (4.2)).[44]

**Table 4.3 Percentages of occurrences in dummy variables**

| Variables | Bangladesh % | Pakistan % |
|---|---|---|
| Product innovation | 33.14 | 12.32 |
| Process innovation | 44.96 | 9.60 |
| R&D performers | 42.52 | |
| Located in industrial zone | 17.90 | 34.44 |
| Worker union | 11.09 | 5.79 |
| Usage of web | 26.13 | 23.75 |
| (7+ year) education of a production worker | 31.11 | 14.18 |
| Formal training (of permanent workers) | 21.07 | 8.59 |
| Usage of technology licensed from foreign company | 5.33 | 5.79 |
| Member of any business association | 85.01 | |
| Access to finance | 32.46 | |
| One product firms | 41.30 | |
| Two products firms | 28.26 | |

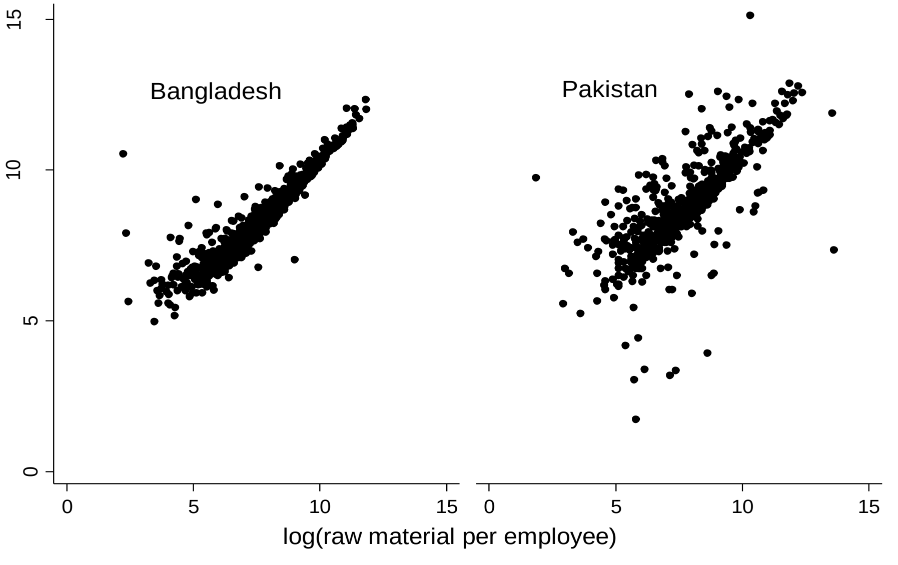
Both figures depict positive relationships of both input indicators with productivity for both of the countries. Moreover, the less dispersed scatter points for raw materials compared to net book values imply a higher significance of the former than the latter, to explain the variability of labor productivity.

In terms of internet usage and foreign-licensed technology, both countries behave similarly, with a slightly higher rate of Bangladesh for the former and of Pakistan for the latter. Surprisingly, the raw estimates show that almost 43% of Bangladeshi firms reported to engage

[44] We also examined these relationships in rigorous econometric settings. The details are described in later sections.

in R&D activities, while the R&D investment (scaled by sales) is 0.55% for all firms of Bangladesh and 1.28% when we consider only

**Figure 4.1 Scatter plot of log of raw material per employee and log of labor productivity**



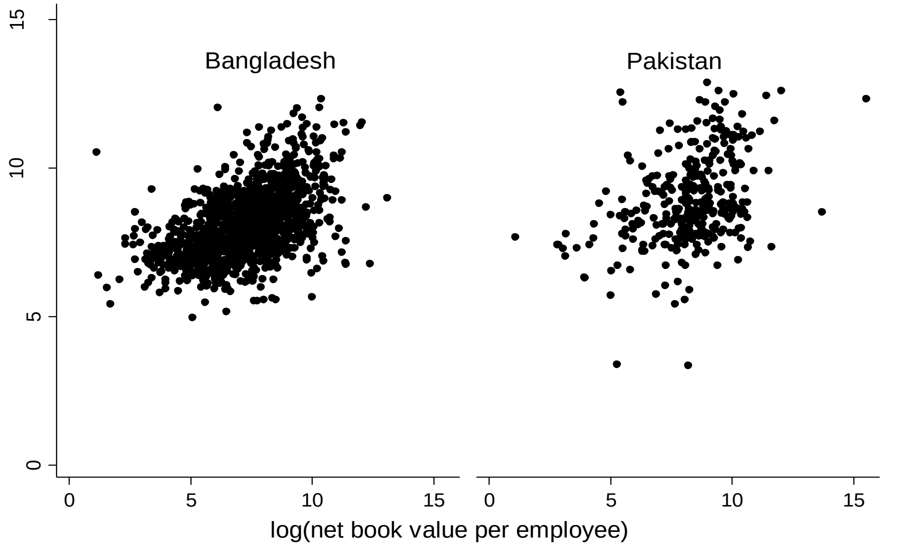

R&D performers.[45] If we compare the first, second (median), and third quartiles, all continuous variables are observed to be positively skewed for both countries, except for a slight negative skewness of both countries' production workers intensities.

Recall that in chapter (2), we compared both regions studied in chapters (3)-(5) of this thesis (i.e., Latin America and South Asia) in terms of different technology and innovation indicators. It would also be interesting to compare our samples' descriptive statistics of innovation activities across these regions. If we compare product innovators and R&D across regions (Tables (3.1) and (4.3)), the maximum share of product innovators in Argentina with a value of 75% is more than double that of maximum product innovator in South Asia, i.e. Bangladesh with value of 33%.[46] The fraction of 12% in Pakistan is also very low compared to the lowest ranking product innovator in Latin

[45] We do not have R&D information for Pakistani firms.

[46] See footnote (6).

**Figure 4.2 Scatter plot of log of net book value per employee and log of labor productivity**




America, i.e. Mexico with 35%. Overall, 63% Latin American firms reported to be product innovators, while the proportion of South Asia is only 25%, suggesting a large difference in terms of product innovation propensity across both regions. It means that the previously observed dominant position of Latin American with regards to macro level indicators in chapter (2) also holds true regarding micro level (firm-level) product innovation. Regarding R&D performance, 50% of Argentinean firms (again the maximum in this region) reported to carry out R&D activities, while the figure for Bangladesh (the only available information for this region) is 43%. The aggregate share of R&D performing firms in Latin America is 36%.This means that the large difference observed for product innovation does not apply to R&D performance. Finally, if we look closely at the patterns of Latin American countries in all the comparisons (i.e. those in chapter (2) and here in chapter (4)), Argentina holds either the first or the second rank, except for average R&D expenditure, in which category it holds the third rank (column (5) of Table (3.1)). Although Bangladeshi firms are more likely to be product innovators compared with Pakistani firms of our sample the latter ranks higher in a South Asian intra-regional comparison in terms of scientific publications and of technological capability indicator on an aggregate level (Table (A2.7) and (A2.8)), whereas the former performs better in terms of the Global Innovation Index 2011 (GII). The differences of a country's performance by different indicators may be explained by the respective definitions, scales of aggregations, and periods covered for their constructions. Note that our samples in chapters (3)-(5) include only manufacturing units at a micro level (firms), contrary to the aggregate level indices of chapter (2).

Another important aspect of the cross-regional comparison may be to examine the difference between intra-region innovation commitments across industries. It is important to note that the regional trend described above will also be the case when we break our analysis down to industry levels. Simply put if firms in one region are more likely to be innovators, the industries in that region will show the same trend in comparison with the less innovative regions' industries. Therefore, our intention is not to compare regions on industry level innovations, but we analyze intra-regional trends in innovation at the industry level, to find differences in these trends. If we compare the descriptive statistics of Table (3.2) with those of Table (A4.1), we notice that the chemical industry is the highest ranking industry with regard to product innovation in both regions. The leather industry is the second highest ranking industry in South Asia, but we do not have data of this industry for Latin America. The garments industry is the second most product innovative industry in Latin America, while this industry ranks fourth in South Asia. The only R&D data available in South Asia is for Bangladesh; again the chemical industry is the highest ranked R&D performing industry in both regions. This means that both regions confirm the trend which has frequently been described in the literature, i.e. that the chemical industry is an innovation-intensive industry.

## 4.5 Econometric Analysis

### *4.5.1 The Research Equation*

As we already know, R&D expenditure information is only available for Bangladesh; the results of this subsection solely apply to Bangladesh and are reported in Table (4.4).

The significance of $\lambda$ suggests that our data suffers from a selectivity bias, and underpins the use of the Heckman selection model to control for it. The influence of firm sales on the positive R&D decision and on R&D investment is significant and positive. Although firm sales have

**Table 4.4 R&D equation (the Heckman selection model) for Bangladesh. Standard errors are in parentheses**

| Independent Variables | Dependent Variables | | | |
|---|---|---|---|---|
| | LRDI (outcome equation) | | RD (selection equation) | |
| Intercept | -0.503 | (2.068) | -2.698* | (0.348) |
| LSALES | -0.565* | (0.076) | 0.148* | (0.027) |
| DIV1 | -0.391# | (0.196) | -0.244# | (0.102) |
| DIV2 | -0.364# | (0.184) | -0.138 | (0.109) |
| ACCESS | -0.106 | (0.161) | 0.104 | (0.090) |
| UNION | 0.056 | (0.217) | 0.262# | (0.130) |
| TRAIN | 0.458* | (0.164) | 0.105 | (0.105) |
| WEB | 0.774# | (0.323) | 0.559* | (0.105) |
| MEMBER | 0.393 | (0.269) | 0.169 | (0.136) |
| EXPER | | | -0.012# | (0.005) |
| No. of obs. | 1165 | | | |
| censored obs. | 667 | | | |
| $\lambda$ | 1.543# (0.786) | | | |

* Significance at 1% level # Significance at 5% level
† Significance at 10% level
Note: All regressions include industry dummies

a positive influence on R&D expenditure, the increase in R&D investment is proportionally lower than the increase in firm sales.[47] As

[47] The coefficient of sales in Table(4.4) is in fact negative, but it does not imply a negative relationship between sales and R&D expenditure because our dependent variable is R&D expenditure to sales. More precisely, suppose a simple R&D expenditure model for the $i^{th}$ firm as $r_i = a + bs_i + cz_i + \varepsilon_i$, where $r_i$ and $s_i$, in logarithm form, are the firm's R&D expenditure and sales volume, and $z_i$ is a vector of other explanatory variables with $c$ is a coefficient vector. We can then measure the proportionate change of R&D expenditure with respect to sales as the departure of coeffi-

expected, the results reveal a significantly positive influence of product diversification on both R&D decision and its intensity. We anticipated a priori t the firms which perceive access to finance as the major obstacle in their operation have less commitment to R&D activities, but the insignificance of ACCESS, for both R&D decision and intensity, does not corroborate this argument, at least for Bangladeshi firms in our dataset. The effect of unionization on the R&D decision is significant and positive while the effect on the R&D intensity variable is insignificant; formal training has the opposite trend. The variable labeled WEB (an indication of firms' broad international exposure, especially in the context of developing countries, and of an advanced internet infrastructure) has a highly positive influence on the R&D indicator and on the subsequent R&D expenditure. Moreover, a membership in a business association (e.g. chamber of commerce) does not contribute to either R&D-related variable, suggesting institutional apathy towards innovation efforts through R&D. Finally, the signs and significances of the regression coefficients EXPER as determinants of the R&D decision empirically follow the pattern we had anticipated in the discussion of exclusion restrictions in section (4.3).

### *4.5.2 The Innovation Output Equation*

Unlike the research equation, we estimated the knowledge output equation for all firms and for Pakistan and Bangladesh separately. We estimated two innovation equations for Bangladesh: one with R&D (used in the FCDM), and the other without R&D (used in the RCDM), as an input of innovation output.

Table (4.5) shows the innovation output equation results for Bangladesh based on equations (4.3) and (4.4), and we call them models (3A) and (4A) respectively. Subsequently, we estimate the innovation output equation for Bangladesh without considering R&D (i.e. by using vector *w*), but the reason to estimate model (4A) in Table (4.5) is

---

cient *b* from unity. We can rewrite the model as $r_i$-$s_i$=$a$+($b$-$1$) $s_i$+$cz_i$+$\varepsilon_i$. The coefficient of $s_i$, i.e. *b-1,* now measures the proportionate change by its departure from zero.

to compare both models (including and excluding R&D) in the same model specification because the vectors $y_1$ and $w$ do not include the

**Table 4.5 Innovation output equation (the bivariate probit model) based on equations 4.3 and 4.4, for Bangladesh. SEs (bootstrapped for columns (1-2) and robust for columns (3-4)) are in parentheses**

| Independent Variables | Dependent Variables | | | |
|---|---|---|---|---|
| | PDINN | PRINN | PDINN | PRINN |
| | Model 3A | | Model 4A | |
| Intercept | 0.103<br>(0.431) | -0.953[#]<br>(0.378) | -0.246<br>(0.373) | -1.070[*]<br>(0.367) |
| LRDI | 0.826[*]<br>(0.185) | 0.575[*]<br>(0.158) | | |
| LSALES | 0.456[*]<br>(0.099) | 0.422[*]<br>(0.088) | -0.002<br>(0.032) | 0.098[*]<br>(0.030) |
| EXP | -0.475[*]<br>(0.159) | -0.173<br>(0.155) | -0.455[*]<br>(0.152) | -0.192<br>(0.139) |
| IMP | 0.269[#]<br>(0.118) | 0.092<br>(0.125) | 0.321[*]<br>(0.122) | 0.121<br>(0.118) |
| EDU | 0.232[#]<br>(0.090) | 0.088<br>(0.090) | 0.204[*]<br>(0.099) | 0.102<br>(0.098) |
| INDZONE | 0.336[*]<br>(0.122) | 0.377[*]<br>(0.108) | 0.292[*]<br>(0.109) | 0.359[*]<br>(0.106) |
| LICE | 0.651[*]<br>(0.211) | 0.590[*]<br>(0.215) | 0.800[*]<br>(0.201) | 0.715[*]<br>(0.211) |
| WEB | -0.231<br>(0.168) | -0.142<br>(0.143) | 0.457[*]<br>(0.109) | 0.324[*]<br>(0.105) |
| MEMBER | -0.413[#]<br>(0.161) | -0.134<br>(0.154) | -0.146<br>(0.128) | 0.051<br>(0.126) |
| AGE | -0.011[*]<br>(0.003) | -0.012[*]<br>(0.004) | -0.013[*]<br>(0.004) | -0.013[*]<br>(0.004) |
| DIV1 | | | -0.711[*]<br>(0.104) | -0.477[*]<br>(0.101) |
| DIV2 | | | -0.410[*]<br>(0.110) | -0.208[#]<br>(0.104) |
| ACCESS | | | 0.074<br>(0.090) | -0.164[†]<br>(0.086) |
| UNION | | | 0.209<br>(0.127) | 0.181<br>(0.129) |
| TRAIN | | | 0.119<br>(0.110) | 0.037<br>(0.107) |
| No. of obs. | 1149 | | 1149 | |
| LR test for $\rho = 0$ | 279.34[*] | | 213.92[*] | |

[*] Significance at 1% level [#] Significance at 5% level [†] Significance at 10% level

Note: All regressions include industry dummies

same variable inputs.[48] Model (3A) is the second equation of the FCDM model, and model (4A) is the first equation of the RCDM. Research intensity may be endogenous in the innovation output equation, so in model (3A) we utilized the predicted values of LRDI from

[48] One reason for this difference is that the estimations which include $w$ are based on data of both Pakistan and Bangladesh, and include the same set of inputs for both countries to acquire comparable results.

Table (4.4) as an instrument to avoid these biases.[49] The hypothesis of zero correlation between the disturbance terms of the PDINN and PRINN equations is rejected, as can be seen throughout Table (4.5), suggesting that both innovation outputs are influenced by common unknown forces (see footnote (37)). Table (4.5) shows that research intensity is a significant determinant of both product and process innovation.[50] Both models produced similar results for both innovation outputs (product and process) at a reasonable significance level (i.e. 5%), except for LSALES for product innovation and WEB for both product and process innovation. In model (3A) firm sales show a positive effect on product innovation, but they become insignificant for model (4A). To examine this phenomenon in more depth, we performed another bivariate probit by including (the predicted values of) LRDI and by excluding LSALES (the results are not reported) and found LRDI as a predictor of PDINN was insignificant. Hence, we deduced that LRDI and LSALES have significant impacts on PDINN only if they are used as determinants of PDINN together, implying perhaps complementarities between them to influence product innovation. The variable WEB is a positive, significant determinant of both product and process innovation in model (4A), but lose its importance in model (3A). According to results in Table (4.5), use of foreign-licensed technology and premises at an industrial park are beneficial for both knowledge outputs, whereas the influence of firm age on both innovation types is negative and significant. Moreover, we always observe a significant, positive effect of firm sales on process innovation. Furthermore, we found a significantly increasing influence of workforce education on product innovation, but we found its contribution to process innovation to be insignificant. The reason might be that

[49] The other measure to avoid endogeneity could be plugging the lagged values of research efforts, but we did not have panel data; therefore, we had to rely on predicted values.

[50] Recall that in Latin America in chapter (3), research intensity is an insignificant determinant of product innovation. One possibility for this contradiction could be the use of different research intensity definitions: for Latin America, research intensity was measured as R&D expenditures per employee, but in chapter (4) it was calculated as the ratio of R&D expenditure to sales.

our variable EDU captures the education of typical production workers, who arguably affect product innovation more directly than process innovation because product innovation is the final outcome of a firm's research efforts and/or adaptation of developed world technologies (in the case of developing countries' innovations). Although production workers are primarily responsible for manufacturing rather than innovation, they may be better able to understand the sophistications involved in the manufacturing of a novelty if they are sufficiently educated. The process innovation variable does not capture these benefits of an educated production-related labor force since it focuses primarily on the non-production-related activities of a firm[51]. The effect of MEMBER on product innovation is significant, negative in model (3A), whereas it has no relationship with process innovation. The regression coefficients of Table (4.5) also disclosed that UNION and MEMBER are unimportant determinants of both innovations in model (4A). So, we can argue that the previously observed negligibility of institutions on R&D efforts also prevails in the output phases of innovations. The effects of trade-orientation are the same as for the Bangladeshi part of Table (4.6), and are discussed therein. The main objective of Model (4A) is to find the predicted values of innovation variables used in the productivity equation, to compare FCDM and RCDM. Since it is an auxiliary model, we skip interpreting the remaining coefficients as determinants of innovation.

Table (4.6) depicts the empirical results of the knowledge output equation by applying equation (4.5), to all firms taken together and to Pakistan and Bangladesh separately. Since Table (4.6) does not include R&D information, it is equivalent to the first equation of the RCDM. Similar to Table (4.5), we find a strong correlation between the error terms of both the PDINN and PRINN equations. The variable

[51] The process innovation variable also gathers some information about improvements in the production process (see the description of PRINN in Table (4.1)) which could also be linked to production-related employees. However, in our opinion, this link is not as strong as in the case of product innovation, which is ultimately an outcome of the production department's employment.

**Table 4.6 Innovation output equation (the bivariate probit for PDINN and PRINN) based on the equation (4.5), for all firm and for Pakistan and Bangladesh separately. Robust SEs are in parentheses.**

| Independent Variables | All firms | | Bangladesh | | Pakistan | |
|---|---|---|---|---|---|---|
| | PDINN | PRINN | PDINN | PRINN | PDINN | PRINN |
| Intercept | -1.106* | -1.612* | -0.995* | -1.627* | -2.298* | -2.761* |
| | (0.278) | (0.295) | (0.336) | (0.331) | (0.569) | (0.676) |
| LSALES | 0.022 | 0.107* | 0.024 | 0.123* | 0.037 | 0.046 |
| | (0.024) | (0.025) | (0.029) | (0.028) | (0.049) | (0.052) |
| EXP | -0.381* | -0.113 | -0.498* | -0.169 | 0.472# | 0.300 |
| | (0.119) | (0.118) | (0.146) | (0.137) | (0.220) | (0.264) |
| IMP | 0.344* | 0.193† | 0.299# | 0.115 | 0.822* | 0.881* |
| | (0.110) | (0.107) | (0.120) | (0.116) | (0.255) | (0.254) |
| EDU | 0.305* | 0.142† | 0.239# | 0.101 | 0.624* | 0.342† |
| | (0.086) | (0.086) | (0.097) | (0.095) | (0.191) | (0.200) |
| INDZONE | 0.268* | 0.362* | 0.314* | 0.375* | -0.083 | 0.125 |
| | (0.085) | (0.088) | (0.105) | (0.105) | (0.170) | (0.177) |
| LICE | 0.975* | 0.794* | 0.753* | 0.669* | 1.434* | 0.969* |
| | (0.163) | (0.162) | (0.190) | (0.202) | (0.268) | (0.260) |
| WEB | 0.431* | 0.378# | 0.414* | 0.314* | 0.271 | 0.587* |
| | (0.093) | (0.091) | (0.107) | (0.102) | (0.218) | (0.226) |
| AGE | -0.005# | -0.006# | -0.011* | -0.011* | 0.008 | 0.008 |
| | (0.003) | (0.003) | (0.003) | (0.004) | (0.006) | (0.005) |
| PAK | -0.699* | -1.326* | | | | |
| | (0.109) | (0.120) | | | | |
| No. of obs. | 1824 | | 1153 | | 671 | |
| LR test for $\rho = 0$ | 295.34* | | 223.72* | | 63.70* | |

* Significance at 1% level  # Significance at 5% level  † Significance at 10% level

Note: All regressions include industry dummies

LICE produce significant coefficients for both process and product innovation for all estimation outputs (i.e. for all firms and for Pakistan and Bangladesh separately). Firm sales happen to be an insignificant determinant of product innovation in all regressions; however, its influence on process innovation is significant for Bangladesh and for all firms together, albeit insignificant for Pakistan. Hence, these findings suggest that size does not matter for Pakistani firms' likelihood to be innovators. The empirical findings for Pakistan are in line with the general idea of a positive link between firm imports and innovation (both PDINN and PROINN), while exports are a significant and positive determinant of product innovation and insignificant of process innovation. However, Exports have a significant, negative and imports have a positive and significant influence on Bangladeshi firms' product innovation, and both have insignificant contribution to PRINN. If we look at the trade-related results, we come to the conclusion that Bangladeshi exporters are not generally strong innovation-seekers. Firm age also has mixed results: a negative influence on both dependent variables, for Bangladesh and for the whole dataset, but has an insignificant effect for Pakistan. The results suggest that INDZONE is an insignificant determinant of both innovation outputs for Pakistan, but a significant factor for the other estimations. We find that education (of production workers) is an important stimulus for PDINN and to PRINN in Pakistan and for all firms. Similar to Table (4.5) education is a significant (an insignificant) predictor of product (process) innovation of Bangladeshi firms. Bearing in mind the argument discussed in Table (4.5) that this difference in effects of education on both process and product innovation of Bangladeshi firms, and the significant impact of education on both innovation types of Pakistani firms may lead to the conclusion that Pakistani firms are more often vertically integrated than Bangladeshi firms. Our results disclose that the coefficient of the Pakistan dummy (PAK) is significant and negative for both innovation outputs, confirming econometrically that Bangladeshi manufacturing firms are more often innovators than Pakistani ones as suggested by the results seen in Table 4.3. Finally, we notice that the results for all firms in Table (4.6) generally follow the pattern (with respect to sign and significance) of Bangladeshi firms. This may be due to a larger representation of Bangladeshi firms compared with Pakistani ones (63% vs. 37%) in the pool of all firms.

### *4.5.3 The Productivity Output Equation*

The final and major objective of this chapter is to investigate the determinants of firms' productivity by introducing innovation as one of its potential inputs. We followed the traditional Cobb-Douglas model for this purpose. All of our subsequent productivity equation estimations involve predicted values of PDINN and PRINN as determinants of productivity in separate productivity equations; for the sake of convenience we called them PDINN-included and PRINN-included respectively.[52] Since the predicted values were included as regressors, we used bootstrapped standard errors.

**Table 4.7 Productivity equation for Bangladesh (the predicted values of PDINN and PRINN are obtained from Table (4.5)). Bootstrapped SEs are in parentheses. Dep. var.: LPROD**

| Independent variables | Basic | | | | Extended | | | |
|---|---|---|---|---|---|---|---|---|
| | FEBS | | TEBS | | FEES | | TEES | |
| Intercept | 2.23* | 2.29* | 2.23* | 2.29* | 2.49* | 2.43* | 2.46* | 2.44* |
| | (0.15) | (0.15) | (0.16) | (0.15) | (0.23) | (0.23) | (0.20) | (0.20) |
| LMATERIAL | 0.71* | 0.69* | 0.71* | 0.70* | 0.70* | 0.69* | 0.70* | 0.69* |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.03) | (0.02) | (0.02) |
| LNETBOOK | 0.06* | 0.06* | 0.06* | 0.06* | 0.05* | 0.05* | 0.05* | 0.05* |
| | (0.02) | (0.01) | (0.02) | (0.01) | (0.01) | (0.02) | (0.01) | (0.02) |
| LEMP | 0.03 | 8.8e$^{-05}$ | 0.03† | 0.01 | 0.02 | -5.6e$^{-04}$ | 0.02 | 3.9e$^{-03}$ |
| | (0.02) | (0.01) | (0.01) | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) |
| PDINN | 0.14† | | 0.15# | | -0.07 | | 2.4e$^{-03}$ | |
| | (0.07) | | (0.08) | | (0.12) | | (0.08) | |
| PRINN | | 0.47* | | 0.42* | | 0.50* | | 0.41* |
| | | (0.11) | | (0.14) | | (0.17) | | (0.15) |
| EDU | | | | | 0.08# | 0.05 | 0.07# | 0.05† |
| | | | | | (0.03) | (0.03) | (0.03) | (0.03) |
| WEB | | | | | 0.10# | 0.02 | 0.09* | 0.03 |
| | | | | | (0.05) | (0.04) | (0.03) | (0.03) |
| BONUS | | | | | -0.01 | -0.01 | -0.01 | -0.01 |
| | | | | | (0.01) | (0.01) | (0.01) | (0.01) |
| LICE | | | | | 0.04 | -0.10 | 0.02 | -0.08 |
| | | | | | (0.06) | (0.07) | (0.06) | (0.07) |
| PRODIN | | | | | -0.10 | -0.07 | -0.09 | -0.08 |
| | | | | | (0.08) | (0.09) | (0.07) | (0.09) |
| No. of obs. | 1121 | 1121 | 1121 | 1121 | 1119 | 1119 | 1119 | 1119 |
| coeff. of det. | 0.89 | 0.89 | 0.89 | 0.89 | 0.89 | 0.90 | 0.89 | 0.90 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: All regressions include industry dummies

Table (4.7) reveals the estimation outputs of the productivity equations of the FCDM and the RCDM in the basic and extended versions for Bangladesh. For FEBS and FEES, we utilized the predicted values

[52] We also analyzed these equations by using both innovation outputs simultaneously in one productivity equation (the results have not been reported)and investigated our doubts that both might be collinear because they share many common characteristics, because both predicted values are based on the same model specification, and also because empirically we found that the unknown factors (captured by their respective equations' errors) influencing both of them are highly correlated. Our investigation came to the conclusion that PDINN and PRINN are highly collinear, so we avoided combining them in one equation.

of PDINN and PRINN obtained from model (3A) in Table (4.5), i.e. both are final equations of the FCDM, and TEBS and TEES incorporate the predicted values from the bivariate probit of model (4A) in Table (4.5), meaning that they are final equations of the RCDM. One striking result is that we are unable to reject the CRS assumption in any of our regressions at a reasonable significance level (i.e. 5%). Our results unveil another important finding: the factors contributing to both innovation outputs describe virtually the same pattern in both FCDM and RCDM, suggesting that we could be indifferent between these models to determine the influence of innovation output on productivity.[53]One small difference is that contrary to the significance of PDINN in PDINN-included FEBS at 10% level, we find significance of PDINN in PDINN-included TEBS at 5% level. One purpose of having controls in the extended version is to ascertain the robustness of our principal (basic) productivity output model, which is mostly confirmed. Our findings demonstrate that process innovation of Bangladeshi firms is a significant determinant of their labor productivity, while the coefficient of product innovation shows mixed results: product innovation is an important (unimportant) factor of productivity in two- and four-equation basic (extended) version. The elasticities of productivity with respect to material costs and net book value are significant and positive, implying their remarkable role in firm productivity.[54]The insignificance of both BONUS and PRODIN prevail for

[53] Our results are not directly comparable to those that were obtained by Mairesse et al.(2005)because of different model specification and of different definitions of innovation outputs. However, for the sake of the nearest possible comparison, they also found that, with respect to significance, the effect of innovative sales on labor productivity showed a similar pattern (significant in both cases) in complete and reduced version of the CDM. In addition to estimating the full CDM by utilizing the R&D choice and intensity at the research equation stage, they also estimated a complete and a reduced CDM by using only binary indicators of R&D, product and process innovations. The innovation output variables in this specification were the same as ours, but the research equation had only one R&D choice indicator. In this specific comparison, they found a pattern similar to that observed for innovation sales.

[54] Note that LPROD, LMATERIAL, and LNETBOOK are used in logarithmic forms; therefore, the estimated coefficients give the interpretations of elasticities directly.

both FEES and TEES, suggesting that these seemingly beneficial indicators do not contribute to productivity. In Tables (4.5) and (4.6) we have concluded that EDU is a significant determinant of PDINN, but not of PRINN for Bangladesh; Table (4.7) confirms that education is a more significant determinant of Bangladeshi firms' productivity output in the PDINN-included equation in TEES than in the PRINN-included equation in TEES, and only significant in the FEES version of the PDINN-included. We noticed that the inclusion of PRINN (instead of PDINN) collapses the significance of WEB as a productivity determinant. This means that the importance of using the internet (to communicate with clients or suppliers) is crowded out by process innovation. The use of foreign-licensed technology happens to be a

**Table 4.8 Productivity equation for all firm taken together. Bootstrapped SEs are in parentheses. Dep. var.: LPROD**

| Independent variables | Basic | | | | Extended | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1a) | (2a) | (3a) | (4a) |
| Intercept | 2.73* | 2.39* | 2.79* | 2.48* | 2.88* | 2.66* | 2.69* | 2.62* |
| | (0.13) | (0.16) | (0.13) | (0.17) | (0.16) | (0.18) | (0.14) | (0.18) |
| LMATERIAL | 0.71* | 0.69* | 0.68* | 0.67* | 0.70* | 0.68* | 0.65* | 0.65* |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| LNETBOOK | | 0.06* | | 0.06* | | 0.06* | | 0.05* |
| | | (0.02) | | (0.01) | | (0.01) | | (0.02) |
| LEMP | 0.01 | 0.01 | -0.05# | -0.03 | $1.4e^{-03}$ | 0.01 | -0.06# | -0.03 |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| PDINN | 0.47* | 0.40* | | | 0.45† | 0.30 | | |
| | (0.14) | (0.10) | | | (0.24) | (0.20) | | |
| PRINN | | | 1.26* | 0.92* | | | 2.32* | 1.59* |
| | | | (0.17) | (0.17) | | | (0.35) | (0.41) |
| EDU | | | | | 0.06 | 0.06 | -0.02 | $2.0e^{-03}$ |
| | | | | | (0.05) | (0.04) | (0.05) | (0.04) |
| WEB | | | | | 0.07 | 0.05 | -0.18* | -0.13† |
| | | | | | (0.05) | (0.05) | (0.06) | (0.07) |
| LICE | | | | | -0.16 | -0.08 | -0.61* | -0.38* |
| | | | | | (0.15) | (0.12) | (0.13) | (0.14) |
| PRODIN | | | | | -0.11 | -0.25# | -0.11 | -0.25# |
| | | | | | (0.12) | (0.10) | (0.11) | (0.10) |
| PAK | 0.50* | 0.59* | 0.77* | 0.78* | 0.50* | 0.56* | 1.13* | 1.00* |
| | (0.08) | (0.09) | (0.07) | (0.08) | (0.07) | (0.08) | (0.10) | (0.13) |
| No. of obs. | 1789 | 1435 | 1789 | 1435 | 1788 | 1435 | 1788 | 1435 |
| coeff. of det. | 0.76 | 0.83 | 0.77 | 0.83 | 0.76 | 0.83 | 0.78 | 0.84 |

* Significance at 1% level  # Significance at 5% level  † Significance at 10% level

Note: All regressions include industry dummies

statistically insignificant determinant of productivity in Bangladeshi companies. The coefficient of LICE is negative in PRINN-included equation and positive in PDINN-included equation, meaning that inclusion of process innovation instead of product innovation changes the coefficient signs from positive to negative. This may be an indication that firms might consider them (LICE and WEB) as a change in their process, and their significance is undermined by using a more appropriate definition of process innovation: PRINNIt is important to accentuate that the following empirical estimations of the productivity equations will be based on a simultaneous two-equation system (i.e. the second and final equation of the RCDM). We estimated both productivity equations (PDINN-included and PRINN-included) by using only LMATERIAL (and call this regression LM) and by employing both LMATERIAL and LNETBOOK (called LMN), as determinant(s) of productivity.[55] Table (4.8) reports the results of the large pool of all firms. The CRS assumption is accepted in all cases, except for PRINN- included LM in the basic and extended versions (we have decreasing returns to scale in these cases). It is important to note that in this particular regression we included only LMATERIAL, which deviates from the traditional definition of physical capital. When we included LNETBOOK, even in conjunction with LMATERIAL, CRS was accepted[56]. Similar to Table (4.7) material and net book value intuitively are very important factors of labor productivity for all firms. The values of PDINN and PRINN are the predicted values obtained from the first two columns of Table (4.6). One of the striking findings is that in all regressions both product and

[55] In Table (4.7), we used LMATERIAL and LNETBOOK in one equation for Bangladesh. Recall that we have 301 Pakistani firms with zero net book value which we have to leave out of the analysis for Pakistan, but we do not want to lose other information of these 301 zero-reportingnet book value firms. Hence, we ran two regressions by including only LMATERIAL (i.e. LM) and by using both LMATERIAL and LNETBOOK (i.e., LMN). We already emphasized that we wanted to achieve comparable results for Pakistan, Bangladesh, and for all firms, so we performed the two above described regressions for all three cases.

[56] We demonstrated that our CRS assumption is with respect to material cost, net book value, and employment, conditional on the inclusion of only the first and of both the first and the second.

process innovation contributes importantly to productivity of all firms, except insignificance of product innovation in PDINN-included LMN in extended version. We conclude that our results are robust after comparing the basic and extended versions, with only one exception which we have just pointed out. Considering all firms education is insignificant determinant for productivity in all regressions. The role of internet is insignificant (with positive coefficient signs) in PDINN-included equations and negative and significant in PRINN-included equations. The effect of LICE is negative in all regressions, but significant for only PRINN-included equations. Similar to Table (4.7), the inclusion of PRINN undermines the effect of LICE and WEB as determinants of productivity. The percentage of permanent production workers in permanent employment produces disappointing results

**Table 4.9 Productivity equation for Bangladesh (the predicted values of PDINN and PRINN are obtained from Bangladeshi part of Table (4.6)). Bootstrapped SEs are in parentheses. Dep. var.: LPROD**

| Independent variables | Basic | | | | Extended | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1a) | (2a) | (3a) | (4a) |
| Intercept | 2.38* | 2.23* | 2.46* | 2.31* | 2.63* | 2.41* | 2.55* | 2.37* |
| | (0.12) | (0.13) | (0.16) | (0.15) | (0.17) | (0.20) | (0.15) | (0.17) |
| LMATERIAL | 0.74* | 0.71* | 0.72* | 0.69* | 0.74* | 0.71* | 0.71* | 0.68* |
| | (0.02) | (0.02) | (0.03) | (0.02) | (0.02) | (0.02) | (0.03) | (0.03) |
| LNETBOOK | | 0.06* | | 0.06* | | 0.05* | | 0.05* |
| | | (0.01) | | (0.02) | | (0.01) | | (0.01) |
| LEMP | 0.04* | 0.02† | 2.3e-03 | -0.01 | 0.02† | 0.02 | 2.54e-04 | -0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| PDINN | 0.18# | 0.22# | | | -0.19 | -0.03 | | |
| | (0.09) | (0.08) | | | (0.14) | (0.13) | | |
| PRINN | | | 0.61* | 0.60* | | | 0.79* | 0.81* |
| | | | (0.17) | (0.15) | | | (0.25) | (0.25) |
| EDU | | | | | 0.12* | 0.07# | 0.07# | 0.03 |
| | | | | | (0.03) | (0.03) | (0.03) | (0.03) |
| WEB | | | | | 0.11# | 0.09† | -0.03 | -0.03 |
| | | | | | (0.05) | (0.04) | (0.04) | (0.04) |
| LICE | | | | | 0.07 | 0.02 | -0.18# | -0.18† |
| | | | | | (0.06) | (0.07) | (0.09) | (0.10) |
| PRODIN | | | | | -0.12 | -0.09 | -0.11 | -0.07 |
| | | | | | (0.08) | (0.08) | (0.07) | (0.06) |
| No. of obs. | 1131 | 1124 | 1131 | 1124 | 1131 | 1124 | 1131 | 1124 |
| coeff. of det. | 0.89 | 0.89 | 0.89 | 0.90 | 0.89 | 0.89 | 0.89 | 0.90 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: All regressions include industry dummies

since we find negative signs in all regressions. The coefficient is insignificant in both of the LM regressions and significant in both LMNs. Finally, the Pakistan dummy (PAK) is highly significant in all of our regressions, confirming the Pakistan's high labor productivity compared with Bangladesh suggested by the descriptive statistics.

Table (4.9) depicts the results of the productivity equation for Bangladesh. The productivity equation for Bangladesh is also shown in Table (4.7), albeit the focus of both tables is different. Table (4.7) provides a mechanism to compare the full and reduced CDM, and Table (4.9) is an attempt to show the results of Bangladesh in a format comparable to the results for the Pakistani and for all firms. In Table (4.9), innovation outputs are approximated by the predicted values from the Bangladeshi part of Table (4.6). Again, the CRS assumption is accepted at the 5% significance level in all cases but the PDINN-included LM for the basic version for which we found increasing returns to scale. Similar to previous outcomes, material and net book value elasticities are significant and positive. Both product and process innovation happen to be important determinants of Bangladeshi firms' productivity output in all basic versions. The results for extended versions are mixed: process innovation increases firms' productivity, while the effect of product innovation is insignificant. The results in Table (4.9) show that education of production workers is an important factor to enhance labor productivity, except PRINN-included LMN. The use of internet (foreign-licensed technology) is observed to be positive and significant (insignificant) in all PDINN-included equations and negative and insignificant (significant) in all PRINN-included regressions. This means that the already observed hegemonic position of process innovation compared with WEB and LICE for Bangladesh and for all firms is established again.

The empirical findings of the separate productivity analysis of Pakistani firms are outlined in Table (4.10). Innovations are measured by the predicted values acquired from the Pakistani portion of Table (4.6). Similar to the empirical findings for Bangladesh and for all firms together, both the material and physical capital variables intuitively have sizeable impact on productivity of Pakistani firms. Recall that Figures (4.1) and (4.2) revealed that material had a more significant impact than net book value for both countries. The econometric findings also corroborate this phenomenon: we find the coefficient of

**Table 4.10 Productivity equation for Pakistan only. Bootstrapped SEs are in parentheses. Dep. var.: LPROD**

| Independent variables | Basic | | | | Extended | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1a) | (2a) | (3a) | (4a) |
| Intercept | 3.83* | 3.50* | 3.97* | 3.62* | 4.10* | 4.22* | 4.16* | 4.25* |
| | (0.23) | (0.39) | (0.22) | (0.41) | (0.29) | (0.51) | (0.36) | (0.52) |
| LMATERIAL | 0.66* | 0.62* | 0.65* | 0.62* | 0.64* | 0.60* | 0.64* | 0.60* |
| | (0.03) | (0.04) | (0.03) | (0.05) | (0.03) | (0.05) | (0.03) | (0.04) |
| LNETBOOK | | 0.07# | | 0.07# | | 0.07* | | 0.07# |
| | | (0.03) | | (0.03) | | (0.03) | | (0.03) |
| LEMP | -0.05 | -0.02 | -0.09 | -0.05 | -0.09† | -0.05 | -0.10† | -0.06 |
| | (0.05) | (0.07) | (0.06) | (0.09) | (0.05) | (0.07) | (0.05) | (0.08) |
| PDINN | 0.88# | 0.94# | | | 1.90* | 1.70# | | |
| | (0.40) | (0.41) | | | (0.69) | (0.74) | | |
| PRINN | | | 1.41* | 1.29# | | | 2.32* | 1.84* |
| | | | (0.40) | (0.53) | | | (0.77) | (0.69) |
| EDU | | | | | -0.19 | -0.10 | -0.09 | 0.02 |
| | | | | | (0.17) | (0.17) | (0.15) | (0.19) |
| WEB | | | | | 0.15 | 0.09 | 0.01 | $-2.5e^{-03}$ |
| | | | | | (0.15) | (0.18) | (0.16) | (0.22) |
| LICE | | | | | -0.82† | -0.71† | -0.73† | -0.56† |
| | | | | | (0.46) | (0.37) | (0.42) | (0.32) |
| PRODIN | | | | | -0.09 | -0.65# | -0.08 | -0.62# |
| | | | | | (0.25) | (0.32) | (0.28) | (0.31) |
| No. of obs. | 658 | 311 | 658 | 311 | 657 | 311 | 657 | 311 |
| coeff. of det. | 0.61 | 0.67 | 0.62 | 0.68 | 0.62 | 0.68 | 0.63 | 0.68 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: All regressions include industry dummies

LMATERIAL to be larger than that of LNETBOOK (although both are significant) in all productivity analyses of all firms and of Pakistan and Bangladesh separately.[57] The results of Table (4.10) depict that the CRS assumption is not rejected at 5% level for Pakistani manufacturers. The significant and positive regression coefficients of PDINN and PRINN imply the importance of both product and process innovation for labor productivity of Pakistani firms. Education has an insig-

[57] Both coefficients are comparable because we do not encounter any measurement scale problems: both are in same monetary unit, standardized by employment, and in logarithmic form.

nificant influence in all cases, contrary to the findings for Bangladesh. A reason may be that Pakistani firms have, on average, less educated workers as revealed by the summary statistics, and their share compared with Bangladeshi firms is too small to have a substantial impact on firm productivity. The impact of foreign-licensed technology appears to be negative and significant in all regressions (although significance is at the 10% level), while WEB has insignificant coefficients in all cases. This means that. This means that the presence of process innovation does not undermine the effect of LICE and WEB for Pakistani firms, contrary to the Bangladeshi ones. Finally, similar to previous results PRODIN does not have any significant, positive effects on productivity; we even find some significant, negative results.

## 4.6 Conclusions

In this chapter, we observed the (labor) productivity impact of both process and product innovation, for two South Asian economies (Pakistan and Bangladesh), by using the World Bank Enterprise Survey data, covering 1st July 2003 through 30th June 2006. In all empirical analyses, we corrected our econometric estimations for the selectivity bias of R&D and for the endogeneity bias of both R&D and innovation.

Our results suggest that firm size (sales) is an important determinant of R&D and (the likelihood of) process innovation of Bangladeshi firms. However, we the significant relationship between sales and product innovation is less clear. The size of Pakistani firms does not impact their likelihood to be product and/or process innovators. Pakistani firms' imports and exports induce product innovation, while imports (exports) are important (unimportant) factor of process innovation. Exports have a negative and imports have a positive impact on probability of product innovation in Bangladesh, while the effects of these variables are insignificant on process innovation. The prevailing concept is that innovation generally does not enjoy its due status in the industrial strategies of developing countries. In our dataset, we did not notice any significant commitment from Bangladeshi business associations (such as the Chamber of Commerce, etc.) to either R&D activities or innovation outputs. The effect of firm age on the likelihood of both innovation outputs is negative for Bangladesh and insignificant for Pakistan. The education of production workers appears to be a more important determinant of product innovation than of process innovation: education is a significant determinant of product innovation and has no influence on process innovation for Bangladesh; it has a more significant effect on product innovation than on process innovation for Pakistan.

The constant returns to scale assumption is confirmed most of the time in our empirical findings. The productivity analysis of Bangladesh shows that if we compare the effect of both process and product innovation on productivity, which either stems from the R&D-included or the R&D-excluded innovation output stage, we have virtually the same results, implying that one can be indifferent between the use of the full and the reduced CDM. We do not have R&D information to examine this phenomenon for Pakistan. In addition, we find that both material and capital inputs are important factors of productivity, and these findings are robust with respect to different versions of the CDM.

Both process and product innovation show their significant importance as determinants of productivity in all regressions of Pakistan. The results of all firms and of Bangladesh show that process innovation induce productivity significantly. The results of product innovation for the latter two cases show a few insignificant coefficients. A careful look at the results leads to the conclusion that product innovation is also a significant and positive determinant of productivity for all firms and for Bangladeshi ones. One interpretation of the positive effect of all and Bangladeshi firms' process innovation and the insignificant influence of their product innovation on productivity could be that consumers often approach new products reluctantly, and that products take time to mature and to earn profits. Process innovation is a tool to modify a production process for cost-cutting, laborcurtailment, and efficiency gains benefits. These benefits translate into rapid productivity increases (note that our productivity variable is sales/employment). Based on our empirical analysis, we argue that the innovation-productivity nexus follows the patterns observed in developed countries: innovation has a positive effect on productivity output.

The education level of Pakistani workers does not contribute to their productivity, while we find some support for a positive effect of education in Bangladesh. The use of the internet to communicate with clients is unimportant for the productivity of Pakistani firms, and shows some positive effect in Bangladesh. All other non-traditional inputs fail to contribute to productivity. In sum, the traditional production inputs appear to be more influential input factors of productivity than non-traditional ones (controls in our case).

Although Pakistani firms are less likely to be product and process innovators than Bangladeshi ones, our results show that their labor productivity is substantially higher than that of Bangladeshi firms. Moreover, the descriptive statistics suggest that Pakistani firms have comparatively large amounts of both traditional input factors: material and physical capital, and our econometric analyses show a remarkably significant impact of these inputs on both countries' labor productivity. This means that the difference between both countries' labor productivity is primarily due to the larger stock of capital and the larger flow of material inputs towards Pakistani firms. The implication of these findings is that these countries depend more heavily on traditional input factors than technological improvements for their productivity whose ultimate goal is sales and in turn profits. These empirical findings may be in line with the argument of Gu (1999) that growth in developing countries depends mainly on capital investment rather than on knowledge and learning. Our results also corroborate the studies of Dahlman and Collin on this specific region, which state that the NIS of South Asia are confronted with institutional and societal problems (Dahlman, 2007); however, the regions have generally shown continuous economic growth since the 1980s (Collin, 2007).

# Chapter 5

## The Employment Effect of Innovation: Microdata Evidence from Bangladesh and Pakistan


### Summary

The analysis of the impact of innovation on employment growth is an important topic for policy makers, because (un)employment is an important social topic, and the effects of innovation on employment are often poorly understood. Despite the significance of this relationship, very few studies on this topic are yet available for developing countries compared with developed ones. This chapter contributes to this scant literature by investigating the employment effect of innovation for two South Asian developing countries: Bangladesh and Pakistan. We further analyze whether this relationship shows country-specific and industry-specific differences. Finally, we investigate whether a complementarity between process and product innovation exists to influence employment growth.

Our analysis shows that both product and process innovation spur employment in this region as a whole, in both low-tech and high-tech industries, even after controlling for a number of firm-specific characteristics. Moreover, although both innovation types also have significantly positive impacts on employment growth of all Bangladeshi and of all Pakistani firms separately, they are important factors for employment growth of only high-tech Bangladeshi firms and of only low-tech Pakistani firms. We observe a strong complementarity between both innovation types to stimulate employment. Contrary to most previous studies, we witness an insignificant, negative effect of labor cost on employment change, perhaps due to the availability of cheaper labor force compared with developed countries. We notice that some of the innovation determinants exert different influences

across industries and across both countries. The same holds true for the determinants of employment growth.

## 5.1 Introduction

The impact of technological innovation on firm performance can primarily be observed in two ways: the productivity impact of innovation and the effect of innovation on employment.[58] The former is mainly an area of interest for managers/industrialists, while the latter is a crucial one for policy makers. The effect of technology on firm productivity is a relatively straightforward phenomenon and often shows a positive link (Geroski et al., 1993; Lööf and Heshmati, 2006; Koellinger, 2008; Hall et al., 2009), but the relationship between innovation and employment growth is a complex one.[59] One of the reasons of this complexity is the variety of channels through which both product and process innovation can affect employment growth, because although both types of innovation often coexist, the motivation and implication to have them in place are rather different.

One of the desired effects of product innovation is market expansion[60] (especially when the new product is not a direct substitute of an old one), demanding more labor force. If the innovating firm is a first-mover and launches a radically new product into the market, which is difficult to imitate by latecomers and if it also protects the product through exclusivity rights (e.g. patents, trademarks, etc.), the innovating firm can operate from a monopoly position. The employment effect of product innovation may then be negative, because the monopolist may restrict output and instead raise prices. Process innovations are often reduce the amount of labor needed since they are operationalzed to make more efficient production processes to obtain the same output with lower cost or less labor (per unit), suggesting a negative

[58] Innovation can affect both the quantity and quality of employment (skill-biased technical change paradigm). The latter is beyond the scope of this chapter.
[59] A very good survey of studies on the innovation-employment relationship can be found in Pianta (2005), Vivarelli(2007), and Chennells and Van Reenen (1999).
[60] There are two sources of expansion: innovation may increase product demand in the same product market or may open entirely new markets for the innovator.

impact of process innovation on labor demand. The cost reduction may eventually translate into price reductions, especially in a competitive environment depending on the price elasticity of demand; this may cause an increase in product demand. This demand shift would induce the firm to expand its production which entails an increase in workforce, counterbalancing the "displacement effect" of process innovation. The expansion-related effect of product innovation (compensation effect) may dominate its "displacement effect". This might be the reason why studies generally postulate a positive impact of product innovation on employment growth (Hall et al., 2008; Harrison et al., 2008, inter alia). However, it is hard to determine unequivocally which effect of process innovation dominates; this explains the empirically mixed findings regarding the link between process innovation and employment.

Whether technology creates or destroys jobs is a highly investigated topic in the developed world, but very few studies on developing countries exist hitherto.[61]The apparent differences among national innovation systems (NISs) of developed and developing countries and their different economic and societal paradigms assert that the sources, motivations, and implications of innovation (and/or of imitation) differ between both regions. Hence, it is not justifiable to derive conclusions for developing countries on the basis of the outcomes of studies on the innovation-employment relationship for developed countries. And the issue needs to be addressed in the particular context of the developing world. It is also important for developing countries' policy principles to investigate thoroughly which effects innovations have on employment[62]. Hence, this study contributes to this field by investigating whether innovation creates or destroys jobs in developing countries.

[61] One reason for this scarcity is data-driven.
[62] Unemployment, of course, is a problem which developed countries also face, and currently some of them have higher unemployment rates than developing countries. However, developed countries' policy makers can address this problem, in the short and long run, more aptly with the help of social security benefits, etc. Therefore, the societal problems related to unemployment more severe in developing countries.

Similar to many other developing countries, the work of Dahlman (2007) showed that South Asian countries' innovation systems suffer from many institutional problems. In contrast, Collin(2007) argued that this region has shown economic growth since the 1980s, suggesting that the region relies more on tradition production inputs than innovation in order to enhance its productivity. However, these two statements do not provide any insights into the employment effect of innovation in this region, a much needed area of research. Hence, we investigated the employment effect of innovation for two South Asian developing economies (Bangladesh and Pakistan) by using the World Bank enterprise survey conducted in 2006-07. As Bogliacino and Pianta (2010) pointed out, one of the problems of the existing literature on innovation and employment is its reliance on the assumption that the employment effect of innovation is uniform across industries. We investigated this relationship for low- and high-tech industries separately, for all firms as well as by country to ascertain whether disparities of the employment effect of innovation exist between the sectors. Although most studies of the innovation-employment nexus endeavored to explicitly disentangle the effects of both process and product innovation on employment, they did not address the complementarity of these effects to enhance employment demand. We try to fill this gap by analyzing whether the effects of both product and process innovation differ if they occur in isolation or in conjunction. It has been observed that mostly both innovations are carried out together and share many commonalities. Hence, it is interesting to explore whether they complement or substitute to increase employment growth.

In the empirical analysis we principally follow Van Reenen's (1997) model, with some modifications since he originally used it for in a panel data setting, while we have a cross-sectional data set. We also expand Van Reenen's specification by including control variables to disentangle the complexity of the innovation-employment relationship more aptly. While observing the relationship of innovation and employment, the endogeneity of innovation could distort the findings of the econometric analysis. We address this endogeneity by applying the appropriate estimation methods.

Our results strongly indicate both product and process innovation as factors driving employment growth in Pakistan and Bangladesh as a whole. However, in the low and high tech sectors, we observed differences across the two countries. Apart from than innovation and labor costs the effects of all determinants of employment seem to be sensitive to inter-country and inter-industry differences. The labor cost coefficient appears to be insignificant and negative throughout the analysis, contrary to the well-established notion of a significant, negative effect of labor cost on employment growth.

This chapter is organized as follows. Section (2) describes the findings of past studies. The model is specified in section (3), while section (4) discusses the dataset and descriptive statistics. The results of the empirical analysis are presented and discussed in section (5). Section (6) concludes the chapter.

## 5.2 Literature Review

The question whether technology creates or destroys jobs is not a new topic. At the beginning of the industrial revolution in the mid-18th century, it was feared that the introduction of machinery would be detrimental to employment.[63] In the chapter "On Machinery" Ricardo (2001) retracted his previous position and propagated the negative effects of technology on employment. Further evolution of the theoretical and empirical framework led analysts to investigate the technology-employment connection more tightly focused, i.e. in terms of the innovation-employment nexus.

The effect of innovation on employment involves a plethora of intricacies, which makes this relationship difficult to understand unequivocally. However, it is not unreasonable to believe that technological innovation influences employment growth through its laborsaving (displacement effect) and/or market expansion (compensation effect)

[63] See Rothwell and Zegveld (1979) for industry-level case studies analyzing the impact of mechanization on employment.

effects. It is difficult to determine the dominance of one effect over the other, especially regarding process innovation because it heavily depends on the specific context in which it occurs. These complexities require more research to understand the innovation-employment connection thoroughly and establish a consensus. One of the possibilities to resolve the disagreement is to disentangle both process and product innovation and to define a clear distinction between them to investigate their impacts on employment (Smolny, 1998; Edquist et al., 2001, among others). Although the relationship is complex most empirical studies confirmed a significant, positive influence of product innovation on employment, whereas the link between process innovation and employment is observed to be varied. One strand of the literature showed a positive relationship, whereas the other argued a negative association. The studies have also found the relationship between process innovation and employment growth to be insignificant.

Using two consecutive waves of the CIS (CIS2 and CIS3) for ten European countries Mastrostefano and Pianta (2009) concluded that new products' sales (both in levels and in percentage changes) are a significant, positive determinant of employment change, along with a positive (negative) influence of demand (wages). In addition, they found that the proportion of innovative firms (usually process innovation was dominant) has a significant, positive impact on employment change; however, increasing this share contributes nothing towards employment change. With data from four European countries Harrison et al. (2008) divided firms' sales into two mutually exclusive groups: sales of new products (product innovation) and of old ones and introduced a process innovation dummy. They proposed a model relating these innovation measures to employment growth. They found a strong, positive relationship between product innovation and employment, but the effect of process innovation was not as clear as the effect of product innovation. The study of Brouwer et al. (1993) conducted on Dutch firms showed that R&D intensity has a negative (but insignificant) impact on employment growth between 1983 to 1988, while the effect of growth of R&D intensity for the same period is significant and negative. They further considered only product-related R&D and found a significant, positive influence on employment growth. Regarding firm-specific characteristics the relationships between employment and sales growth (1982-1983) and between employment and firm size is significant and positive and significant and negative respectively. Freel and Robson (2004) showed that the share of technologists/scientists has a positive influence on employment growth of manufacturing firms in Scotland and Northern England, whereas an increase of professionals/managers in service firms decreases their employment growth. Moreover, product innovation significantly increases employment in both sectors (manufacturing and service); however, the effect of process innovation is insignificant. The work of Antonucci and Pianta (2002) on eight main EU economies revealed that the effect of total innovation expenditure (per sales) on employment demand is negative, and mixed in terms of significance (they analyzed it in different specifications). Using different proxies for innovation the general picture of the significance of product and process innovations that arises is that the former has a positive and the latter has a negative effect, although both are mostly insignificant. They further calculated that a positive change of demand (proxied by the value added) induces a positive employment change, while the effect of labor cost is significant and negative. By utilizing the data of 31 two-digit German manufacturing firms, Ross and Zimmermann (1993) reported laborsaving technological progress as one of the significant determinants which hinder labor growth, alongside insufficient demand and labor costs. Smolny (1998) developed a theoretical model and applied it to West German manufacturing firms revealing that both product and process innovation are conducive to employment. Doms et al. (1995) observed the effect of advanced manufacturing technologies (process innovations, e.g. computer-controlled machines, lasers, robots, etc.) on employment growth between 1987 to 1991 for firms in the United States, after correcting for the selectivity bias attributable to firms' exit. Their empirical findings suggest that the use of advanced technologies and capital intensity (measured by the capital-labor ratio) is significantly and positively correlated with employment growth and negatively associated with firm exit. Moreover, the effects of capital intensity are not affected by the inclusion of other controls, but the technology-related outcomes are sensitive to firm size. The positive effect of introduction of new technologies on employment in case of Australia and the UK can be found in Blanchflower and Burgess (1998). The study of Vivarelli et al. (1996) for Italian manufacturers showed a modestly positive effect of total innovation costs on the use of labor. But their further split of innovation variable into different innovation characteristics revealed that R&D expenditure (design and engineering expenditures) has a significant, positive (negative) impact on employment. The effect of process innovations was found to be significant and negative.

As the above review shows, the relationship between innovation and employment has been analyzed extensively in developed economies, but we can only find very few studies on developing countries. Benavente and Lauterbach (2008) found a significant, positive impact of sales of new products (product innovation) on the employment growth of Chilean firms, but the effect of process innovation appeared to be insignificant. The study of Meriküll (2010) on Estonian enterprises revealed that innovation is an important determinant of employment, when he did not distinguish between product and process innovation. When he made that distinction he found that both product and process innovation exert a positive effect on employment, but only the impact of process innovation is a significant one. A significant and positive influence of innovative activities (R&D and patents) on employment demand of Taiwanese manufacturing firms can be found in Yang and Lin (2008). Their analysis of splitting patents into both product and process patents showed that both can translate into significant employment growth. The analysis of employment effects of innovation of Costa Rican manufacturing firms conducted by Monge-González et al. (2011) revealed that both product and process innovation are conducive to employment growth.

## 5.3 The Model Specification

In this section we propose a model to investigate the innovation-employment relationship strictly in a firm-level cross-sectional data-set.

Table (5.1) provides the definitions and notations of the variables used in this section and in our empirical analysis. To some extent, our model follows the specification of Van Reenen (1997) who derived a static panel data model of labor demand as:[64]

$$\log(employment_{it}) = \beta_1 innovation_{it} + \beta_2 \log(wages) + \beta_3 \log(capital) + \tau_t + e_{it} \tag{5.1}$$

Where $\tau_t$ is a vector of time dummies and $e_{it}$ is a white noise error term. We modified (5.1) according to the cross-sectional nature of our dataset. Firstly, our model does not include the term $\tau_t$ for obvious reasons. Moreover, the panel data structure of equation (5.1) connotes employment on the left hand side in terms of employment growth.[65] Hence, we defined employment growth in a traditional way and constructed our dependent variable as:[66]

$$EGROWTH = \frac{employment_{2005/06} - employment_{2002/03}}{employment_{2002/03}} \tag{5.2}$$

We replaced fixed capital with raw material cost since our dataset misses a lot of information for the former. Hence, our employment growth model for the $i^{th}$ firm has the following form:

$$EGROWTH_i = \beta_0 innovation_i + \beta_1 WAGE_i + \beta_2 MATERIAL + \gamma Z_i + e_i \tag{5.3}$$

---

[64] He also used the dynamic panel structure to include a lagged dependent variable. See Van Reenen(1997) for the derivation of (5.1).

[65] In addition to using employment levels and a lagged dependent variable, Van Reenen(1997) also utilized first differences which define the dependent variable in terms of employment change.

[66] We use only growth in permanent employment due to the unavailability of information pertaining to temporary employment in 2002-2003.

We used different measures as innovation variables: PDINN, PRINN, PDPR, PDONLY, and PRONLY. In order to address the complexities of the innovation-employment association more rigorously, we extended Van Reenen's model by including a vector of control variables $z_i$ with the corresponding coefficients vector $\gamma$. Our vector of control variables includes the following entries:

$$z = (LBUY, UNION, AGE, TRAIN)$$

In addition, all regression analyses include industry intercepts and, whenever needed, a country intercept to control for heterogeneities attributable to the different industry paradigms and to the differences between NISs of both countries.

Endogeneity of the innovation variables could exist through various channels. For example, if a firm anticipates an upward demand shift, it will increase its employment and innovate simultaneously to cope with this market expansion (Van Reenen, 1997). Van Reenen addressed endogeneity by instrumenting innovation variables and using their lagged values, but we have cross-section data. Therefore, we first predicted our innovation variables by using corresponding probit regressions (we have all innovation variables in qualitative form) and used them as instruments in the employment growth equations.

## 5.4 Data and Summary Statistics

The World Bank investment climate survey (enterprise survey) for manufacturing firms of two developing countries (Pakistan and Bangladesh), conducted in 2006-2007, is used for the empirical analysis in this chapter. The dataset presents information of firms' innovation activities (of both process and product innovation) as dichotomous variables, along with a large range of other firm-level characteristics important for our analysis. After cleaning for non-responses and potential outliers, we were left with 2,085 firms in total, 62% of these are Bangladeshi. Moreover, our dataset includes nine manufacturing

**Table 5.1 Variables and their description**

| Variables | Descriptions |
|---|---|
| EGROWTH | Employment growth of full-time permanent workers (2002/03 – 2005/06) |
| WAGE | Total annual cost of labor per employee (including wages, salaries, bonuses, allowances etc.) in 2005/06 (in log.) |
| SALES | Total annual sales of a firm in 2005/06 (in log.) |
| AGE | Age of a firm in years |
| MATERIAL | Total annual cost of raw material per employee in 2005/06 (in log.) |
| PRODIN | Ratio of permanent production workers in permanent employment |
| LBUY | Dummy if a firm's principal buyer is a large firm with more than 100 employees in 2005/06 |
| INDZONE | Dummy if a firm located in industrial zone (park) |
| ASSET | Dummy if a firm purchases fixed assets (machinery, vehicles, equipments, land, or buildings) in 2005/06. |
| LICE | Dummy if a firm uses technology licensed from foreign-owned company. |
| WEB | Dummy if a firm uses website to communicate with its clients or suppliers. |
| TRAIN | Dummy if a firm runs formal training programs for its permanent employees in 2005/06 |
| UNION | Dummy if a worker union exists in the firm. |
| PDINN | Dummy if a firm introduces into the market any new or significantly improved product during the last three fiscal years, whether it has or has not a process innovation |
| PRINN | Dummy if a firm introduces into the market any new or significantly improved production process, including methods of supplying services and ways of delivering products, during the last three fiscal year, whether it has or has not a product innovation |
| PDPR | Dummy if a firm has both product and process innovations during the last three fiscal years |
| PDONLY | Dummy if a firm has only product innovation during the last three fiscal years |
| PRONLY | Dummy if a firm has only process innovation during the last three fiscal years |
| PAK | Dummy if country is Pakistan |

industries aggregated at a two-digit level.[67] A divide between low-tech and high-tech industries[68] reveals that we have 1,715 (82%) for the former and 370 firms (18%) for the latter, suggesting that this region's

[67] In chapter (5) we used the same dataset as in chapter (4). Therefore, the industries are food, chemicals, garments, non-metallic minerals, leather, textiles, machinery and equipments, electronics, and other manufacturing. Since only 11 firms in this dataset fall in the category of non-metallic minerals industry, and none of them is in Bangladesh. Therefore, for computational purposes, we merged these 11 firms into a broader industrial sector: other manufacturing.

[68] To split our sample into low-and high-tech industries, we followed the definition of the OECD. More specifically, chemicals, electronics, and machinery and equipments are categorized as high-tech, and the other industries fall into the low-tech sector.

industrial structure heavily depends on the low-tech sector. The distribution of low- and high-tech industries across countries shows that 77% of the 1,301 Bangladeshi firms are low-tech firms, while 90% of the 784 Pakistani firms belong to this industrial sector. This means that, according to our sample, while low-tech industries abound, the prevalence of low technology firms is higher in Pakistan than in Bangladesh.

The survey collected all pecuniary information in local currency units. To achieve homogeneity and acquire comparable results, we converted all monetary variables into a common currency unit: USD.

We emphasize the need for a clear distinction between the innovation variables we used in our econometric analysis. We have five innovation variables: “both innovations” is a variable which states that the firm carries out both product and process innovation, the two variables “only product innovation” and “only process innovation” state that a firm only performs one or the other, and two variables “product innovation” and “process innovation” indicates a firm’s status with regard to one type of innovation irrespective of the other (see Table (5.1) for the notations and descriptions of these variables).

Table (5.2) presents the descriptive statistics (averages) of different variables for all firms and for Bangladesh and Pakistan separately. According to these statistics, 25% firms are reported to be product innovators, while the share of process innovators is 31%. We observe that, among innovators, most of the firms carry out both innovations together since almost 20% firms happen to be “both innovators”, while the fractions of “only product innovators” and “only process innovators” are 5.15% and 11.27% respectively. When we consider innovation statistics across countries, Bangladeshi firms have a high proportion of both types of innovations compared with Pakistan: 33.13% vs. 12.32% for product innovation and 44.96% vs. 9.6% for process innovation. Contrary to Bangladesh and the whole region the share of product innovating firms is slightly higher than that of process innovators in Pakistan. In addition, the cost of labor in Pakistan is almost three times higher than in Bangladesh while, employment growth in Bangladesh with 22.54% is more than twice as high as the corresponding value of 10.02% in Pakistan. The above-mentioned high wages in Pakistan maybe a reason for its relatively slow employment growth. In the respective literature high labor costs are frequently reported to hinder employment growth. Moreover, the cost of raw materials in Pakistan appears to be almost double that of Bangladesh, suggesting that it is more likely to be a substitute than a complement of employment, especially in Pakistan. The average permanent employment in Bangladeshi firms is 264.39, which is considerably higher than the average employment of 90.38 in Pakistani firms. The average net book values show that on average Pakistani firms are

**Table 5.2 Summary statistics**

| Variables | All | Bangladesh | Pakistan |
|---|---|---|---|
| Permanent employment | 199.1[illegible] | 264.39 | 90.38 |
| Wages per employee (000$ | 0.94 | 0.56 | 1.58 |
| Age (years) | 18.1[illegible] | 16.95 | 20.20 |
| Material cost per employee (000$) | 7.35 | 5.13 | 11.09 |
| Purchase of fixed assets (% | 39.2[illegible] | 52.11 | 17.90 |
| Use of web (%) | 25.2[illegible] | 26.13 | 23.75 |
| Formal training (%) | 16.1[illegible] | 21.07 | 8.59 |
| Large buyer (%) | 17.7[illegible] | 23.86 | 7.48 |
| Workers' union (%) | 9.10 | 11.09 | 5.79 |
| Production workers intensity (%) | 80.6[illegible] | 82.75 | 77.26 |
| Employment growth (%) | 16 | 22.54 | 10.02 |
| Product innovation (%) | 24.9 | 33.13 | 12.32 |
| Process innovation (%) | 31.0[illegible] | 44.96 | 9.60 |
| Both innovations (%) | 19.81 | 27.56 | 7.84 |
| Only product innovation (% | 5.15 | 5.58 | 4.50 |
| Only process innovation (% | 11.2[illegible] | 17.40 | 1.80 |

worth $2,894, while the corresponding value for Bangladesh is $5,930. The descriptive statistics on human capital (employment and employment growth) and financial capital (raw material cost and net book value) reveal that Bangladeshi firms are more human capital-intensive, whereas Pakistani firms are far ahead in the latter category. The proportion of Bangladeshi firms reported to purchase fixed assets is 52%, while only 18% Pakistani firms appear to conduct this kind of purchase. Bangladeshi firms are also more likely to use the internet, have workers' unions, run formal training programs, and have large buyers than Pakistani ones; the disparities for the first two indicators are not as stark the last two.

Table (5.3) reports the descriptive statistics for low- and high-tech industries separately, for all firms and across both countries. For all firms taken together, both "product innovation" and "process innovation" occur more often in the high-tech than low-tech sector. The result remains the same if we consider the firms which report to have "both innovations"; however, the outcomes are reversed in case of "only product innovation" and "only process innovation". These results suggest that the complementarity between both types of innovations may be more pivotal in high-tech than in low-tech industries.

**Table 5.3 Summary statistics for the low-and high-tech industries**

| Variables | All | | Bangladesh | | Pakistan | |
|---|---|---|---|---|---|---|
| | Low-tech | High-tech | Low-tech | High-tech | Low-tech | High-tech |
| Permanent employment | 202.81 | 182 | 280.00 | 210.96 | 92.70 | 68.49 |
| Wage per employee (000$) | 0.94 | 0.91 | 0.50 | 0.74 | 1.58 | 1.56 |
| Age (years) | 17.53 | 21.15 | 15.70 | 21.26 | 20.14 | 20.74 |
| Material cost per employee (000$) | 6.35 | 11.87 | 4.62 | 6.79 | 8.80 | 32.42 |
| Purchase of fixed assets (%) | 37.30 | 48.38 | 51.04 | 55.78 | 38.20 | 19.74 |
| Use of web (%) | 23.74 | 32.16 | 24.03 | 33.33 | 23.34 | 27.63 |
| Formal training (%) | 13.65 | 28.24 | 17.93 | 32.20 | 7.95 | 14.47 |
| Large buyer (%) | 19.48 | 9.73 | 28.16 | 9.18 | 7.01 | 11.84 |
| Workers union (%) | 9.09 | 9.19 | 11.84 | 8.50 | 5.13 | 11.84 |
| Production workers intensity (%) | 81.43 | 76.57 | 84.39 | 76.94 | 77.47 | 75.27 |
| Employment growth (%) | 15.77 | 18.73 | 22.54 | 22.57 | 9.98 | 10.33 |
| Product innovation (%) | 22.01 | 39.12 | 29.56 | 45.83 | 11.95 | 15.79 |
| Process innovation (%) | 28.14 | 45.00 | 42.58 | 53.41 | 8.94 | 15.79 |
| Both innovations (%) | 16.41 | 36.17 | 23.27 | 42.80 | 7.26 | 13.16 |
| Only product innovation (%) | 5.61 | 2.94 | 6.30 | 3.03 | 4.70 | 2.63 |
| Only process innovation (%) | 11.78 | 8.82 | 19.32 | 10.61 | 1.71 | 2.63 |

The wages are almost the same for both industrial sectors, whereas firm age, material cost, and employment growth are higher in high-tech than in low-tech ones. Fixed asset purchase and internet usage are more likely in the high-tech sector, while the occurrence of workers' unions does not substantially differ between both industrial sectors. The descriptive statistics reveal that the share of high-tech firms which run formal training programs is 28%, which is almost twice as high as that of low-tech firms. The results for large buyers are the opposite: almost 20% low-tech and almost 10% high-tech firms have large buyers with more than 100 employees. The last four columns of Table (5.3) depict these descriptive statistics for both countries. The results of the innovation-related variables reveal almost the same pattern as that of all firms, except that the "only process innovation" variable shows a slightly higher proportion of innovators in the high-tech sector in Pakistan. In addition, wages are higher and firms are older in Bangladeshi high-tech industries than in its low-tech firms. The statistics of these variables show that they are almost the same for both sectors in Pakistan. The cost of raw material is higher in the group of high-tech industries for both countries; however the difference is much bigger in Pakistan than Bangladesh. All firms taken together, we noticed that employment growth is slightly higher in high-technology firms, but the corresponding point estimates across countries disclose that both sectors have almost the same employment growth in Bangladesh, while the Pakistani high-tech sector has slightly higher employment growth.

## 5.5 Microeconometric Analysis

As mentioned already, we used the predicted values of the innovation variables as instruments in the employment growth equations to avoid endogeneity problems. These predicted values were obtained from separate probit regressions of both product and process innovation. We calculated the predicted values which were used in the corresponding employment equations.

### *5.5.1 Determinants of Innovation*

Although the primary objective of the probit regressions is to obtain innovation instruments, the results are helpful to acquire an insight into the innovation determinants in this region as well.

Table (5.4) shows the results of probit regressions of both types of innovations separately, for all firms and with and without splitting the dataset into low-tech and high-tech industries. For all firms taken together (reported in the first two columns), it is observed that firm size

**Table 5.4 Probit regressions of PDINN and PRINN for all firms. Robust SEs are in parentheses**

| Independent Variables | All PDINN | All PRINN | Low-tech PDINN | Low-tech PRINN | High-tech PDINN | High-tech PRINN |
|---|---|---|---|---|---|---|
| SALES | 0.031 | 0.102* | 0.001 | 0.083* | 0.177* | 0.210* |
| | (0.021) | (0.022) | (0.025) | (0.025) | (0.046) | (0.050) |
| WEB | 0.536* | 0.415* | 0.556* | 0.390* | 0.438# | 0.515* |
| | (0.087) | (0.087) | (0.098) | (0.098) | (0.191) | (0.197) |
| ASSET | 0.363* | 0.423* | 0.370* | 0.437* | 0.372# | 0.446* |
| | (0.076) | (0.074) | (0.086) | (0.083) | (0.167) | (0.171) |
| PRODIN | -0.442† | -0.338 | -0.453† | -0.443† | -0.136 | 0.417 |
| | (0.231) | (0.233) | (0.273) | (0.269) | (0.456) | (0.470) |
| INDZONE | 0.312* | 0.414* | 0.310* | 0.368* | 0.479# | 0.740* |
| | (0.081) | (0.084) | (0.091) | (0.093) | (0.194) | (0.201) |
| AGE | -0.006# | -0.006# | -0.007# | -0.007# | -0.002 | -0.004 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.005) | (0.006) |
| LBUY | -0.121 | 0.043 | -0.119 | -0.006 | 0.133 | 0.658# |
| | (0.096) | (0.093) | (0.103) | (0.099) | (0.293) | (0.328) |
| PAK | -0.639* | -1.224* | -0.586* | -1.245* | -1.090* | -1.356* |
| | (0.103) | (0.111) | (0.113) | (0.121) | (0.247) | (0.275) |
| Intercept | -0.968* | -1.460* | -0.587† | -1.120* | -2.865* | -3.453* |
| | (0.310) | (0.318) | (0.343) | (0.348) | (0.706) | (0.782) |
| No. of obs. | 1925 | 1926 | 1591 | 1592 | 334 | 334 |
| Pseudo $R^2$ | 0.153 | 0.241 | 0.116 | 0.215 | 0.265 | 0.335 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: All regressions include industry dummies

(sales) appears to be an insignificant determinant of product innovation and a significant, positive factor for process innovation. The factors captured by WEB (which could be a proxy for a firm's international exposure, especially in developing countries and a measure of internet use), purchase of fixed assets, and whether or not the firm is located in an industrial zone are important indicators of both types of innovations. Older firms are less likely to be product and process innovators than younger ones. Our results also disclose that an increase of production workers' share of the workforce decreases the likelihood of product innovation. Production workers are, in principle, hired for production purposes, not for innovation. The relative increase of production workers implies a relative decrease of non-production workers, e.g. administrators, managers, R&D personnel, etc., which are more responsible for innovation. Hence, the results that a decrease in non-production workers reduces the chances of product innovation are in line with intuition. Production workers' share of the workforce has an insignificant, negative impact on the occurrence of process innovation. The demand side variable measured by LBUY[69] does not contribute to either product or process innovation. Recall that the descriptive statistics showed that Pakistani firms are less frequently innovators than Bangladeshi ones; this is confirmed econometrically since we obtained statistically significant and negative signs for the coefficients of the Pakistan dummy (PAK), for both types of innovations[70]. A further split into low and high technology firms reveals more interesting results. The findings of the low-tech sector follow the pattern we discussed above in the context of all firms, except one case: PRODIN is a modestly significant predictor of a decrease in low-tech firms' process innovation, in addition to its negative impact on low-tech product innovation. Contrary to almost the same patterns of the last two cases (all and low-tech firms), we noticed differences in the outcomes of high-tech firms. Recall that firm size (sales) does not contribute to low-tech firms' likelihood of product innovation, but it is an important determinant in the case of high-tech industries. One reason for this difference may be that high-tech firms are more R&D-

[69] Of course, our variable LBUY does not capture the "demand-pull" indicator used in the innovation literature. Hence, we cannot interpret the results of LBUY as an innovation effect of the demand-pull.

[70] Note that both product and process innovation determinants for all (Bangladeshi and Pakistani) firms taken together were also investigated empirically in the first two columns of Table (4.6), but with a bivariate probit and by using some, not all, different explanatory variables. We can compare these results with the corresponding columns of Table (5.4), for a robustness check on the variables which are included in both regressions; both tables show the same results for these common variables.

intensive by definition; it is generally believed that R&D induces innovation and that large firms undertake more formal R&D activities (through their R&D departments). There is a possibility that large firms' formal R&D activities translate more aptly into product innovations compared to small firms' R&D activities. Similar to low technology industries firm size is beneficial for process innovation. The results of WEB, ASSET, and INDZONE follow the same pattern in low and high technology sectors, showing significant, positive effects of these indicators on both types of innovations. The negative significance of PRODIN for low-tech industries disappears in the high technology sector, although the coefficient for product innovation still has a negative sign. This means that the previously found effect of the production workers' share is not as strong in the high-tech as is in the low-tech sector. The significant, negative impact of firm age on both product and process innovation for low-tech firms also disappears for the group of high-tech firms, meaning that the technology-intensive characteristics of the high-tech sector compel older firms to innovate to hedge the risks of losing market power or profits which is exerted by their younger rivals. Large buyers appear to be an influential determinant of high-tech firms' inclination towards process innovation, while these have no impact on their product innovation efforts.

The results of the probit regressions on PDINN and PRINN, for all Bangladeshi firms and for low and high technology Bangladeshi firms, are depicted in Table (5.5). Most of the results for all Bangladeshi firms are similar to those that were obtained for all Bangladeshi and Pakistani firms taken together (compare the first two columns of Table (5.4) with the respective columns of Table (5.5)). We do not discuss the same findings but shed some light on the different result: the share of production workers in total permanent employment is an insignificant indicator of product innovation and large buyers as a determinant of product innovation constitute a significant, discouraging factor now. Comparing the first two columns of Table (5.5) (all Bangladeshi firms) with the subsequent two columns of Table(5.5) (low-tech Bangladeshi firms), we notice that all determinants of both

**Table 5.5 Probit regressions of PDINN and PRINN for Bangladesh. Robust SEs are in parentheses**

| Independent Variables | All | | Low-tech | | High-tech | |
|---|---|---|---|---|---|---|
| | PDINN | PRINN | PDINN | PRINN | PDINN | PRINN |
| SALES | 0.029 | 0.113* | -0.024 | 0.082* | 0.189* | 0.242* |
| | (0.026) | (0.025) | (0.032) | (0.029) | (0.049) | (0.053) |
| WEB | 0.499* | 0.334* | 0.548* | 0.278# | 0.363† | 0.530# |
| | (0.103) | (0.099) | (0.122) | (0.114) | (0.202) | (0.206) |
| ASSET | 0.253* | 0.303* | 0.241# | 0.295* | 0.340† | 0.429# |
| | (0.086) | (0.082) | (0.100) | (0.093) | (0.177) | (0.183) |
| PRODIN | -0.332 | -0.279 | -0.345 | -0.460 | -0.107 | 0.747 |
| | (0.275) | (0.275) | (0.340) | (0.334) | (0.479) | (0.498) |
| INDZONE | 0.323* | 0.404* | 0.315* | 0.354* | 0.403† | 0.649* |
| | (0.101) | (0.100) | (0.117) | (0.113) | (0.211) | (0.218) |
| AGE | -0.013* | -0.011* | -0.019* | -0.012* | -0.003 | -0.008 |
| | (0.003) | (0.003) | (0.005) | (0.004) | (0.006) | (0.006) |
| LBUY | -0.274* | -0.031 | -0.256# | -0.041 | -0.020 | 0.435 |
| | (0.105) | (0.101) | (0.113) | (0.107) | (0.324) | (0.377) |
| Intercept | -0.859# | -1.432* | -0.104 | -0.878# | -3.107* | -4.019* |
| | (0.358) | (0.353) | (0.413) | (0.394) | (0.746) | (0.840) |
| No. of obs. | 1196 | 1196 | 933 | 933 | 263 | 263 |
| Pseudo $R^2$ | 0.094 | 0.093 | 0.071 | 0.056 | 0.183 | 0.258 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level
Note: All regressions include industry dummies

innovation types of all Bangladeshi firms (column (1) and (2) of Table (5.5)) and of low technology Bangladeshi firms (column (3) and (4) of Table (5.5)) are same with respect to their coefficients' signs and statistical significance. Similar to the full dataset (Table (5.4)), we discovere some differences between the outcomes of high-tech and low-tech Bangladeshi firms and between high-tech and all Bangladeshi firms. Contrary to low-tech Bangladeshi firms and similar to all high-tech firms, firm size (sales) increases the likelihood of product innovation. The factors captured by WEB, ASSET, and INDZONE increase the chance of both types of innovation activities for both low and high technology Bangladeshi firms, showing that the effects of these three determinants are similar to those that were observed for the low-tech and high-tech pool of both Bangladeshi and Pakistani firms. The significance of the negative effect of low tech firms' age on innovations dissipates in the high-tech sector, though the coefficients are still negative. Large buyers exert a negative impact on product innovation in all and in low-tech Bangladeshi firms, and their relationship with process innovation is statistically insignificant in both cases. Large buyers' negative influence on product innovation is not significant in the high-tech sector, and they do not induce high-tech firms to carry out process innovation (these findings are similar to those of the low-tech sector). Our interpretation is that a firm primarily sells products rather than processes to its buyers and large buyers provide an important boost for product demand. The results show that this relatively large demand, in comparison with small buyers' demands, is mostly for non-innovating products, especially in low-tech industries because of the nature of this sector, which discourages product innovation. In high-tech sector buyers' demand more innovating products which does not discourage product innovation[71].

The empirical findings of Pakistani firms are reported in Table (5.6). A comparison of these results with Bangladesh's results unveils some interesting differences. We fail to find a significant, positive relationship between firm size (sales) and both innovation types for all Pakistani firms and for both low- and high-tech Pakistani firms, except a slight significance for low-tech process innovation. Similar to Bangladesh, the significance of ASSET as an explanatory factor of both types of innovation is established for all Pakistani firms and for low-tech Pakistani industries but, differing from Bangladesh, Pakistani high-tech firms' purchases of fixed assets do not contribute to their innovations (neither product nor process). Throughout the results of Bangladesh PRODIN appear to be an unimportant factor of both types of innovation, but we observe that it substantially decreases the likelihoods of product and process innovation in high-tech Pakistani firms. Use of internet has a positive influence on PDINN and PRINN in all cases (i.e. all and low and high technology Pakistani firms). The empirical findings of Bangladesh reveal that firms located in industrial zones enjoy the benefits of a more formally embedded infrastructure and translate it into product and process innovation regardless

---

[71] Similar to footnote (71), if we compare the third and fourth columns of Table (4.6) with the first and second columns of Table (5.5), we can conclude that common variables in both model specifications on Bangladeshi firms show the same result patterns.

**Table 5.6 Probit regressions of PDINN and PRINN for Pakistan. Robust SEs are in parentheses**

| Independent Variables | All | | Low-tech | | High-tech | |
|---|---|---|---|---|---|---|
| | PDINN | PRINN | PDINN | PRINN | PDINN | PRINN |
| SALES | 0.060 | 0.073 | 0.066 | 0.093† | 0.121 | 0.068 |
| | (0.041) | (0.052) | (0.044) | (0.056) | (0.167) | (0.120) |
| WEB | 0.668* | 0.693* | 0.601* | 0.691* | 4.031# | 2.611# |
| | (0.179) | (0.198) | (0.188) | (0.206) | (1.899) | (1.190) |
| ASSET | 0.626* | 0.941* | 0.626* | 0.984* | -1.416 | -0.781 |
| | (0.166) | (0.173) | (0.171) | (0.178) | (1.208) | (0.836) |
| PRODIN | -0.374 | -0.177 | -0.192 | -0.061 | -7.420* | -3.636# |
| | (0.451) | (0.390) | (0.308) | (0.191) | (2.729) | (1.685) |
| INDZONE | -0.086 | 0.160 | -0.134 | 0.049 | 1.674† | 1.708# |
| | (0.159) | (0.183) | (0.170) | (0.192) | (0.978) | (0.862) |
| AGE | 0.005 | 0.004 | 0.006 | 0.001 | -0.022 | 0.014 |
| | (0.005) | (0.005) | (0.006) | (0.006) | (0.026) | (0.022) |
| LBUY | 0.734* | 0.547# | 0.746* | 0.415† | 2.729# | 2.229# |
| | (0.215) | (0.225) | (0.231) | (0.239) | (1.249) | (0.935) |
| Intercept | -2.171* | -2.966* | -2.354* | -3.184* | -2.131 | -1.961 |
| | (0.622) | (0.737) | (0.576) | (0.739) | (2.811) | (1.999) |
| No. of obs. | 726 | 719 | 658 | 648 | 68 | 71 |
| Pseudo $R^2$ | 0.233 | 0.354 | 0.209 | 0.332 | 0.660 | 0.635 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level
Note: All regressions include industry dummies

which industrial sector they belong to. However, in the case of Pakistan this particular variable induces innovations only in the high-tech sector. Another contradiction is that throughout Table (5.6) firm age appears to be an insignificant determinant of both product and process innovation. Finally, contrary to Bangladesh, large buyers (a possible proxy of firms' demand) encourage both types of innovation in Pakistani firms, whether they are low-tech or high-tech[72].

### *5.5.2 Innovation as a Determinant of Employment Growth*

The primary objective of this chapter is to investigate the innovation-employment connection. Before going further, it is worthwhile to note that especially to enable comparisons with similar studies our dependent variable is the employment change of permanent employees instead of an employment change of the whole labor force since our

[72] Similar to footnotes (71) and (72), both regressions on Pakistani firms (i.e. columns 5 and 6 of Table (4.6) and columns 1 and 2 of Table (5.6)) provide almost the same result patterns for the common predictors.

dataset does not have information on the latter. However, we argue that our results might be more robust (less volatile) because innovation is a long term process, which requires the labor force on a permanent basis to carry out and take care of the innovative activities of a firm or which requires members of the permanent labor force to be dismissed/made redundant after innovation activities have been completed. We do not discard the fact that innovation may generate/destroy temporary employment, but we believe that this effect is significantly lower than the effect on permanent employment.

Table (5.7) depicts the regression results of the analysis of employment growth determinants of all firms (both Pakistan and Bangladesh), for the full sample and for the low- and high-tech sector separately. We first inserted (the predicted values of) both PDINN and

**Table 5.7 Employment growth equation for all firms. Bootstrapped S.Es. are in parentheses. Dep. var: EGROWTH**

| Independent variables | All (1) | | Low-tech (2) | | High-tech (3) | |
|---|---|---|---|---|---|---|
| PDINN | 0.323* | | 0.313# | | 0.350# | |
| | (0.122) | | (0.135) | | (0.167) | |
| PRINN | | 0.263* | | 0.256# | | 0.299# |
| | | (0.099) | | (0.127) | | (0.139) |
| MATERIAL | -0.012 | -0.014† | -0.011 | -0.014 | -0.008 | -0.008 |
| | (0.008) | (0.007) | (0.008) | (0.009) | (0.023) | (0.025) |
| WAGE | -0.015 | -0.014 | -0.016 | -0.016 | -0.013 | -0.011 |
| | (0.016) | (0.014) | (0.016) | (0.017) | (0.039) | (0.038) |
| LBUY | 0.102* | 0.085* | 0.099* | 0.085* | 0.111 | 0.083 |
| | (0.032) | (0.029) | (0.035) | (0.031) | (0.117) | (0.119) |
| AGE | -0.001# | -0.001# | -0.001# | -0.001# | -0.003 | -0.003 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0003) | (0.002) |
| UNION | -0.054† | -0.054† | -0.048 | -0.050† | -0.061 | -0.054 |
| | (0.031) | (0.028) | (0.030) | (0.029) | (0.099) | (0.104) |
| TRAIN | -0.026 | -0.024 | -0.011 | -0.010 | -0.095 | -0.092 |
| | (0.028) | (0.031) | (0.035) | (0.029) | (0.065) | (0.061) |
| PAK | -0.045 | -0.012 | -0.038 | 0.002 | -0.082 | -0.086 |
| | (0.036) | (0.041) | (0.040) | (0.053) | (0.078) | (0.072) |
| Intercept | 0.349* | 0.336* | 0.342* | 0.334* | 0.400 | 0.387 |
| | (0.098) | (0.090) | (0.096) | (0.101) | (0.247) | (0.257) |
| No. of obs. | 1375 | 1375 | 1155 | 1155 | 220 | 220 |
| $R^2$ | 0.064 | 0.063 | 0.063 | 0.061 | 0.079 | 0.078 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: All regressions include industry dummies

PRINN in a single employment equation and tested for multicollinearity, which is found at a significant level.[73] Hence, we entered these variables in separate employment equations to avoid collinearity. If we consider all firms one of the striking results is that both types of innovation have a significant, positive influence on employment growth, even after controlling for a number of firm-specific characteristics. Moreover, the coefficients of cost of both raw materials and wages have negative signs, but significance is achieved only for the former when the employment equation includes process innovation (PRINN-included). The literature often argues that an increase in demand for a firm's products translates into an increase in employment (Ross and Zimmermann, 1993; Pianta, 2001). Our demand side variable (LBUY), although is not a direct indicator of demand for firms' products but denotes that large buyers generate more demand than small ones, also shows a significant and positive influence on employment change. A negative relationship of employment growth with firm age and with unionization was found by Variyam and Kraybill (1992) and by Blanchflower et al. (1991) respectively. Long (1993), for Canadian firms, and Leonard (1992), for Californian manufacturing plants, also found that these factors hinder employment growth, especially in large firms. According to our results it also appears that firm age and workers' union-membership reduce employment growth. A possible reason may be that younger firms introduce new products by definition and need to continuously increase their labor force to meet market requirements for the growth phase of their products life cycle until reaching a level of maturity, which is followed by decline and in turn destruction of jobs. The reason for the negative impact of unionization on employment growth could be that a firm's workers primarily take care of their own interest and have a fear of job losses or wage losses due to new employees, and exert pressure through the union to discourage job creation. A union's power to negotiate better

[73] It is observed that both types of innovations are often carried out simultaneously, and one of the primary reasons of this collinearity also is that PDINN and PRINN are predicted values obtained from the same model specification.

conditions for workers (high wages, job security, high severance payments, etc.) may instigate a firm to be hesitant to increase employment.[74] The results for formal training show that it does not contribute to employment growth in our sample, contrary to the findings of Cosh et al. (2000) who found a positive effect of training on employment growth. Finally, the coefficients of the Pakistan dummy for both product and process innovation are negative but the standard errors render them insignificant, meaning that there is no substantial difference between the employment change in Pakistan and Bangladesh, although the descriptive statistics showed that employment growth is substantially higher in Bangladesh.[75]

A further analysis with the sample split into low- and high-tech firms shows that both innovation types are significant, positive predictors of employment growth for both industrial sectors. The result patterns of wages and training do not vary between both industrial sectors, and also follow the pattern of all firms taken together. Raw material cost is an insignificant determinant for both sectors. The effects of large buyers and firm age in the low-tech sector differ from those of the high-tech sector: large buyer is a significant, positive and age is a significant, negative predictor of low-tech firms' employment change, but both are insignificant in the high-tech sector, although age still exerts a negative influence. The relationship between unionization and employment growth is insignificant in the high-tech sector, but shows slight significance of negative effect in the low-tech industries. The general picture is that, for both countries together, innovation induces

---

[74] See Long(1993) for a number of arguments which shapes the union-employment relationship.

[75] There are two possible interpretations of this contradiction. We can argue that the higher employment growth of Bangladesh, in the descriptive statistics, is not actually attributable to the geographical location of the firms, but to other unobserved forces. Secondly, recall that the Pakistan dummy was introduced to the innovation equations with a large, negative effect on innovations; this negative influence was carried over into the predicted values of innovations and subsequently undermines their negative effects in the employment equations. We explored this argument by excluding innovations from the employment equations (the results are not reported) and surprisingly observed a significant, negative effect of the Pakistan dummy (PAK) in all cases (for all firms and low- and high-tech firms separately).

employment regardless of the industrial sector, and many other determinants of employment change are heavily influenced by the sector-specific factors.

**Table 5.8 Employment growth equation for Bangladesh. Bootstrapped S.Es. are in parentheses. Dep. var: EGROWTH**

| Independent variables | All (1) | | Low-tech (2) | | High-tech (3) | |
|---|---|---|---|---|---|---|
| PDINN | 0.282† | | 0.231 | | 0.461† | |
| | (0.147) | | (0.203) | | (0.247) | |
| PRINN | | 0.250† | | 0.183 | | 0.329† |
| | | (0.131) | | (0.158) | | (0.186) |
| MATERIAL | 0.008 | 0.001 | 0.016 | 0.009 | -0.025 | -0.021 |
| | (0.010) | (0.014) | (0.013) | (0.015) | (0.033) | (0.036) |
| WAGE | -0.022 | -0.022 | -0.032 | -0.032 | -0.002 | 0.003 |
| | (0.030) | (0.034) | (0.044) | (0.044) | (0.064) | (0.051) |
| LBUY | 0.118* | 0.093# | 0.120* | 0.101* | 0.036 | 0.009 |
| | (0.038) | (0.038) | (0.046) | (0.039) | (0.090) | (0.087) |
| AGE | -0.002† | -0.002# | -0.002† | -0.003# | -0.002 | -0.002 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) | (0.003) |
| UNION | -0.019 | -0.021 | -0.027 | -0.029 | 0.019 | 0.035 |
| | (0.035) | (0.035) | (0.034) | (0.042) | (0.109) | (0.125) |
| TRAIN | -0.062† | -0.063† | -0.051 | -0.050 | -0.119† | -0.114† |
| | (0.033) | (0.036) | (0.041) | (0.043) | (0.064) | (0.068) |
| Intercept | 0.279† | 0.291† | 0.297 | 0.333 | 0.289 | 0.230 |
| | (0.149) | (0.169) | (0.241) | (0.231) | (0.391) | (0.356) |
| No. of obs. | 686 | 686 | 536 | 536 | 150 | 150 |
| $R^2$ | 0.038 | 0.038 | 0.040 | 0.038 | 0.055 | 0.050 |

* Significance at 1% level  # Significance at 5% level  † Significance at 10% level
Note: All regressions include industry dummies

The results of the separate analysis of Bangladeshi firms are shown in Table (5.8). Both innovation types appear to be important indicators of employment growth in all and high-tech Bangladeshi firms, but they lose their significance looking at low-tech firms separately (the signs are still positive and the magnitudes of the coefficients are reasonably high). Throughout the regressions for Bangladesh (Table 5.8) raw material, wage cost, and union status do not contribute to employment change. Large buyers stimulate employment and firm age impedes it, formal training also shows a significant and negative effect on employment growth of all Bangladeshi firms. When we consider the last these three employment determinants in the low-and high-tech sector, we observe interesting differences. Large buyers and firms' age respectively encourage and discourage low-tech firms' employment growth, whereas they have no influence on high technology firms' employment growth, although the coefficient signs are same. Formal training has a significant, negative influence on high-tech employment change and an insignificant impact on low-tech employment change.

**Table 5.9 Employment growth equation for Pakistan. Bootstrapped S.Es. are in parentheses. Dep. var: EGROWTH**

| Independent variables | All (1) | | Low-tech (2) | | High-tech (3) | |
|---|---|---|---|---|---|---|
| PDINN | 0.349# | | 0.346# | | 0.873 | |
| | (0.150) | | (0.149) | | (0.860) | |
| PRINN | | 0.254# | | 0.269# | | -0.158 |
| | | (0.120) | | (0.128) | | (0.343) |
| MATERIAL | -0.023# | -0.023# | -0.025# | -0.025# | 0.021 | 0.019 |
| | (0.010) | (0.011) | (0.010) | (0.011) | (0.036) | (0.037) |
| WAGE | -0.014 | -0.015 | -0.013 | -0.014 | -0.034 | -0.040 |
| | (0.017) | (0.017) | (0.017) | (0.016) | (0.057) | (0.056) |
| LBUY | 0.033 | 0.077 | -0.006 | 0.045 | 0.137 | 0.359 |
| | (0.074) | (0.067) | (0.048) | (0.039) | (0.183) | (0.354) |
| AGE | -0.001 | -0.001 | -0.001 | $-2.8e^{-04}$ | -0.007 | -0.003 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.007) | (0.004) |
| UNION | -0.137* | -0.147* | -0.130* | -0.128* | 0.071 | -0.198 |
| | (0.047) | (0.049) | (0.048) | (0.048) | (0.335) | (0.228) |
| TRAIN | 0.051 | 0.068 | 0.060 | 0.066 | -0.553 | 0.217 |
| | (0.042) | (0.043) | (0.048) | (0.046) | (0.724) | (0.275) |
| Intercept | 0.369# | 0.376# | 0.372# | 0.382# | 0.203 | 0.045 |
| | (0.164) | (0.159) | (0.146) | (0.150) | (0.419) | (0.418) |
| No. of obs. | 686 | 679 | 619 | 609 | 67 | 70 |
| $R^2$ | 0.044 | 0.049 | 0.041 | 0.042 | 0.186 | 0.144 |

* Significance at 1% level  # Significance at 5% level  † Significance at 10% level
Note: All regressions include industry dummies

The findings of the employment growth analysis for Pakistani firms are reported in Table (5.9). Similar to previously observed findings of both countries together and of Bangladeshi firms only, both product and process innovation appear to be conducive and important determinants of employment change of all Pakistani firms. However, we witness some differences between both countries regarding the industrial sectors: both innovation types are significant (insignificant) determinants of low-tech (high-tech) Pakistani firms' employment change, exactly the opposite of the result pattern of Bangladesh. This means that the effect of innovation on industry-specific employment change heavily depends on the prevailing national innovation systems (NISs), but inter-country differences are less important when we consider the employment effect of innovation as a whole. Higher material costs exhibit less employment growth in all Pakistani firms, meaning that in Pakistan human capital and raw material are substitutes rather than complements.[76] This variable also has a negative effect on low-tech firms' employment but is insignificant for the high-tech sector. Throughout Table (5.9) we can see that wages do not contribute to employment change. Surprisingly, in all cases large buyers (our crude proxy of product demand) are unable to stimulate employment, though the signs are positive most ofthe time. One reason might be that the percentage of large buyers in Pakistan is only 7.48, which is quite low compared to 23.86% in Bangladesh, suggesting that Pakistani firms have lower product demand than Bangladeshi ones at an aggregate level. Moreover, the previously observed negative effect of firm age, especially for all and low-tech firms, disappears, and it becomes an insignificant predictor throughout Pakistan's results. Unlike the unionization effect seen in Bangladesh, unionized Pakistani firms show significantly less employment growth than those with a non-unionized workforce in the cases of all firms taken together and of low-tech industries. The insignificant relationship between unionization and employment growth in Bangladeshi high-tech firms can also be found in the corresponding group in Pakistan. We also noticed a difference between the impacts of formal training on employment growth. In all Pakistani cases (all firms and low- and high-tech sector) training is an inconsequential predictor of employment growth.

[76] The relationship between material cost and employment growth in Tables (3.7)-(3.9) mostly has negative signs, which is an usual outcome. Although having almost 300 less firm if we include an available proxy of capital (i.e. net book value), we ran our analysis using this variable (the results are not reported). The results generally did not show a positive relationship between employment growth and fixed capital. Another possibility could be the use of ASSET to proxy fixed investment. We did the analysis using this variable also (the results are not reported), but the outcomes were almost the same as previous.

In all regressions of both countries together and separately, a negative influence of wages on employment growth is found, yet contrary to the outcomes of most previous studies we find this relationship to be insignificant. The reason might be that our regressions also include unionization as an explanatory variable which displays a significant and negative influence on employment change, especially for all firms and for Pakistani firms separately. The negative effect of high labor costs (salaries, bonuses, and allowances etc., which are included in our wage variable) is captured by unionization,[77] which undermines the negative effect of the labor wages variable in our model. Hence, we explored this phenomenon that the variables (union status and wages cost) are not affected by the problem of multicollinearity. The findings show that both variables are not collinear (results are not reported). Nonetheless we ran another set of regressions excluding unionization (the results are not reported) and found no difference in the effects of wages. This suggests that the insignificant, negative effect of labor cost is a true phenomenon in our data set.

### *5.5.3 Complementarity between Process and Product Innovation*

So far we analyzed each innovation type regardless of the status of a firm with respect to the other.[78] Moving forward we defined three new innovation variables to find out whether both innovation types are complements or which effect (displacement or compensation) of one innovation type dominates the other. Our newly defined variables are PDPR (firms have both product and process innovation), PDONLY (firms carry out only product innovation), and PRONLY (firms perform only process innovation). We used predicted values of these innovation variables which were obtained by running the multinomial probit (MNP) regression on these variables using the same model spe-

---

[77] Recall the previously discussed channels through which unionization may hinder employment growth.

[78] For example, if we defined a firm as a product innovator, we did not consider whether it is also a process innovator or not.

cifications as in the previous probit regressions and taking "no innovation" as a reference category. However, we do not report the results,

**Table 5.10 Complementarity analysis for all firms**

| Independent Variables | All | Low-tech | High-tech |
|---|---|---|---|
| | (1) | (2) | (3) |
| PDPR | 0.327* | 0.299# | 0.434# |
| | (0.117) | (0.128) | (0.210) |
| PDONLY | 0.656 | 0.787 | 0.249 |
| | (0.677) | (0.662) | (0.913) |
| PRONLY | -0.117 | 0.045 | -0.577 |
| | (0.289) | (0.370) | (1.226) |
| MATERIAL | -0.010 | -0.009 | -0.009 |
| | (0.009) | (0.008) | (0.024) |
| WAGE | -0.015 | -0.015 | -0.017 |
| | (0.015) | (0.017) | (0.043) |
| LBUY | 0.114* | 0.105* | 0.171 |
| | (0.035) | (0.038) | (0.227) |
| AGE | -0.001# | -0.001† | -0.004 |
| | (0.001) | (0.001) | (0.003) |
| UNION | -0.052† | -0.048† | -0.073 |
| | (0.030) | (0.029) | (0.091) |
| TRAIN | -0.027 | -0.011 | -0.105 |
| | (0.030) | (0.036) | (0.070) |
| PAK | -0.065 | -0.039 | -0.099 |
| | (0.059) | (0.067) | (0.071) |
| Intercept | 0.338* | 0.300# | 0.467 |
| | (0.108) | (0.125) | (0.308) |
| No. of obs. | 1375 | 1155 | 220 |
| $R^2$ | 0.065 | 0.064 | 0.083 |
| Complementarity test (p value) *H0: β(PDPR)-β(PDONLY)-β(PRONLY)≥0* | 0.392 | 0.271 | 0.712 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level
Note: All regressions include industry dummies

because our goal to run these regression were to extract the predict values. We ran the same employment growth equation specifications as we did previously, apart from inclusion of these new innovation definitions simultaneously in one employment growth equation. Recall that the reason to use innovation variables separately in previous employment equations was that they were collinear. Since these new innovation variables are not affected from multicollinearity[79], we can

[79] One reason of no multicollinearity is that these variables are the predicted values obtained from the multinomial probit regression, which includes original innovation variables as mutually exclusive by definition. We also tested empirically and found

safely use them in one regression. We focus solely on the innovation results since the purpose of these regressions is to understand the above stated phenomenon, and since the results of all other variables do not differ substantially between both sets of regressions (the previously discussed and the ones discussed subsequently). The innovation variables used in the MNP regression (i.e. PDPR, PDONLY, and PRONLY) have very low proportions for Pakistan, which made it impossible to run MNP regression on Pakistani firms. Hence, we have to skip the complementarity analysis for Pakistan.

Since we used MNP regression taking "no innovation" as a reference category to obtain the predicted values for employment growth equations, our hypothesis to test complementarity between product and process innovation to increase employment is the following:

$$HO: \beta(PDPR) - \beta(PDONLY) - \beta(PRONLY) \geq 0$$ [80]

where $\beta$ is the corresponding coefficient of each innovation variables obtained by the regression of employment growth on these innovation variables.

Table (5.10) reports the results for both countries' firms together. Both PDONLY and PRONLY are insignificant determinants of employment growth, but the variable "both product and process innovation" is a positive and significant predictor of employment change of all firms. Same holds for the low and high technology sector. This means that both process and product innovation have positive and significant effects on employment growth when carried out together instead of performing them in isolation. This is an indication of a complementarity between both innovations. We examined this by using formal test, which supports a complementarity between product

---

no indication of multicollinearity.

[80] The hypothesis $H0: \beta(PDPR) - \beta(PDONLY) - \beta(PRONLY) + \beta(no\ innovation) \geq 0$ is usually used to test complementarity. Our PDPR, PDONLY, and PRONLY are the predicted values from the MNP regression, which has "no innovation" as a reference category. Hence the variable "no innovation" is already incorporated in our null hypothesis.

and process innovation to increase employment in all firms and in the low- and high-tech sector.

**Table 5.11 Complementarity analysis for Bangladesh**

| Independent Variables | All | Low-tech | High-tech |
|---|---|---|---|
| | (1) | (2) | (3) |
| PDPR | 0.278† | 0.225 | 0.661# |
| | (0.162) | (0.182) | (0.317) |
| PDONLY | -0.043 | 0.030 | 0.304 |
| | (0.699) | (0.623) | (1.762) |
| PRONLY | -0.088 | -0.190 | -1.113 |
| | (0.489) | (0.524) | (0.976) |
| MATERIAL | 0.006 | 0.017 | -0.034 |
| | (0.016) | (0.019) | (0.035) |
| WAGE | -0.025 | -0.035 | -0.008 |
| | (0.032) | (0.044) | (0.057) |
| LBUY | 0.115† | 0.123† | 0.167 |
| | (0.061) | (0.068) | (0.132) |
| AGE | -0.002# | -0.002# | -0.005 |
| | (0.001) | (0.001) | (0.003) |
| UNION | -0.023 | -0.029 | -0.012 |
| | (0.040) | (0.039) | (0.147) |
| TRAIN | -0.065† | -0.054 | -0.122† |
| | (0.038) | (0.046) | (0.073) |
| Intercept | 0.344† | 0.352 | 0.515 |
| | (0.194) | (0.257) | (0.467) |
| No. of obs. | 686 | 536 | 150 |
| $R^2$ | 0.039 | 0.041 | 0.066 |
| Complementarity test (p value) *H0: β(PDPR)-β(PDONLY)-β(PRONLY)≥0* | 0.702 | 0.693 | 0.751 |

* Significance at 1% level # Significance at 5% level † Significance at 10% level

Note: All regressions include industry dummies

Table (5.11) presents the outcomes for Bangladesh and Pakistan. Analyzing all and high-tech Bangladeshi firms we notice that PDPR is an important determinant and PDONLY and PRONLY are insignificant factors of employment growth. For low-tech Bangladeshi firms, these variables are insignificant predictors of employment growth. The conclusion from the p values of complementarity test is that both product and process innovation are complements to enhance employment growth.

## 5.6 Conclusions and Policy Discussion

Albeit knowing whether innovation is conducive or detrimental to job creation in developing countries is paramount to policy making very few studies have tried to explore this relationship. This chapter contributes to this by analyzing the phenomenon in two developing countries: Pakistan and Bangladesh. We examined if this relationship differs across countries or across low-tech and high-tech industries. We asked whether process and product innovation are complements to induce or impede employment growth, and which effect (displacement or compensation) of one innovation type dominates the other. In our empirical analysis, we took care of the endogeneity of innovation in the employment equation by using its predicted values as an instrument.

Firm size (sales) appears to induce process innovation in the region of analysis as a whole and for Bangladesh separately; however, it has a very modest effect for Pakistan. Schumpeter's hypothesis that large firms are more likely to be product innovators is rejected for both countries combined as well as individually. High-tech firms' sales induce the product innovation in both countries together and Bangladesh while this effect is neither industry-specific nor significant in Pakistan, suggesting a complementarity between large firm size and R&D activities (high-tech firms are more R&D-intensive by definition) in two former cases. We found evidence of a negative effect of production workers' share of a firm's workforce on innovation, especially on product innovation of all firms which did not apply to the high-tech sector. Our interpretation is that a relative decrease in non-production workers (who are more likely to be responsible for innovation than production workers) implies a relative decrease of innovation activities. According to our results, the effects of the innovation determinants analyzed show some disparities across the low and high technology sector as well as across countries; the latter differences are more pronounced.

The innovation-employment analysis reveals that innovation (both product and process) encourages employment growth, even after controlling for a number of firm specific characteristics.[81] This means that the "compensation effect" of innovation dominates its "displacement effect". For product innovation these results are in line with the literature. Our results corroborate the arguments of those who assert a positive effect of process innovation on employment growth instead of a negative influence; the latter may be more dominant, but our empirical analysis validates the former. This means that the short-term "displacement effect" of the laborsaving characteristics of process innovation is weaker than the long-term "compensation effect" which works through price reduction and in turn demand expansion. These positive effects of both innovation types are not altered by the geographical locations of firms; they remain significant and positive across countries. Innovation is also conducive to employment growth in the low- and high-tech sector of the region combined. Analyzing sectors across countries, the positive effect of innovation on employment growth is confirmed only in high-tech Bangladeshi firms and low-tech Pakistani firms. Splitting the sample into low and high technology does not change the outcome for the whole region, it does for individual countries, however. Due to this disparity we argue that both countries have specific circumstances such as policies (of course, according to their own circumstances) regarding innovation pursuance, labor expertise, societal know how of novelties, etc. which favor one industrial sector or the other. Recall that 90% Pakistani firms compared with 77% of Bangladeshi ones are low-tech firms, and the very nature of the high-tech sector might lead policies to favor this sector more in Bangladesh than in Pakistan.

In addition, we observed an insignificant, negative impact of labor cost on employment growth throughout this is contrary to the widely observed significant, negative effect in previous studies. One reason might be that labor in these countries is cheaper than in developed

[81] This positive correlation between employment quantity and innovation, however, does not indicate the sign of inclusive growth. Innovation may increase employment on the one hand but substitute unskilled workers by the skilled ones on the other, suppressing opportunities for unskilled employees. There are no employment quality variables in our dataset to explore this question.

ones, hence firms' cost-related reluctance to hire new labor may not be significant enough to suppress employment growth. The intermediate input of productivity (raw material) have significant and negative effect on employment growth in both sectors combined and in the low-tech firms of Pakistan, suggesting substitutability with labor. The effect of material in high-tech firms might be insignificant because of the complex nature of the high-tech sector's production processes which does not allow firms to enhance one production factor with sacrificing other. We did not find this negative effect in Bangladesh and in all firms taken together, except one regression of all firms. The descriptive statistics on raw material and employment, coupled with above mentioned relationships of material and employment, suggest that Pakistani firms rely more on material input while Bangladeshi firms rely more on employment for their productivity. We found differences between the performance of other control variables across countries and across industries, suggesting that the complex nature of the employment effect is sensitive to the NISs of different countries and to different industrial paradigms. Another striking result of our study is that we observed a complementarity between both process and product innovation to stimulate employment, suggesting that both should be carried out together to induce employment growth.

Unemployment is a curse which has more severe effects in developing countries than in the developed world, since developed countries generally have a series of compensation allowances in terms of social security, unemployment allowance, etc. to prevent an involvement of the unemployed labor force in destructive activities which can easily destroy the equilibrium of a peaceful society. Hence, to avoid unemployment and its associated consequences in developing countries, it is indispensable for policy makers to initiate and foster policies. Based on our empirical analysis, we strongly recommend the initiation of new and further development of ongoing innovation projects on the micro level and the rectification of the problems of NIS son the macro level to reduce unemployment.

# Chapter 6

## Concluding Remarks

### 6.1 Introduction

The long debated effects of technology on economic development and on social welfare can be exerted through various channels. Two of the possible channels are the increase of labor productivity with the help of machines on one hand, and the destruction of jobs due to the introduction of these machines on the other. The effects of technology have been studied extensively in the literature. The existence of innovation surveys has made it possible to investigate these effects in a more systematic way by employing econometric techniques rigorously. These surveys also translated the macro level concept "technology" into the micro level notion "innovation", and have allowed researchers to examine the determinants of innovation on the one hand and innovation as a determinant of firm performance on the other. The use of these surveys to investigate the technological characteristics of a country in terms of innovative behavior on firm-level is now common practice.

The majority of contributions to innovation studies is put forth by the developed world, and the frequency of these studies for developing countries is very low. The obvious reason for this scarcity is that the economically poor regions of the world are also technologically backward. This technological backwardness should motivate developing countries' innovation researchers to understand why they lag behind and how can they improve, yet we have not seen reasonable progress on this front. This thesis is an attempt to fill this gap in the literature by investigating the firm-level innovation characteristics of two developing regions of the world (Latin America and South Asia) by using the Enterprise Survey (Investment Climate Survey) of the World Bank. We examined the effects of innovation determinants in Latin America, while the investigation of innovation as a determinant of firm performance (productivity and employment growth) is based on South Asia.

## 6.2 Innovation Culture in Developing Countries

One of the important prerequisites for a successful innovation culture is the availability of sufficient knowledge stock. In this thesis we observe developing countries as those which have low levels of education and knowledge bases (both technical and non-technical). They lack formalized infrastructures needed for the smooth progression of innovation. The low level of knowledge stock hinders firms to be progressive in terms of enhancing technological capabilities and absorptive capacities. Although strong commitments to R&D activities can enrich innovation capabilities, we note that developing countries lag far behind the developed world in this respect. The national innovation systems of developing countries need to be improved to achieve optimal results. These are some of the topics on which these countries have to work consistently to improve their firms' innovative capabilities.

Despite the aforementioned innovation limitations, the creation of an innovation culture on an individual, societal, and institutional level in developing countries is not an insurmountable target. However, this cannot be done overnight. The introduction of innovation policies and most importantly their implementation with honesty and a long term commitment can result in enhanced innovation capabilities. Some these policies could be the introduction of foreign experts and the direct import of foreign technology at the first stage. The local workforce then could learn new skills more easily by interacting with these knowledge sources in the workplace. Eventually the local workers will be capable of carrying out high quality innovations. Political stability and attractive employment conditions for researchers would complement other prerequisites of successful innovation polices in these developing regions.

The national and firm level innovation limitations do not directly indicate that the innovation determinants that are important for the developed countries are not significant factors of the developing countries' firm-level innovations. These limitations do not undermine the importance of innovation in firms' performances in developing countries that is frequently observed in the developed world. We notice a scarcity of both types of innovation studies (i.e. determinants of innovation and innovation as a determinant of firm performance) with particular reference to the developing world. It is not advisable to establish innovation policies for the developing world based on the developed world's findings. All these factors necessitate a large range of innovation studies in the developing world to understand firm-level innovation phenomena in these regions better. Therefore, we discuss innovation culture (and its limitations) in developing countries and conduct three applied econometric analyses based on (some of) these countries' firm-level survey data. The first analysis investigates innovation determinants, while the second and third analyze the productivity and employment effects of innovation respectively.

## 6.3 Innovation Determinants in Developing Countries

The analysis of innovation determinants is based on data of manufacturers of fourteen Latin American countries. The innovation input determinants can behave differently from the determinants of innovation output. Therefore, we use both innovation types as dependent variables. To avoid a selectivity bias in our R&D analysis caused by a large number of non-R&D-performers, we use the Heckman two step procedure. The empirical findings of firm size (employment in our case) as a determinant of both innovation types follow the same pattern as in the developed world: employment increases the likelihood of a positive R&D choice and of product innovation; it also increases R&D intensity (R&D expenditure per capita) but at a less than propionate rate. Another investigated determinant is product market competition which shows that product competition induces product innovation, but has no influence on R&D expenditure. This means that to respond to product market competition, Latin American firms choose the short route of slight modifications of existing products and/or imitations of developed countries' technologies rather than a long-term route of carrying out formal R&D to produce product innovation. This particular argument is strengthened by the failure of R&D intensity as a determinant of product innovation in the empirical analysis.

In addition to these two Schumpeterian determinants, we include control variables to enrich our econometric analysis. Another important innovation determinant frequently reported to have a positive influence, is the firm's trade orientation (both imports and exports). Trade orientation may be more important for developing countries to induce innovation. Our empirical analysis reveals that both imports and exports induce both R&D and product innovation. As argued, an educated labor force can be fruitful for the success of innovation projects, and we find the same results empirically. Our results also corroborate the well-established notion of the importance of cross-country and cross-industry differences in innovation activities.

Another aspect of our innovation determinants analysis is to observe any disparities between the innovation determinants in large and small firms and in different competition environments, because it is possible that a particular firm size and competition environment provide more appropriate conditions for (some) innovation determinants than other size classes and competition environments. According to the empirical analysis in chapter (3), no particular size class is beneficial for either employment and competition to induce R&D activities (both choice and expenditure), or for employment to stimulate product innovation. However, competition is a more important determinant of product innovation in large firms than in small ones, suggesting the contradiction to the Schumpeter's view of complementarity between monopolies and large firm size for innovation. R&D as a determinant of product innovation is insignificant when looking at the whole sample. We also explore whether large firms provide a more beneficial environment for R&D to induce innovation than small ones, because they might have formal organization of their R&D departments. Our dataset does not confirm this hypothesis, since R&D as a determinant of product innovation does not behave differently in small and large firms; the same holds true for different competition environments.

We extend the analysis of disparities in innovation determinants from an individual to an aggregate level, and examine whether there are any differences in the joint influence of these determinants in different size classes and in different competition environments. The determinants of R&D expenditure as a whole differ between small and large firms, whereas the determinants do not behave differently in different competition environments. The determinants of the R&D decision jointly do not behave differently in either case. Moreover, product innovation determinants in different size classes behave differently as a whole. The disparity between the joint performances of these determinants is also noted for competition environments.

The role of innovation determinants in our analysis and in many other innovation studies on developing countries generally does not contradict the developed world's empirical findings. For example, an educated workforce is an important factor for successful innovation activities in developed and developing countries, etc. The innovation problems in developing countries are not due to the characteristics of these determinants per se, but because of the environment, i.e. a lack of conducive determinants/sources and an abundance of obstacles. Hence, the key to innovation success in the developing world is the removal of innovation obstacles and the enrichment of innovation sources, as already argued in chapter (2).

## 6.4 Innovation as a Determinant of Labor Productivity in Developing Countries

The second part of this thesis, i.e. the effect of innovation as a determinant of firm performance is observed in its dual role: the labor productivity effect of innovation and which effect innovation has on employment. To understand these relationships in more detail, we investigate the impacts of both process and product innovation.

The productivity effect of innovation analysis is based on the firm-level survey dataset for Pakistani and Bangladeshi manufacturers.

This analysis is carried out using the CDM model, which investigates the effect of R&D on productivity implicitly and the effect of innovation output on productivity explicitly, by using a systematic three-stage econometric model. The first stage connect R&D to its determinants, while the second stage links innovation output to R&D and other determinants, and finally the productivity effect of innovation output is found in the third stage. We take care of the endogeneity of R&D (in the innovation output equation) and of innovation output (in the productivity output equation). We apply two versions of the CDM: the full CDM with all stages and is applied only to Bangladesh and the reduced CDM with only innovation output and productivity output stages is applied to Pakistan and Bangladesh. One reason to apply two versions is that we do not have R&D information for Pakistani manufacturers. The other reason is our aim to compare the results of both versions.

As expected the effect of firm size (sales) is significant and positive for the R&D choice and positive but at a less than proportional rate for R&D expenditure in Bangladeshi firms. This result is similar to the preceding chapter's results on Latin American manufacturers. More diversified firms are more likely to perform R&D activities. The results reveal that obstacles to access to finance are unimportant determinant of firms' positive R&D decision and expenditure.

As argued, one important reason for a lack of innovation in developing countries is the absence of regular innovation policies with full commitment. For Bangladeshi firms this view is corroborated empirically by the insignificance of firms' membership in a business association (e.g. chamber of commerce) as a determinant of firms' R&D and process innovation, and by its significant, negative effect on product innovation.

Subsequently, we discuss the results of innovation output (both process and product) determinants, for both Pakistan and Bangladesh as well as for all firms together. As a whole and for Bangladesh, firm sales appear to be a significant, positive determinant of process innovation, but have no impact on product innovation. In Pakistan firm sales are an inconsequential factor for both innovation types. The previously observed positive effect of trade orientation (both imports and exports) on Latin America's product innovation is also revealed in our analysis on Pakistan. Exports (imports) appear to be significant, negative (positive) factors of product innovation of all firms taken together (Pakistan and Bangladesh) and of Bangladeshi firms only. Giving the high proportion of product innovators in Bangladesh than in Pakistan, the negative influence of exporters on product innovation is surprising. The possible reason of this finding is that buyers of Bangladeshi firms' exports are less innovation-seeker than buyers of Pakistani exports. As mentioned in chapter (2), with particular reference to South Korea and Usiminas (a Brazilian steel producer), the use of foreign licensed technology can be a way to enhance local innovation capabilities in developing countries. We find a positive, significant role on both product and process innovation, for both countries and as a whole. Hence, in addition to the direct role of foreign technologies in innovation outputs, it may also improve local innovation capabilities of the firms that use these technologies, because empirically they are more likely to be innovators than non-users. The role of education is observed to be important for both innovation types as a whole and for Pakistani firms. However, education is an insignificant determinant of Bangladeshi firms' process innovation, yet significant for their product innovation.

The most important stage of this analysis is the productivity equation, which is an augmented Cobb-Douglas production function which includes both innovation types as productivity inputs. We use different model specifications. Along with innovation and labor inputs, we use intermediate input (raw material cost) and fixed capital input (proxied by net book value). In addition, we estimate the extended version of the aforementioned models by adding control variables.

Our productivity analysis mostly does not reject the constant returns to scale assumption. After comparing summary statistics and the results of the country dummy in the econometric analysis, we notice that Bangladeshi firms are more likely to be innovators, whereas labor productivity is larger in Pakistan. We observe important effects of fixed capital and intermediate capital (raw material) on both countries' labor productivity. These two findings indicate that firm productivity in this region depends more on traditional inputs (capital, labor, and intermediate inputs such as raw material) than knowledge and learning (one well established source of productivity in the developing world). This does not mean that innovation per se is not an important determinant of productivity; we apply a rigorous econometric analysis to examine this relationship.

The most striking finding of our innovation-productivity relationship analysis is that both innovation types are significant determinants to increase labor productivity in the region as a whole and in countries individually, even after controlling for a number of firm-specific characteristics. The effect of innovation output on productivity remains the same whether we include the R&D equation in our system (i.e. apply the full CDM) or do not have it (i.e. apply the reduced CDM), suggesting that both are equally effective.

Hence, the findings strongly encourage innovation friendly policies in this region particularly, and in the developing world generally. Consistent innovation policies will build up the innovation capabilities of these countries' labor force,and increase their productivity.

## 6.5 Innovation as a Determinant of Employment in Developing Countries

The importance of innovation as a productivity determinant has been established in the above analysis. However, this importance might be offset by the job destruction effect of innovation. Hence, it would be interesting to examine the impact innovation has on the employment structure of this region to shape innovation policies more aptly. Also recall that labor productivity is measured by sales per employee in our productivity analysis. Hence, it is ambiguous whether the positive productivity effect of innovation is an effect of production increase with the same workers or whether it is an effect of the same production with fewer employees. Of course, the effect of innovation on productivity can be interpreted in both ways, but it is interesting to know which effect dominates, because the latter would not be an optimal outcome of innovation as a contributor to social welfare.

Analyzing the employment effect of innovation is very important for labor and innovation policies in developing countries, because unemployment in the developing regions are socially more problematic than in the developed world. In developing countries, there is larger risk of social unrest, because these countries often do not have safety nets such as financial unemployment benefits (e.g. social security, etc.).

The effect of innovation on employment is observed empirically for Pakistan and Bangladesh. An important empirical finding is that both innovation types (product and process) induce employment in this region as a whole. This means that the "compensation effect" of innovation dominates the "displacement effect". This positive effect of innovation is also obtained in separate analyses of low-tech and high-tech industries of the whole region. If we break our analysis down to country level, the significant, positive effects of both product and process innovation are also obtained for all Bangladeshi and for all Pakistani firms. However, the sector level analysis across countries shows disparities: both innovation types are important determinants of employment growth only in high-tech Bangladeshi firms and only in low-tech Pakistani firms, suggesting that both countries may have specific policies in terms of innovation and of labor expertise at sector level. One reason for sector-specific policies may be that Bangladesh in our sample has a share of 23% high-tech firms, which is more than double the 10% of Pakistan; the very nature of the high-tech industry causes public policies to favor this sector more in Bangladesh than in Pakistan. In sum, we can safely argue that, similar to the productivity increase effect of both innovation types, this region also strongly benefit from both innovations for increasing employment.

It has been observed frequently that wages are significant, negative determinants of employment growth. The reason for this effect of wages on employment growth to be insignificant (but still negative) in our case may be the availability of labor force at lower rates in this region compared to the developed world. The significant and negative effect of raw material on employment growth for all and for low-tech firms in Pakistan and the whole region (more significant for Pakistan) suggests its substitutability instead of complementarity with labor, especially in Pakistan. Our interpretation of the insignificance of this predictor for high-tech Pakistani firms is that high-tech productions are more complex so that a decrease in human capital does not necessarily lead to increased material input and vice versa. The results of Bangladesh in all cases reveal an insignificant influence of this intermediate input on labor growth.

Having understood the employment effect of innovation, we examine another important issue. We ask whether both innovation types are complementary to induce employment. Our empirical results support the complementarity between both innovation types, suggesting that to increase employment opportunities, both innovations should be carried out together.

## 6.6 Final Remarks

This thesis endeavors to understand innovation phenomena in developing countries by using both theoretical concepts and empirical analysis. Although innovations in the developing world are often incremental compared to the radical innovations prevalent in the developed world, we conclude that the behaviors of the innovation determinants are generally the same for both regions. This means that the low innovation intensity of the developing world is directly related to the inherent insufficiency of positive determinants, whose ratios are higher in developed countries, as observed in the second chapter. If the developing world increases these positive determinants, it can enhance its innovation capacity. This is a long terms process, entailing shrewd planning, commitment, and integrity at an individual and institutional level. We argue that it is not essential for developing countries to follow the developed countries' innovation policies minutely; they should device policies that are suitable to their local context, because innovation in both regions has different definitions. Once these policies initiate incremental innovations and in turn growth in these countries, they can be extended further to contribute towards the global technological frontier by enabling these countries to produce radical innovations.

Innovation cannot be carried out in isolation, and many factors enhancing innovation capabilities of a country are interlinked. One reason of poor NISs in developing countries is that the factors whose connections build a NIS in a country do not work optimally. They are unable to understand the sophistications involved in their connections to make a strong NIS. We argue that once a developing country has sufficient set of those factors that enhance innovation capacity and devises innovation friendly policies at the national level, it can be easily transformed into a country having healthy national innovation system.

Although this and other studies have observed that industrial innovation is not a significant factor in developing countries, the empirical analysis of Pakistan and Bangladesh shows that it affects these countries' productivity and employment positively. Hence policy makers of this region in particular, and of developing countries in general, should focus on innovation policies to increase their industrial productivity and to control unemployment.

Finally, our empirical findings advocate innovation policies not only in the regions that are included in our dataset, but also in other developing regions of the world, because most problems of innovation are common throughout the developing world. However, more empirical studies on the countries included in this thesis, and on other developing countries, based on the industrial dataset of the countries included in this thesis and of other developing countries will help to shape innovation policies in these regions/countries more aptly.

# References


Abramovitz, M., 1956. Resource and output trends in the United States since 1870. The American Economic Review 46, 5–23.

Abramovitz, M., 1986. Catching up, forging ahead, and falling behind. Journal of Economic History 46, 385–406.

Acs, Z.J., Audretsch, D.B., 1987. Innovation, market structure, and firm size. The Review of Economics and Statistics 69, 567–574.

Acs, Z.J., Audretsch, D.B., 1988. Innovation in large and small firms: an empirical analysis. The American Economic Review 78, 678–690.

Acs, Z.J., Audretsch, D.B., 1991a. Innovation and technological change: an overview, in: Acs, Z.J., Audretsch, D.B. (Eds.), Innovation and Technological Change:An International Comparison. Harvester Wheatsheaf, New York, pp. 1–23.

Acs, Z.J., Audretsch, D.B., 1991b. R&D, firm size and innovative activity, in: Acs, Z.J., Audretsch, D.B. (Eds.), Innovation and Technological Change: An International Comparison. Harvester Wheatsheaf, New York, pp. 39–59.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and innovation: an Inverted-U Relationship. Quarterly Journal of Economics 120, 701–728.

Alcorta, L., Peres, W., 1998. Innovation systems and technological specialization in Latin America and the Caribbean. Research Policy 26, 857–881.

Antonucci, T., Pianta, M., 2002. Employment effects of product and process innovation in Europe. International Review of Applied Economics 16, 295–307.

Archibugi, D., Coco, A., 2004. A new indicator of technological capabilities for developed and developing countries (ArCo). World Development 32, 629–654.

Archibugi, D., Coco, A., 2005. Measuring technological capabilities at the country level: a survey and a menu for choice. Research Policy 34, 175–194.

Archibugi, D., Evangelista, R., Simonetti, R., 1995. Concentration, firm size and innovation: evidence from innovation costs. Technovation 15, 153–163.

Arocena, R., Sutz, J., 2000. Looking at national systems of innovation from the south. Industry and Innovation 7, 55–75.

Arocena, R., Sutz, J., 2005. Innovation systems and developing countries. DRUID Working Paper No. 02-05.

Arvanitis, S., 1997. The impact of firm size on innovative activity–an empirical analysis based on Swiss firm data. Small Business Economics 9, 473–490.

Aubert, J.E., 2004. Promoting innovation in developing countries: a conceptual framework. World Bank Institute.

Audretsch, D.B., Vivarelli, M., 1996. Firms size and R&D spillovers: Evidence from Italy. Small Business Economics 8, 249–258.

Ayyagari, M., Demirguç-Kunt, A., Maksimovic, V., 2007. Firm innovation in emerging markets: the roles of governance and finance. World Bank Policy Research Paper No. 4157.

Benavente, J.M., 2006. The role of research and innovation in promoting productivity in Chile. Economics of Innovation and New Technology 15, 301–315.

Benavente, J.M., Lauterbach, R., 2008. Technological innovation and employment: complements or substitutes? The European Journal of Development Research 20, 318–329.

Blanchflower, D.G., Burgess, S.M., 1998. New technology and jobs: comparative evidence from a two country study. Economics of Innovation and New Technology 5, 109–138.

Blanchflower, D.G., Millward, N., Oswald, A.J., 1991. Unionism and employment behaviour. The Economic Journal 101, 815–834.

Blundell, R., Griffiths, R., Van Reenen, J., 1999. Market share, market value and innovation in a panel of British manufacturing firms. Review of Economic Studies 66, 529–554.

Bogliacino, F., Pianta, M., 2010. Innovation and employment: a reinvestigation using revised Pavitt classes. Research Policy 39, 799–809.

Bogliacino, F., Pianta, M., 2011. Engines of growth. Innovation and productivity in industry groups. Structural Change and Economic Dynamics 22, 41–53.

Bound, J., Cummins, C., Griliches, Z., Hall, B.H., Jaffe, A., 1984. Who does R&D and who patents?, in: Griliches, Z. (Ed.), R & D, Patents, and Productivity. University of Chicago Press, pp. 21–54.

Braga, H., Willmore, L., 1991. Technological imports and technological effort: an analysis of their determinants in Brazilian firms. The Journal of Industrial Economics 39, 421–432.

Brouwer, E., Kleinknecht, A., Reijnen, J.O.N., 1993. Employment growth and innovation at the firm level. Journal of Evolutionary Economics 3, 153–159.

Carlsson, B., Jacobsson, S., Holmén, M., Rickne, A., 2002. Innovation systems: analytical and methodological issues. Research Policy 31, 233–245.

Carter, C.F., Williams, B.R., 1958. Investment in innovation. Oxford University Press, London.

Chennells, L., Van Reenen, J., 1999. Has technology hurt less skilled workers? an econometric survey of the effects of technical change on the structure of pay and jobs. Institute for Fiscal Studies Working Paper No. 99/27.

Cohen, W.M., Levin, R.C., Mowery, D.C., 1987. Firm size and R & D intensity: a re-examination. The Journal of Industrial Economics 35, 543–565.

Cohen, W.M., Levinthal, D.A., 1989. Innovation and learning: the two faces of R & D. The Economic Journal 99, 569–596.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35, 128–152.

Collin, S.M., 2007. Economic growth in South Asia: A growth accounting perspective, in: Ahmed, A., Ghani, E. (Eds.), South Asia: Growth and Regional Integration. Macmillan India Ltd.

Comanor, W.S., 1967. Market structure, product differentiation, and industrial research. The Quarterly Journal of Economics 81, 639–657.

Cosh, A.D., Hughes, A., Weeks, M., 2000. The relationship between training and employment growth in small and medium-sized enterprises. Department for Education and Employment Research Report No. 245.

Crane, D., 1977. Technological innovation in developing countries: a review of the literature. Research Policy 6, 374–395.

Crepon, B., Duguet, E., Mairesse, J., 1998. Research, innovation and productivity: an econometric analysis at the firm level. Economics of Innovation and New technology 7, 115–158.

Crespi, F., Pianta, M., 2008. Demand and innovation in productivity growth. International Review of Applied Economics 22, 655–672.

Crespi, G., Zuniga, P., 2012. Innovation and productivity: evidence from six Latin American countries. World Development 40, 273–290.

Dachs, B., Ebersberger, B., Lööf, H., 2008. The innovative performance of foreign-owned enterprises in small open economies. The Journal of Technology Transfer 33, 393–406.

Dahlman, C.J., 2007. Improving technology, skills and innovation in South Asia, in: Ahmed, A., Ghani, E. (Eds.), South Asia: Growth and Regional Integration. Macmillan India Ltd.

Dahlman, C.J., Ross-Larson, B., Westphal, L.E., 1987. Managing technological development: lessons from the newly industrializing countries. World Development 15, 759–775.

de Mel, S., McKenzie, D., Woodruff, C., 2009. Innovative firms or innovative owners? Determinants of innovation in micro, small, and medium enterprises. IZA Working Paper No. 3962.

Deeds, D.L., 2001. The role of R&D intensity, technical development and absorptive capacity in creating entrepreneurial wealth in high technology start-ups. Journal of Engineering and Technology Management 18, 29–47.

Doms, M., Dunne, T., Roberts, M.J., 1995. The role of technology use in the survival and growth of manufacturing plants. International Journal of Industrial Organization 13, 523–542.

Edquist, C., 2004. System of innovation: perspectives and challenges, in: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), The Oxford Handbook of Innovation. Oxford University Press, pp. 181–208.

Edquist, C. (Ed.), 1997. Systems of innovation: technologies, institutions, and organizations. Pinter, London.

Edquist, C., Hommen, L., McKelvey, M., 2001. Innovation and employment: process versus product innovation. Edward Elgar, Cheltenham, UK and Northampton, USA.

Edwards, K.L., Gordon, T.J., 1984. Characterization of innovations introduced on the US market in 1982. The Futures Group, U.S. Small Business Administration.

Evangelista, R., Mastrostefano, V., 2006. Firm size, sectors and countries as sources of variety in innovation. Economics of Innovation and New Technology 15, 247–270.

Fabrizio, K.R., 2009. Absorptive capacity and the search for innovation. Research Policy 38, 255–267.

Fagerberg, J., Srholec, M., 2008. National innovation systems, capabilities and economic development. Research Policy 37, 1417–1435.

Fagerberg, J., Srholec, M., Verspagen, B., 2010. Innovation and economic development, in: Hall, B.H., Rosenberg, N. (Eds.), Handbook of the Economics of Innovation. North-Holland, pp. 833–872.

Flatten, T.C., Engelen, A., Zahra, S.A., Brettel, M., 2011. A measure of absorptive capacity: scale development and validation. European Management Journal 29, 98–116.

Freel, M.S., Robson, P.J.A., 2004. Small firm innovation, growth and performance: evidence from Scotland and Northern England. International Small Business Journal 22, 561–575.

Freeman, C., 1987. Technology and economic performance: lessons from Japan. Pinter, London.

Freitas, I.M.B., Clausen, T., Fontana, R., Verspagen, B., 2011. Formal and informal external linkages and firms' innovative strategies. A cross-country comparison. Journal of Evolutionary Economics 21, 91–119.

Furman, J.L., Porter, M.E., Stern, S., 2002. The determinants of national innovative capacity. Research Policy 31, 899–933.

Gaillard, J., 2010. Measuring research and development in developing countries: main characteristics and implications for the Frascati manual. Science Technology & Society 15, 77–111.

Galvez, A., Maqueda, M., Martinez-Bueno, M., Valdivia, E., 2000. Scientific Publication Trends and the Developing World: what can the volume and authorship of scientific articles tell us about scientific progress in various regions? American scientist 88, 526–533.

Geroski, P., Machin, S., Van Reenen, J., 1993. The profitability of innovating firms. The RAND Journal of Economics 24, 198–211.

Gilbert, R., 2006. Looking for Mr. Schumpeter: where are we in the competition-innovation debate?, in: Jaffe, A.B., Lerner, J., Stern, S. (Eds.), Innovation Policy and the Economy. The MIT Press, pp. 159–215.

Girma, S., Görg, H., 2005. Foreign direct investment, spillovers and absorptive capacity: evidence from quantile regressions. Deutsche Bundesbank Discussion Paper No. 13/2005.

Goedhuys, M., Veugelers, R., 2011. Innovation strategies, process and product innovations and growth: frim-level evidence from Brazil. Struct. Change Econ. Dyn., doi: 10.1016/j.strueco.2011.01.004.

Griffith, R., Huergo, E., Mairesse, J., Peters, B., 2006. Innovation and productivity across four European countries. Oxford Review of Economic Policy 22, 483–498.

Griliches, Z., 1978. Economic problems of measuring returns to research, in: Elkana, Y., Lederberg, J., Merton, R.K., Thackray, A., Zuckerman, H. (Eds.), Toward a Metric of Science: The Advent of Science Indicators. John Wiley & Sons, Inc., New York.

Griliches, Z., 1998. R&D and productivity: the econometric evidence. University of Chicago press, Chicago.

Gu, S., 1999. Implications of national innovation systems for developing countries: managing change and complexity in economic development. UNU-INTECH Discussion Paper No. 9903.

Hall, B.H., Lotti, F., Mairesse, J., 2008. Employment, innovation, and productivity: evidence from Italian microdata. Industrial and Corporate Change 17, 813–839.

Hall, B.H., Lotti, F., Mairesse, J., 2009. Innovation and productivity in SMEs: empirical evidence for Italy. Small Business Economics 33, 13–33.

Hall, B.H., Mairesse, J., 1995. Exploring the relationship between R&D and productivity in French manufacturing firms. Journal of Econometrics 65, 263–293.

Hamberg, D., 1964. Size of firm, oligopoly, and research: the evidence. Canadian Journal of Economics and Political Science 30, 62–75.

Hansen, J.A., 1992. Innovation, firm size, and firm age. Small Business Economics 4, 37–44.

Harhoff, D., 1998. R&D and productivity in German manufacturing firms. Economics of Innovation and New Technology 6, 29–49.

Harrison, R., Jaumandreu, J., Mairesse, J., Peters, B., 2008. Does innovation stimulate employment? A firm-level analysis using comparable micro-data from four European countries. NBER Working Paper No. 14216.

Henderson, R., Cockburn, I., 1996. Scale, scope, and spillovers: the determinants of research productivity in drug discovery. Rand Journal of Economics 27, 32–59.

Holmstrom, B., 1989. Agency costs and innovation. Journal of Economic Behavior & Organization 12, 305–327.

INSEAD, 2011. The Global Innovation Index 2011. INSEAD.

Intarakumnerd, P., Chairatana, P., Tangchitpiboon, T., 2002. National innovation system in less successful developing countries: the case of Thailand. Research Policy 31, 1445–1457.

Jaffe, A.B., 1989. Real effects of academic research. The American Economic Review 79, 957–970.

Kamien, M.I., Schwartz, N.L., 1982. Market structure and innovation. Cambridge University Press, Cambridge.

Kim, L., 1980. Stages of development of industrial technology in a developing country: a model. Research Policy 9, 254–277.

Kim, L., 1997. Imitation to innovation: the dynamics of Korea's technological learning. Harvard Business School Press, Massachusetts.

Klomp, L., Van Leeuwen, G., 2001. Linking innovation and firm performance: a new approach. International Journal of the Economics of Business 8, 343–364.

Koellinger, P., 2008. The relationship between technology, innovation, and firm performance–Empirical evidence from e-business in Europe. Research Policy 37, 1317–1328.

Kumar, N., Saqib, M., 1996. Firm size, opportunities for adaptation and in-house R & D activity in developing countries: the case of Indian manufacturing. Research Policy 25, 713–722.

Lee, C., 2011. Trade, productivity, and innovation: Firm-level evidence from Malaysian manufacturing. Journal of Asian Economics 22, 284–294.

Lee, C.Y., Sung, T., 2005. Schumpeter's legacy: a new perspective on the relationship between firm size and R&D. Research Policy 34, 914–931.

Leiponen, A., 2005. Skills and innovation. International Journal of Industrial Organization 23, 303–323.

Leonard, J.S., 1992. Unions and employment growth. Industrial Relations 31, 80–94.

Lettl, C., 2007. User involvement competence for radical innovation. Journal of Engineering and Technology Management 24, 53–75.

Levin, R.C., Cohen, W.M., Mowery, D.C., 1985. R & D appropriability, opportunity, and market structure: new evidence on some Schumpeterian hypotheses. The American Economic Review 75, 20–24.

Liu, X., White, S., 2001. Comparing innovation systems: a framework and application to China's transitional context. Research Policy 30, 1091–1114.

Long, R.J., 1993. The effect of unionization on employment growth of Canadian companies. Indus. & Lab. Rel. Rev. 46, 691.

Lööf, H., Heshmati, A., 2002. Knowledge capital and performance heterogeneity: an innovation study at firm level. International Journal of Production Economics 76, 61–85.

Lööf, H., Heshmati, A., 2006. On the relationship between innovation and performance: a sensitivity analysis. Economics of Innovation and New Technology 15, 317–344.

Lucas, R.E.J., 1988. On the mechanics of economic development. Journal of Monetary Economics 22, 3–42.

Lundvall, B.Å. (Ed.), 1992. National systems of innovation: toward a theory of innovation and interactive learning. Pinter, London.

Lunn, J., Martin, S., 1986. Market structure, firm structure, and research and development. Quarterly Review of Economics and Business 26, 31–44.

Mairesse, J., Mohnen, P., 2005. The importance of R&D for innovation: a reassessment using French survey data. Journal of Technology Transfer 30, 183–197.

Mairesse, J., Mohnen, P., Kremp, E., 2005. The importance of R&D and innovation for productivity: a reexamination in light of the

French innovation survey. Annals of Economics and Statistics / Annales d'Économie et de Statistique 487–527.

Mairesse, J., Sassenou, M., 1991. R&D productivity: a survey of econometric studies at the firm level. NBER Working Paper No. 3666.

Mansfield, E., 1963. Size of firm, market structure, and innovation. The Journal of Political Economy 71, 556 – 576.

Mastrostefano, V., Pianta, M., 2009. Technology and jobs. Economics of Innovation and New Technology 18, 729–741.

Meriküll, J., 2010. The impact of innovation on employment. Eastern European Economics 48, 25–38.

Monge-González, R., Rodríguez-Alvarez, J.A., Hewitt, J., Orozco, J., Ruiz, K., 2011. Innovation and employment growth in Costa Rica: a firm-level analysis. IDB Publications No.54278.

Nieto, M., Quevedo, P., 2005. Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort. Technovation 25, 1141–1157.

NSF, 2012. Science and engineering indicators 2012. National Center for Science and Engineering Statistics, and the Patent Board™, Special Tabulation (2011) from Thomson Reuters, SCI and SSCI.

OECD, 1992. Innovation manual: proposed guidelines for collecting and interpreting innovation data. OECD, Paris.

OECD, 2002. Frascati manual: proposed standard practice for surveys on research and experimental development. OECD, Paris.

Pakes, A., Griliches, Z., 1980. Patents and R&D at the firm level: a first look. Economics Letters 5, 377–381.

Parisi, M.L., Schiantarelli, F., Sembenelli, A., 2006. Productivity, innovation and R&D: Micro evidence for Italy. European Economic Review 50, 2037–2061.

Pavitt, K., Robson, M., Townsend, J., 1987. The size distribution of innovating firms in the UK: 1945-1983. The Journal of Industrial Economics 35, 297–316.

Pianta, M., 2001. Innovation, demand and employment, in: Soete, L., Petit, P. (Eds.), Technology and the Future of European Employment. Edward Elgar, Aldershot.

Pianta, M., 2005. Innovation and employment, in: Fagerberg, J., Mowery, D., Nelson, R.R. (Eds.), The Handbook of Innovation. Oxford University Press, Oxford.

Pla-Barber, J., Alegre, J., 2007. Analysing the link between export intensity, innovation and firm size in a science-based industry. International Business Review 16, 275–293.

Radas, S., Božić, L., 2009. The antecedents of SME innovativeness in an emerging transition economy. Technovation 29, 438–450.

Reddy, P., 2005. R&D-related FDI in developing countries: implications for host countries. United Nations Conference on Trade and Development, Geneva.

Ricardo, D., 2001. On the principles of political economy and taxation, 3rd ed. Batoche Books, Kitchener, Ontario, Canada.

Robson, M., Townsend, J., 1984. Users manual for ESRC archive file on innovations in Britain since 1945. Photocopied. Sussex, UK: University of Sussex, Science Policy Research Unit.

Rogers, M., 2004. Networks, firm size and innovation. Small Business Economics 22, 141–153.

Romer, P.M., 1986. Increasing returns and long-run growth. The Journal of Political Economy 94, 1002–1037.

Romer, P.M., 1990. Endogenous technological change. The Journal of Political Economy 98, S71–S102.

Ross, D.R., Zimmermann, K.F., 1993. Evaluating reported determinants of labor demand. Labour Economics 1, 71–84.

Rothwell, R., Zegveld, W., 1979. Technical change and employment. Frances Printer, London.

Santarelli, E., Sterlacchini, A., 1990. Innovation, formal vs. informal R&D, and firm size: some evidence from Italian manufacturing firms. Small Business Economics 2, 223–228.

Scherer, F.M., 1965a. Size of firm, oligopoly, and research: a comment. Canadian Journal of Economics and Political Science 31, 256–266.

Scherer, F.M., 1965b. Firm size, market structure, opportunity, and the output of patented inventions. The American Economic Review 55, 1097–1125.

Scherer, F.M., 1967. Market structure and the employment of scientists and engineers. The American Economic Review 57, 524–531.

Schubert, A., Telcs, A., 1986. Publication potential—an indicator of scientific strength for cross-national comparisons. Scientometrics 9, 231–238.

Seker, M., 2009. Importing, exporting, and innovation in developing countries. World Bank Policy Research Paper No. 5156.

Smolny, W., 1998. Innovations, prices and employment: a theoretical model and an empirical application for West German manufacturing firms. The Journal of Industrial Economics 46, 359–381.

Soete, L.L.G., 1979. Firm size and inventive activity: the evidence reconsidered. European Economic Review 12, 319–340.

Solow, R.M., 1957. Technical change and the aggregate production function. The Review of Economics and Statistics 39, 312–320.

Stock, G.N., Greis, N.P., Fischer, W.A., 2002. Firm size and dynamic technological innovation. Technovation 22, 537–549.

Subodh, K., 2002. Market concentration, firm size and innovative activity: a firm-level economic analysis of selected Indian industries under economic liberalization. WIDER Working Paper No. 2002/108.

Tang, J., 2006. Competition and innovation behaviour. Research Policy 35, 68–82.

Tsai, W., 2001. Knowledge transfer in intraorganizational networks: effects of network position and absorptive capacity on business unit innovation and performance. The Academy of Management journal 44, 996–1004.

United Nations, 2011. World population prospects: the 2010 revision, CD-ROM Edition. Department of Economic and Social Affairs, Population Division.

Van Leeuwen, G., Klomp, L., 2006. On the contribution of innovation to multi-factor productivity growth. Economics of Innovation and New Technology 15, 367–390.

van Leeuwen, T., 2006. The application of bibliometric analyses in the evaluation of social science research. Who benefits from it, and why it is still feasible. Scientometrics 66, 133–154.

Van Reenen, J., 1997. Employment and technological innovation: evidence from UK manufacturing firms. Journal of Labor Economics 15, 255–284.

Variyam, J.N., Kraybill, D.S., 1992. Empirical evidence on determinants of firm growth. Economics Letters 38, 31–36.

Verspagen, B., 1995. R&D and productivity: a broad cross-section cross-country look. Journal of Productivity Analysis 6, 117–135.

Verspagen, B., 2004. Innovation and economic growth, in: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), The Oxford Handbook of Innovation. Oxford University Press.

Veugelers, R., 1997. Internal R & D expenditures and external technology sourcing. Research Policy 26, 303–315.

Vivarelli, M., 2007. Innovation and employment: a survey. IZA Discussion Paper No. 2621.

Vivarelli, M., Evangelista, R., Pianta, M., 1996. Innovation and employment in Italian manufacturing industry. Research Policy 25, 1013–1026.

Von Hippel, E., 1986. Lead users: a source of novel product concepts. Management Science 32, 791–805.

Wooldridge, J.M., 2009. Introductory econometrics: a modern approach, 4th ed. South-Western Cengage Learning, Mason, OH 45040, USA.

Yang, C.H., Huang, C.H., 2005. R&D, size and firm growth in Taiwan‘s electronics industry. Small Business Economics 25, 477–487.

Yang, C.H., Lin, C.H.A., 2008. Developing employment effects of innovations: microeconometric evidence from Taiwan. The Developing Economies 46, 109–134.

# Appendix

**Table A2.1 World share of scientific publications (articles) and population of Sub-Saharan Africa**

| Countries | World share (%) of | | | | Differences (2009-1999) | |
|---|---|---|---|---|---|---|
| | pop. | articles | pop. | articles | | |
| | 1999 | | 2009 | | Pop. | articles |
| Angola | 0.22 | 0 | 0.27 | 0 | 0.05 | 0 |
| Benin | 0.1 | 0 | 0.12 | 0.01 | 0.02 | 0.01 |
| Botswana | 0.03 | 0.01 | 0.03 | 0.01 | 0 | 0 |
| Burkina Faso | 0.2 | 0 | 0.23 | 0.01 | 0.03 | 0.01 |
| Burundi | 0.1 | 0 | 0.12 | 0 | 0.02 | 0 |
| Cameroon | 0.25 | 0.01 | 0.28 | 0.02 | 0.03 | 0.01 |
| Cape Verde | 0.01 | 0 | 0.01 | 0 | 0 | 0 |
| Central African Republic | 0.06 | 0 | 0.06 | 0 | 0 | 0 |
| Chad | 0.13 | 0 | 0.16 | 0 | 0.03 | 0 |
| Comoros | 0.01 | 0 | 0.01 | 0 | 0 | 0 |
| Congo (Brazzaville) | 0.05 | 0 | 0.06 | 0 | 0.01 | 0 |
| Congo (Kinshasa) | 0.79 | 0 | 0.93 | 0 | 0.14 | 0 |
| Côte d'Ivoire | 0.27 | 0.01 | 0.28 | 0.01 | 0.01 | 0 |
| Djibouti | 0.01 | 0 | 0.01 | 0 | 0 | 0 |
| Equatorial Guinea | 0.01 | 0 | 0.01 | 0 | 0 | 0 |
| Eritrea | 0.06 | 0 | 0.07 | 0 | 0.01 | 0 |
| Ethiopia | 1.05 | 0.02 | 1.18 | 0.02 | 0.13 | 0 |
| Gabon | 0.02 | 0 | 0.02 | 0 | 0 | 0 |
| Gambia | 0.02 | 0 | 0.02 | 0 | 0 | 0 |
| Ghana | 0.31 | 0.01 | 0.35 | 0.01 | 0.04 | 0 |
| Guinea | 0.13 | 0 | 0.14 | 0 | 0.01 | 0 |
| Guinea-Bissau | 0.02 | 0 | 0.02 | 0 | 0 | 0 |
| Kenya | 0.5 | 0.04 | 0.57 | 0.04 | 0.07 | 0 |
| Lesotho | 0.03 | 0 | 0.03 | 0 | 0 | 0 |
| Liberia | 0.04 | 0 | 0.06 | 0 | 0.02 | 0 |
| Madagascar | 0.24 | 0 | 0.29 | 0 | 0.05 | 0 |
| Malawi | 0.18 | 0.01 | 0.21 | 0.01 | 0.03 | 0 |
| Mali | 0.18 | 0 | 0.22 | 0 | 0.04 | 0 |
| Mauritania | 0.04 | 0 | 0.05 | 0 | 0.01 | 0 |
| Mauritius | 0.02 | 0 | 0.02 | 0 | 0 | 0 |
| Mozambique | 0.29 | 0 | 0.33 | 0 | 0.04 | 0 |
| Namibia | 0.03 | 0 | 0.03 | 0 | 0 | 0 |
| Niger | 0.17 | 0 | 0.22 | 0 | 0.05 | 0 |
| Nigeria | 1.98 | 0.07 | 2.24 | 0.06 | 0.26 | -0.01 |
| Rwanda | 0.12 | 0 | 0.15 | 0 | 0.03 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 | 0 | 0 |
| Senegal | 0.15 | 0.01 | 0.18 | 0.01 | 0.03 | 0 |
| Sierra Leone | 0.07 | 0 | 0.08 | 0 | 0.01 | 0 |
| Somalia | 0.12 | 0 | 0.13 | 0 | 0.01 | 0 |
| South Africa | 0.72 | 0.38 | 0.72 | 0.36 | 0 | -0.02 |
| Sudan | 0.55 | 0.01 | 0.62 | 0.01 | 0.07 | 0 |
| Swaziland | 0.02 | 0 | 0.02 | 0 | 0 | 0 |
| Tanzania | 0.54 | 0.01 | 0.63 | 0.02 | 0.09 | 0.01 |
| Togo | 0.08 | 0 | 0.09 | 0 | 0.01 | 0 |
| Uganda | 0.39 | 0.01 | 0.47 | 0.02 | 0.08 | 0.01 |
| Zambia | 0.16 | 0 | 0.18 | 0 | 0.02 | 0 |
| Zimbabwe | 0.2 | 0.02 | 0.18 | 0.01 | -0.02 | -0.01 |

Source: Same as Table (2.1).

**Table A2.2 World share of scientific publications (articles) and population of OECD-32**

| Countries/ Region | World share (%) of | | | | Differences (2009-1999) | |
|---|---|---|---|---|---|---|
| | pop. | articles | pop. | articles | | |
| | 1999 | | 2009 | | pop | articles |
| Australia | 0.32 | 2.35 | 0.33 | 2.4 | 0.01 | 0.05 |
| Austria | 0.14 | 0.68 | 0.13 | 0.61 | -0.01 | -0.07 |
| Belgium | 0.17 | 0.94 | 0.16 | 0.92 | -0.01 | -0.02 |
| Canada | 0.51 | 3.63 | 0.51 | 3.68 | 0 | 0.05 |
| Czech Republic | 0.17 | 0.39 | 0.16 | 0.5 | -0.01 | 0.11 |
| Denmark | 0.09 | 0.78 | 0.08 | 0.67 | -0.01 | -0.11 |
| Estonia | 0.02 | 0.06 | 0.02 | 0.07 | 0 | 0.01 |
| Finland | 0.09 | 0.77 | 0.08 | 0.63 | -0.01 | -0.14 |
| France | 1 | 5.14 | 0.95 | 4.03 | -0.05 | -1.11 |
| Germany | 1.4 | 7.04 | 1.25 | 5.71 | -0.15 | -1.33 |
| Greece | 0.18 | 0.43 | 0.17 | 0.62 | -0.01 | 0.19 |
| Hungary | 0.17 | 0.36 | 0.15 | 0.3 | -0.02 | -0.06 |
| Iceland | 0 | 0.02 | 0 | 0.03 | 0 | 0.01 |
| Ireland | 0.06 | 0.24 | 0.07 | 0.35 | 0.01 | 0.11 |
| Israel | 0.1 | 0.97 | 0.11 | 0.8 | 0.01 | -0.17 |
| Italy | 0.97 | 3.33 | 0.92 | 3.39 | -0.05 | 0.06 |
| Japan | 2.13 | 9.06 | 1.94 | 6.3 | -0.19 | -2.76 |
| Luxembourg | 0.01 | 0 | 0.01 | 0.02 | 0 | 0.02 |
| Netherlands | 0.27 | 1.99 | 0.25 | 1.89 | -0.02 | -0.1 |
| New Zealand | 0.06 | 0.48 | 0.06 | 0.4 | 0 | -0.08 |
| Norway | 0.08 | 0.5 | 0.07 | 0.56 | -0.01 | 0.06 |
| Poland | 0.64 | 0.84 | 0.57 | 0.93 | -0.07 | 0.09 |
| Portugal | 0.17 | 0.28 | 0.16 | 0.53 | -0.01 | 0.25 |
| Slovakia | 0.09 | 0.16 | 0.08 | 0.13 | -0.01 | -0.03 |
| Slovenia | 0.03 | 0.12 | 0.03 | 0.16 | 0 | 0.04 |
| South Korea | 0.76 | 1.39 | 0.71 | 2.82 | -0.05 | 1.43 |
| Spain | 0.68 | 2.38 | 0.69 | 2.73 | 0.01 | 0.35 |
| Sweden | 0.15 | 1.62 | 0.14 | 1.2 | -0.01 | -0.42 |
| Switzerland | 0.12 | 1.34 | 0.12 | 1.2 | 0 | -0.14 |
| Turkey | 1.03 | 0.53 | 1.05 | 1.05 | 0.02 | 0.52 |
| United Kingdom | 1 | 7.67 | 0.93 | 5.79 | -0.07 | -1.88 |
| United States | 4.71 | 30.81 | 4.61 | 26.46 | -0.1 | -4.35 |

Source: Same as Table (2.1).

**Table A2.3 World share of scientific publications (articles) and population of South Asia**

| Countries | World share (%) of | | | | Differences (2009-1999) | |
|---|---|---|---|---|---|---|
| | pop. | articles | pop. | articles | | |
| | 1999 | | 2009 | | pop. | articles |
| Afghanistan | 0.36 | 0 | 0.44 | 0 | 0.08 | 0 |
| Bangladesh | 2.09 | 0.03 | 2.14 | 0.03 | 0.05 | 0 |
| Bhutan | 0.01 | 0 | 0.01 | 0 | 0 | 0 |
| India | 17.03 | 1.67 | 17.57 | 2.53 | 0.54 | 0.86 |
| Iran | 1.06 | 0.11 | 1.07 | 0.8 | 0.01 | 0.69 |
| Maldives | 0 | 0 | 0 | 0 | 0 | 0 |
| Nepal | 0.39 | 0.01 | 0.43 | 0.01 | 0.04 | 0 |
| Pakistan | 2.32 | 0.05 | 2.48 | 0.13 | 0.16 | 0.08 |
| Sri Lanka | 0.31 | 0.01 | 0.3 | 0.02 | -0.01 | 0.01 |

Source: Same as Table (2.1).

**Table A2.4 World share of scientific publications (articles) and population of Latin America and Caribbean**

| Countries | World share (%) of | | | | Differences (2009-1999) | |
|---|---|---|---|---|---|---|
| | pop. | articles | pop. | articles | | |
| | 1999 | | 2009 | | pop. | articles |
| Argentina | 0.61 | 0.43 | 0.59 | 0.46 | -0.02 | 0.03 |
| Bahamas | 0 | 0 | 0 | 0 | 0 | 0 |
| Barbados | 0 | 0 | 0 | 0 | 0 | 0 |
| Belize | 0 | 0 | 0 | 0 | 0 | 0 |
| Bolivia | 0.13 | 0.01 | 0.14 | 0.01 | 0.01 | 0 |
| Brazil | 2.84 | 0.96 | 2.83 | 1.56 | -0.01 | 0.6 |
| Chile | 0.25 | 0.17 | 0.25 | 0.24 | 0 | 0.07 |
| Colombia | 0.64 | 0.04 | 0.67 | 0.08 | 0.03 | 0.04 |
| Costa Rica | 0.06 | 0.01 | 0.07 | 0.01 | 0.01 | 0 |
| Cuba | 0.19 | 0.04 | 0.17 | 0.03 | -0.02 | -0.01 |
| Dominican Republic | 0.14 | 0 | 0.14 | 0 | 0 | 0 |
| Ecuador | 0.2 | 0 | 0.21 | 0.01 | 0.01 | 0.01 |
| El Salvador | 0.1 | 0 | 0.09 | 0 | -0.01 | 0 |
| Grenada | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | 0.18 | 0 | 0.2 | 0 | 0.02 | 0 |
| Guyana | 0.01 | 0 | 0.01 | 0 | 0 | 0 |
| Haiti | 0.14 | 0 | 0.14 | 0 | 0 | 0 |
| Honduras | 0.1 | 0 | 0.11 | 0 | 0.01 | 0 |
| Jamaica | 0.04 | 0.01 | 0.04 | 0.01 | 0 | 0 |
| Mexico | 1.63 | 0.47 | 1.64 | 0.52 | 0.01 | 0.05 |
| Nicaragua | 0.08 | 0 | 0.08 | 0 | 0 | 0 |
| Panama | 0.05 | 0.01 | 0.05 | 0.01 | 0 | 0 |
| Paraguay | 0.09 | 0 | 0.09 | 0 | 0 | 0 |
| Peru | 0.42 | 0.01 | 0.42 | 0.02 | 0 | 0.01 |
| Saint Lucia | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Vincent | 0 | 0 | 0 | 0 | 0 | 0 |
| Suriname | 0.01 | 0 | 0.01 | 0 | 0 | 0 |
| Trinidad and Tobago | 0.02 | 0.01 | 0.02 | 0.01 | 0 | 0 |
| Uruguay | 0.06 | 0.02 | 0.05 | 0.03 | -0.01 | 0.01 |
| Venezuela | 0.39 | 0.08 | 0.42 | 0.04 | 0.03 | -0.04 |

Source: Same as of Table (2.1).

**Table A2.5 World share of scientific publications (articles) and population of Other Africa and Middle East**

| Countries | World share (%) of | | | | Differences (2009-1999) | |
|---|---|---|---|---|---|---|
| | pop. | articles | pop. | articles | | |
| | 1999 | | 2009 | | pop. | articles |
| Algeria | 0.49 | 0.03 | 0.51 | 0.08 | 0.02 | 0.05 |
| Bahrain | 0.01 | 0.01 | 0.02 | 0 | 0.01 | -0.01 |
| Egypt | 1.09 | 0.21 | 1.16 | 0.29 | 0.07 | 0.08 |
| Iraq | 0.38 | 0 | 0.45 | 0.01 | 0.07 | 0.01 |
| Jordan | 0.08 | 0.04 | 0.09 | 0.05 | 0.01 | 0.01 |
| Kuwait | 0.03 | 0.05 | 0.04 | 0.03 | 0.01 | -0.02 |
| Lebanon | 0.06 | 0.02 | 0.06 | 0.03 | 0 | 0.01 |
| Libya | 0.08 | 0 | 0.09 | 0 | 0.01 | 0 |
| Morocco | 0.47 | 0.07 | 0.46 | 0.05 | -0.01 | -0.02 |
| Oman | 0.04 | 0.01 | 0.04 | 0.01 | 0 | 0 |
| Qatar | 0.01 | 0 | 0.02 | 0.01 | 0.01 | 0.01 |
| Saudi Arabia | 0.32 | 0.1 | 0.39 | 0.09 | 0.07 | -0.01 |
| Syria | 0.26 | 0.01 | 0.29 | 0.01 | 0.03 | 0 |
| Tunisia | 0.15 | 0.04 | 0.15 | 0.13 | 0 | 0.09 |
| UAE | 0.05 | 0.02 | 0.1 | 0.03 | 0.05 | 0.01 |
| Yemen | 0.28 | 0 | 0.34 | 0 | 0.06 | 0 |

Source: Same as Table (2.1).

**Table A2.6 World share of scientific publications (articles) and population of some East and South-East Asian countries**

| Countries | World share (%) of | | | | Differences (2009-1999) | |
|---|---|---|---|---|---|---|
| | pop. | articles | pop. | articles | | |
| | 1999 | | 2009 | | pop. | articles |
| China | 20.81 | 2.58 | 19.55 | 9.39 | -1.26 | 6.81 |
| Singapore | 0.06 | 0.31 | 0.07 | 0.53 | 0.01 | 0.22 |
| Taiwan | 0.36 | 1.09 | 0.34 | 1.78 | -0.02 | 0.69 |
| Thailand | 1.03 | 0.09 | 1.01 | 0.26 | -0.02 | 0.17 |

Source: Same as Table (2.1).

**Table A2.7 Country ranks with respect to the world share of scientific publications and of scientific publications per 1000 people (SP)**

| Ranks | World share of scientific publications | | Scientific publications per 1000 people | |
|---|---|---|---|---|
| | Country | World share (%) | Country | SP |
| 1 | United States | 26.46 | Switzerland | 1.19 |
| 2 | China | 9.39 | Sweden | 0.97 |
| 3 | Japan | 6.30 | Denmark | 0.92 |
| 4 | United Kingdom | 5.79 | Finland | 0.89 |
| 5 | Germany | 5.71 | Norway | 0.88 |
| 6 | France | 4.03 | Netherlands | 0.86 |
| 7 | Canada | 3.68 | Israel | 0.84 |
| 8 | Italy | 3.39 | Australia | 0.83 |
| 9 | South Korea | 2.82 | Singapore | 0.83 |
| 10 | Spain | 2.73 | Canada | 0.83 |
| 11 | India | 2.53 | Iceland | 0.80 |
| 12 | Australia | 2.40 | New Zealand | 0.71 |
| 13 | Netherlands | 1.89 | United Kingdom | 0.71 |
| 14 | Taiwan | 1.78 | United States | 0.65 |
| 15 | Brazil | 1.56 | Belgium | 0.65 |
| 16 | Sweden | 1.20 | Ireland | 0.62 |
| 17 | Switzerland | 1.20 | Taiwan | 0.59 |
| 18 | Turkey | 1.05 | Slovenia | 0.59 |
| 19 | Poland | 0.93 | Austria | 0.55 |
| 20 | Belgium | 0.92 | Germany | 0.52 |
| 21 | Israel | 0.80 | France | 0.48 |
| 22 | Iran | 0.80 | South Korea | 0.46 |
| 23 | Denmark | 0.67 | Spain | 0.45 |
| 24 | Finland | 0.63 | Italy | 0.42 |
| 25 | Greece | 0.62 | Greece | 0.41 |
| 26 | Austria | 0.61 | Portugal | 0.37 |
| 27 | Norway | 0.56 | Estonia | 0.37 |
| 28 | Portugal | 0.53 | Japan | 0.37 |
| 29 | Singapore | 0.53 | Czech Republic | 0.37 |
| 30 | Mexico | 0.52 | Luxembourg | 0.27 |
| 31 | Czech Republic | 0.50 | Hungary | 0.23 |
| 32 | Argentina | 0.46 | Poland | 0.19 |
| 33 | New Zealand | 0.40 | Slovakia | 0.18 |
| 34 | South Africa | 0.36 | Turkey | 0.11 |
| 35 | Ireland | 0.35 | Chile | 0.11 |
| 36 | Hungary | 0.30 | Tunisia | 0.10 |
| 37 | Egypt | 0.29 | Argentina | 0.09 |
| 38 | Thailand | 0.26 | Iran | 0.09 |
| 39 | Chile | 0.24 | Grenada | 0.08 |
| 40 | Slovenia | 0.16 | Kuwait | 0.08 |
| 41 | Slovakia | 0.13 | Uruguay | 0.07 |
| 42 | Pakistan | 0.13 | Jordan | 0.06 |
| 43 | Tunisia | 0.13 | Brazil | 0.06 |
| 44 | Saudi Arabia | 0.09 | Lebanon | 0.06 |
| 45 | Colombia | 0.08 | South Africa | 0.06 |
| 46 | Algeria | 0.08 | China | 0.05 |
| 47 | Estonia | 0.07 | Barbados | 0.05 |
| 48 | Nigeria | 0.06 | Oman | 0.04 |

(continued to next page)

**Table A2.7 (continued)**

| Ranks | World share of scientific publications | | Scientific publications per 1000 people | |
|---|---|---|---|---|
| | Country | World share (%) | Country | SP |
| 49 | Jordan | 0.05 | Qatar | 0.04 |
| 50 | Morocco | 0.05 | UAE | 0.04 |
| 51 | Kenya | 0.04 | Mexico | 0.04 |
| 52 | Venezuela | 0.04 | Trinidad and Tobago | 0.04 |
| 53 | Iceland | 0.03 | Bahrain | 0.03 |
| 54 | Bangladesh | 0.03 | Thailand | 0.03 |
| 55 | Cuba | 0.03 | Egypt | 0.03 |
| 56 | Uruguay | 0.03 | Saudi Arabia | 0.03 |
| 57 | Kuwait | 0.03 | Botswana | 0.02 |
| 58 | Lebanon | 0.03 | Costa Rica | 0.02 |
| 59 | UAE | 0.03 | Panama | 0.02 |
| 60 | Cameroon | 0.02 | Cuba | 0.02 |
| 61 | Ethiopia | 0.02 | Jamaica | 0.02 |
| 62 | Tanzania | 0.02 | Algeria | 0.02 |
| 63 | Uganda | 0.02 | Mauritius | 0.02 |
| 64 | Luxembourg | 0.02 | India | 0.02 |
| 65 | Sri Lanka | 0.02 | Colombia | 0.01 |
| 66 | Peru | 0.02 | Venezuela | 0.01 |
| 67 | Benin | 0.01 | Morocco | 0.01 |
| 68 | Botswana | 0.01 | Gabon | 0.01 |
| 69 | Burkina Faso | 0.01 | Gambia | 0.01 |
| 70 | Côte d'Ivoire | 0.01 | Bhutan | 0.01 |
| 71 | Ghana | 0.01 | Maldives | 0.01 |
| 72 | Malawi | 0.01 | Cameroon | 0.01 |
| 73 | Senegal | 0.01 | Kenya | 0.01 |
| 74 | Sudan | 0.01 | Bahamas | 0.01 |
| 75 | Zimbabwe | 0.01 | Belize | 0.01 |
| 76 | Nepal | 0.01 | Sri Lanka | 0.01 |
| 77 | Bolivia | 0.01 | Swaziland | 0.01 |
| 78 | Costa Rica | 0.01 | Pakistan | 0.01 |
| 79 | Ecuador | 0.01 | Namibia | 0.01 |
| 80 | Jamaica | 0.01 | Benin | 0.01 |
| 81 | Panama | 0.01 | Peru | 0.01 |
| 82 | Trinidad and Tobago | 0.01 | Libya | 0.01 |
| 83 | Iraq | 0.01 | Ecuador | 0.00 |
| 84 | Oman | 0.01 | Senegal | 0.00 |
| 85 | Qatar | 0.01 | Bolivia | 0.00 |
| 86 | Syria | 0.01 | Congo (Brazzaville) | 0.00 |
| 87 | Angola | 0.00 | Zimbabwe | 0.00 |
| 88 | Burundi | 0.00 | Uganda | 0.00 |
| 89 | Cape Verde | 0.00 | Cape Verde | 0.00 |
| 90 | Central African Republic | 0.00 | Ghana | 0.00 |
| 91 | Chad | 0.00 | Guyana | 0.00 |
| 92 | Comoros | 0.00 | Guinea-Bissau | 0.00 |
| 93 | Congo (Brazzaville) | 0.00 | Malawi | 0.00 |
| 94 | Congo (Kinshasa) | 0.00 | Syria | 0.00 |

(continued to next page)

**Table A2.7 (continued)**

| Ranks | World share of scientific publications | | Scientific publications per 1000 people | |
|---|---|---|---|---|
| | Country | World share (%) | Country | SP |
| 95 | Djibouti | 0.00 | Tanzania | 0.00 |
| 96 | Equatorial Guinea | 0.00 | Burkina Faso | 0.00 |
| 97 | Eritrea | 0.00 | Nigeria | 0.00 |
| 98 | Gabon | 0.00 | Côte d'Ivoire | 0.00 |
| 99 | Gambia | 0.00 | Saint Vincent | 0.00 |
| 100 | Guinea | 0.00 | Zambia | 0.00 |
| 101 | Guinea-Bissau | 0.00 | Equatorial Guinea | 0.00 |
| 102 | Lesotho | 0.00 | Iraq | 0.00 |
| 103 | Liberia | 0.00 | Ethiopia | 0.00 |
| 104 | Madagascar | 0.00 | Suriname | 0.00 |
| 105 | Mali | 0.00 | Nicaragua | 0.00 |
| 106 | Mauritania | 0.00 | Nepal | 0.00 |
| 107 | Mauritius | 0.00 | Djibouti | 0.00 |
| 108 | Mozambique | 0.00 | Bangladesh | 0.00 |
| 109 | Namibia | 0.00 | Paraguay | 0.00 |
| 110 | Niger | 0.00 | Madagascar | 0.00 |
| 111 | Rwanda | 0.00 | Mali | 0.00 |
| 112 | Sao Tome and Principe | 0.00 | Lesotho | 0.00 |
| 113 | Sierra Leone | 0.00 | Guatemala | 0.00 |
| 114 | Somalia | 0.00 | Sudan | 0.00 |
| 115 | Swaziland | 0.00 | Mozambique | 0.00 |
| 116 | Togo | 0.00 | Rwanda | 0.00 |
| 117 | Zambia | 0.00 | Togo | 0.00 |
| 118 | Afghanistan | 0.00 | Yemen | 0.00 |
| 119 | Bhutan | 0.00 | Niger | 0.00 |
| 120 | Maldives | 0.00 | Central African Republic | 0.00 |
| 121 | Bahamas | 0.00 | El Salvador | 0.00 |
| 122 | Barbados | 0.00 | Mauritania | 0.00 |
| 123 | Belize | 0.00 | Honduras | 0.00 |
| 124 | Dominican Republic | 0.00 | Eritrea | 0.00 |
| 125 | El Salvador | 0.00 | Haiti | 0.00 |
| 126 | Grenada | 0.00 | Comoros | 0.00 |
| 127 | Guatemala | 0.00 | Sao Tome and Principe | 0.00 |
| 128 | Guyana | 0.00 | Dominican Republic | 0.00 |
| 129 | Haiti | 0.00 | Sierra Leone | 0.00 |
| 130 | Honduras | 0.00 | Afghanistan | 0.00 |
| 131 | Nicaragua | 0.00 | Guinea | 0.00 |
| 132 | Paraguay | 0.00 | Angola | 0.00 |
| 133 | Saint Lucia | 0.00 | Burundi | 0.00 |
| 134 | Saint Vincent | 0.00 | Congo (Kinshasa) | 0.00 |
| 135 | Suriname | 0.00 | Chad | 0.00 |
| 136 | Bahrain | 0.00 | Somalia | 0.00 |
| 137 | Libya | 0.00 | Liberia | 0.00 |
| 138 | Yemen | 0.00 | Saint Lucia | 0.00 |

Source: Same as Table (2.1)

**Table A2.8 World share of scientific publications (articles) and population of the selected Latin American and South Asian countries in 2009**

| Countries | World share (%) of | |
|---|---|---|
| | pop | articles |
| Latin America | | |
| Argentina | 0.59 | 0.46 |
| Bolivia | 0.14 | 0.01 |
| Chile | 0.25 | 0.24 |
| Colombia | 0.67 | 0.08 |
| Ecuador | 0.21 | 0.01 |
| El Salvador | 0.09 | 0 |
| Guatemala | 0.2 | 0 |
| Honduras | 0.11 | 0 |
| Mexico | 1.64 | 0.52 |
| Nicaragua | 0.08 | 0 |
| Panama | 0.05 | 0.01 |
| Paraguay | 0.09 | 0 |
| Peru | 0.42 | 0.02 |
| Uruguay | 0.05 | 0.03 |
| South Asia | | |
| Bangladesh | 2.14 | 0.03 |
| Pakistan | 2.48 | 0.13 |

Notes and sources: same as Table (2.1).

**Table A2.9 Technological capability indicator (ArCo) across countries, for the selected countries of Latin America and South Asia, 1990-2000**

| Ranks | Country | ArCo |
|---|---|---|
| | Latin America | |
| 40 | Argentina | 0.426 |
| 41 | Chile | 0.424 |
| 43 | Uruguay | 0.417 |
| 51 | Panama | 0.382 |
| 63 | Mexico | 0.358 |
| 67 | Peru | 0.345 |
| 71 | Colombia | 0.331 |
| 76 | Paraguay | 0.323 |
| 79 | Ecuador | 0.319 |
| 83 | El Salvador | 0.311 |
| 87 | Bolivia | 0.305 |
| 102 | Honduras | 0.258 |
| 108 | Nicaragua | 0.238 |
| 109 | Guatemala | 0.234 |
| | South Asia | |
| 120 | Pakistan | 0.191 |
| 137 | Bangladesh | 0.123 |

This table is a modified version of Table (1) of Archibugi and Coco (2004).

**Table A2.10 Ranks of selected Latin American and South Asian countries with respect to Global Innovation Index (GII) 2011**

| Ranks | Country | Score |
|---|---|---|
| Latin America | | |
| 38 | Chile | 38.84 |
| 58 | Argentina | 35.36 |
| 64 | Uruguay | 34.18 |
| 71 | Colombia | 32.32 |
| 74 | Paraguay | 31.17 |
| 77 | Panama | 30.77 |
| 81 | Mexico | 30.45 |
| 83 | Peru | 30.34 |
| 86 | Guatemala | 29.33 |
| 90 | El Salvador | 29.14 |
| 93 | Ecuador | 28.75 |
| 98 | Honduras | 27.81 |
| 110 | Nicaragua | 25.78 |
| 112 | Bolivia | 25.44 |
| South Asia | | |
| 97 | Bangladesh | 26.75 |
| 105 | Pakistan | 28.05 |

Source: INSEAD 2011

**Table A3.1 Country threshold to split data into small and large firms**

| Country | No. of employees (90.5th percentile) |
|---|---|
| Argentina | 340 |
| Bolivia | 157 |
| Chile | 252 |
| Colombia | 120 |
| Ecuador | 200 |
| El Salvador | 325 |
| Guatemala | 254 |
| Honduras | 250 |
| Mexico | 200 |
| Nicaragua | 90 |
| Panama | 135 |
| Paraguay | 120 |
| Peru | 320 |
| Uruguay | 118 |

**Table A4.1 Cross industry distribution of product innovation for both Pakistan and Bangladesh and of R&D activities for only Bangladesh**

| Industry | Product Innovation (all firms) | | R&D (only for Bangladesh) | |
|---|---|---|---|---|
| | No of firms | % of Innovators | No. of firms | % of R&D Performers |
| Food | 369 | 17.62 | 214 | 20.56 |
| Chemicals | 171 | 54.39 | 146 | 68.49 |
| Garments | 348 | 26.15 | 292 | 53.08 |
| Non-Metallic Minerals | 11 | 9.09 | | |
| Machinery and Equipment | 95 | 16.84 | 44 | 31.82 |
| Textiles | 322 | 20.19 | 156 | 40.38 |
| Electronics | 74 | 32.43 | 70 | 42.86 |
| Leather | 254 | 37.01 | 239 | 35.98 |
| Other Manufacturing | 336 | 13.39 | 15 | 53.33 |
| Total | 1980 | 24.95 | 1176 | 42.52 |

# Summary (English)

The notion of technological innovation is largely established in developed countries, and a plethora of studies is available in the literature analyzing the innovation phenomenon in this region. The focus in developing countries is, however, still lacking. This thesis contributes to the literature by investigating, both theoretically and empirically, the innovation phenomenon in the developing world. The study first compares different innovation-related indicators across developing and developed countries, and comes to the conclusion that the developing world is the region which substantially lacks many of them as compared to the developed world.

The thesis further explores empirically two different aspects of innovation: which factors (determinants) induce the firm to innovate and what effects innovation has on the firm performance. The analysis on the innovation determinants is based on fourteen Latin American countries. We primarily analyze the effects of firm size and product market competition on both innovation input (R&D) and its output (product innovation), after including some control variables. The results are almost similar to what we have already observed empirically in the literature on the developed world. It means that the lower innovation intensity of the developing world is directly related to the indigenous insufficiency of these positive determinants, whose ratios, on the other hand, are higher for developed countries, as observed also in this thesis.

The second phase of the empirical analysis focuses on the productivity and employment impacts of innovation. This analysis is based on two South Asia economies: Bangladesh and Pakistan. Although it is generally believed that industrial innovation is not a significant notion in developing countries, the empirical analysis in this thesis concluded its positive influence on both productivity and employment increase. Hence, based on our empirical findings, we can argue that policy makers of this region should focus on those policies which in-

crease the innovation culture, in order to enhance this region's industrial productivity and to control unemployment.

# Summary (Dutch)

## Samenvatting

Het begrip technologische innovatie is grotendeels ontwikkeld in een context van ontwikkelde landen, en in de literatuur is een overvloed aan studies beschikbaar die innovatie analyseren vanuit het perspectief van ontwikkelde landen. De focus op ontwikkelingslanden ontbreekt echter nog grotendeels in de literatuur. Dit proefschrift draagt bij aan de literatuur door innovatie in ontwikkelingslanden te onderzoeken, zowel theoretisch als empirisch. De studie vergelijkt eerst de verschillende innovatie-indicatoren tussen ontwikkelingslanden en ontwikkelde landen, en komt tot de conclusie dat, ten opzichte van de ontwikkelde wereld, veel informatie voor verschillende indicatoren ontbreekt voor ontwikkelingslanden.

In de rest van het proefschrift wordt nader empirisch ingegaan op twee verschillende aspecten van innovatie: welke factoren (determinanten) leiden een bedrijf tot innoveren, en welke effecten innovatie heeft op de bedrijfsprestaties. De analyse van de innovatie determinanten is gebaseerd op veertien Latijns-Amerikaanse landen. Vooral de effecten van bedrijfsgrootte en concurrentie op de productmarkten op zowel innovatie-input (O & O) en de output (productinnovatie) worden onderzocht, inclusief een aantal controlevariabelen. De resultaten zijn redelijk sterk vergelijkbaar met wat al empirisch bekend is in de literatuur over de ontwikkelde wereld. Dit impliceert dat de lagere innovatie-intensiteit in ontwikkelingslanden rechtstreeks verband houdt met een onvoldoende niveau van de positieve determinanten (die in hogere mate aanwezig zijn in ontwikkelde landen, zoals ook waargenomen in dit onderzoek) in de ontwikkelingslanden.

De tweede fase van de empirische analyse richt zich op de effecten van innovatie op productiviteit en werkgelegenheid. Deze analyse is gebaseerd op twee Zuid-Aziatische economieën: Bangladesh en Pakistan. Hoewel algemeen wordt aangenomen dat industriële

innovatie geen belangrijke rol speelt in ontwikkelingslanden, laat de empirische analyse voor deze twee landen in dit proefschrift een positieve invloed op de productiviteit en de werkgelegenheid zien. Op basis van de empirische bevindingen kan gesteld worden dat beleidsmakers in deze landen zich moeten richten op beleidslijnen die de innovatiecultuur versterken, om zodoende in deze regio de industriële productiviteit te verhogen en de werkloosheid te verlagen.