Dynamics and Determinants of Innovation in the Non-R&D Scenario

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Abstract

R&D is considered to be the key determinant of innovation in any industrial sector. Evolution in innovation thought since Schumpeter's pioneering work during the 1930s and 40s has led us to shed this myopic view and recognize the influence of other factors. We contend that innovation, essentially non-linear in nature, can be observed in developing countries like Pakistan characterized by low-technology sectors that have zero or very low R&D intensity. However, little is known about this form of innovation which is influenced by its own peculiar set of context-driven factors. Applying a case study approach and using mixed methods, this paper presents insights on the dynamics and determinants of innovation in a non-R&D SME sector. Findings reveal limited instances of incremental product and process innovation. A set of 87 factors are found that help explain lack of innovation in the industry. These factors have been collectively presented as 42 determinants categorized as being internal of external to a firm and across their micro-meso-macro origins. Future work emanating from this research will focus on enriching relevant research by seeking consensus around the most influential determinants of innovation in zero R&D scenarios in developing country contexts.

1. Introduction

The confusion over how innovation occurs dates back to the pioneering works of Joseph Schumpeter during the 1930s, 40s and 50s. In both of Schumpeter's Mark I and II (Nelson & Winter, 1982; Kamien & Schwartz, 1982) a central characteristic is causality of economic growth. While Mark I is characterized by new smaller firms using existing technologies to innovate Mark II refers to large firms using R&D and other resources to achieve the same (Schumpeter, 1934, 1942). Both conceptualize innovation occurring as a result of a unidirectional process thus contributing to economic growth. This led to a 'linear' perspective whereby innovation was believed to happen as a result of technologies and R&D, two of the key inputs. Rothwell (1992) provides a chronology of innovation thought and evolution of models whereby he starts with the initial 'first generation – technology push' inspired by

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Schumpeter and prevalent in the 1950s and early 60s. This led developed countries of the post-industrial revolution to invest in high technologies (HT) and R&D to achieve innovation success and acquire economic growth. Radauer and Streicher (2007) point out two widespread beliefs contributing to this. Firstly, industries characterised by high-tech grow faster thus contributing more to economic growth of a country. Secondly, the economies of developed countries are structured to suit high-tech sectors more while outsourcing low-and medium-technologies (LMT) and low-technologies (LT) to developing countries with lower labour costs.

Of late there has been an increasing focus in innovation literature on the importance of studying LT/LMT sectors characterized by no or limited R&D. This is specially an interesting phenomenon since LT is termed as the 'forgotten sector in innovation policy' (Hirsch-Kreinsen, 2008a). An evidence of the reviving interest is the special issue of Research Policy journal on 'Innovation in Low-and Medium-Technology Industries' that was published in April 2009 and threefold increase in relevant research publications over the last 2 to 3 years (Nouman, 2011). The increasing attention also derives from growing criticism of the 'high-tech myopia' which makes us assume that economic growth results primarily from high-tech sectors and innovation in these sectors driven by research and development (Von Tunzelmann & Acha, 2005). The argument favouring high-tech is considered relatively weak because even in developed economies where LT/LMT sectors comprise a dominant portion of national economies (Bender, 2004; Hirsch-Kriensen & Jacobson, 2008). Making the case for their significance Hirsch-Kreinsen (2008b) argues that innovation is not necessarily only possible because of intensive R&D but also a result of incremental product improvements, customer-focus and 'optimisation' of processing technologies. Additionally, innovation can also occur as a result of tacit and experiential knowledge as well as formal/informal diffusion of this knowledge and learning among firms (Jacobson & Heanue, 2005 via Heidenreich, 2009). This is a considerably relevant notion particularly because knowledge and technology are considered the key ingredient of innovation (Edquist, 2005). Underscoring the importance of LT/LMT sectors Robertson et al. (2009) point out that they contribute more than 90% of the output in highly developed countries including the EU, USA and Japan as well as dominate economies of developing nations. Kirner et al. (2009) analyze 1663 German manufacturing firms and stress the importance of studying low-technology innovation at the level of firm. Their findings suggest that low-tech firms are at par with high-tech firms in terms of process innovations however they lag behind in product innovations.

Using empirical analysis based on 27 EU countries' 'Fourth Community Innovation Survey (CIS4)', Heidenreich (2009) concludes that industries or sectors dominated by LMT can demonstrate innovations that are process, organizational and market-oriented. Also, firms in such sectors rely more on provision of support in terms of machines and equipment improvements from external sources rather than being able to generate them using internal capabilities. Consequently R&D itself is not the only determinant of innovation. There are many other factors internal and external to firms that influence their innovation capabilities (Becheikh et al., 2006). However, when studying LT/LMT innovations especially in the context of developing countries, one might presume that many sectors or firms may not show any signs of it due to extremely poor infrastructure and market development, use of outdated technologies and low quality products (Nouman, 2009). A broader definition of innovation will need to be considered whereby product designs or manufacturing processes that are new to a firm in terms of their first time application even though they are not new to the 'universe' surrounding the firm can be termed innovations as well (Nelson and Rosenberg, 1993).

2. Setting the Innovation Context

Deriving from the above discussion understanding the nature of innovation in zero R&D scenarios and its contribution to economies in developing countries that are generally perceived as marred by poor technologies and other infrastructures becomes even more important to consider. Based on initial review it has been observed that the literature uses two relevant terms (1) low-technology (LT) and (2) low- and medium-technology (LMT). The primary difference between the two as described by Hirsch-Kreinsen (2008b) and influenced from OECD classification is with respect to level of R&D intensity (ratio of R&D expenditure to company turnover or a sector's output value). LT are characterized by having R&D intensity between zero and 0.9 percent, LMT between 0.9 and 5 percent and HT above 5 percent. Consequently, it becomes important to consider the difference between LT and LMT when deciding the scope of any research study.

This research focuses on generating an understanding of the dynamics and determinants of innovation in a sector/industry characterized by zero R&D and located in a developing country. More specifically, the marble sector of north-west region of Pakistan has been chosen. Marble sector is characterized by two types of firms (small and medium-size enterprises – SMEs); marble mining units and marble processing units along with other stakeholder organizations and institutions. Different kinds of marble (a semi-precious stone) prod-

ucts are produced by the sector mainly using obsolete and outdated mining and production technologies with a few exceptions. The deployment and usage of low technologies with a non-existent R&D intensity amongst firms makes it a low-technology (LT) sector thus making the case for studying LT innovations.

3. Determinants of Innovation: Reviewing Empirical Work

In order to determine the current status of research and enhance our understanding of innovation in zero or very limited R&D scenarios, a review of literature has being carried out. The main focus is on empirical studies conducted during the last 12 years (1999 – 2010-11). Online databases including Elsevier, Wiley Interscience, Jstor and others have been accessed. The key words or terms searched in databases include 'low technology innovation', 'low and medium technology innovation', 'LT', 'LMT', 'determinants', 'factors'. Some of the key studies are reviewed in the ensuing discussion to assess the current status of research with regards to determinants of non-R&D or LT innovation.

Pavitt (1984) and later Pavitt et al. (1989) examine 2000 and 4000 innovations respectively to suggest a taxonomy comprising of four sectoral patterns of innovation. These include (1) 'supplier-dominated' sectors, (2) 'production intensive' sectors including (2a) 'large scale producers' or 'scale intensive', (2b) 'specialized suppliers' and (3) 'science-based' sectors. Findings indicate size of firm and principal or core business activity as two major determinants of innovation. Additionally Wolfe (1994) and Souitaris (1999; 2002) suggest the firm's industrial sector and the overall environment of the country where the sector and its constituent firm exist as other important determinants. Heidenreich (2009) suggests that LMT sectors generally adhere to supplier-dominated sectoral pattern suggested by Pavitt. Pavitt (1984) himself points out that in supplier-dominated' sectors it is factors like professional skills, aesthetic designs, trademarks and advertising that firms can use to innovate rather than relying on advanced technologies. In some cases large customers and government supported research and extension services may also influence innovations among this sector. Focusing on collaborations Freel (2003) analyses a sample of 597 SMEs in Scotland and Northern England to point out that existence of firm-level product and process innovations is not a sufficient precondition to support collaborative innovation within a sector. Results vary considerably when compared against Pavitt's sectoral taxonomy. This suggests lack of conclusive evidence that sectors belonging to a particular taxonomy will demonstrate a particular level of collaboration to influence sectoral innovations. Sectors studied include furniture, vehicles equipment, metal, chemicals, publishing/printing and others.

Van-de-Vrande et al. (2009) study 605 innovative SMEs in Netherlands mainly comprising of LT sectors including food and beverages, chemical, machinery and equipment and others. Customer demand and competitive pressure are found to be the main drivers to innovation. Thornhill (2006) uses 845 observations from Canadian firms to compare high-tech and low-tech sectors. For low-tech investments in firm-level knowledge and training are found to have the greatest impact on innovation. Tsai and Wang (2009) investigate 753 LMT firms in Taiwan and observe that 95% firms acquire technology from licenses, 32% engage in R&D outsourcing to influence innovation while the sources of external technological knowledge include collaborations with research organizations, suppliers, clients and competitors.

A different set of determinants emerge in the evaluation study of 183 new product projects in Spain's LT sectors. These include lower level of uncertainty within a sector, clarity of organizational goals and incentives in terms of speed-based rewards contributing to innovations (Carbonell and Rodriguez-Escudero, 2009). Presenting a very different perspective Akgun et al. (2009) in a study of 174 Turkish LMT firms find emotional capability amongst a firm's members involving 'dynamics of encouragement, displaying freedom, playfulness, experiencing, reconciliation, and identification' having positive effects on a firm's product and process innovation. While pointing out lack of innovation research in LT industries Hansen and Serin (1999) study Denmark's metal packaging sector and suggest science-push, spread of wage labour, urbanization process, changing lifestyles, interactions of knowledge and technologies from various industries.

Swan and Allred (2003) study 187 LMT subsidiaries in US and suggest that internal and external process technology development decisions influence innovation. In a study of low R&D intensive biotech firms Hall and Bagchi-Sen (2007) point out production-based innovation factors and strategies of market access and maintaining customer connections as influential factors. An empirical study of 1234 small firms in Netherlands by De Jong and Marsili (2006) innovation budget, innovation capacity (time to implement innovation), innovation specialists, suppliers, customers, scientific development, innovative orientation of managers, documented planning for innovation, consultation with external organizations (non-firms) and collaboration with other firms and non-firms as innovation determinants. Becheikh et al. (2006) review empirical studies on innovation in manufacturing sectors conducted from 199 to 2003. Although most of the sectors they review belong to LMT category they do not make a particular reference to the LMT terminology. A total of 46 (36 internal to firms and 10 external) variables or factors are identified as influencing innovation in different manufacturing sectors.

Like Hirsch-Kreinsen's findings highlighted earlier, Santamaria et al. (2009) suggest that it is the greater importance of non-R&D activities like design, use of advance machinery and better training that contributes significantly to innovation especially product innovations Also, in line with Heidenreich's findings they use empirical evidence to underscore the greater role of external sources. Utilizing expertise of consultants, hiring better personnel, collaborations outside the firm including help from external sources of R&D can play a significantly important role in process innovations.

An important aspect of LT/LMT innovation studies is that most highlight activities/determinants that support innovations. However a few point out barriers as well. For example, Albuquerque (2000) studies innovation system of Brazil and compares patent data of 479 LMT firms (mining, machinery, chemicals, rubber, leather and other sectors) with USA. Lack of consistent patent activity, declining role of machinery sector in terms of patents (the sector is a major source of process innovations in other sectors) and existence of adaptive technological innovations (not possible to patent locally) are pointed out as hurdles to innovations. March-Chorda et al. (2002) investigate 65 SMEs in Spain's LMT sectors (chemical, plastics, paper, beverages and food processing). Major barriers to new product innovation include costs associated with the development process, uncertainty about market acceptance, lack of top management support, technical uncertainty, fear of failure, conservative attitude of market and problems ensuing failure of product innovation. Similarly, Blanes and Busom (2004) review survey data of more than 2000 manufacturing firms in Spain. Low-tech firms are found to have lower probability of participating in R&D programs. Factors considered influential include human capital (employee skills influence firm's ability to engage in R&D), path dependency (firms with no R&D experience are less likely to engage in it), technological opportunity (sectors with no/limited opportunities are less likely to engage in R&D), firm size (smaller firms with less ability to afford sunk cost of R&D will less likely participate), financing constraints (R&D investments are more risky and firms/sectors with less access to finance will not engage in R&D), domestic ownership (firms with international or foreign ownership can take advantage of parent company's research, not so with domestically owned firms). Dunk (2007) analyzes data from 119 functional managers in Australian manufacturing organizations that include pharmaceuticals, whitegoods, foodstuffs, building materials and chemicals sectors. Findings indicate the constraining affect of innovation budgets that at times may discourage firms from investments with potential to improve quality and speed of innovation process.

The discussion about activities or determinants suggests a large number influencing innovation however these are specific to specific sectors with their particular set of product groups and types of firms. Explaining the lack of R&D in low-tech sectors it is argued that mostly these sectors operate in markets that have mature demand leading to slow growth and greater reliance on price-based competition (Robertson et al. 2009). Acknowledging that LMT sectors are generally characterized by having lower technological sophistication, Tsai and Wang (2009) argue that issues concerning technology itself are still vital within such sectors since they contribute significantly to economic activities in any country and it is possible for firms in these sectors to use innovation as a means to achieve competitive advantage.

Using evidence from case studies of 43 LMT sectors in 9 EU countries Hirsch-Kreinsen (2008b, pp. 38) concludes that innovation can occur in LT sectors, however firms within such sectors are 'innovative in a very specific way' especially when compared to high-tech. Provided below is an understanding of innovation in LT sectors based on various considerations;

Drawing from the above discussions it is safe to assume that low-tech innovations (zero R&D scenarios) are mostly;

Table 1.1: Adopted from Hirsch-Kreinsen (2008b, pp, 39)

Factors	'Innovation modes' in LT sectors
'Key drivers'	New technologies, market demand
Strategies	Broad, mainly incremental & architectural
Firm size	Predominantly SMEs
'Knowledge-base'	'Internal:' reliance on practical knowledge, [possibly implicit] 'External: codified'
Firm capabilities/competences	Reliance on management & unskilled workers
Links with institutions	'Loose coupling with most institutional conditions other than industrial structure' [sectoral structure]

- Incremental in nature
- Exist in SMEs
- Exhibit themselves in various forms including process innovations

- Influenced by their own set of activities/determinants that are not R&D-specific
- Occur within specific contexts of actors, knowledge-base, technologies, institutional set-ups and interactions among them

However, the review of literature on determinants of innovation in zero R&D scenarios reveals that there is a lack empirical work that identifies an exhaustive list of such determinants for industries in developing countries. This forms the basis for undertaking this research study and address the gap.

4. Methodology and Methods:

Since this research focuses on the marble industry of north-west Pakistan in order to identify the determinants of innovation, case study (Yin, 2003) as a research strategy was found to be suitable. This is because it offers a context-rich (zero R&D scenario) understanding of a phenomenon (innovation) and can use mixed methods as long as they help gather relevant data to address research objectives. Yin (2003, pp. 3-4) suggests that a case study inquiry will;

- Have 'many more variables of interest' and
- Depend 'on multiple sources of evidence' whereby data needs to be triangulated so as to converge it

The mixed methods used to collect data include semi-structured in-depth interviews, structured interviews and questionnaires. Twelve in-depth interviews have been conducted with the following types of stakeholders using purposive sampling – heterogeneous or maximum variation (Saunders et al., 2006).

a. Entrepreneurs/Owners/Managers of mining and processing units
b. Suppliers/Middlemen of marble equipments/machineries/technologies
c. Sector experts
d. Representatives of government and marble sector support organizations

These interviews while exploring various dimensions of LT innovations and identifying issues and perspectives inform the ensuing structured interview and questionnaire. Twenty structured interviews with mining units and seventy questionnaires with processing units are being conducted to gather triangulated results. Data has been analyzed using Miles and Huberman (1994) and Dey (1993). The 'framework for integrating innovation findings' provided

by Becheikh et al. (2006, pp. 648) comprising of internal and external/contextual factors was used to help categorize determinants of LT innovation. Contextual factors were further sub-divided into three categories namely (1) supply-side factors, (2) demand-side factors and (3) others. Further, a micro-meso-macro analytical framework (Nouman, 2011) has been applied on the data to interpret findings whereby micro refers to the individual (firm owner/manager), meso refers to the firm itself and macro refers to a firm's contextual environment. The figure below provides geographical distribution of the area of study that includes three regions of north-west Pakistan named Peshawar, Buner and Mohmand Agency dominated by mining and processing units and presence of other stakeholders.

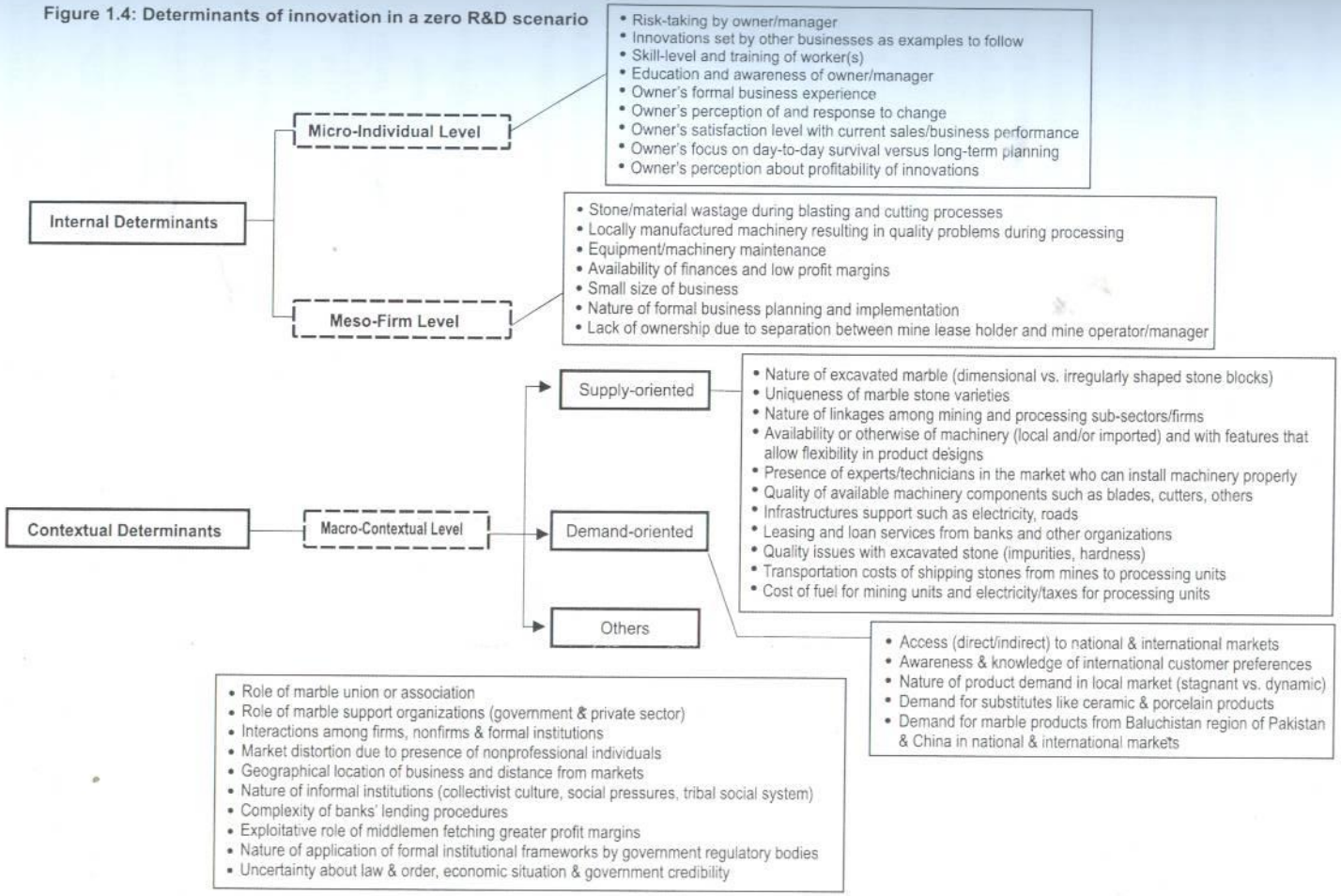
5. Findings

This section provides findings of the research based on analysis of the completed semi-structured in-depth interviews as well as preliminary results from structured interviews and questionnaires. Results indicate existence, though limited, of innovation in marble sector which in many cases comes within the conceptual domain of innovation's definition offered by Nelson and Rosenberg (1993). Other characteristics of LT innovation found include;

1. None of the firms accessed to collect primary data had any R&D focus
2. Incremental product and process innovations are the two dominant forms whereby the former depends on the latter. Some evidence of marketing innovation has also been observed especially firms offering products in a different regional market of Pakistan
3. Innovations are supplier-driven (greatly influenced by excavation processes of mining units) and technology provision in line with Pavitt's (1984) sectoral taxonomy
4. Marble sector possesses all characteristics of SIS including its elements and structure
5. Firms struggle to innovate in the sector without support from non-firms and lack of well-placed formal institutional setup.
6. Firms interact amongst themselves and with non-firms more in the form of informal networks and relationships than formal interactions
7. Firms mostly acquire knowledge and technology through informal means
8. LT innovations in the sector have their own set of activities/determinants influenced by the sector's elements and structure

A total of 46 determinants/factors for processing units and 41 for mining units have been identified that influence innovation in zero R&D scenarios. While most of the determinants are the same for both categories of firms there are some differences also. Figure 1.4 combines and presents a categorized layout of these determinants.

Figure 1.4: Determinants of innovation in a zero R&D scenario



6. Conclusions and Future Work

This research offers a first-time perspective on the dynamics and determinants of innovation in a sector characterized by zero R&D. While little evidence of innovation is observed, findings reveal existence of incremental product and process innovations with a strong dependence of the former on the latter. Supplier-dominated sectoral pattern is observed whereby mining sub-sector and provision of upgraded technologies greatly influence processing units' ability to innovate. A total of 87 factors influencing innovation have been identified that are combined and categorized into 42 determinants. These determinants also highlight nature of interactions between various stakeholders and players within the marble industry. Future research needs to focus on generating consensus around the most important determinants of innovation in an industry where R&D does not occur at all. Moreover, empirical work should also be carried out to find which determinants have the strongest influence on innovation and need to be paid attention to by the government and policy makers accordingly.

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