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Review

'The Forgotten Sector': An Integrative Framework for Future Research on Low- and Medium-Technology Innovation

Muhammad Nouman, Mohammad Sohail Yunis *, Muhammad Atiq *, Owais Mufti and Abdul Qadus

Department of Management Sciences, Institute of Management Sciences Peshawar, Peshawar 25100, Pakistan; muhammad.nouman@imsciences.edu.pk (M.N.); owais.mufti@imsciences.edu.pk (O.M.); abdulqadus@imsciences.edu.pk (A.Q.)

* Correspondence: sohail.younis@imsciences.edu.pk (M.S.Y.); muhammad.atiq@imsciences.edu.pk (M.A.)

Abstract: Despite apparent significance, innovation in low-technology (LT) and low-to-medium technology (LT/LMT) sectors has enticed relatively less consideration from scholars and policy-makers than high-technology (HT) sectors, thus, earning the label 'the forgotten sector'. In this paper, we critically review the extant research on this forgotten sector, with the vital objective of proposing an integrated research framework from a diffuse literature base. We believe our findings can be utilized by innovation scholars to do more coherent research on the LT/LMT sector in the future. Our research presents important contributions and implications for scholars, business, and policy-makers as we propose a multi-level, integrated thematic framework that highlights the importance of LT/LMT sectors in innovation ecosystems (NIS) and offers avenues for future research.

Keywords: innovation in low-technology; developing countries; low-to-medium technology; LMT; innovation ecosystems; mall and medium enterprise; SMEs

Citation: Nouman, M.; Yunis, M.S.; Atiq, M.; Mufti, O.; Qadus, A. 'The Forgotten Sector': An Integrative Framework for Future Research on Low- and Medium-Technology Innovation. *Sustainability* **2022**, *14*, 3572. https://doi.org/10.3390/su14063572

Academic Editors: Marta Peris-Ortiz, Jaime A. Gómez and Sofía Estellés-Miguel

Received: 26 January 2022
Accepted: 5 March 2022
Published: 18 March 2022

1. Introduction

This paper focuses on innovation in low-technology (LT) and low-to-medium technology (LT/LMT) sectors, i.e., those characterized by low-intensity research and development (R&D). Drawing from Organization for Economic and Co-operation and Development (OECD) taxonomy, LT sectors are characterized by R&D intensity between 0 and 0.9 percent, LT/LMT between 0.9 and 5 percent, and high-tech (HT) over 5 percent [1]. While comparing LT/LMT innovations with HT innovations, identifying the various facets of LT/LMT innovations and the nature of sectors where these innovations can occur, this paper points towards an intrinsic paradox emerging from a detailed review of the literature and attempts to explain it. On one hand, compared to HT, LT/LMT sectors dominate a region or country's overall economy and should be ripe for innovations due to their greater role and inherent characteristics. Yet, the very same sectors demonstrate low innovation output and thus have received much less attention from researchers. For example, as evident from the name, LT/LMT sectors are characterized by low and/or medium use of technology as well as market, administrative, and incremental process innovations. They have well-defined and stable market segments. The research focus on LT/LMT is necessary as "LT has been termed as the forgotten sector in innovation policy" [1]. Trott and Simms [2] assert that LT/LMT sectors have a leading position, not only in the developing but developed economies also. Indeed, as Robertson et al. [3] point out, LT/LMT is defined by what it is not (not HT, usually meaning biotech and information/communication technologies) and what it does not do (spend more than 5% on R&D), rather than what it does well in its own right. LT/LT/LMT sectors warrant special scholarly focus, which thus far, has been more inclined towards innovation in HT sectors. Scholars have been skeptical and criticized the concept of "high-tech myopia" and argued that economic development and growth is predominantly a result of HT and R&D focused sectors [4–6], despite the evidence that

there is little difference between HT and LT in terms of their capacity to explore and implement new technological trends [7,8]. Notably, while recognizing the explanations for this potential HT bias, Hansen and Winther [9] argued that HT sector industries potentially can have faster growth. In addition, they can create an impression that it contributes more towards the economic growth and development of a country than they actually do. Generally, economies in the western developed countries are structured to support HT sectors, while outsourcing LT and LT/LMT to developing countries with lower labor costs [9,10]. However, it is important to note that in most developed countries, LT/LMT sectors still consist of a prevailing portion of the national economy [11,12]. They contribute over 90% of the growth output in highly developed economies such as Japan, the European Union (EU), and the United States of America) [2] while remaining dominant in many developing countries. In Europe, LT sectors employ five times more individuals than HT sectors and produce more than twice the output of HT sectors [13].

In this paper, we review the scientific scholastic and research work on innovation in the LT/LMT sectors to try and address these doubts. Our review is timely, as there are two issues that are central to the competitiveness of LT/LMT firms in developed and developing countries. Firstly, LT/LMT industries are not supported in equal measure like HT industries in developed countries. Although the metrics are contentious, the policies are focused on HT industries because of their perceived value-added capacity and growth rate compared to LT/LMT [14–16]. In doing so, the potential of LT/LMT may not be fully realized, and thus it becomes a missed opportunity. Secondly, globalization has given rise to competition from developing countries, [17], meaning LT/LMT industries are more viable options for them to compete with developed countries as compared to HT industries [10]. This is a concern for developed economies because of LT/LMT industries' significant economic contribution overall to the GDP of developing economies [3,9,18].

We, therefore, argue for the need to recognize innovation in LT/LMT sectors as a more central topic in innovation research. As Nouman et al. [19] maintain, understanding these innovations is undermined by diffuse and fragmented literature that spans 30 countries across five contents and five major sectors (Table 1) but is heavily skewed towards developed countries. This is perhaps surprising given the heavy reliance of developing countries on LT/LMT.

Table 1. Industries and countries included in empirical work on LT/LT/LMT innovation (1999 to 2010-11). Source: adapted from Nouman et al. [19].

Notable LT/LT/LMT SECTORS STUDIED (Focus on Manufacturing Sectors)	MAJOR REGION/CONTINENT CONTEXTS
Mining & Minerals sector; Industrial Manufacturing sector (e.g., steel, rubber, plastic, leather, textile, fertilizer, others); Construction and Housing sector; Home Appliances sector; Industrial Equipment sector	15 countries in Europe; 04 countries in North America (USA, Canada, Mexico, Jamaica); 02 countries in South America (Chile, Brazil); 08 countires in Asia and Australia

Further, the field is not united by any overarching conceptual or theoretical framework that helps us understand the lack of research on LT/LMT sectors and limiting conditions for innovation activity within such sectors despite their overall importance. Most studies report descriptive surveys or case studies at the firm or industry level. There is a need to conduct a deeper analysis that goes beyond the surface morphology described above, to generate meaningful findings. Thus, through this paper, we make an attempt to fill the gaps with regards to innovation scholars' existing knowledge of LT/LMT innovation and drawing on insights from the extant research, we try to explain why LT/LMT sectors struggle to innovate despite the presence of conditions that should trigger innovations otherwise.

The paper is structured as follows: firstly, the methodology and the process adopted for this paper have been described. Afterward, using a detailed review of the literature, an integrated framework for LT/LMT innovation is presented and discussed. This framework helps explain the nature of these innovations by focusing on the visible dichotomy within these sectors and the prevalent conditions that on one hand should support innovations and yet, they are inhibited. The paper concludes with an agenda for future research.

2. Methodology: Paper Identification

The paper is based on literature covering the period 1999–2018, plus a small number of key studies prior to 1999. Online archives including Elsevier, Wiley InterScience, Emerald, and JSTOR have been searched using the keywords 'low technology innovation', 'low and medium technology innovation', 'LT', and 'LT/LMT'. We screened the articles initially by focusing on titles and abstracts only. Papers that included empirical content were selected since their findings and conclusions are supported by tangible evidence drawn from the field. Studies that were conceptual in nature or relied only on literature review were also included due to their relevance to the topic and their identification or clarification of concepts relevant to LT/LMT innovation. The screening process was continued by further focusing on the conclusions and/or recommendations sections along with a review of the main body of the paper. The purpose was to ascertain if the central argument of the study and its main findings were significant with regard to LT/LMT innovation (although LT/LMT was not necessarily explicitly mentioned). Studies, where LT/LMT innovation was merely a tangential issue, were removed. Hence, in the end, we were left with 156 relevant research papers on LT/LMT innovation. Microsoft Excel was used as a tool to aid the categorization of the papers and to organize around the development of themes.

3. Developing the Framework through the Literature Review

To develop the framework, we began by searching for emergent themes or insight categories within the literature that could enable the development of insights that would not only build on what has gone before but also to signpost areas rich for future development. To initiate the development of deeper themes, all the relevant findings of each study were identified through a careful review of each paper. The insights were then categorized in a three-stage process as shown in Figure 1:

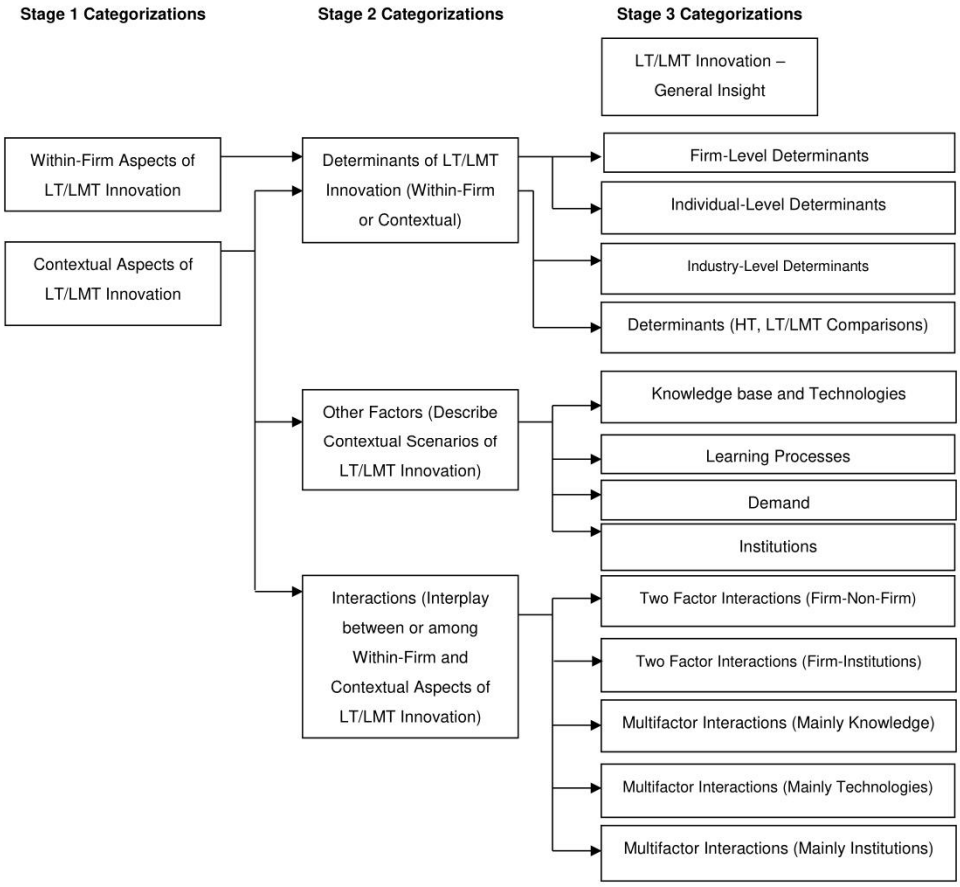

Figure 1. The Three Stages of Insight Categorizations.

Stage 1 is founded on the premise that innovation within a firm takes place in its specific context. Firms do not operate in isolation and are influenced by their context or environment including the nature of the industry and the region [20,21]. Consequently, two broad categories emerged whereby the insights either related to (i) Within-Firm Aspects of LT/LMT Innovation or (ii) Contextual Aspects of LT/LMT Innovation. Stage 2 shows three broad categorizations: (i) Determinants, (ii) Other factors, and (iii) Interactions. Further reflection on keywords and terms surrounding the central notion of LT/LMT in the research papers resulted in Stage 3, where a further subdivision took place. This three-stage process resulted in a total of 14 insight categories. Table 2 describes the basis for generating each insight category.

Further, the review of the literature also helped in identifying key insights about LT/LMT sectors that were then allocated to the relevant insight category along with references. See Table 3 for further details.

Table 2. Basis for Generating Key Insights about Low Technology Innovation (adapted from Nouman et al. [19].

Stage 3 Categorization	Justification for Identifying an Insight-Category
LT/LMT Innovation–General Insights	Provide the general meaning and broader characteristics of LT/LMT innovation. Remain conceptual in nature and not backed by empirical analysis
Firm-Level Determinants	Discuss the factors within firms that result in LT/LMT innovation. These can include factors like firm strategies/approaches, firm resources (financial and nonfinancial), firm competencies and capabilities
Individual-Level Determinants	Discuss those factors that focus on the role of key personnel or individuals within the firm that results in LT/LMT innovation or otherwise. Such individual-level factors are more important to understand as most LT/LMT firms are small enterprises having pivotal influence on key personnel such as firm owners and top-level managers
Industry-Level Determinants	Focus on the contextual factors within the LT/LMT sectors that influence innovations in such firms. These may include factors such as within-industry competition, preferences of customers, nature and use of technologies within the sector, dynamics of suppliers and others
Determinants (HT, LT/LMT Comparisons)	Provide insights on factors related to LT/LMT innovation through a discussion on or comparison with HT innovation
Knowledgebase and Technologies	Discuss the nature and dynamics of knowledge and technologies within LT/LMT sectors as both remain two of the key inputs for innovation in these sectors
Learning Processes	Provide information about learning processes as identified within LT/LMT sectors. Findings suggest the presence of these processes not only at the level of LT/LMT firms but also LT/LMT industries
Demand	Help explain the various dimensions related to LT/LMT markets particularly the nature of demand and its role in triggering innovation or otherwise
Institutions	Relate to insights on the nature and role of various formal institutions such as laws, regulations and informal institutions such as norms and practices in influencing LT/LMT innovation
Two-Factor Interactions (Firm-Non-Firm)	Emphasize on the interactions of LT/LMT firms with organizations other than LT/LMT firms that can lead to or deter LT/LMT innovation. Basis for such insights emanates from the consensus within literature that firms cannot innovate on their own and are influenced by other stakeholders
Two-Factor Interactions (Firm-Institutions)	Focus on the interactions of LT/LMT firms with formal and informal institutions that can trigger innovation or otherwise
Multifactor Interactions (Mainly Knowledge)	Provide insights on LT/LMT innovations emerging from the interaction of firms with knowledge as a key factor. The literature not only focuses on knowledge available within LT/LMT firms but also knowledge that permeates into these firms through interactions with non-firms
Multifactor Interactions (Mainly Technologies)	Provide insights on LT/LMT innovations emerging from the interaction of firms with technologies as a key factor. The literature emphasizes on the role of non-firms in offering these technologies to LT/LMT firms
Multifactor Interactions (Mainly Institutions)	Relate to insights that emphasize on explaining LT/LMT innovation from the perspective of firms' interactions with institutions along with other factors (knowledge, demand, others) and non-firms simultaneously

Table 3. Key Insights along with Relevant Insight Category and Reference.

Example Insight-Category	Some Examples of Key Insights about LT/LMT Innovation	Selected References
Firm-Level Determinants	"Process and product design; innovation budget; advanced machinery and equipment; technological and market access, integrative and internal R&D capabilities; customer-focus; employee/worker skills and training; innovation capacity (time to implement innovation); innovation specialists; documented planning for innovation; collaboration with firms and non-firms; internal vs. external technology development decisions; organizational practices such as teamwork, intra-firm knowledge transfer, extensive workflows, and production scheduling; organizational culture including innovation propensity, market-orientation, value-orientation, organizational constituency, organizational learning; creativity and empowerment and innovation implementation context; top management support; top management diversity; learning orientation; export intensity or orientation; technological innovation capabilities; ideas/suggestions from employees; diversification focus; diverse technology base"	Akgun et al. (2009), Buech et al. (2010), Dobni (2008), Dunk (2007), Filippetti (2011), Freel (1999), Hall and Bagchi-Sen (2007), Hernandez-Espallardo and Delgado-Ballester (2009), Huang and Chen (2010), Kirner et al. (2009), Lokshin et al. (2011), Macher and Mowery (2003), McAdam et al. (1998), Morone and Testa (2008), Pullen et al. (2009), Swan and Allred (2003), Talke et al. (2010), Yam et al. (2010)
Industry-Level Determinants	"Competitive intensity; customer demand; external R&D; science and technology push, e.g., availability of R&D funds, informal and formal research; spread of wage labour; urbanization and changing lifestyles; interactions of knowledge and technologies; usage of intellectual property rights (IPRs), costs of learning usage of IPRs, patent activities; costs of innovation development process; market uncertainty in terms of innovation acceptance; technology uncertainty; market attitude (conservative vs. liberal); technology transfer network (comprising of non-firms e.g., industrial liaison office); existence of academic-entrepreneurial role-models; cultural differences between research organization (university) and industry; incentives for collaboration among actors within a sector; nature of price (low or high) within the market; knowledge flows and utilization within sector; sectoral environment (fast-changing vs. stable, less innovation in case of latter); level of regional economic progress (firms in better-off regions less innovative); human capital within sector; technology generation and adoption trends; availability of modern equipment from suppliers; market size; user sophistication; regional environment; technology turbulence in an industry"	Albuquerque (2000), Aldas-Manzano et al. (2005), Avermaete et al. (2003), Bigliardi and Dormio (2009), Buesa et al. (2010), Duguet (2006), Fernandez et al. (2010), Gu and Tang (2004), Guerzoni (2010), Hanel (2008), Hansen and Serin (1999), Jantunen (2005), Jimenez-Jimenez et al. (2008), Jones-Evans et al. (1999), Keskin (2006), Kirbach and Schmiedeberg (2008), March-Chorda et al. (2002), Woodcock et al. (2000), Kim (2018), Sakka et al. (2019)
Individual-Level Determinants	"Owner/managers' innovation orientation, risk-taking behavior, proactive behavior, and other psychological characteristics have an indirect influence on innovation through mediating role of entrepreneurial processes within the firm Owner/manager's emotional capabilities including encouragement, displaying freedom, playfulness, experiencing, reconciliation and identification influence product/process innovations"	Akgun et al. (2009), Entrialgo et al. (2000)

Table 3. *Cont.*

Example Insight-Category	Some Examples of Key Insights about LT/LMT Innovation	Selected References
Knowledgebase and Technologies	LT/LMT sectors are well established and saturated. A relatively slower market and technological environment. Knowledge exploration is more common than R&D Technological spill-over is often from HT sectors and this substantially increases firms' absorptive capacities There are three categories of knowledge utilization by LT/LMT sectors (1) Original HT inventions (2) Technological knowledge from elsewhere, (3) knowledge technological development from other sectors Traditionally, a technological flow is from HT to LT/LMT sectors. Benefits of innovations and technological advancement in HT sectors are realized when LT/LMT sectors utilize them. Notably, quick dissemination of knowledge is important for economic development. A radical innovation in HT sectors could spill over to LT/LMT sectors and consequently interrupt competition in the market For LT/LMT, competitor and customer knowledge (market knowledge) are the main sources of external knowledge. Knowledge is freely accessible to LT/LTM for innovation Knowledge flow has a significant geographical importance Innovations due to knowledge flows across knowledge clusters disseminate faster Incremental knowledge is often accumulated in LT/LMT firms LT/LMT firms with knowledge integration and outsourcing perform better on new product development. Small size and an internal knowledge base make firms more flexible in response to the market. Start-up firms that emerged from university research often rely on specific knowledge inputs to innovate. However 'unsponsored spin-offs' depends on general knowledge. Firms with a formal knowledge base, often produce value-added products, explicit product innovation goals, and greater technological integration. Product design management has a strong positive influence on innovation. Knowledge from one LT/LMT sector can also influence innovation in another LT/LMT sector External technological sourcing is common	Balthelt et al. (2010), Bergek et al. (2008), Chiva-Gomez et al. (2004), Grimpe and Sofka (2009), Hauknes and Knell (2009), Jantunen (2005), Lee and Veloso (2008), Lindman (2002), Pedersen (2005), Robertson and Patel (2007), Rundquist and Halila (2010), Schmidt (2009), Schmierl and Kohler (2005), Tether and Tajar (2008), Vale and Caldeira (2008), Varis and Littunen (2010), Veugelers and Cassiman (1999), Von Tunzelmann and Acha (2005), Waguespack and Birnir (2005), Yang and Kang (2008)
Learning Processes	Learning processes in LT/LMT sectors are typically informal at the firm level and 'learning by doing' is the common norm in small firms Market orientation is highly correlated with a learning orientation and thus has a strong influence on a firm's ability to innovate For LT/LMT firms, four factors (namely, the complexity of technology, the interconnectedness between product and process, path dependency of knowledge searching, and incremental technology development) influence their learning processes and learning opportunities Differences in learning amongst firms can be elucidated through the differences in the conditions for learning	Keskin (2006), Van Mierlo (2010), Von Tunzelmann and Acha (2005)

Table 3. *Cont.*

Example Insight-Category	Some Examples of Key Insights about LT/LMT Innovation	Selected References
Demand	Demand changes relatively slowly in LT/LMT sectors Firms explore new markets to manage slow demand changes Demand is often inelastic. Most LT/LMT products cater to consumer 'necessities' New technological developments help firms to improve product quality.	Guerzoni (2010), Von Tunzelmann and Acha (2005), Galati et al. (2016)
Institutions	➢ Institutional systems can help to understand interactions between sectoral elements related to LT/LMT. ➢ The role of institutions within LT/LMT sectors can be explained by understanding their link with national, regional, and local institutions ➢ National institutions have the ability to influence an LT/LMT industry through their industry-specific effects ➢ Formal institutions like 'technology-forcing regulations' can influence technological innovation amongst LT/LMT firms ➢ The influence of technology parks on LT/LMT innovation is still questionable ➢ Governments can pressure firms through regulations to improve products ➢ Government-supported tax credits on R&D improve innovational performance of LT/LMT firms.	Carlsson (2006), Casper and Whitley (2004), Czarnitzki et al. (2011), Fisher-Vanden and Terry (2009), Geels (2004), Lee and Von Tunzelmann (2005), Lee et al. (2010), Malerba (2004), Radosevic and Myrzakhmet (2009), Robertson and Patel (2007), Scott (2001), Storz (2008), Sun and Liu (2010)
Two-Factor Interactions (Firm-Non-Firm)	➢ Weak interactions between firms and non-firms (e.g., firms and banks for accessing finance) result in poor innovation performance. ➢ More than the existence of relationships, it is their strength that influences LT/LT/LMT innovation ➢ Non-firm 'bridging' organizations can help firms link up with knowledge, information, and other actors. Technology intermediaries and industrial liaison offices can link firms with research centers and universities respectively ➢ Intra-industry links amongst firms and non-firms influence innovation more rather than inter-industry links ➢ Firm collaborations with research organizations are a source of external technological knowledge ➢ Research organizations need to support firms (as users) in technology adoption while accounting for the nature of a firm's innovation ➢ External information flows (incoming spillovers) increase chances of collaboration among firms for innovation ➢ Stronger collaboration between firms and research institutes, and weaker collaboration between firm and competitor ➢ Public financial support encourages collaboration between firms and research institutes ➢ Competitors respond to product innovations of an LT/LMT firm mostly through price changes rather than product variety, better promotion or distribution	Abramovsky (2004), Debruyne et al. (2002), Douthwaite et al. (2001), Freel (1999), Jones-Evans et al. (1999), Petroni (2000), Ronde and Hussler (2005), Sapsed et al. (2007), Soofi and Ghazinoory (2010), Spithoven et al. (2010), Tomlinson, (2010), Tsai and Wang (2009), Vale and Caldeira (2008),

Table 3. *Cont.*

Example Insight-Category	Some Examples of Key Insights about LT/LMT Innovation	Selected References
Two-Factor Interactions (Firm-Institution)	➢ More theoretical and empirical research is needed to understand the role of institutions in influencing LT/LMT innovation ➢ Formal institutions (regulations) tend to have a restrictive influence on innovation in LT/LMT firms. ➢ However, transnational policy institutions in Europe do not have a restrictive influence on innovation ➢ Policy consistency within LT/LMT industries helps firms to innovate ➢ Innovation-oriented institutional infrastructure (interactions amongst firms, government, and non-government organizations) plays a vital role in facilitating innovation in LT/LMT sectors ➢ Institutions should be differentiated in terms of their industry-specific, regional or national motives ➢ Informal institutions, from the perspective of the local social context of an industry, can have a strong relationship with the adoption of technology in that industry	Boymal et al. (2007), Centindamar (2001), Faulkner (2009), Moxley and Lang (2006), Vonortas (2002)
Multi-Factor Interactions (Mainly Knowledge)	➢ Knowledge exchanges can occur among different sectors due to sectoral proximity ➢ LT/LMT sectors (especially with small firms) generally lack the absorptive capacity to internalize knowledge from external sources. The role that technology intermediaries (non-firms) provide between research centers and firms is crucial ➢ Firms can innovate through improved product designs. They need capabilities to access and interpret tacit and distributed knowledge through interactions with different stakeholders including users, firms, designers, products, communication media, cultural centers, and artists. ➢ Collaborating organizations' divergent mindsets (derived from their knowledge contexts) influence NPD strategies. ➢ Weak collaborations among actors (lack of joint activities, low R&D focus, poor absorptive capacities, especially knowledge transfer to employees resulting from poor organizational structure) hinder innovations in LT/LMT sectors ➢ Firm collaborations for R&D with different non-firms differ from each other in terms of their breadth of new knowledge and ease of knowledge access	Andersen and Munksgaard (2009), Cetindamar and Ulusoy (2008), De Faria et al. (2010), Dell'Era and Verganti (2010), Ronde and Hussler (2005), Spithoven et al. (2010), Un et al. (2010),

Thus, deriving from the approach of Three-Stage Categorization, coupled with the Key Insights and their logical allocation to various Insight Categories, an 'Integrative Framework' with various themes has been developed. See Figure 2 below. The stronger the outline of a themed box, the more relevant the insights we have identified through the literature review and vice versa. Moreover, within each box, the framework provides avenues and suggestions for future research within each theme.

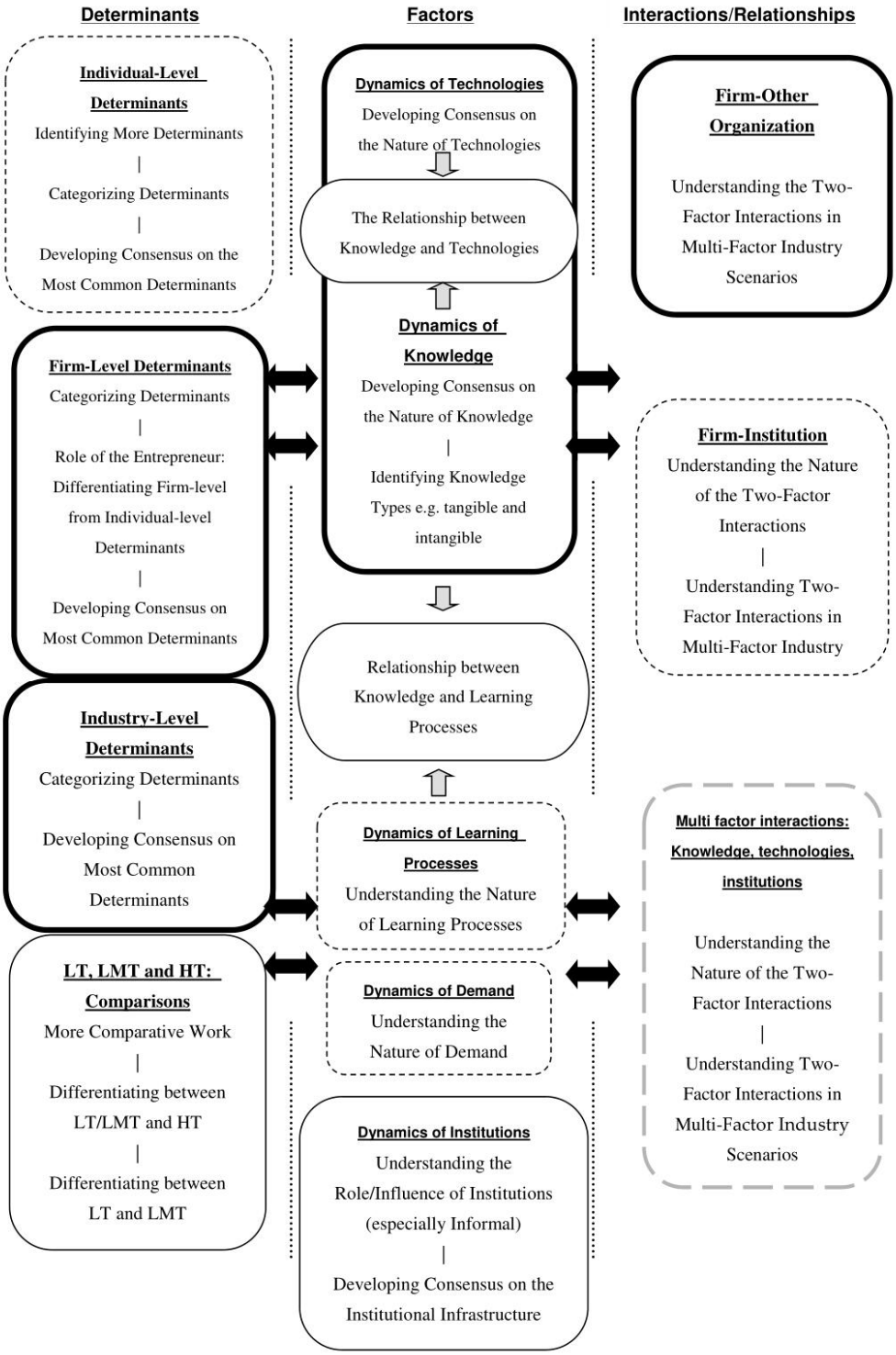

Figure 2. Research on LT/LT/LMT Innovation: An Integrative Framework.

4. Results and Discussions from the Review of Literature and the Integrative Framework

When drawing conclusions from the above literature and framework, it is imperative that the classifications of HT and LT/LMT innovations based on R&D intensity do not always present a consistent picture of what is happening, especially given the diversity in the sector and the lack of sufficient sectoral data. Further, it fails to take an account for spikes in growth and fails to reflect the accumulation of R&D expenditures in a given industry [1]. Notably, more recent studies continue to question the construct [22]. These authors point to interpretation issues of R&D intensity data. The variations of R&D intensity of different industries at different aggregation levels means data might be skewed. This is very relevant and important for policy because it determines whether differences are intrinsic due to firms' underinvestment in R&D, or structural due to differences in the sectors that make up the economy.

Nonetheless, extant literature reveals that innovation in firms operating in LT/LMT industries tends to have the following features: (1) innovations are incremental extensions rather than radical [9,13]; (2) innovations are primarily process-related [12,14,23]; (3) the impulse to innovate comes from market demand rather than technology orientation [1,24]; (4) relevant knowledge is practical rather than scientific [2,25], and; (5) knowledge is primarily sourced from external entities such as suppliers [23,26], customers [12,27], and technology intermediaries [28,29]. In addition to the features of LT/LMT firms, are the characteristics of the industries in which the firms operate. Industry characteristics include: (1) LT/LMT industries reside in relatively stable market segments [17] with relatively low dynamism [13,30]; (2) markets are well-defined [2], and; (3) products produced are typically standardized [26].

This study set out to highlight the significance of LT/LMT in the economic ecosystem and counsel policy-makers not to neglect LT/LMT interactions if the overall health of the system is to be maintained. Not surprisingly, there are barriers to innovation that pertain specifically to LT/LMT industries. The narrow scope of LT/LMT firm activities makes it hard for them to enact change alone. This is because markets are well defined and products are established and often standardized [31]. A general consequence that arises from this is the high path dependency it creates and consequently hinders development opportunities [32]. Further barriers to development include a lack of capital to fund formal R&D investment [33], and a lack of environmental dynamism [34,35].

Yet despite the distinctiveness and value of LT/LMT, research is beset by the same concerns as innovation research generally–a mass of interdisciplinary perspectives (economics, business, entrepreneurship, sociology, psychology), on a multi-faceted, multi-level (macro-meso-micro) phenomenon that is generally under-theorized. This section provides some further discussion to support the significance of the framework illustrated above, as significant areas for further development to support further research in pursuit of this aim. The key themes of determinants, knowledge and technologies, learning processes, demand, and institutions are discussed below.

One obvious predominant strand in innovation research generally is that many studies have concerned determinants of innovation, with much of this focused on the industry or firm level, although there are some studies of determinants at the individual level. LT/LMT innovation is no exception to this emphasis, as seen above. However, while the relationship of the firm to its industry or sector is at the heart of innovation success, there is a lack of consensus on the classification, or relative importance of factors/determinants for a given sectoral context [36–40]. In a recent study, Kearney et al. [13] test the determinants of product innovation management in both HT and LT sectors of the Netherlands and report significant sectoral heterogeneity with regards to the impact of the determinants. Nevertheless, empirical and comparative studies such as those by [13], are scarce, and this is an area for future development of LT/LMT, with more work to be done on classifying and differentiating determinants, and the relationships between them.

There is also limited understanding of the interactions between the different levels of analysis, although the relation between the industry and firm levels has been apparent since

Pavitt's influential work. Pavitt [41] and later Pavitt, Robson, and Townsend [42], connect the firm to the industry context in a classic set of studies where 2000 and 4000 innovations respectively were examined to suggest a classification based on four sectoral patterns of innovation. These patterns include "supplier-dominated, large scale producers, specialized suppliers, and science-based sectors" [42]. Similarly, for LT/LMT, Heidenreich [23] suggests that firms often opt for a supplier-dominated sectoral pattern. These firms' innovation is often based on process, organization, and the market and not actually generated internally from R&D [11]. These firms are dependent on the provision of support in terms of, for example, machines and equipment improvements from external sources [28,29]. Pavitt [41] emphasizes that in 'supplier-dominated' sectors, it is factors like "professional skills, aesthetic designs, trademarks, and advertising" that firms can capitalize to innovate and not often have to depend on advanced technologies. Occasionally, large customers and regulatory authorities help and support research that results in innovation in this sector. Wolfe [37], Souitaris [38,39], and Vega-Jurado et al. [43] further suggest that the overall environment (economic, social, and political) of the country where the sector operates has a significant impact on sectoral innovation.

Knowledge and technologies also feature heavily in the LT/LMT innovation literature, though the themes are diverse and conclusions not oriented towards developing any organizing framework. Innovation in the LT/LMT sector tends to arise from non-R&D activities and often involves internally experimenting, transforming the general stock of knowledge into economically useful, knowledge-adapting technologies, and learning [2,25]. The more LT/LMT firms connect with external knowledge sources, the more they are able to enhance and multiply their value [26] by enhancing their propensity to innovate [33]. LT/LMT industries typically source such knowledge from competitors, tradeshows [27], collective research centers, and technology intermediaries [28]. Often, HT is considered as more research and development-oriented, however, Yang and Kang [44] indicate that the impact of the firms' innovation competencies and knowledge is equally essential for both LT/LMT and HT. Traditionally, LT/LMT sectors have relatively "low levels of knowledge appropriability, low cumulativeness amongst firms, and low innovation activity" [8,33,45]. Additionally, knowledge attained from other sectors could enhance innovation, however, it is important to note that the firm's own capacity and capability competencies play a vital role in achieving this goal. The ability to compete through acquired knowledge and technology from other sectors "underscores the importance of LT/LMT firms' search patterns which need to focus on external sources of knowledge from competitors and customers" [27,28,46]. However, firms with greater vertical integration may struggle to acquire external knowledge [47]. To address this, firms may use "knowledge access, reliability, and transferability" as trade-offs [24]. Most LT/LMT sectors are categorized as a result of informal knowledge and technologies [48–51], public-funded R&D activities [52], and freely accessible knowledge sources [53,54].

Technologies are a fundamental and essential input to innovation in the LT/LMT sector [55], with process technologies most likely to be adopted [10,56]. Technology intermediaries are recognized as valuable filters that collect, aggregate and translate relevant knowledge to affiliated firms [28,29]. To actualize external knowledge and to be equipped to act in increasingly dynamic environments (e.g., globalization), LT/LMT firms need to create a systematic framework to do so. Technologies need to match with an LT/LMT firm's requirements and capabilities [57,58]. In general, LT/LMT firms are operating in an industry where sectors are saturated and knowledge, technologies, and market dynamics change relatively slower than HT [59]. In this context, "knowledge search, identification, and proof" of usefulness for existing technologies are the main activities [3,60], rather than the creation of new technology [30]. However, R&D-related innovation should not be overlooked in LT/LMT sectors [24,25]. Process specialization, scientific knowledge, and new technologies are critical to LT innovations that are "resorted to in a targeted and selective way to solve practical innovation problems" [17,33]. Thus, scientific knowledge

that resides in R&D activities cannot be discarded as insignificant to LT/LMT industries, though they usually rely on external partners to stimulate innovation [2,29].

An important concern for LT/LMT firms is the relation between knowledge management and internal processes. Nevertheless, Lee and Veloso [61] argue that the boundary between internal and external can be flexible, particularly in times of uncertainty. In this context, Schmierl and Kohler [62] suggest that firms with unique norms (such as informal job training and incremental knowledge accumulation) contribute to the development of the firm. Similarly, LT/LMT firms' reliance on "in-house knowledge bases" is generated through a strong understanding of user conditions. Particularly, a firm's flexibility due to its small size allows them to be effective at new product development [63,64]. Enablers for innovation in stable manufacturing industries include training and up-skilling staff [30], as a combination of innovation and training is important to revenue growth. Direct relationships with customers are important for non-R&D SMEs-gatekeepers, sales, and management [27]. LT/LMT firms can compensate for R&D resources by acquiring externally generated knowledge and taking an incremental step-by-step approach [31]. Innovation in LT/LMT industries can thus be thought of as "hybrid innovations" based on "distant market-oriented modifications" of available resources and existing knowledge as well as their combination with new high technology components [14]. Thus, awareness and absorptive capacity [65] give rise to 'connect and develop' rather than 'research and develop' strategies [14]. Another aspect of knowledge management stems from whether it has been assimilated "formally", "informally" and/ or through a combination of both. As noted in the earlier discussion, knowledge is often informal in LT/LMT sectors, and in these cases, improvement in the product design to innovate is the most obvious and common choice [66,67]. On the other hand, firms with a formal and codified knowledge base may be potentially in a better position to manufacture value-added products and collaborate more with external technology infrastructures [68].

Knowledge and technologies have an organic relationship and it is not possible to disconnect, of course, from learning processes [60]. Learning processes amongst LT/LMT firms and sectors are influenced by variables such as the "complexity of technology" in an industry, "market orientation", "interconnectivity between product and process", "path dependency of knowledge searching", and "incremental development of technology" [69,70]. While 'learning by doing' still tends to be the norm [60], there is nonetheless a knowledge gap as to how to improve learning in LT/LMT contexts that Van Mierlo et al. [71] stress the need to address. Considering knowledge, technologies, and learning overall, studies have been influenced by the amount of work that has been carried out in the HT domain, in areas such as cluster formation and development, spillovers, absorptive capacity, and dynamic capabilities [33]. Detailed papers are sparse, yet this area is clearly significant in light of our earlier identification of the significance of LT/LMT in the innovation system overall, and one that would benefit from a more systematic study.

LT/MT and innovation literature is also integrated with product and market demand. It has been argued that in the case of LT/MT firms, product demand is often stringent [16]. Therefore, a firm's common strategy is to explore new markets. In addition, firms use new and innovative technology to change existing market conditions [59]. Guerzoni [72] presents a useful and clear understanding of the nature of demand in LT/LMT sectors. He proposed four distinctive patterns of demands in LT/LMT markets. First, a small size market with low user sophistication, where, firms are not generally innovative (called a passive market). Second, a large-sized market with standard goods and low user sophistication where firms often adopt low-cost reduction innovation (mass markets). Third, a small market with high user sophistication, where firms have a high product innovation (niche market). Finally, the fourth market (dual market), where market size is large with high user sophistication. There are two types of firms in this market. The first type focuses on "process innovations" and produces products for a large number of users. the second type focuses on niches by providing product innovations for sophisticated consumers.

With market conditions, it is also interesting to explore the role of institutions in LT/LMT sectors. Institutions can broadly be described as sets of norms, habits, practices, policies, rules, and laws that influence the relationships among individuals and organizations, including their propensity to innovate, as has been recognized in systemic perspectives on innovation [73–76]. To date, however, much of the literature on institutional practices tended to focus on the support of HT initiatives, although Hirsch-Kreinsen [1,17], Radosevic and Myrzakhmet [77], and Nouman, Yunis, and Mufti [78] stress the importance of understanding the overall institutional infrastructures and policy initiatives in place for LT/LMT sectors. The government, through its role as a regulator, implementer, and procurer, remains the key influencer on LT/LMT innovation amongst firms [79–81]. On the one hand, the government's regulatory pressure can hinder firms' innovation propensity [82], while on the other hand, its industry support policies can influence innovation positively [83]. Stressing the need for an effective government policy, Robertson and Patel [51] point out that such a policy can also help manage the diverse nature of knowledge sources in LT/LMT industries. Here, it is important to understand how the LT/LMT sector operates in a national institutional context. In this regard, Storz [84] argues that national institutions can have a significant impact on innovation in an LT/LMT industry. Similarly, Carlsson [85] believes that in the case of SMEs, national and sub-national institutions context (including sectoral) may play a vital role. The work of scholars such as Malerba [86], and Lee and Von Tunzelmann [87], suggests that countries may show similarities across their national systems of innovation (NSI); however, differences would emerge amongst them across industry-level influences of NSI. Certainly, any policy initiatives should take into account the industry-specific nature of innovation [70], though overall, the role of institutions for LT/LMT development is not well understood.

In summary, this review has highlighted that for LT/LMT, innovation does not occur in isolation, and innovating firms rely on interactions or relationships in complex ecosystems [58,88–90]. Our thematic analysis has surfaced key areas such as learning, knowledge, determinants, and institutions that permeate many levels and facets of the innovation ecosystem. As our framework illustrates, many studies focus on interlinkages between different facets which can be intricate and difficult to unravel from each other. This has, in part, led to the diffuse body of literature that detracts from deeper understanding overall. For example, industries "characterized by strong contacts among firms and non-firms have a higher capability to diffuse technology leading to innovation" [91–93]. Amongst these interactions, the strongest influence on innovation comes from firm-supplier interactions [94,95]. Interactions with technology intermediaries and 'bridging' organizations are also influential [28,96,97] as well as intra-industry or intra-regional links [45,98,99]. Regarding firm-institution interactions, Faulkner [100] stresses the need for more research as little is known for LT/LMT. However, some attempts have been made to offer relevant insights through the concept of institutional infrastructure [101] and the social context of an industry [102]. As evident from these perspectives, different studies conceptualize interactions differently [103–105] while some like Douthwaite et al. [106] remain vague. This underscores the need for streamlining extant scholarly work to give greater coherence to our understanding of the role of interactions/relationships in influencing LT/LMT innovation. Malerba [86] points to the value of a sectoral system approach for better understanding of innovation and production generally, as such approaches focus on "knowledge base and learning processes", "basic technologies", "inputs and demand", and the type and "structure of interactions among firms and non-firm organizations". The overlap with some aspects of our framework, and the focus on interactions through the co-evolutionary underpinnings of this approach suggests that this may well offer the promise for more theoretically grounded and better-integrated research for the future, particularly in developing countries, as there is a dearth of studies on LT/LMT in the context of developing countries.

5. Conclusions

The paper began by stating reasons for why more research on innovation in LT/LMT firms and sectors was justified: the relative importance of LT/LMT sectors and their position in the modern industrialized markets; the dissemination of innovation to LT/LMT firms; and the roles played by LT/LMT firms and industries in opting for new technologies to fit into existing technological frameworks [3]. Overall, our review has highlighted firstly, the lack of studies in developing country contexts, where better knowledge may contribute to more effective development policy; secondly, the need for more studies in the thematic areas identified; thirdly, the need for more theoretical studies that embrace the interconnected nature of the LT/LMT innovation ecosystem, particularly the firms' relation to the institutional and policy contexts.

Research work on LT/LMT innovation is not united by any overarching conceptual or theoretical framework that helps us understand the lack of research on LT/LMT sectors, and limiting conditions for innovation activity within such sectors despite their overall importance. By conducting a detailed and critical review of extant literature, backed by a systematic analysis of previous findings that go way beyond any kind of surface morphology or rudimentary results, this paper generates more meaningful findings and presents them through a structured and integrated framework for the first time that sets the agenda for future research. Further, it successfully attempts to identify the gaps with regards to innovation scholars' existing knowledge, and draws on insights from the extant research, to explain why LT/LMT sectors struggle to innovate despite the presence of conditions that should trigger innovations otherwise.

In developing countries, the socio-economic environment is challenging and institutional conditions are not favorable for SMEs [107]. This review reveals that if LT/LMT is a forgotten sector (in comparison to HT), particularly, developing countries are the "forgotten research contexts". This is an area of concern for scholars, practitioners, and policy-makers because unlike in the developed world, LT/LMT predominantly dominates economies. Innovation and LT/LMT importance cannot be ignored, we need to understand and study this in more detail in order to recommend policy interventions for local industries. Serious interest and contributions from all stakeholders will enable SMEs to improve through innovation and make a more positive contribution to the economies.

LT/LMT sectors contribute more to the GDP of developing countries than HT sectors do but still, LT/LMT remains a forgotten sector in comparison to HT. Therefore, based on the results of this study, Governments of developing countries should devise such policies that promote the ease of doing business for LT/LMT sectors and further unlock their creative potential. For the owner-managers of firms in the LT/LMT sectors, we suggest that LT/LMT firms need to collaborate with external technology partners and develop a more codified knowledge base to successfully manufacture and market value-added products.

Author Contributions: We confirm following contribution of the authors: M.N. conceived and developed the idea. O.M. and M.A. helped in the access and structure of secondary data; M.N., M.S.Y. and A.Q. finalized, reviewed and proof read the paper. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable, as this study is based on secondary data.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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