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Concept Paper

Invention and Open Innovation Processes, and Linkages: A Conceptual Framework

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Abstract: A conceptual model has been developed to present comprehensively the processes and linkages of invention and open innovation for those knowledge workers who want to transform idea of a new product or service into a reality. The progression of idea conceptualization, realization and marketing is further divided into two phases; first is invention and second is open innovation. These phases are integrated into a complex framework representing a comprehensive flowchart which provides a snapshot of gradual transition of invention processes into open innovation processes. The conceptual model rests on existing literature that methodologically connects access to finance, funding constraints, cognitive and social dimensions, skills, mental model, conceptual knowledge and knowledge production capacity of the scientists (i.e., knowledge worker), scope and pioneering of the invention, technological infrastructure, collaboration with private firms and universities and utilization of digital technologies. The invention, as well as open innovation activities, are discussed with respect to World Intellectual Property Organization and Global Innovation Index country rankings and the number of patents filed and granted to the world including Pakistan. The framework is a rigorous but rewarding process for a knowledge worker who designs and develops a new product, process, procedure, mechanism and methodology to serve humanity and the marketplace.

Keywords: Invention; open innovation; novel idea; knowledge worker; market; conceptual model

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1. Introduction

The innovator's dilemma is unresolved due to consistently arising challenges relating to changes in competition, markets, technologies, regulations and the external environment. The most promising and rewarding strategy recommended to tackle this dilemma is ambidextrous alignment of organization in order to embrace these changes. Accordingly, breakthrough innovations are considered essential in these situations to gain and sustain competitive advantage in the marketplace. Similarly 'Breakthrough Innovation (BI)' capabilities has three building blocks which are discovery, incubation and acceleration. This means that inventions are initial inputs to innovations that eventually make them a marketable offering and further long-term investment in research and development by an organization to ensure sustainable success and growth [1–3]. Therefore, in this research study an important question regarding invention and innovation has been explored and a comprehensive framework relating invention and innovation processes and linkages has been designed and developed. The statement of the problem is: is invention possible or a doable task, and how does invention further translate into innovation (framework)? The study of Cohen and Caner [1] highlighted this problem as, "it is important for scholars and managers to understand what enables firms to produce breakthrough product innovations". This question has been extended and explored in considerable detail by considering various facets of the topic in-order to grasp the true essence of invention and open innovation processes and linkages. Therefore, this conceptual research study has been conducted based-on a qualitative review of literature.

The citied literature has discussed multiple conceptual models including mental model, open innovation model for research and development firms, triple helix, expected license revenue per faculty model, quadruple-helix model, intrapreneurship leading culture model for open innovation dynamics and system dynamics model under entrepreneurial cyclical dynamic model [4–13]. Earlier studies relating conceptual modelling have considered open innovation as central issue in an organizational setting whereas invention has not been linked to open innovation under the BI capabilities which foster organizational ambidexterity. Consequently, based on the reasoning provided, this study is an effort to bring invention and open innovation together in a meaningful conceptual model which explains a framework in terms of a flowchart, the processes and linkages defining interconnectedness among these integrated essential concepts.

Generally, the process of invention starts with a dream of a new and novel idea or a mental map because according to Roberts [14] "Innovation is composed of two parts, the first part is the generation of an idea or invention and the second part is the conversion of that invention into a business or other useful application". Consequently, curiosity driven creative thinking encompasses multiple possibilities and relationships as well as connections. In reality, a mind that is capable of invention certainly revolutionizes the lives of the common man (the end user). Similarly, innovation is the extension of the invention in the sense that it modifies the concept with the ever changing need(s) of the market. Notably, in the last millennium, human history has come across hundreds of new inventions which have totally changed lifestyles and considerably improved quality of life. It all became possible due to those scientists/researchers/scholars who invented new processes, products, equipment(s), procedures, etc. This argument is supported by the work of Johnson and Evenson [15] which has explained that industrial growth is directly linked with invention, innovation and research & development (R&D) activities. Moreover, the products, services and technologies we experience these days are the result of interlinked as well as interconnected invention and open innovation processes.

Today, the human race needs more trained minds that are capable of generating new ideas [16]. The ideas are in their realized form when an invention has been commercialized. This commercialized invention could further be processed by deploying open innovation processes and essential procedures in a business model. This realization process encompasses an array of factors including but not limited to access to funds, applications of cognitive and social dimensions, mental and mechanical modeling, collaboration with internal and external environments, research relating market size, scope and pioneering of invention, knowledge production capacity of skilled knowledge worker and technological infrastructure [5,10,17,18].

Subsequently, considering the world in general and a developing country like Pakistan in particular, there is a dire need to focus on training minds that are capable of producing valuable knowledge which is utilized to create new knowledge in the form of technology, products, procedures, services, etc. Henceforth, considerable work has to be done in this domain and issues relating accessibility to funds need to be resolved by allocating more funds (at-least more than 14 percent of the annual revenues of an organization) for R&D activities, as has been done by Huawei to become the telecommunication industry leader in the world [19]. These R&D activities are an integral part of universities where multiple departments have stakes involved in these activities [10,20]. Therefore, as china has achieved success in developing universities, the hub of R&D activities, and fueled dozens of industries with inventive and innovative solutions, Pakistan needs to arrange, align and sustain R&D activities to fill the market gap in terms of new technology, products or services [19,21]. Explicitly, it is achievable in the larger interest of Pakistan with a capable, honest, dedicated and sincere regime.

This research study is devoted to answering the research questions asked at the beginning of the study by means of a qualitative review of available literature. The main contribution of this study is to identify processes and linkages of invention and open innovation outlined in Tables 1 and 2, which has been further modeled into a conceptual framework of the study. Therefore, this study has been able to answer the questions in a comprehensive manner. The designing and development of a conceptual model (the framework) has carefully explained the processes and linkages of invention and open innovation which are undoubtedly attributed to the hard work of the knowledge worker (generally known as scholar, research/faculty scientist) who works in an intellectual environment. These processes and linkages bridge two distinct but integrated concepts of 'invention and open innovation' essential for the commercialization of a new product or service. Figure 1 is the illustration of these processes and linkages and it is certainly worth understanding that inventors initially work in an intellectual environment that promotes research culture with commitment, motivation, leadership and learning capacity to transform his or her idea into reality. Alongside multiple constraints linked to cognitive and social dimensions in these settings, the knowledge worker secures reasonable funding for his/her mental/mechanical modelled idea under prevailing risk factors. Additionally, it is essential that the internal and external environments should be scanned to assess market size as well as scope and pioneering of invention. These efforts by knowledge workers further demand human intelligence that normally relies on learning knowledge originated from integrated subject matter. It is further suggested that the acquired knowledge should be enhanced and refreshed regularly by utilizing available knowledge databases. Therefore, engagement of knowledge workers in these activities enhances his/her skills relating to knowledge production capacity and eventually results into market driven invention. The knowledge worker further needs to manage invention by spinning a company or granting rights (i.e., patent rights or agreements) to an entity that could commercialize the invention in the marketplace. This is possible under technology transfer protocols as suggested by Ozel and Penin [22] after thorough market research, assessment and placement arrangements. Accordingly, the proposed framework also links the invention processes with the open innovation processes by explaining that if invention needs to survive in the market for a longer period of time, further market driven appropriate knowledge should be acquired. This acquired knowledge should explain monopoly and Ricardian rents which are the driving forces behind open innovation, meaning outsourcing innovation to gain competitive advantage in the marketplace [23]. Additionally, it is further suggested that before indulging in innovation processes, a proper community support and deployment of low cost and differentiation marketing strategies need to be ensured to scale-up the invention. This means integration of closely net internal and external networks identified by Lopez and Esteves [24] as "the enablers of knowledge acquisition and appropriation which would be used to promote innovation within the organization" are required to be exercised effectively. Once innovation as an extension of invention has been done in an organizational setting as discussed earlier under the breakthrough innovation capabilities concept, the innovation needs to be properly managed along-with regular and proactive market research, assessment and placement of products or services based-on open innovation modalities. Furthermore, in a digital world, open innovation is currently considered as a key factor of economic growth [25,26]. Therefore, open innovation driven policies and practices need to be incorporated in business models and inclusive innovation mechanisms need to be encouraged in an industrial setting nationally as well as globally. Thus, the definition of open innovation brought forward by Chesbrough [6,8,27] needs to be followed globally, which states that, "A paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology" [28]. The recent practical example of this definition is seen in the case of Huawei, the world leader in telecommunication equipment manufacturing that developed Huawei Innovation Research Program (HIRP), initiated to create an open eco-system which encouraged academia and industry linkages and simultaneously enabled co-creation among people, organizations and the sectors of the society.

Table 1. Invention processes and linkages.

Authors & Ref.	Process Variables	Linkages
Albers et al. [29]	Market demand, market penetration	Product Generation Engineering (PGE)
Carlson and Gorma [5]	Intellectual and social forces, mental model, physical artifacts, informed and intellectually motivated, learned	Cognitive and social dimensions
Clark [20]	Ability to imagine and create new categorization in the mind, practical business skills and attitude to create new commercially viable products	Specific course on invention for effective entrepreneurial activities
Caviggioli et al. [27]	Patent monetization process; licensing agreements, technology transfers, mergers and acquisitions, partnerships agreements, spinoffs and outright sales	Market-mediated channels
Fox [30]	low financial and professional barriers to entry	Do-it-yourself paradigm
Filho, Tahim, Serafim and Moraes [9]	Creativity, persistence, freedom of thought and action	Triple helix
Griliches [31]	Tradeoff between cost and future income, access to risk finance, financing of risk ventures, entrepreneurial ventures	Commercialization of new idea
Gross et al. [32]	New Technology research, market opportunities, commercialization, market	Research to market opportunities to commercialization
Harmon [33]	Commitment, motivation, leadership and learning capacity of the inventor/knowledge worker	Education of current and past technologies to generate intellectual capital
Johnson & Brown [34]	Increases in the number of institutions of higher education, scientists and engineers	Technological infrastructure
Lach and Schankerman [10]	Faculty scientists, revenue earned by invention, commercial value of the invention, quality effects on the value of the invention and stochastic shock of model, and license by the Technology Licensing Office	Expected license revenue per faculty
Lettice, Roth & Forstenlechner [35]	Effective exploitation, vibrant commercialization strategies, reuse of knowledge, creation of new knowledge	Knowledge based performance measurement system
Lyman [17]	Knowledge creation capacities of the knowledge workers	Archives of historical data and documentary records
Nerkar and Shane [36]	Scope and pioneering nature of the invention, commercialization of technological invention	Competitive advantage and higher profitability
Ozel and Penin [22]	Licensed inventions, technology transfer, generic and embryonic inventions.	University and industry technology transfer modalities
Pana [37]	Renewal of cultural system, intellectics, technics, inventics	Intellectual thinking and invention culture
Sutthiphisal [16]	Highly skilled manpower with relevant technological knowledge	Cutting edge technology based production
Weber, Dixon & Llorente [18]	Creativity and invention	Joining factor of mechanical hand tools

Table 2. Innovation processes and linkages.

Authors & Ref.	Process Variables	Linkages
Al-Belushi, Stead, Gray and Burgess [4]	Breadth and depth in the number and diversity of network collaborations	Inbound open innovation strategy
Albers et al. [29]	Analyze, identifying potential, conception, specification, realization, release of the product	Agile Systems Design (ASD)
Aschehoug, Lodgaard and Schulte [38]	Knowledge management, team formulation, managerial activities, employee motivation and collaboration among the networks	Inbound open innovation technique
Erol and Klug [39]	Organizational culture, practical learning of open innovation, academic sphere, policy sphere, citizen sphere and business sphere, fostering; stakeholders learning, ideation, making and meeting facility.	Regional open innovation learning lab
Gross et al. [32]	Development, new idea, technological solution, designing, testing, application, improvement, knowledge generation, evaluation, screening, research, market formation, development, demonstration, prototyping/pilot testing, niche market, enhancement, exploitation, growth & diffusion, widespread, obsolescence.	Phase 1: Development; Phase 2: market formation; Phase 3: growth & diffusion
Lopez and Esteves [24]	Knowledge acquisition based-on laid-out rules, processes, procedures and strategies	Internal and external networks
Reed, Storrud-Barners and Jessup [40]	Reputation, employee knowhow, culture, networks and databases	Monopoly and ricardian rents
Sivam, Dieguez, Ferrira and Silva [28]	Internal and external resources, scientific, technical, business, market research and design efforts, culture, leadership and strategy.	Knowledge management strategies & human side of creative thinking and idea generation mechanisms
Sutopo, Astuti and Suryandari [41]	Significant improvements in marketing assistance strategies, business network expansion, universities internal regulations, strategies, physical facilities and mentoring and couching activities.	Technology transfer offices of Universities
Vicente-Saez, Gustafsson and Brande [42]	Transparency, accessibility, authorization and participation using open repositories, open physical labs, transdisciplinary platform, open source softwares and digital technologies	Policies and practices open science and innovation
Yun and Liu [43]	Open innovation, evolutionary change and complex adaptive system, closed open innovation, social open innovation and market open innovation	Quadruple-helix model
Yun, Won and Park [19]	Market Open Innovation, Closed Open Innovation, Social Open Innovation	System dynamics model under Entrepreneurial Cyclical Dynamic model
Yun, Zhao, Jung and Yigitcanlar [11]	Entrepreneurship of novice entrepreneur, intrapreneurship of employee of an existing organization, organizational entrepreneurship of the firm	Intrapreneurship leading Culture
Zhu, Xiao, Dong and Gu [44]	Open innovation breadth and open innovation depth	New product development speed

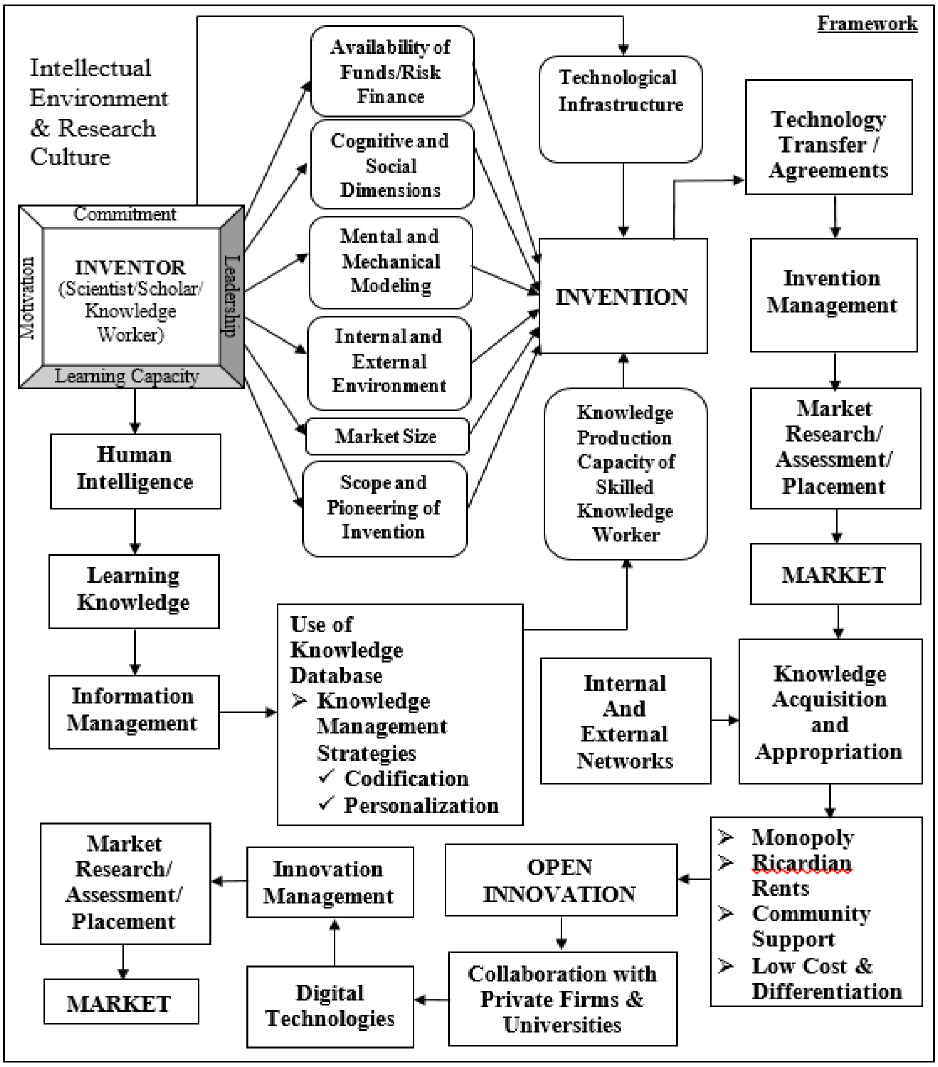

Figure 1. Conceptual Model of Invention and Open Innovation Processes & Linkages.

The flow diagram illustrated as Figure 1 above has been designed and developed based-on qualitative review of literature relating invention and open innovation processes and linkages identified and presented in Tables 1 and 2. This is the conceptual model conceived/designed from the cited literature. This model can be further tested empirically and deductions can be made to report findings based-on the results generated after conducting appropriate statistical evaluations of the variables, processes and interlinkages.

This research study is arranged and organized such that the proceeding introduction and literature review section explains the existing body of research available relating invention and open innovation. Then, Tables 1 and 2 outline invention and open innovation processes and linkages identified from the cited literature. Furthermore, conceptual understanding relating these processes and linkages has been briefly explained which is then followed by the conceptual model (the framework) illustrated as a flowchart. Afterwards, the discussion is initiated, relating a prevailing scenario in the country and practical implications of the formulated conceptual model of the study. Lastly, the conclusion, future research, policy implications and recommendations sections are presented to finish the article.

2. Literature Review

The literature review has been divided into two parts to cover the literature relating invention and open innovation domains in a comprehensive and consolidated manner. The cited literature suffices for the development of a conceptual model which further establishes processes and linkages between invention and open innovation in a holistic interconnected framework. The studies cited here are further outlined systematically in Tables 1 and 2 to identify the relevant invention and open innovation processes and linkages. The conceptual model formulated has been developed based-on the process variables and linkages identified in the tables. We are confident that the literature cited here is diverse and comprehensive to justify the design and development of the conceptually modeled framework of the study.

2.1. Studies Concerning Invention

Generally, the academic-based inventions involving knowledge workers, scholars and research scientists are considered high-risk, but these inventions can serve as the basis for new technologies, and their applications may even pave the way for entirely new industries [45,46]. Consequently, the general definition for invention states that, "invention is a process in which a person manipulates both a device-like conception (mental model) and a set of physical artifacts (mechanical representations) in order to create a new object" [5]. Moreover, it is defined as "a psychical super-activity combined with professional competence and refined by social motivation" [37].

Fundamentally, according to Griliches [31] the commercialization of new idea by an inventor depends on the tradeoff between cost and future income. This fact is also endorsed by Goniadis and Varsakelis [47] who highlighted that in a small economy like Greece's financial restraint is one of the most significant external factor in entrepreneurial development. Financial restraint, coupled with the source of knowledge, the perceptions about market opportunities and past business experience, restrict the inventor's decision to start a new venture. So, access to "risk finance" is the main factor that hinders the policy of any organization or country to invest in new risk driven investments usually termed as enhanced entrepreneurial activity. Most of the funding agencies like US Aid, the World Bank and the European Union have recognized this fact and consider financing of risk ventures to be the basis of increases in entrepreneurial ventures.

Carlson and Gorman [5] linked invention with both cognitive and social dimensions and emphasized the fact that intellectual as well as social forces inform the inventor and shape his mind to invent new products. According to authors "invention is a process in which a person manipulates both a device-like conception (mental model) and a set of physical artifacts (mechanical representations) in order to create a new object". The example of the invention of the kinetoscope by Edison is an excellent example which had explained this phenomenon in real world. Hence, if an informed and intellectually motivated learned (conceptually cleared) scholar works simultaneously on the development of mental model as well as the physical mechanical framework of a new idea than a new product of value can be invented.

Weber, Dixon and Llorente [18] presented a "hand tool" as the means to enter the domain of creativity and invention. Authors mention that hand tools are simple inventions like hammers, nuts and bolts, etc., and considered these simple machines the basic building blocks of more complex machines and procedures that these simple tools generate or create. Mechanical inventions were mentioned as results of the 'joining factor' of these tools.

Lyman [17] emphasized the knowledge creation capacities of the knowledge workers in a society. According to the author, the year 2020 will offer knowledge workers the archives of historical data and documentary records relating organizations, machines, nature, the history of science, allied fields and identity. Therefore, the author claimed invention as the mother of necessity.

Fox [30] discussed a do-it-yourself paradigm which altogether changed the way products were manufactured. Under this paradigm "low financial and professional barriers to entry enable ordinary individuals to invent, produce and sell goods". So, all the invention and production mechanisms need web-based selling activity that enables inventions to reach people across the globe. The do-it-yourself invention could revolutionize the manufacturing sector of any country and if adapted and installed with proper planning, could generate wealth for the country. Thus, under this paradigm new do-it-yourself products could be invented, produced and sold to new buyers in newly created markets worldwide.

Johnson & Brown [34] considered factors of technological infrastructure including cumulative research funding, increases in the number of institutions of higher education, or increases in the number of scientists and engineers as the driving force that had the power to bring about an economic revolution in the country. According to authors these were the primary factors which inverted the traditional patterns of inventions in the northwest and southwest countries. So, emphasis on geographical concentration and shifts in policy frameworks based on extensive planning energized American scientists to regain an almost lost position of patent dominance in the world.

Sutthiphisal [16] examined the association between geographical location of invention and production during the era of the second industrial revolution (1870–1910). Authors empirically analyzed the technologically emerging electrical equipment and supplies industry as well as the textile and shoes industry. They reported no association of invention and production locations and argued that due to differences in the industrial production patterns, the variables had no direct association. Technically, highly skilled manpower with relevant technological knowledge had produced larger quantities of technologically driven inventions in the 18th century. In the nineteenth-century the concentration of technically knowledgeable persons devised the rule for cutting edge technology and due to this undeniable fact, Japan, Sweden and Germany dominated in technology-based cutting-edge inventions.

Lettice, Roth & Forstenlechner [35] focused on New Product Development Process and developed knowledge-based performance measurement system. They used measurement cube methodology and argued that "invention without exploitation does not lead to successful new product". Here, exploitation means, effective exploitation of technically developed new product and use of vibrant commercialization strategies to sustain the long-term existence of the product in the market. This argument is true from the knowledge perspective which further extends into reuse of knowledge as well as creation of new knowledge as integral parts of the knowledge value chain. So, creation of new knowledge assets is possible by means of the invention process, portfolio, organization and tools.

Pana [37] emphasized the synthesis of intellectual thinking and invention. Invention is itself a complex system which has the following definition: "it is a psychical super-activity combined with professional competence and refined by social motivation". The 'intellectual invention' is a resultant of renewal of the prevailing cultural system in our societies and the renewal cultural system is based on intellectics and inventics which are established fields of study. Moreover, intellectics, technics and inventics are integral parts of a system that works in harmony to generate intellectual inventions. It is done by managing information intellectually by using expert IT systems in an artificial intelligent environment to foster invention culture.

Harmon [33] argued that invention of new technologies is possible if education of current and past technologies is inculcated to a new generation who is capable of creating and inventing new technologies. These new technology inventors are the intellectual capital of an organization. Moreover, if these newly invented technologies are further refined and modified, they become the intellectual assets of the organization called intellectual property rights or patents. So, the Science-Technology-Innovation (STI) process developed by Harmon is backed by an existing knowledge base in the organization and factors like commitment, motivation, leadership and learning capacity of the inventor/knowledge worker.

Nerkar and Shane [36] argued that the commercialization of technological invention is directly and significantly linked with the scope and pioneering nature of the invention and also has a U-shaped relationship with the age of the invention. So, if a firm has invented a technologically driven product, then its pioneered availability to the target market can create competitive advantage and the firm gets benefits in terms of higher profitability.

Lach and Schankerman [10] undertook research in the USA to examine at what level cash-flows from university inventions affects the licensing revenues generated by universities. In the USA, the royalty income is shared between inventor and university based on set intellectual property policies and royalty sharing schedules. Lach and Schankerman developed a model representing the expected license revenue per faculty, which was determined by revenue earned by invention, commercial value of the invention, the quality effects on the value of the invention and the stochastic shock of model, and it is licensed by the Technology Licensing Office of the university. Lach and Schankerman found that private universities in the USA had generated license income greater than public sector universities. Additionally, strong loyalty incentives were provided by United States universities to their faculty scientists that resulted into greater license income for the inventors. Hence, support in terms of motivation which had originated from encouragement, cash and equipment, facilitated United States faculty scientists to work diligently to produce more intellectually driven inventions that had generated greater license income for the universities.

Clark [20] opened discussion by providing the example of the Massachusetts Institute of Technology (MIT) as a hive of invention, where a specific course on invention is taught to technology interested students. Similarly, a course on invention was designed by Clark at the University of Glamorgan in Wales, UK to teach students of enterprise and business how to invent. The course was focused on developing effective entrepreneurs who have practical business skills and attitudes suited to creating new commercially viable products. Clark further argued that students' ability to imagine and create new categorizations in the mind is necessary step that leads to the stage of critical evaluation of existing ideas or patents. The newly designed course on invention was introduced to the students in the first year of business class and in class alertness exercises and, further-on, creativity was promoted among students. These in-class activities were enhanced and inventive gaps were considered opportunities. The inventive approaches were devised to expedite neural activities fostering invention and more effective entrepreneurial activities were actually generated which resulted in winning two patents: one in UK and other international.

Filho, Tahim, Serafim and Moraes [9] conducted research by considering individual (independent) inventors in Brazil and Peru. The triple helix which comprises government, private firms and universities has been identified as the invention and innovation process which plays a significant role in bringing out individuals' inventions into the marketplace. The individual inventors have been identified as the major contributors towards the increase in patents filed in Brazil and Peru. Filho et al. have claimed that not much research had been done on individual inventors who were always recognized better than corporate inventors because they enjoy freedom of thought and action due to creativity and persistence. The individual inventors have been identified as the drivers of exponential growth in intellectual property rights which foster technological innovation and ultimately the economic development of Brazil and Peru was enhanced. Furthermore, innovations done based on inventions need to be strengthened by introducing innovation policies and a better environment must be created to protect the individual inventors in Brazil and Peru.

An interesting study by Gross, Hanna, Gambhir, Heptonstall and Speirs [32] shed light on the time scale required to transform invention into innovation in the energy sector. Gross et al. considered commercialization of the low carbon technologies which could play a role in the reduction of carbon emissions in the backdrop of the devastation of climate change. According to Gross et al. the process of making energy supply as well as end-use new technologies available to masses takes 20 to 70 years to be widely and properly deployed. The invention to innovation process defined by Gross et al. starts from research and after finding market opportunities for the commercialization of the new low carbon emission energy technology become widespread in the market. The innovation timeline illustrated in the study explains that new technology move through three phases until commercialized in a specified market. These three phases are; development, market formation and growth & diffusion. Initially in the development phase invention of new idea relating technological solution to an existing problem is completed, which go through the processes of designing, testing, application and improvement.

Additionally, during this phase, knowledge is generated relating invention of new technology by means of evaluation, screening and research. Right after this process, the phase of market formation starts, which includes a market formation phase which encompasses research, development and demonstration of newly created technology as a prototype or pilot, also known as the pre-innovation cycle. The accepted performance of the new technology during the prototyping is further tested in a selective market setting normally considered a niche for further enhancement and exploitation of the new technology. In the last phase of the innovation, new technology is then spread throughout the market. The growth phase may further lead to obsolescence of the new technology or may be replaced by a new technology in the marketplace.

Albers, Heimicke, Walter, Basedow, ReiB, Heitger, Ott and Bursac [29] introduced Agile Systems Design for Product Generation Engineering processes. In the absence of holistic understanding of the relevant factors, it is extreme difficult for a product or service to be successful in the marketplace. Therefore, according to Albers et al., product profile definition and explanation during the early stages of product development had been identified as an important process. More emphasis was on the innovation because once invention had been recognized as a satisfactory means of meeting the market demand and successfully penetrated the market it became ready to be transformed into innovation. Albers et al. highlighted Product Generation Engineering (PGE) as the transformation mechanism that bridges the transition of invention into innovation. In this process, Agile Systems Design (ASD) consisted of continuous interaction of operation, objectives and objects systems which work based on available situation and existing need in the market. This ASD as a holistic part of innovation process, as according to Albers et al., consists of multiple phases of product engineering including; analyze, identifying potential, conception, specification, realization and release of the product. Therefore, in this context, product profile had been defined by Albers et al. as, "A product profile is a model of a number of benefits that makes the intended provider, customer and user benefits accessible for validation and explicitly specifies the solution space for the design of a product generation". Thus, Albers et al. established that once an invention had been technically proved as demand-driven output, the product profiles then amplify an innovation after the successful launch in the marketplace.

Ozel and Penin [22] in their work validated university-generated knowledge as a substantial resource for industrial innovation and economic growth. In the last three decades the university-based patents had been increased and licenses delivered to firms had revolutionized the technology transfer channel from universities to industries. The research carried-out relied on the original data relating 91 inventions contained in 62 intellectual property licenses issued to two French universities during the period 2005 to 2014. Ozel and Penin reported that there is no relationship between characteristics of invention and degree of exclusivity either in the cases of generic and embryonic inventions. Furthermore, Ozel and Penin highlighted the significant role of university and industry technology transfer modalities in the case of licensed inventions that could result in superior performance.

Caviggioli, Marco, Montobbio and Ughetto [27] discussed monetization of patents granted to the top 58 universities in the United States as intellectual assets which had been initiated as a federally funded research projects. The technology monetization activities had gained momentum in the academic institutions of America and due to the creation of Institution's Technology Transfer Offices, in 2016, 7021 technology patents had been won by US universities. The research output in the form of a patent by the research centers of the US universities had been monetized by using multiple mechanisms identified by Caviggioli et al. as "market-mediated channels". These mechanisms or monetization processes included licensing agreements, technology transfers, mergers and acquisitions, partnerships agreements, spinoffs and outright sales. It had been reported that 29.7 percent of inventions that had 'patents' registered by the universities in the United States during the study period 2002 to 2010 had been licensed out to be commercialized for regular markets. Caviggioli et al. considered patent value, technical merit, legal robustness, technological complexity and science basicness as the main characteristics of the universities' which had been employed to generated patents during the transaction process in the marketplace. It had been reported that the legally protected patents with technical merit were mostly regarded by the acquirers of new technology in the US market.

2.2. Studies Concerning Open Innovation

Reed, Storrud-Barners and Jessup [40] explored the affects' of open innovation arising from competitive advantage on firm's profitability which is directly linked with controlled intellectual property rights. Authors argued that monopoly and Ricardian rents are the driving forces behind open innovation, which means outsourcing innovation that could be firm controlled, third-party controlled and community controlled. Authors mentioned reputation, employee knowhow, culture, networks and databases as drivers of Ricardian rents. So, Ricardian rents basically arise from owning scarce and valuable resources. Authors signified the importance of community-controlled open innovation because it drives competitive advantage for the firm. Hence, invention leads to innovation and this phenomenon is beneficial for the firm if open innovation is accepted as the source of long-term survival and sustainability of the new product, technology or service in the marketplace.

Lopez and Esteves [24] conducted case study research and analyzed intertwined networks of knowledge acquisition in one of the leading Spanish banks (BBVA). In the comprehensive and extended analyses Lopez and Esteves found that the important components of organizational innovation are internal and external networks along with reorganization of classical structures according to the laid-out rules, processes, procedures and strategies. Therefore, Lopez and Esteves argued that the configuration of external networks requires a good-oriented strategy of knowledge acquisition which guides an organization in identification of possible knowledge requirements and tools necessary to acquire the knowledge. This acquisition process is workable when the decision making process is fast enough to meet the challenges of knowledge acquisition. So, internal networks deal with these challenges and require support from top management that must be available to the people who create innovative solutions to new challenges. Hence, internal and external networks are identified by Lopez and Esteves as "the enablers of knowledge acquisition and appropriation which would be used to promote innovation within the organization".

Al-Belushi, Stead, Gray and Burgess [4] explained that the concept of open innovation was first introduced by Chesbrough [6–8] in his book which defined the transition from a closed to open innovation model for Research and Development firms. The open innovation is defined by him as, "the use of both inflow and outflow of knowledge to improve internal innovation and expand the markets for external exploitation of innovation". The widespread nature of the concept of open innovation rests on the phenomenon of globalization which encourages collaboration among innovation value chains. Therefore, in this context the inbound innovation dimensions are breadth and depth in the number and diversity of firm network collaborations. Al-Belushi, Stead, Gray and Burgess developed and tested a new measure of inbound open innovation of marine bio-industry sector of Oman and reported that open innovation index is a valuable tool to assign scores and rank firms that engaged in open innovation activities.

Sutopo, Astuti and Suryandari [41] highlighted an important aspect of new technology commercialization and measurement efficiency of university research-based technologies marketed by the technology transfer offices. Besides the main objectives of the universities to achieve higher performance in the domains of teaching and education, research and development and public service, new dimension demanding commitment from universities includes; commercialization of research output, autonomy status enhancement and economic development. Therefore, according to Sutopo, Astuti and Suryandari universities need to take concrete measures to improve quality and competitiveness of their technology products which could sustain the transition from technology development to technology commercialization processes. The goals of the technology transfer office need to be defined and measured based on factors which employ policies which foster higher efficiency frontier value. In this context, the commercialization of technology products could be improved if, according to Sutopo, Astuti and Suryandari, the universities ensure significant improvements in marketing assistance strategies, business network expansion, universities internal regulations and strategies, physical facilities and mentoring and couching activities.

Yun, Won and Park [12] argued that in twenty-first century capitalism, firms operating around the globe need to create a medium balance between Market Open Innovation, Closed Open Innovation and Social Open Innovation as a subset economies of Entrepreneurial Cyclical Dynamics of open innovation. These factors had been transformed to formulate a model known as the "system dynamics model" which was further simulated by Yun, Won and Park to identify the U shaped link between subset economies. The Entrepreneurial Cyclical Dynamic model was discussed by considering the economic conditions of South Korea, India and Japan in the context of conglomerates operating in these economies. It was further recommended that firms need to maintain or move to a point in the economic growth where there is a medium balance between sub-economies of the Entrepreneurial Cyclical Dynamics model of open innovation.

Sivam, Dieguez, Ferrira and Silva [28] conducted research to identify factors that significantly contribute towards open innovation in an organization. Sivam et al. collected responses from 25 researchers who were engaged in innovation related activities in a research intensive scientific and technological development institute in Portugal. According to Sivam, Dieguez, Ferrira and Silva the definition of innovation provided in the OECD Manual [48] has been, "An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)". Furthermore, in this context, open innovation is explained as an integrated set of activities that could not function in isolation and therefore is the result of a complex co-creation process that involves knowledge flows through entire social and economic environments which opens the innovation processes to all the participants actively involved in it. Thus, the definition of open innovation brought forward in the study of Chesbrough [6,8] is, "A paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology". This definition involves utilization of internal and external resources available to an organization which relay knowledge management strategies as well as take into account the human side of creative thinking and idea generation mechanisms. Accordingly, it has been argued that innovation is not a linear path, rather it is a dynamic process generated as a result of scientific, technical, business, market research and design efforts. Moreover, Sivam, Dieguez, Ferrira and Silva identified culture, leadership and strategy as the drivers of the open innovation arena and called them conditions that drive innovative dynamics in the form of adaptability, agility and that initiate change in an innovation driven research organization.

Aschehoug, Lodgaard and Schulte [38] discussed the critical nature of maintaining competitive advantage in the marketplace based on the ability and capacity of the companies to bring innovative solutions in the form of shorter life cycle products. These are the inter-company as well as intra-company processes and activities including knowledge management, team formulation, managerial activities, employee motivation and collaboration among the networks. The inbound open innovation technique has been identified as the most widely used process by Norwegian manufacturing companies. Thus, according to Aschehoug, Lodgaard and Schulte, open innovation strategies, along with careful integration of human and managerial aspects, could result in a successful launch of open innovation projects by the companies. This fact is also supported by the study of Hyvarinen Keskinen and Levanen [23] which endorsed knowledge-based innovation management under uncertain and resource constrained environments to maintain competitive advantage in the marketplace.

Yun and Liu [11] had introduced micro and macro dynamic factors and associated them with the Quadruple-helix model. The main factors relating to micro dynamics include open innovation, evolutionary change and a complex adaptive system. However, the main factors relating to macro dynamics include closed open innovation, social open innovation and market open innovation. These micro and macro dynamic factors had been considered as the dynamic factors essential for a firm to gain sustainable growth and prosperity in the fourth industrial revolution. Moreover, a shared economy perspective had been advocated by Yun and Liu which rests on the idea of collaboration among economic stakeholders including government, society, industry and university. Thus, a more comprehensive framework relating sustainable development of economy, society and environment in the context of open innovation had been discussed in the study.

Yun, Zhao, Jung and Yigitcanlar [13] discussed the importance of culture as the major facilitator of innovation in an organization. The main question answered in the study was related to the significance of culture for open innovation dynamics and a model representing "Intrapreneurship leading Culture" was introduced to explain the interaction between three different dimensions of entrepreneurship including entrepreneurship of the novice entrepreneur, intrapreneurship of the employee of an existing organization and organizational entrepreneurship of the firm; these are also called sub-types of entrepreneurship. Therefore, in this study, Yun, Zhao, Jung and Yigitcanlar defined a cultural mechanism required to practically implement open innovation dynamics. The requisite culture, along with its prerequisites, had been suggested as suitable for implementation in an industrial firm as well as in a public sector organization.

Zhu, Xiao, Dong and Gu [44] explained the effectiveness of open innovation in terms of a business model and new product development speed. New Product Development had been considered central for the survival of the firm in the fast-changing global business arena. The conceptual model developed by Zhu, Xiao, Dong and Gu had taken into account two open innovation strategies: the horizontal strategy, called open innovation breadth, and the vertical strategy, named open innovation depth. Furthermore, business model fits had been included as moderating variables for the interrelationship between open innovation and new product development speed. The empirical results of the study had established that both open innovation strategies had positively impacted the new product development speed. Moreover, Zhu, Xiao, Dong and Gu also explained that different types of business models, including efficient as well as novel, should be aligned with the open innovation breadth and depth. In this context, the efficient business model had been identified as the best model fit with open innovation depth, however open innovation depth is best suited for the novel business model.

Vicente-Saez, Gustafsson and Brande [42] opened debate on the new frontiers of the open exploration era the world is currently experiencing, relating new principles and practices of open science and innovation. The open data sharing, open access publishing and participatory designing is fostering the concept of open science and innovation which supports the notion of transparent as well as accessible knowledge that could be shared and developed in a collaborative setting around the globe. Therefore, Vicente-Saez, Gustafsson and Brande discussed the recent developments in policies and practices undertaken by the research teams at universities to adopt as well as adapt new digital technological transformations to revolutionize traditional closed innovation methodologies. Inbound and outbound innovations have been identified as two novel types of open innovation which have been utilized by universities as the mechanism used to harness results from open innovation in a digitalization era. Thus, according to Vicente-Saez, Gustafsson and Brande, openness in innovation is remodeled by the universities based-on new principles, including transparency, accessibility, authorization and participation by using open repositories, open physical labs, a transdisciplinary platform, open source software and digital technologies. Therefore, open innovation has accelerated the learning, creation of new knowledge and research frontiers to find a solution to societal issues and nurture the growth of entrepreneurs.

Yan and Huang [19] conducted a study on the unbeatable success of Huawei based on successful implementation of open innovation policies and strategies in the last three decades. Huawei had developed 5G technology and owned 37 percent of patents relating 5G technology of telecommunication equipment manufacturing. It has been explained that the long-term commitment to invest in Research and Development (R&D) activities are the primary reason for Huawei's success in the global telecommunication sector. Additionally, Huawei expanded its R&D based on an open innovation policy and collaboration with university scholars. Huawei Innovation Research Program (HIRP) developed an open eco-system that encouraged academia and industry linkages and simultaneously enabled co-creation among people, organizations and sectors of the society. The open innovation mechanism, according to Yan and Huang, must support a successful business model which includes value creation and value capture. Huawei became the world technology leader because it invested 14 percent of its sales revenue in R&D activities every year during the last 26 years of its existence. Huawei created the Science and Technology Fund in 1999 to fund top Chinese universities to work on industry related projects. Huawei designed and developed strategic plans to forecast future technological development trends, customer demands and linked R&D issues and thus flagship research projects had been funded and relevant research partner universities were selected. Thus, Huawei adopted a systematic approach and successfully employed open innovation while collaborating with academic partner universities in China.

Erol and Klug [39] discussed the benefits of open innovation in Austria by introducing the concept of a regional open innovation learning lab. This concept rests on the notion that sustainable innovativeness for a firm is possible if open innovation is adopted to share ideas with reliable external parties that could maximize productivity. Erol and Klug had identified two leading factors, which are organizational culture and the practical learning of open innovation. Moreover, educational institutions had been identified as key stakeholders, enablers and partners of innovation systems designed to foster co-innovation in the industrial regions in Austria. Open innovation according to Erol and Klug is a complex endeavor which has been recognized as a key factor for sustainable economic growth and prosperity. The practical significance of these types of arrangements could be a close coordination among SMEs and universities to get benefits from each other in the areas of ideas, expertise and knowledge. Moreover, Erol and Klug, based on interview sessions with 26 managers of industrial companies, had identified academic sphere, policy sphere, citizen sphere and business sphere as the integral components of an open innovation learning lab established in the University of Austria. This learning lab had been considered a learning environment for education institutions which embrace industry 4.0 in such a way that under a roof all the essential infrastructure is available which facilitate learning, ideation, making and meeting for the stakeholders to practice open innovation in an industrial region.

3. Conceptual Understanding

In the light of the cited literature, it is established that invention depends on a necessity/need/want that arises and a call for a solution in terms of fulfillment of that necessity/need/want. This need is either basic or complex, and must first be evaluated by subject experts through a process known as need assessment analysis. This process basically segregates false needs from the true ones. Once the need is identified in true letter and spirit the next step is to find the source of funding to finance the new venture or entrepreneurial activity. So, entrepreneurial access to funds is an essential part of the invention development phase. Market size and invention costs also hinder the production capacity of the invention that reaches the assembly line. So, market and cost benefit analysis is the third but most important part of the invention development process. The process of transformation of new ideas into newly invented products depends on the intellectual and social forces that ultimately shape the mind of the inventor. During this process the scope and pioneering of invention must be the first priority of the inventor in-order to gain competitive advantage in terms of higher profitability. Moreover, the knowledge creation capacity of the knowledge worker (inventor) is considered the driving force which transforms countries into economic powers like America, Europe and of course, certainly the rising country of China [21]. Furthermore, continuity in the advancement and modification of an invention in terms of open innovation must be the forefront strategy of an inventor in-order to maintain pace with the rapidly changing possibilities as well as competitive advantage in the business world. In this context the concept of open innovation is important for the sustainability and survival of the invention in the ever-changing dynamics of the marketplace around the globe. Therefore, open innovation advocates adoption of openness in innovation which calls for remodeling of universities based on new principles including transparency, accessibility, authorization and participation. This is possible by using open repositories, open physical labs, transdisciplinary platforms, open source software and digital technologies to transform the business model of the firm [42]. Thus, utilization of internal and external resources available to an organization, which relays knowledge management strategies as well as takes into account the human side of creative thinking and idea generation mechanisms, is an important facet of open innovation. It is needed today because organizational culture transformation and practical learning of open innovation is required to align different types of business models, including efficient as well as novel, with the open innovation breadth and depth to embrace knowledge-driven industrial revolution 4.0.

4. Discussion

The discussion section is divided into two parts, one deals with the prevailing scenario in the Country and the second elaborates the practical implications of the proposed conceptual model.

4.1. Prevailing Scenario in the Country

Pakistan, as a developing country, has had considerable achievements in establishing basic infrastructure (technological & physical) conducive for R&D activities in the last decade. The Higher Education Commission (HEC), Government of Pakistan has played a vital role in promoting education and research in the country. Multifarious educational and training projects were initiated by the HEC and, as a consequence, research publications from research organizations and universities increased to such a level that the international community has appreciated these efforts and named Pakistan as a "Rising Star". The education and research transformational process adopted by HEC has also been copied by other developing countries. All these efforts have paved the way for those researcher/scholars/scientists/knowledge workers who want to create new products by means of innovation or invention in their respective disciplines of research. The basic driving force behind an inventor is his/her motivation and zeal coupled with conceptual in-depth knowledge that drives him/her towards success; research that is really beneficial for human race is called a paradigm shift [35].

The real achievement in terms of invention and innovation is normally represented by the number of patents filed and won by the researchers of a country [15]. Therefore, in this regard, as a sign of significant growth in terms of invention and innovation, Pakistani researchers had significantly filed patents in the World Intellectual Property Organization (WIPO) [43,49] (WIPO, an agency of the United Nations). From 2000 to 2014 17,875 applications were filed, out of which 4731 were granted. However, 73 patents had been filed and 22 granted to Pakistani universities since 2006. If considering total data available on the WIPO official webpage, the calculations regarding percentage increase in patent applications filed from 1980 to 2014 is 127 percent. Subsequently, in 2018, as of 2019 report by WIPO, Pakistan is ranked 67 in patents, 33 in trademarks and 61 in industrial designs in overall total categories. Mostly the patent applications have been filed by the non-resident Pakistanis compared to the residents. In the case of trademark, residents have filed higher applications equaling around 65 percent compared to non-residents who have applications equaling 35 percent. Similarly, industrial designs have been filed higher by the residents as compared to non-residents. The 2019 WIPO report clearly stated that Pakistan has experienced 27.8 percent rapid growth in the case of patent applications. However, if we look at a report published by Cornell University, INSEAD (the business school for the world originated from Paris, France in 1957), on the Global Innovation Index (GII) [50] Pakistan is ranked 105th in the world. However according to Global Innovation Index [51] Pakistan was at 131st and according to the World Intellectual Property Organization (WIPO) Pakistan in 2013 was ranked 137th in the world. This rank was 109th in 2018 and it improved to 105th in the world in 2019.

This is a significant growth by Pakistan in terms of innovation in terms of growth in institutions, political environment, regulatory environment and business environment, human capital and research in terms of overall education scenario, tertiary education, research and development, infrastructure (which includes information and communication technologies), general infrastructure, ecological sustainability, market sophistication in terms of credit, investment, trade, competition and market scale, business sophistication in terms of knowledge workers, innovation linkages, knowledge absorption, knowledge & technology output in terms of knowledge creation, knowledge impact, knowledge diffusion, creative outputs in terms of intangible assets, creative goods & services, online creativity. Moreover, according to Thomson Reuter's ISI web of science, the research publications done by Pakistani universities have increased substantially during the last five years (2015 to 2019). These figures are encouraging, however more attention and resources are required to expedite the filing and granting of patents as well as to achieve higher ranking in GII in the South Asian region. Open innovation is the solution and way forward for developing countries because economic growth is directly linked with it and it is evident from cited literature that public as well as business policies need to be aligned to achieve the objectives of open innovation in the era of the industrial revolution 4.0.

4.2. Practical Implications

The conceptual model proposed here is comprehensive and dynamic in nature. This is a complex model conceived from existing literature which can be tested practically, which means slashing the complex model into simple regression equations separating the ideologies for invention and innovation. However, an inventor, who is commonly represented in our societies as scholar, scientist or knowledge worker, needs an intellectual environment that fosters the consolidation of idea into a reality. Moreover, an inventor needs full support from all allied departments if he or she is a part of a research organization or a university that belongs to any part of the world. Normally, it is observed in academic or professional settings that high-ranking officials of a university point fingers towards the knowledge worker for the acquisition of funds and manpower to execute research, whether in a lab or office. It is totally inappropriate to isolate a scholar by saying "raise your research productivity level" without providing full support when it is needed the most by the knowledge worker. In this context, delays and prompt provision of necessary support sometimes results into losing success into the hands of another nation who behaves proactively and realizes the importance of invention or innovation in the era of information and the industrial revolution 4.0.

Undeniably, invention-centric research culture that promote open innovation is a prerequisite to support the knowledge worker in his/her pursuit to overcome possible constraints that impede invention or innovation capacities required to serve his/her country. Additionally, a reliable and active network comprised of a trustworthy team is required to launch the new invention or innovation according to the demand of the customers in the market. This means in-time market assessment, knowledge, intelligence and demographics are the key for a successful and sustainable new product or service launch in the market. Therefore, it is evident that the application of the conceptual model (the framework) that has been comprehensively explained relating its processes and linkages needs to be discussed among researchers, academicians, practitioners, industrialists and politicians and among those who are serious in making invention and open innovation central in their pursuit towards gaining a leading edge in the world of highly competitive markets.

5. Conclusions

This conceptual research study used a comprehensive qualitative review of literature to establish that invention is possible and is undoubtedly linked with innovation, that is more appropriately termed open innovation. Additionally, it is very important for scholars and managers to understand the interconnectedness of invention and open innovation processes, which are considered necessary to materialize breakthroughs in a marketplace. Accordingly, an in-depth understanding of invention and open innovation processes and linkages has been illustrated in the flowchart presented as Figure 1 that has been further explained in reference to the cited literature. The extension of invention processes and linkages into open innovation has been identified as an important strategy for a firm to achieve sustainable competitive advantage in an industry. Furthermore, the connection of open innovation with an invention depicts demand-led modifications, which further improves the utility of the new product, technology, process, procedure or service in a marketplace. The essence of this study clearly establishes that invention, as well as open innovation, are a systematic and organized set of interlinked processes and activities, where a scientist, 'the knowledge worker', working with full devotion, dedication and in a meticulous professional manner, contributes significantly to make ideas reality. Hence, it is established with confidence that invention is a doable task and once invention is done open innovation plays a significant role in serving mankind for a longer period of time.

6. Future Research

The conceptual model of the study needs to be empirically tested to justify the processes and linkages of the variables defined in the framework. Moreover, validation of the flow of invention and open innovation need to be strengthened based on additional research conducted in these domains worldwide. Furthermore, expansion of the conceptual framework could be done based-on new research publications in world leading journals. Additionally, more insightful research studies are required to be conducted relating knowledge worker's efforts in making it possible for organizations to create an enabling intellectual environment capable of generating state-of-the-art knowledge-driven products or services at the right time, when world needs them desperately.

7. Policy Implications and Recommendations

This conceptual research study is extremely useful for policy makers to understand and learn the holistic nature of invention and open innovation connectedness in their processes and linkages illustrated in a modeled framework. Industrial policies and practices of global industrial sectors must be aligned in accordance with the demands of the industrial revolution 4.0 which rests on knowledge creation and sharing in a dynamic digital world. In this regard, the leading example of the success of Huawei in China recommends that regimes and organizations across the globe allocate maximum resources for R&D activities in-order to gain maximum benefits from interlinkages of invention and open innovation processes—linkages defined and explained in this research study. Moreover, business models need to be upgraded and modified to practically create inventive as well as open innovative research culture within the network of organizations ecosystem which is capable of achieving sustainable competitive advantage in a marketplace.

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