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Patterns in the Innovative Activities of Ghanaian Manufacturing and Services Firms

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Innovative activities of firms differ with respect to their orientation, intensity, use of internal and external knowledge as well as the factors that necessitated the innovation. Using firm-level data for Ghana, an attempt was made to describe patterns in the innovative activities of Ghanaian Manufacturing and Services firms based on a cluster analysis of some innovation measures. The main aim was to establish which innovative activities were widespread, identify which types of firms tend to be more innovative and ascertain the basic determinants of innovation along any established pattern. Without a proper understanding of these issues, policy makers may easily be misled or made to divert relevant innovation policy away from the needs of firms that needed them the most. The exercise yielded three innovation clusters (patterns), which were characterised by some firm specific-information. One main finding of the study is the establishment of low correspondence between firms that shared similar innovation characteristics (clusters) and sectors. This suggests individual firms seem to dispose of a certain degree of freedom in selecting economically viable innovation strategies even under similar economic and/or technological conditions. More importantly, results from the study suggests that some underlying firm-specific microeconomic processes overcome pressures in the technological nvironment towards homogenous behaviour by firms, even in the same sector.

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1. Introduction

The pattern of innovative activities will not be the same across different industries (Malerba and Orsenigo, 1997). Even within industries, there is much heterogeneity in the innovative behaviour of individual firms (Peneder, 2010). More importantly, these innovative activities can take place over the course of several stages, ranging from basic research to market penetration and by means of the introduction of new products or the introduction of new production techniques (Hollenstein, 2003). Therefore, in order to adequately describe patterns in the innovative activities of firms, different indicators are needed each addressing some specific aspects of a firm's innovative activity. The common way of doing this to be found in the more recent innovation literature is through the use of a system of innovation indicators, as this does not enforce homogenization upon the heterogeneous nature of innovation processes and allows the coexistence of different innovation types even within a particular firm (Arvanitis and Hollenstein, 1998).

Theoretically, differences in the innovative activities of firms emerged from the Schumpeterian literature through the recognition of two such patterns (Malerba and Orsenigo, 1997). The first is the creative destruction pattern whereby innovations are introduced by firms that have never innovated (this is mostly identified as the Schumpeter Mark I pattern). The second is the creative accumulation pattern whereby innovations are introduced by firms that have innovated in the past (this is also identified as the Schumpeter Mark II pattern). More recently, the theoretical literature has argued for the use of technological (learning) regimes, to describe innovation patterns, because of some inherent weaknesses in the use of the Mark I and II patterns (Breschi, Malerba and Orsenigo, 2000). These weaknesses have to do with the failure of Mark I and II patterns to recognize mutual causation between innovation, market structure and firm size and the absence of important explanatory factors relating to the nature of technology. For instance, Levin, Cohen and Mowery (1985) and Cohen and Levin (1989) identified factors such as technological opportunity and appropriability conditions to be very important but absent in the Mark I and II patterns.

The concept of technological regimes therefore addresses these weaknesses in the Mark I and II patterns by using specific combinations of technological opportunities, appropriability of innovations, cumulativeness of technical advances and the properties of knowledge base to describe firms' innovation patterns (Nelson and Winter, 1982 and Winter, 1982). One basic assumption underlying the concept is that firms in the same regime tend to organize innovative behaviour in similar ways and that there is the tendency for such firms to have homogenous behaviour (Leiponen and Drejer, 2007). Indeed, earlier applications of the concept defined technological regimes along industrial boundaries or strategic groups, since such firms are likely to share similar sources of information, ideas about innovations and users that provide ideas and demand for innovation (Leiponen and Drejer, 2007). Yet, there is an alternative argument from the evolutionary economic theory of industry dynamics, which argues that firms, even within the same technological regimes, differ in terms of their innovative behaviour (Leinthal, 1997).

Empirically, the recent studies describing patterns in the innovative activities of firms often refer to the work of Pavitt (1984), who identified three categories of the structural characteristics and organization of innovative firms: supplier-dominated, production intensive and science based firms. Conclusions from his work have been central to explaining the sources and directions of technical change, firm's diversification behaviour, the dynamic relationship between technology and industrial structure and the formation of technological skills and advantages at the level of the firm, the region or country. Since the work of Pavitt (1984), there have been several extensions or revisions to his original work: see for instance, Arvanitis and Hollenstein (1998); Hollenstein, (2003); de Jong and Marsili (2006) and Peneder (2010). Yet, most of these empirical works are for developed countries. For many developing countries, including Ghana, such works are difficult to find due to the non-availability of a comprehensive data on innovation.

Currently, Ghana has developed a national science, technology and innovation policy that, amongst other things, seeks to increase the competitiveness of firms and ensure industrial growth. This is to be achieved through the mastering of firm scientific and technological capabilities, providing a framework for inter-institutional efforts in developing science, technology and innovation programmes in all sectors and the creating of conditions for the improvement of scientific and technological infrastructure for research, development and innovation. More importantly, these policies are to address important development challenges. Unfortunately, no comprehensive study can be found describing patterns in the innovative activities of firms.

This paper therefore attempts to fill this gap by focusing on the innovative activities of Ghanaian manufacturing and services firms and by using a dataset that has extensive information on firm innovation orientation, intensity of innovation, use of internal and external knowledge as well as factors that necessitated the introduction of an innovation. Specifically, the paper uses a classificatory approach to describe patterns in the innovative activities of firms, establish which innovative activities are widespread, identify which types of firms tend to be more innovative and ascertain the basic determinants of innovative activities along any established pattern. The motivation of the paper is twofold. First, it aims to fill the gap on these issues within the context of a developing country. Second, it attempts to establish whether the attempt to develop innovation policy by assuming that firms are homogenous within industries or sectors is valid. Without a proper understanding of these issues, policy makers may easily be misled or made to divert relevant innovation policy away from firms that need them the most.

The main technique for estimation is the cluster analysis of some innovation measures that are comparable to those used in the innovation literature; see for instance Arvanitis and Hollenstein (1998), Hollenstein (2003), de Jong and Marsili (2006) and Peneder (2010). Cluster analysis is a technique used to combine observations that share similar characteristics by finding non-overlapping empirically based typologies or groups for a given set of variables. Indeed, these techniques have been very useful in building innovation taxonomies, as they offer very interesting ways to organize and understand the diversity in innovative activities.

The main results of the paper can be summarized as follows. Three distinct patterns were established and labelled respectively as low, median and high innovators. More generally, very few firms have innovated in all the measures used. This notwithstanding, a greater proportion of the firms are process innovators, implying they have introduced new or significantly improved methods of producing products or offering services. Again, most firms invest in innovation logistics and marketing. In terms of the sources of information about these innovations, the popular sources are the internet and business associations. The types of firms that are found to be more innovative include larger firms, exporting firms, firms whose owners/managers have at least a vocational degree or are engaged in businesses similar to those of their parents. Finally, a low degree of correspondence is observed between the clusters constructed across sectors. Intuitively, this suggests individual firms seem to dispose of a certain degree of freedom in selecting viable innovation strategies even under similar economic and/or technological conditions.

The rest of the paper is structured as follows: the theoretical and empirical literature on patterns in the innovative activities of firms are discussed in the second section of the paper. The database, innovation indicators as well as the estimation techniques used are described in section 3. The empirical results are presented in section 4. Finally, some conclusions are drawn with the proposal of some issues for future research.

2. Literature Review

2.1 Theoretical Literature

The theoretical literature explaining patterns in the innovative activities of firms can be found in the Schumpeterian literature and in two specific themes. The first relates to the fundamental distinction between Schumpeter Mark I and Mark II patterns (see for instance Malerba and Orsenigo, 1997; Breschi, Malerba and Orsenigo, 2000; and Peneder, 2010). The second focuses on the classification of firms along the lines of technological regimes (see Nelson and Winter, 1982 and Winter, 1982). The following paragraphs discusses each of these theoretical perspectives.

The Schumpeter Mark I and Mark II patterns were developed by Nelson and Winter (1982) and Kamien and Schwartz (1982) to characterize the theoretical models of innovation patterns identified by Schumpeter in his books: The Theory of Economic Development (1934) and Capitalism, Socialism and Democracy (1942). Both concepts attempted to describe patterns in the innovative activities of firms by relying on a firms 'time' of innovating relative to its underlying structure. For instance, the Schumpeter Mark I pattern is characterized by a 'creative destruction pattern' with technological ease of entry for firms and a fundamental role played by entrepreneurs and new firms in driving innovative activities. Creative destruction, as defined by Schumpeter (1934), implies the establishment of innovative activities that are outside the range of the existing practice and replaces outdated ones. Accordingly, Mark I firms are characterized by an innovation pattern where new entrepreneurs emerge in an industry with new ideas and innovations, launching new enterprises that challenge established firms and continuously disrupt the most recent methods of production, organization and distribution, thus wiping out the quasi rents associated with previous innovations (Breschi, Malerba and Orsenigo, 2000).

The second pattern, Schumpeter Mark II, are instead characterized by a 'creative accumulation pattern' with the prevalence of large established firms, the presence of relevant barriers to entry for new innovators and the importance of industrial R&D laboratories for technological innovation (Breschi, Malerba and Orsenigo, 2000). Creative accumulation is the process whereby incumbent firms persistently and successfully exploit innovations built on established knowledge (Schumpeter, 1934). According to Breschi, Malerba and Orsenigo (2000), such large established firms with their accumulated stock of knowledge in specific technological areas, their competencies in R&D, production and distribution and their relevant financial resources create relevant barriers to entry for new entrepreneurs and small firms. Therefore, unlike the Schumpeter Mark I pattern where newer firms innovate, older firms innovate in the Schumpeter Mark II pattern. In addition, Mark II firms are more able to protect their innovations while continuously improving upon them, unlike the Mark I firms, which are unable to protect their innovations nor continuously improve upon them (Malerba, 2002).

Malerba and Orsenigo (1997) distinguish between these two innovation patterns by using the concepts of 'widening' and 'deepening', respectively. The widening pattern entails innovative activities that are continuously growing through the entry of new innovators and the erosion of the competitive and technological advantages of other established firms. The deepening pattern, on the other hand, is related to the dominance of a few firms, which are continuously innovating through the accumulation of technological and innovative capabilities overtime.

While the two patterns appear distinct, Klepper (1997) suggests they are not static since changes along the evolution of industries can lead to the transformation of one pattern into another. For instance, Malerba and Orsenigo (1997) alluded that in the industry life cycle viewpoint, a Schumpeter Mark I firm can turn into Schumpeter Mark II and vice versa. Regarding how Mark I firms can evolve into Mark II firms, Malerba and Orsenigo (1997) suggested that early in the history of an industry, when technology is changing very rapidly, uncertainty is very high and barriers to entry are very low. Therefore, new firms are the major innovators and are key elements in industrial dynamics. However, when the industry eventually matures and technological change follows well-defined trajectories, economies of scale, learning curves, barriers to entry and financial resources become important in the competitive process and large firms with monopolistic power come to the forefront of the innovation process (Malerba and Orsenigo, 1997). Malerba and Orsenigo (1997) conversely explained that in the presence of major technological and market discontinuities, a Mark II firm may become a Mark I firm, since new firms that are using new technologies or focusing on new demand can displace incumbents even with monopolistic power.

Several decades, following the emergence of Schumpeter's proposition, different scholarly traditions have attempted to verify these two archetypes of innovation patterns. These scholarly traditions focused on several issues with the first and oldest focusing on the 'market structure and innovation' approach by attempting to test the relationship between the rate of innovation and firm size, on one hand, and monopoly power, on the other hand (Kamien and Schwartz, 1982). However, two widely acknowledged limitations were found. The first had to do with the failure of the existing models to recognize mutual causation between innovation, market structure and firm size (they were best thought as endogenously co-determined) and the second was the absence of important explanatory factors relating to the nature of technology (Nelson and Winter, 1982; and Dasgupta and Stiglitz, 1980). Some scholars, in an attempt to address these limitations, came up with the concept of technological regimes, since they believed that the specific ways in which innovative activities of a technological class can be organized can better be explained as an outcome of different technological (learning) regimes, implied by the nature of technology (Breschi, Malerba and Orsenigo, 2000).

Nelson and Winter (1982) and Winter (1982), who originally came up with this concept, defined technological regimes as the specific combination of technological opportunities, appropriability of innovations, cumulativeness of technical advances and the properties of knowledge base underpinning firms' innovative activities. Particularly, they believed that the concept has major effects on the intensity of innovation, the degree of industrial concentration and the rate of entry in an industry. Accordingly, the concept of technological regimes became another important theoretical explanation for describing patterns in the innovative activities of firm. It needs to be emphasized that the concept also emanates from the Schumpeterian literature, but unlike the propositions underlying the Schumpeter Mark I and II patterns, it adds some details to the intrinsic differences between technologies with the assumption that firms within the same regime are likely to share some proximate features.

As stated earlier, the concept of technological regimes is underpinned by the following: technological opportunities, appropriability of innovations, cumulativeness of technical advances and the properties of knowledge base. Technological opportunities reflect the likelihood of a firm to innovate for any given amount of money invested in search (Breschi, Malerba and Orsenigo, 2000). Therefore, higher technological opportunities implies an economic environment not functionally constrained by scarcity, but provides higher incentives for innovative activities. Appropriability of innovations summarizes the possibilities of protecting innovations from imitations and of reaping profits from the innovative activities (Breschi, Malerba and Orsenigo, 2000). Higher appropriability refers to the existence of methods to successfully protect imitations, thereby increasing the incentive to invest but reduces the positive efficiency effects of technical advances. A lower appropriability, on the other hand, implies an environment with the existence of widespread externalities (Levin et al, 1987).

Cumulativeness of technical advances is related to the fact that today's knowledge and innovative activities form the bases and building blocks of tomorrow's innovations (Breschi, Malerba and Orsenigo, 2000). Therefore, economic environments characterized by continuities in innovative activities have higher levels of cumulativeness. On the other hand, the properties of the knowledge base relates to the nature of knowledge underpinning firms' innovative activities, which could be generic (broad in nature) or specific to an application, tacit or codified and complex or simple (Breschi, Malerba and Orsenigo, 2000 and Malerba and Orsenigo, 1997).

Ever since Nelson and Winter (1982) introduced the concept of technological regimes to characterize the regularities generated by technological and commercial incentives, some empirical works have argued that firms within an industry behave in correlated ways because they share common sources of information and technology and perceive similar opportunities for innovation. In other words, firms in the same industry are likely to have similar users that provide ideas and demand for innovation (Leiponen and Drejer, 2007). This, according to Leiponen and Drejer (2007), suggested "industry boundaries" define the boundaries of technological regimes. Indeed, this view is popular, as many have argued that industries consist of relatively homogenous organizations, differing mainly with respect to size (Leiponen and Drejer, 2007). Yet, some other scholarly papers have argued along the lines of the evolutionary economic theory of industry dynamics to suggest that firms, even within the same industry or technological regime, differ in terms of their innovation behaviour (Leiponen and Drejer, 2007). This is because firms are bounded rational actors that evolve largely through local search that even in the same environment might adopt different strategies provided their landscape is rugged (complex) enough (Levintahl, 1997). In addition, the evolutionary economic theory argued that limitations regarding a firm's ability to acquire and process information as well as differences in expectations about returns to R&D investment might lead to differences in the innovative behaviour and performance of firms in the same industry (see Dosi, 1982; Winter, 1984; Audretsch, 1997; and Yildizoglu, 2001).

2.2 Empirical Literature

Generally, very few empirical studies exist describing patterns in the innovative activities of firms. More importantly, these studies are largely advanced country studies. Currently, the most influential studies are those of Pavitt (1984) and Hatzichronoglou (1997). Pavitt (1984) used data on about 2000 significant innovations in Britain to present an empirical classification of sectoral technological trajectories. He classified industries according to whether they are science based, production intensive (further subdivided into scale intensive production or specialized suppliers) or supplier dominated. His classification was based on sources of technology used, requirements of users and the possibilities of appropriation. Conclusions from his work have been fundamental in explaining the sources and directions of technical change, firm's diversification behaviour, the dynamic relationship between technology and industrial structure and the formation of technological skills and advantages at the level of the firm, the region or country. This classification proved extremely influential and motivated numerous extensions and further refinements (see for instance, Arvanitis and Hollenstein, 1998; Hollenstein, 2003; de Jong and Marsili, 2006 and Peneder, 2010).

Hatzichronoglou (1997), on the other hand, attempted a classification of OECD countries' industrial sectors and manufactures by their levels of technology. The concept of technology intensity was used and defined to include both the level of technology specific to a sector (measured by the ratio of R&D expenditure to value added) and the technology embodied in the purchases of intermediate and capital goods. Four groups of industries were identified: high technology, medium-high-technology, medium-low-technology and low-technology.

In addition to the above-mentioned studies, some other studies have attempted to describe innovative activities based on firm level evidence. These studies include the works of Arvanitis and Hollenstein (1998), Evangelista (2000), Hollenstein (2003), De Jong and Marsili (2006) and Peneder (2010) (see Appendix for a summary of the indicators used and patterns established). The common feature of these works is the use of some innovation indicators, mostly about the orientation, intensity and knowledge sources of innovation, to identify groups of firms that share similar innovation characteristics based on cluster analysis. The intuition behind the technique is simply to identify firms that share similar characteristics by finding non-overlapping, empirically based typologies or groups for the given set of variables. More importantly, the established patterns in the innovative activities of firms tend to be similar to that of Pavitt (1984).

3. Conceptual Framework

Typically, the analytical point of reference in selecting measures that adequately describe patterns in the innovative activities of firms is the typology proposed by Schumpeter that relied on firm size and market structure. However, given the limitations in Schumpeter's typology (which have been highlighted earlier on), the more recent innovation literature takes its starting point from the typology proposed by Pavitt (1984) that relies on information about the sources of technology used, requirements of users and the possibilities of appropriation to describe innovation patterns. Pavitt's measures were based on *a priori* assumptions from previous innovation theories that were possibly supported by data. Subsequently, the recent literature has relied on these measures and usually re-categorises them into the following: innovation indicators and knowledge sources; see Arvanitis and Hollenstein (1998), Hollenstein (2003) de Jong and Marsili (2006) and Peneder (2010). The innovation indicators capture the input and the output sides of innovation. The input side reveals the incentives or wherewithal of innovation; i.e. what are a firm's incentive or abilities to support research (Galbraith, 1952 and Tirole, 1988). These measures mostly include a firm's ability to conduct research and development, employ 'specialists' to undertake innovations or the implementation of new logistics and marketing techniques. On the other hand, the output side deals with the outcomes of the input side; though Link (1980) suggests the output side is not necessarily a monotonic transformation of the input side. The common measures include a firm's ability to introduce new or significantly improved products or methods of production (product and process innovations respectively). For the knowledge sources, both informal and formal sources are used; examples include knowledge from R&D cooperation or information from customers, suppliers or employees. It needs to be emphasized that some other studies tend to add other measures such as managerial capabilities or innovation orientation (de Jong and Marsili, 2006).

For the purposes of this paper, similar innovation measures that are relevant within the context of Ghana are used. In addition, a measure that reflects innovation orientation, but captured in our survey explicitly as the reasons that necessitated the various innovations, is included. Accordingly, the innovation input measures used are the firm's ability to conduct research and development, use innovation specialists, use new logistics and marketing procedures, use foreign licensed technology as well as implement organizational changes. For the output side, product and process innovations as well as equipment upgrade were used. The knowledge sources relied on include information from the internet, conferences, parent companies, trade shows, business associations, customers and suppliers. Regarding the factors that necessitated the various innovations, the following factors appeared relevant: employee recommendation, export and import market requirement, domestic competition and domestic user requirements.

4. Data

The data used for the study was part of a survey conducted in Ghana by the r4d project team of the University of Ghana, over a period of 3 months in 2015, by means of computer-assisted personal interviewing. The survey solicited recall data for 2013 and 2014 from business owners or managers of firms registered with the Association of Ghana Industries (AGI) and the National Board for Small-scale Industries (NBSSI). Firms registered with these institutions were used because of the absence of a more recent industrial census for the country (the most recent as at the time of the survey was conducted in 2003).

A total of 600 firms were initially selected based on a stratified random sample across industry, size and location. Out of this, valid responses were obtained for 428 (i.e. 71% of the sample). This sample corresponds very well to the structure of firms registered with both the AGI and NBSSI, as more than 70% were small-scaled with very few large firms. The firms surveyed were mostly in the manufacturing and services sectors and from seven administrative regions in Ghana: Ashanti, Brong-Ahafo, Western, Central, Eastern, Greater Accra and Volta regions. The survey obtained information on the firm's background, characteristics of owners/managers, production, inputs, revenue, profits, assets, exports, employment, technologies, innovations, foreign direct investments, finances and the broader business environment.

This paper uses data from the section of the survey that asked questions about innovation activities. For instance, firm were asked direct questions relating to innovation input measures such as the conduct of research and development (R&D), ownership of patents, copyrights and websites, employment of persons because of new innovations, their use of foreign licensed technologies and whether firms implemented organizational changes or adopted new logistics and marketing procedures. Firms were again asked questions about innovation output measures such the introduction of new or significantly improved products, equipment and processes. In addition, questions were asked about the sources of information for innovations and what actually necessitated them. Comparatively, these measures are similar to variables mostly used in the theoretical and empirical literature to describe patterns in firm's innovative activities, such as the works of Pavitt (1984), Arvanitis and Hollenstein (1998), Evangelista (2000), Hollenstein (2003), De Jong and Marsili (2006) and Peneder (2010).

The information collected enabled the construction of eight innovation indicators and seven knowledge sources over two years. Three of the indicators referred to innovation output measures, five to innovation input. In addition, seven other variables were constructed to measure the various reasons why firms undertook their respective innovations. These variables together with their measurement scale are presented in Appendix. All the variables are qualitative in nature. Although firms were asked to provide corresponding quantitative measures of some of the variables, such as the cost of R&D and certification procedures, fewer firms responded (especially when compared to the qualitative measures). However, the unavailability of this data is not a hindrance for the purposes of finding innovation patterns as Arvannitis and Hollenstein (1994, 1996) have found the information content of the two measures to be very similar for the purpose. More importantly, the predominant use of many qualitative measures in finding innovation patterns is usually not uncommon in the innovation literature (see Hollenstein, 2003 and De Jong and Marsili, 2006).

Table 1 provides some descriptive statistics about the innovation indicators used. With regards to the innovation output measures, process innovation is slightly more widespread than product innovation: 42% of the firms have implemented process innovations, while 40% have implemented product innovations. For the innovation input measures, a larger proportion of the firms dedicated their time to innovation logistics and marketing (37%). Business associations and the internet were found to be the most general sources of information for innovations (29% and 21% respectively).

Table 1: Description Statistics of the Innovation Measures

Category of Firm	Innovation Indicators	Mean	S. D.
Innovation Output	Product Innovation	0.40	0.46
	Process Innovation	0.42	0.49
	Equipment Upgrade	0.42	0.49
Innovation Input	Research and Development	0.25	0.43
	Innovation Specialists	0.29	0.46
	Innovation Logistics and Marketing	0.37	0.42
	Use of Foreign Licensed Technology	0.29	0.46
	Organizational Change	0.12	0.33
Knowledge Source of Process Innovation	Internet	0.21	0.41
	Conference	0.19	0.40
	Parent Company	0.04	0.20
	Trade Shows	0.20	0.40
	Business Association	0.29	0.46
What Necessitated the Innovation	Parent/Partner Company	0.03	0.17
	Employee from Foreign Company	0.05	0.20
	Competing Firm	0.28	0.42
	Export Market	0.07	0.24
	Import Competition	0.07	0.23
	Multinational Buyer	0.07	0.25

Finally, regarding reasons provided by firms for why the innovations were undertaken, a greater proportion of the firms indicated they carried out the innovation due to competition from other firms. The results are not too different from what is in the literature. For instance, Hollenstein (2002) found a larger proportion of Swiss firms to be process innovators and de Jong and Marsili (2005) found firms in Netherlands to be mostly process innovators.

In a slightly different perspective, an attempt was made to investigate which firms were more innovative by using only the innovation indicators (i.e. the input and output sides). The number of activities undertaken on either the input or output sides of innovation defines the firms innovativeness. In that regard, the measure ranges from 0 to 3 for the innovation output measures and 0 to 6 for the innovation input measures. The real number indicates the exact number of innovative activities carried out. For instance, 0 means no innovative activity was carried out and therefore the firm is not innovative. Table 2a and 2b presents the distribution of these measures.

Table 2a: Distribution of Innovation Output activities (in %)

Sector	0	1	2	3
Manufacturing				
Food, beverages and tobacco	43.20	30.40	15.20	11.20
Textiles, leather and paper	25.76	21.21	30.30	22.73
Wood, construction materials and furniture	21.74	17.39	34.78	26.09
Metals	37.84	18.92	29.73	13.51
Chemicals, rubber and plastic products	22.86	17.14	38.57	21.43
Machinery, motor vehicles and transport	33.33	8.33	33.33	25.00
Office, electrical, communication and medical equipment’s	26.32	15.79	26.32	31.58
Services				
Retail and repairs	60.00	30.00	0.00	10.00
Hotels and restaurants	37.50	25.00	12.50	25.00
Transport	22.22	22.22	22.22	33.33
Financial services	50.00	0.00	25.00	25.00
Business services	38.89	33.33	5.56	22.22
Wholesale	0.00	33.33	66.67	0.00

Construction	25.00	29.17	33.33	12.50
Total	32.94	23.36	25.47	18.22

Table 2b: Distribution of Innovation Input activities (in %)

Sector	0	1	2	3	4	5	6
Manufacturing							
Food, beverages and tobacco	48.00	21.60	10.40	8.80	4.00	4.80	2.40
Textiles, leather and paper	40.91	18.18	19.70	13.64	4.55	3.03	0.00
Wood, construction materials and furniture	43.48	17.39	4.35	26.09	4.35	4.35	0.00
Metals	37.84	10.81	16.22	10.81	16.22	8.11	0.00
Chemicals, rubber and Plastic products	24.29	15.71	12.86	14.29	15.71	15.71	1.43
Machinery, motor vehicles and transport	25.00	0.00	25.00	16.67	8.33	25.00	0.00
Office, electrical, communications and medical equipment's	15.79	15.79	36.84	10.53	21.05	0.00	0.00
Services							
Retail and repairs	60.00	0.00	20.00	20.00	0.00	0.00	0.00
Hotels and restaurant	25.00	62.50	0.00	0.00	0.00	12.50	0.00
Transport	11.11	0.00	11.11	44.44	11.11	22.22	0.00
Financial services	25.00	25.00	0.00	25.00	25.00	0.00	0.00
Business services	27.78	11.11	11.11	27.78	5.56	11.11	5.56
Wholesale	33.33	0.00	0.00	66.67	0.00	0.00	0.00
Construction	25.00	33.33	12.50	8.33	12.50	4.17	4.17
Total	36.45	17.99	14.02	14.02	8.64	7.48	1.40

Regarding the innovation output measures (see Table 2a), about 33% of the firms did not innovate in any of the areas indicated, about 23% did innovate in one of the three areas, 25% innovated in two of the three areas and 18% did innovate in all three areas. Regarding which firms were more innovative for these output measures, it can be observed that firms in the transport sector were the most innovative, as they have the highest proportion of firms that innovated in all three areas (see Table 2a). This was followed very closely by firms in the office, electrical, communication and medical equipment's sector. For the non-innovative firms, those into retail and repair could be made mention of, as they did not undertake any of the innovation output measures considered; this was followed by firms in the food, beverages and tobacco sector.

For the innovation input measures (see Table 2b), about 36% of the firms did not innovate in any of the six areas indicated. Conversely, about 60% of the firms have innovated in at least one of the six areas. Of particular mention are the firms that have innovated in all six areas of the innovation input measures indicated: these are firms in the food, beverages and tobacco sector; chemicals, rubber and plastic products sector; business services sector and the construction sector. One interesting finding is that very few firms in the sample were found to be non-innovative. This is quite different from the work in the literature and especially that of Stephan and Valentina (2014) who found more than half of German firms to be non-innovative using similar definitions.

5. Method of Study

To find the patterns in the innovative activities of the firms surveyed, the study relied on the cluster analysis of the selected innovation measures. By definition, cluster analysis is an art for finding groups in data such that the degree of natural association is high among members within the same class and low between members of different classes (Kaufmann and Rousseuw, 1990). The technique proceeds by arbitrarily choosing group centres (cluster seeds) and individual observations are allocated to the nearest centre. This process, during which close observations are merged and distant ones split, continues until stability is achieved with a certain number of clusters.

There are two ways of finding these clusters: the partition and the hierarchical approach. While the partition approach breaks the data into a pre-set number of non-overlapping groups, the hierarchical approach groups' the data by continuously merging observations with similar characteristics until a specified stopping point is reached. Examples of the partition approach are the Kmeans and Kmedians methods; while that for the hierarchical approach is the Ward's linkage approach. Both approaches use randomly selected starting points, but most studies prefer using the centroids based on squared Euclidian distances, which minimise the distance in scores of observations within a single cluster but maximizes those between clusters. The hierarchical approach allows a visual inspection of the clusters through a dendogram or tree diagram.

This study employed both approaches and used the Kappa chance correlation coefficient of agreement to decide on the most robust option. In using the partition approach, between three and five clusters were initially chosen based on the innovation literature (see for instance Pavitt, 1984; Hatzichronoglou, 1997 and de Jong and Marsili, 2005). Accordingly, Kmeans and Kmedians cluster analysis were conducted for groups between three and five (not presented in the study). In addition, the Ward's linkage approach was conducted and the dendogram pointed towards the direction of three clusters (see Appendix). It needs to be indicated that cluster analysis techniques are highly sensitive to outliers and so the test proposed by Weber (2010) was used to eliminate such outliers. For this study, 10 outliers were detected and these cases (firms) were eliminated from the cluster analysis.

However, the cluster analysis technique was not directly applied to the innovation indicators giving the risk that a single indicator may dominate the outcome of the results or irrelevant (non-discriminative) variables may have been included. Principal component analysis was initially used to reduce the number of dimensions and eliminate measures that were not appropriately correlated with other set of measures used for the analysis (see Everitt, 1993 and Hair *et al*, 1998). Intuitively, principal component analysis identifies patterns or variations in a dataset by converting a set of possibly correlated variables into a set of uncorrelated variables.

In performing the principal component analysis, the extraction technique with varimax rotation was used and the latent root criterion that required that the eigenvalues are greater than one was used to select the appropriate number of factors. To test if the variables were suitable for the component analysis, the KMO measure of sampling adequacy was employed. This test validates the factorability assumption of the analysis by ensuring that there is some degree of correlation between variables. Theoretically, KMO measures should exceed 0.5 (see Kaiser, 1974). For this study, three knowledge sources of innovation (i.e. information from suppliers and customers) and two reasons that necessitated innovations (i.e. recommendation from suppliers and customers) did not have satisfactory measures of sampling adequacy (MSA); their respective MSA's were less than 0.5. They were therefore omitted from the set of variables used to compute the factors.

6. Results

Table 3 presents the preliminary results from the principal component analysis. It contains the rotated factor patterns of the principal component analysis, showing how satisfactory the factors obtained are and how the innovation indicators load onto them (scores greater than 0.4 are deemed satisfactory). As can be observed from the table, a five-dimensional solution was obtained from the principal component analysis explaining 51% of the total variance in the indicators. The first factor, which captures about 21% of the total variance, reveals that at most two dimensions of the innovation input measures and at least one knowledge source of innovation and the reason that necessitated an innovation are properly loaded on factor 1. The second factor, which captures about

11% of the total variance, represents primarily the innovation output measures and one dimension of innovation input. The third factor captures about 7% of the total variance and reflects one dimension of the knowledge sources for innovation and what necessitated an innovation. Factor four (captures about 6% of the total variance) referred mostly to what necessitated an innovation. Lastly, factor five captures about 6% of the total variance and captures some variables about the knowledge source of process innovation. In general, the variables used appeared well loaded onto the selected factors.

Table 3: Factor analysis of the innovation indicators used in cluster analysis

	Innovation Indicators	Rotated factor Pattern (equamax)				
		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Innovation Output	Product Innovation	0.01	0.43	0.06	-0.03	0.23
	Process Innovation	0.06	0.42	0.07	-0.07	0.19
	Equipment Upgrade	-0.10	0.45	-0.03	0.17	-0.28
Innovation Input	Research and Development	0.50	-0.07	0.12	0.12	-0.14
	Innovation Specialists	0.00	0.48	-0.09	-0.11	-0.08
	Innovation Logistics and Marketing	0.42	0.22	-0.02	0.05	-0.04
	Use of Foreign Licensed Technology	0.34	0.12	0.07	0.20	-0.10
	Organizational Change	0.03	0.12	0.37	0.05	-0.13
Knowledge Source of Process Innovation	Internet	0.39	0.01	-0.10	-0.06	0.12
	Conference	0.03	0.01	0.01	0.02	0.49
	Parent Company	0.03	-0.04	0.62	-0.07	0.01
	Trade Shows	-0.10	0.19	-0.08	0.22	0.23
	Business Association	-0.06	-0.06	-0.01	0.04	0.52
What Necessitated the Innovation	Parent/Partner Company	-0.05	0.00	0.63	0.01	0.03
	Employee from Foreign Company	0.50	-0.10	-0.13	-0.20	0.12
	Competing Firm	0.01	0.12	0.07	-0.02	0.38
	Export Market	-0.04	0.07	-0.05	0.52	0.01
	Import Competition	0.12	-0.22	0.08	0.40	0.19
	Multinational Buyer	-0.01	-0.03	-0.04	0.60	-0.03
	Variance of factor	2.17	2.12	1.86	1.81	1.76
	Proportion Explained	21.34%	10.72%	6.91%	6.23%	5.93%

Kaiser's overall MSA	0.79

Note: Results based on varimax rotation

Tables 4 presents the results of the cluster analysis. The results are based on the average scores of the clustering variables (principal components) and the clusters generated are labelled in an ascending order with those obtaining lower scores for each of the measures used found in cluster 1 and those obtaining higher scores in cluster 3. The figures in the table represents the proportion of firms with the attribute in the row. The characteristics of these clusters are discussed next.

Table 4: Profile of Cluster Firms and Innovation Indicators

Category of Firm	Innovation Indicator	Cluster 1	Cluster 2	Cluster 3	F-Value
Innovation Output	Product Innovation	0.17	0.58	0.81	100.29***
	Process Innovation	0.16	0.63	0.87	114.23***
Innovation Input	Equipment Upgrade	0.37	0.35	0.62	8.36***
	Research and Development	0.15	0.08	0.67	70.19***
	Innovation Specialists	0.20	0.26	0.59	24.05***
	Innovation Logistics and Marketing	0.21	0.32	0.85	105.79***
	Use of Foreign Licensed Technology	0.15	0.23	0.77	78.18***
	Organizational Change	0.09	0.06	0.21	5.61***
Knowledge Source of Process Innovation	Internet	0.11	0.17	0.59	52.65***
	Conference	0.03	0.49	0.31	69.61***
	Parent Company	0.03	0.00	0.03	1.32
	Trade Shows	0.07	0.41	0.33	37.00***
	Business Association	0.10	0.69	0.38	84.38***
What Necessitated the Innovation	Parent/Partner Company	0.02	0.00	0.00	1.47
	Employee from Foreign Company	0.01	0.01	0.22	46.27***
	Competing Firm	0.12	0.52	0.46	52.38***
	Export Market	0.01	0.12	0.17	20.14***
	Import Competition	0.01	0.11	0.17	17.45***
	Multinational Buyer	0.01	0.13	0.17	18.24***

Note: * p<.1; ** p<.05; *** p<.01

6.1 Cluster 1

This cluster is the largest in terms of the number of firms (57% of the basic sample): it is dominated by many small firms, though there are a few medium and large firms (see Appendix for the size classification of the clusters). Among the three clusters, this cluster displays the lowest score in almost all dimensions of the innovation indicators used with the exception of equipment upgrade, research and development, organizational change and the reliance on parent or partner companies for innovation knowledge (where it ranked second) (see Table 4). This notwithstanding, the prevalent innovation output type by these firms is equipment upgrade, with this innovations essentially responding to competition from other firms. Generally, firms in this cluster employ the least number of innovation specialists and their dominant source of innovation information is the internet, with that from business associations following very closely.

Regarding the selected firm-specific information, most of these firms are located in the Greater-Accra and Ashanti/Brong-Ahafo regions and seem to vary across all age categories used. In terms of skills decomposition, the cluster is on the average dominated by low skilled employees. Interestingly, the average number of highly skilled workers in this cluster is slightly higher than that of Cluster 2, which is associated with a slightly higher level of innovativeness. In terms of their export orientation, fewer firms in this cluster have ever exported their main products, even though a substantial number (14%) are foreign-owned. Finally, productivity (defined as sales per employee) seems to be positively associated with size within the cluster.

6.2 Cluster 2

This cluster is the second largest (24% of the basic sample): comprised mostly of small firms, with a slightly smaller proportion of medium and large firms (see Appendix). In fact, the proportions of medium and large firms are the smallest across clusters, while that of micro and small firms are the second largest after cluster 1. Among the three clusters, this cluster had the second largest score for all the innovation dimensions used with the exception of equipment upgrade, research and development, organizational change and the reliance on parent companies for innovation knowledge (where it ranked lowest). Not surprisingly, these same factors ranked better (second) in Cluster 1. Generally, firms in this cluster are more innovative than those in cluster 1, but not for Cluster 3. Typically, firms in this cluster do a lot more process innovation than product innovation or equipment upgrade, with the dominant source of knowledge for the process innovation coming from business associations. Comparatively, firms in this cluster employ a slightly higher number of innovation specialist to coordinate their innovations. More importantly, firms in the cluster do most of their innovations in response to competition from other firms.

Considering their firm specific information, firms in the cluster have a significantly larger mean number of low-skilled workers. Conversely, this cluster has the lowest mean of highly skilled workers across clusters. In addition, firms in the cluster are to some extent evenly spread across all the regions where the survey was conducted. In terms of export orientation, most firms in the cluster export their products. In contrast to firms in Cluster 1, fewer firms in this cluster have a foreign ownership component. Finally, productivity is lowest mostly for medium and large firms across clusters; for micro and small, it is the second largest across all clusters.

6.3 Cluster 3

This is the smallest cluster (19% of the basic sample). It is dominated by small firms, though the proportions of both medium and large sized firms across sectors are higher. More importantly, there is a possibility of splitting the cluster into two (from the dendogram), but that was not pursued because of sample size issues. Comparatively, this cluster displays the highest score in almost all dimensions of the selected innovation indicators with the exception of obtaining information from conferences or trade shows and innovating because of a parent company or competing firms; in all these cases, it ranked second (for all these dimensions, Cluster 2 had the highest scores). This notwithstanding, firms in this cluster can be described as the highest innovators as they had the highest averages of all the dimensions of innovation indicated and especially employing innovation specialists, doing more research and development, logistics and marketing and use of foreign technology. For the specific innovation output types, firms in the cluster do a lot more process innovation. Knowledge about most of these innovations mostly come from the internet.

In terms of the firm specific information, these firms are mostly small and medium, and located in the Greater Accra and Ashanti/Brong-Ahafo Regions. Firms in this cluster have the highest mean of all skill types across clusters. They also have the highest means for both export orientation and foreign ownership. Productivity in the cluster, increases with firm size, and is the highest across clusters with the exception of large firms where firms in Cluster 1 had the highest productivity.

6.4 Validation of Results

As suggested by Milligan and Cooper (1987), a basic requirement for the validation of such results is to find significant differences in the variables across clusters. De Jong and Marsili (2006), for instance, use the multivariate analysis of variance test and the one-way analyses of variance test to check for differences between innovating clusters (groups). For the purposes of this study, both tests were conducted and significant differences were found in all the variables by cluster (Pillai's Trace F-Value = 32.73 and $p<0.001$; F values of the ANOVA results are reported in Table 4 with all but 2 variables being statistically significant). Besides, validity is supported in the similarity of the work with that of Arvanitis and Hollenstein (1998; 1999), who also derived three clusters with size classifications and level of innovativeness similar to this work. In some respects, results of this study are also comparable to that of de Jong and Marsili (2006). For instance, firms in Cluster 1 share some traits with their supplier-dominated cluster, while those in Cluster 2 share some traits with resource-intensive firms.

6.5 The basic determinants of Innovation

This section uses information from the clusters to find the basic determinants of innovation and validate the earlier results of which types of firms tend to be more innovative. The difference between results in this section and that from Tables 2a and 2b is the use of all measures of innovation. Accordingly, innovativeness is defined by clusters and a regression analysis is conducted on some explanatory variables used in the literature such as information about the workforce employed and other firm-related variables (see Brunow and Nafts, 2014). Because there is a clear order in the clusters, the dependent variable can be defined as a limited dependent variable taking on values ranging from 1 to 3 (lowest to highest innovators). With this type of information, the ordered logit is appropriate, as it delivers consistent and unbiased estimates.

Results of the marginal effects from the logit model are presented in Table 5. As can be observed from the table, the basic determinants of innovation include the size of the firm, its exporting status, education and family involvement in the same business. Specifically, the types of firms that are likely to be more innovative include larger firms, exporting firms, firms whose owners have at least a vocational degree or whose parents are engaged in the same business as their parents. This is because the probability of innovating increases with these variables and across the clusters respectively. These results are similarly to what Robson, Haugh and Obeng (2009) found for Ghana, but using a different framework of analysis. On the other hand, the probability of innovating decreases with the number of low skilled workers. In addition, it can be observed that firms located in Tema and Central/Western zones (relative to Accra) tend to be more innovative. Indeed, these zones are the major Free Zones areas and contain a lot more exporting firms.

Table 5: Average Marginal Effects for the change in Probabilities

	Cluster 1	Cluster 2	Cluster 3
Firm Size	-0.16***	0.06***	0.106***
Wage per Worker	0.00	0.00	0.00
Age of Firm	0.01	-0.00	-0.01
High Skilled Workers	0.00	-0.01	-0.01
Medium Skilled Workers	-0.01	0.00	0.01
Low Skilled Workers	0.01*	-0.00*	-0.01*
Exporting	-0.13***	0.05***	0.09***
Education of Owner (Vocational and Above)	-0.14***	0.05***	0.09***
Parents previously engaged in Business	-0.09*	0.03*	0.06*
Foreign Ownership	-0.07	0.02	0.04
Female Dummy	-0.06	0.02	0.04

Zone			
2. Ashanti /Brong-Ahafo	-0.07	0.03	0.04
3. Central/Western	-0.33***	0.08***	0.26***
4. Eastern/Volta	-0.04	0.02	0.03
5. Tema	-0.17***	0.06***	0.11**
Sector			
Textiles, leather and paper	-0.22***	0.08***	0.14***
Wood, construction materials and furniture	-0.15	0.06	0.08
Metals	-0.03	0.01	0.01
Chemicals, rubber and plastic products	-0.29***	0.10***	0.19***
Machinery, motor vehicles and transport	-0.40***	0.09***	0.31**
Office, electrical, communication and medical equip.	-0.14	0.06	0.08
Retail and repairs	-0.04	0.02	0.02
Hotels and restaurants	-0.27*	0.09***	0.18
Transport	-0.08	0.04	0.04
Financial services	-0.02	0.01	0.01
Business services	-0.08	0.04	0.04
Wholesale	0.20	-0.12	-0.08*
Construction	-0.05	0.02	0.02

Lastly, it can be observed that firms in the following sectors tend to be more innovative (relative to the food, beverages and tobacco): Textiles, leather and paper; Chemicals, rubber and plastic products; Machinery, motor vehicles and transport; and Hotels and restaurants. These results are not too different from earlier results in Tables 3a and 3b.

6.6 The relationship between clusters and sectors

Table 6 shows the characterization of the innovation clusters by sectors. The table is used to ascertain whether the popular attempt to develop innovation policy by assuming that firms are homogenous within industries or sectors and varying only by size is valid. This to a large extent test the relevance of the evolutionary economic theory of industry dynamics that suggests that firms even within the same industry may have different innovation behaviours. The results suggests very significant differences between sectors and clusters.

Generally, a positively low correspondence was established between the sectors and the clusters. More importantly, the results remain unchanged even if firms that were less than three within a cluster were excluded. This result is supported by a statistically significant value of the Goodman-Kruskal gamma, which tendsto suggest that firms seem to dispose of a certain degree of freedom in selecting economically viable innovation strategies even under similar technological conditions. This suggests there might be some underlying processes that overcome pressures in the technological environment towards homogenous behaviour by firms. For instance, results from the earlier sections suggested variables such as exporting status and location were statistically significant variables affecting the probability of innovation.

Table 6: Profile of Cluster Firms by Sector

Sector	Overall	Cluster 1	Cluster 2	Cluster 3
Manufacturing				
Food, beverages and tobacco	122.00	83.00	26.00	13.00
Textiles, leather and paper	66.00	35.00	18.00	13.00
Wood, construction materials and furniture	23.00	10.00	11.00	2.00
Metals	37.00	24.00	6.00	7.00
Chemicals, rubber and plastic products	66.00	27.00	16.00	23.00
Machinery, motor vehicles and transport	11.00	5.00	3.00	3.00
Office, electrical, communication and medical equipment's	18.00	9.00	4.00	5.00
Services				
Retail and repairs	10.00	7.00	3.00	0.00
Hotels and restaurants	8.00	3.00	4.00	1.00
Transport	9.00	5.00	1.00	3.00
Financial services	4.00	3.00	0.00	1.00

Business services	17.00	11.00	2.00	4.00
Wholesale	3.00	2.00	1.00	0.00
Construction	24.00	14.00	7.00	3.00

Note: Goodman–Kruskal gamma = 0.1351 ASE = 0.055; Figures represents the number of firms with the attribute in the row column

7. Conclusions

This paper has described patterns in the innovative activities of Ghanaian manufacturing and services firms. This was based on the Schumpeterian theoretical perspective and more importantly, the analytical typology proposed by Pavitt (1984) as well as several other later revisions. The main aim of the study was to establish whether there are any apparent patterns in the innovative activities of Ghanaian manufacturing and services firms, establish which innovative activities are widespread, identify which types of firms tend to be more innovative and ascertain the basic determinants of innovation along any established pattern. The basic essence is to contribute to the literature on innovation among firms in developing countries.

The main results of the paper can be summarized as follows. Three distinct patterns are established, with most firms found in the group that tend to be less innovative. The basic distinguishing factors between this group of firms and the others is their predominant upgrade of the equipment, conduct of research and development, organizational changes and the reliance on parent or partner companies for innovation. More importantly, a greater proportion of all the firms surveyed are found to be process innovators. These firms also generally invested much into innovation logistics and marketing. Generally, most of the firms employ persons because of the innovative activities being introduced. In terms of information about innovations, the popular sources are the internet and business associations. The types of firms that are found to be more innovative include larger firms, exporting firms, firms whose owners/managers have at least a vocational degree or who are engaged in similar business as their parents. Conversely, the number of low skilled workers were found to reduce the probability of a firm to innovate. Unfortunately, not much could be learned about the sectoral boundaries relevant in describing firm innovative activities. This is because of the low degree of correspondence between cluster and sector. Stated differently, innovation patterns do not seem to follow sectoral definitions. Intuitively, this suggests individual firms seem to dispose of a certain degree of freedom in selecting economically viable innovation strategies even under similar conditions. More importantly, the results suggests there might be some underlying processes that overcome pressures in the technological environment towards homogenous behaviour by firms, thereby laying credence to the evolutionary economic theory of industry dynamics.

Comparatively, the results of the study are not completely different from those found in the literature. For instance, the results about the pattern in the innovative activities established (i.e. characteristics of the clusters developed) are quite similar to those found in the works of Arvanitis and Hollenstein (1994; 1996) and de Jong and Marsili (2006). Besides, the results about the characteristics of firms that innovated were similar to the work of Robson, Haugh and Obeng (2009) for Ghana. Lastly, Leiponen and Drejer (2007) similarly found innovation patterns not to follow sectoral definitions, which are mostly informed by firm size.

For policy purposes, especially in assessing and shaping innovation policy, the attempt to assume that sectors consist of relatively homogenous firms that differed mostly by size needs to be reconsidered. This is because of the finding of the low degree of correspondence that exists between firms that shared similar innovation characteristics (clusters) and sectors. More importantly, this finding implies the inclusion of other relevant information that are critical in affecting the probability of a firm to innovate in the formulating innovation policy for the country. For instance, in addition to the size of a firm, a firm's exporting status as well as its physical location were found to be statistically significant in affecting its probability to innovate. This could be incorporated in the formulation of innovation policy for the country. For further studies, an attempt to verify the long-term performance of the different innovation indicators will be paramount in establishing their sustainability overtime.

8. References

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APPENDIX A: Innovation Indicators

Dimension	Variable	Description
Innovation Output	Product Innovation	Mean Score of two items (Cronbach's alpha=0.89) 1. Firm introduced new or significantly improved products and services for the past two year (yes/no) 2. Firm introduced a product new to the market in the past two years (yes/no)
	Process Innovation	Firm introduced any new or significantly improved methods of producing products or offering services for the past two years (yes/no)
	Equipment Upgrade	Firm upgraded its equipment's for the past two years (yes/no)
Innovation Input	Research and Development	Firm spent on formal research and development (R&D) activities, either in-house or contracted with other companies for the past two years (yes/no)
	Innovation Specialists	Firm increased employments levels because of innovations (new product, new process or improved organizational structure) (yes/no)
	Innovation Logistics	Mean Score of two items (Cronbach's alpha=0.70) 1. Firm introduced new or significantly improved logistics, delivery, or distribution methods for the past two years (yes/no) 2. Firm introduced new or significantly improved marketing methods for the past two years (yes/no)
	Use of Foreign Licensed Technology	Firm at present use technology licensed from a foreign-owned company excluding office software (yes/no)
	Organizational Change	Firm introduced new or significantly improved organizational structure or management practice for the past two years (yes/no)
Sources of Innovation	Internet	Firm acquired new method of production through the internet (yes/no)
	Conference	Firm acquired new method of production through a Conference (yes/no)
	Parent Company	Firm acquired new method of production through a Parent Company (yes/no)
	Trade Shows	Firm acquired new method of production through a Trade Show (yes/no)
	Business Association	Firm acquired new method of production through a Business Association (yes/no)
	Others (Suppliers and Consumers)	Firm acquired new method of production through Other Sources (Suppliers, Customers, Internal Development) (yes/no)

Dimension	Variable	Description
What necessitated the innovation	Parent/Partner Company	Mean Score of two items (Cronbach's alpha=0.90) 1. Firm introduce new products based on recommendations from Parent/Partner Company (yes/no) 2. Firm introduce new processes based on recommendations from Parent/Partner Company (yes/no)
	Employee from Foreign Company	Mean Score of two items (Cronbach's alpha=0.76) 1. Firm introduce new products based on recommendations from an Employee from Foreign Company (yes/no) 2. Firm introduce new processes based on recommendations from an Employee from Foreign Company (yes/no)
	Competing Firm	Mean Score of two items (Cronbach's alpha=0.84) 1. Firm introduce new products because Competing Firms introduced new products (yes/no) 2. Firm introduce new processes because of Competing Firms introduced new processes (yes/no)
	Export Market	Mean Score of two items (Cronbach's alpha=0.89) 1. Firm introduce new products to enter Export Market (yes/no) 2. Firm introduce new processes to enter Export Market (yes/no)
	Import Competition	Mean Score of two items (Cronbach's alpha=0.78) 1. Firm introduce new products because of new import Competition (yes/no) 2. Firm introduce new processes because of New Import Competition (yes/no)
	Multinational Buyer	Mean Score of two items (Cronbach's alpha=0.88) 1. Firm introduce new products to meet requirements of a Multinational Buyer (yes/no) 2. Firm introduce new processes to meet requirements of a Multinational Buyer (yes/no)
	Others (Suppliers and Consumers)	1. Firm introduce new products because of other reasons (Consumers, Suppliers, Internal Development) (yes/no)

Dimension	Variable	Description
		2. Firm introduce new processes because of other reasons (Consumers, Suppliers, Internal Development) (yes/no)

Appendix B: Summary of Empirical Literature

Author	Relevant Dimensions and Variables	Data Source	Industry Classification	Method
Arvanitis and Hollenstein (1998)	Innovation intensity: inputs (R&D, design) and outputs (innovations' value and shares of innovative sales); Sources of knowledge: other firms, institutions, universally accessible information and other inputs (machinery, licenses, personnel)	Swiss KOF-ETH innovation survey 1996; 516 firms with more than 5 employees	Manufacturing: Five Clusters	Firm level Factor Analysis and Clustering
Evangelista (2000)	Innovation intensity: innovation costs per employees, % innovators; Nature of innovation: ratio of product on process innovation; Type of innovation inputs: R&D, design, software, training, machinery, marketing; Sources of information: internal (R&D lab) and external (other firms, institutions, etc.); Innovation strategies: objectives of innovation (market driven, efficiency, etc.)	ISTAT-CNR innovation survey 1997; 19,000 firms with more than 20 employees	Services: technology users, S&T based, interactive and IT based and technical consultancy	Sector level Factor analysis and clustering
Hollenstein (2003)	Innovation-related factors (appropriability, etc.) and Several structural properties of firms (size, etc.)	Swiss Innovation Survey, 1999	Services: Five Clusters	Firm Level Factor/Cluster Analysis
De Jong and Marsili (2006)	Innovation output (product and process); Innovation input (budget, capacity, specialists); Source of innovation (suppliers, customers and scientific development); Managerial Attitude (innovation orientation); Innovation planning (documented plans); External orientation (consultation of external sources and inter-firm cooperation)	EIM Business and Policy Research Data, 2003; 2985 firms with employees not more than 100	Manufacturing and Services: Supplier-dominated, Specialised suppliers, science-based and Resource-intensive	Firm level Factor Analysis and Clustering
Peneder (2010)	Input intensity: labour; capital; advertising sales ratio; R&D sales ratio	Expenditure by investment	Manufacturing: technology-driven, capital intensive, marketing driven,	Sector level Factor analysis and clustering

		category in US firms	labour intensive and mainstream manufacturing	

Appendix C: Profile of Cluster Firms and Some Selected Structural Characteristics

	Overall	Cluster 1	Cluster 2	Cluster 3
Activity Field				
Manufacturing	343 (82.1%)	193 (81.1%)	84 (82.4%)	66 (84.6%)
Services	75 (17.9%)	45 (18.9%)	18 (17.7%)	12 (15.38)
Total Employments				
Micro (0-4)	81 (19.4%)	56 (23.5%)	21 (21%)	4 (5.1%)
Small (5-29)	212 (50.7)	120 (50.4%)	61 (60%)	31 (39.7%)
Medium (30-99)	71 (17%)	38 (16%)	8 (7.8%)	25 (32.1%)
Large (>100)	54 (12.92)	24 (10.1%)	12 (11.8%)	18 (23.1%)
Age of Firm				
Less than 5	50 (12%)	38 (16%)	6 (6%)	6 (8%)
5 – 9	85 (20.3%)	50 (21%)	18 (17.7%)	17 (21.8%)
10 – 14	60 (14.4%)	27 (11.3%)	16 (15.7%)	17 (21.8%)
15 – 19	79 (18.9%)	43 (18.1%)	20 (19.6%)	16 (20.1%)
20 and more	144 (34.5%)	80 (33.6%)	42 (41.2%)	22 (28.2%)
Location				
Greater Accra	127 (30.3%)	81 (34.1%)	21 (20.6)	25 (32.1%)
Ashanti/Brong-Ahafo	98 (23.4%)	60 (25.2%)	17(16.7%)	21 (26.9%)
Central/Western	62 (14.8%)	26 (10.9%)	22 (21.6%)	14 (17.9%)
Eastern/Volta	70 (16.8%)	41 (17.2%)	22 (21.6%)	7 (8.9%)
Tema	61 (14.6%)	30 (12.6%)	20 (19.6%)	11 (14.1%)
Skills Decomposition				
Proportion of Highly Skilled	7.1	6.3	5.2	12.3
Proportion of Medium Skilled	5.0	3.5	3.8	10.8
Proportion of Low Skilled	28.6	26.1	28.3	36.8
Export Orientation				
Has ever exported its Products	0.32	0.27	0.36	0.44
Foreign Direct Investments				
Percentage of Foreign Ownership	0.12	0.12	0.09	0.14
Productivity				
(Sales/Permanent Employees)				
Micro (0-4)	21,280.66	20,893.65	19,268.52	38,333.33
Small (5-29)	303,588.5	176,007.7	288,887.2	887,895.7
Medium (30-99)	2,287,317	1,237,091	1,209,652	4,045,534
Large (>100)	8,717,812	13,300,000	4,041,926	4,950,627

Note: The first section are frequencies and the second, average scores.
Figures in the first section represents the proportion of firms with the attribute in the row column

Appendix D: Dendogram