ABSTRACT

In recent years there has been a paradigm shift in the way firms conduct innovation. The new paradigm is that of open innovation. This paper analyzes this phenomenon in the context of co-creation of value. The objective of this paper is to provide an analytical framework for open innovation and co-creation of value. The alternative business models companies use for pursuing innovation are discussed. The drivers for open innovation for select industries are identified. Industry-specific analytical models that relate these drivers to the intensity of open innovation are developed.

KEYWORDS: Innovation, Open Innovation, Business Models for Innovation, Co-Creation, Value Co-Creation

INTRODUCTION

In recent years, no other topic has captured the attention of policy makers - in both developed and emerging economies - business leaders, and business scholars as innovation. In developed countries, strategic importance is attached to innovation. It is seen as a way out of economic stagnation and for maintaining the edge of developed countries in the global economic system. Leaders in those countries are emphasizing policies to promote innovation and create innovation driven economies (Obama’s Speech 2011, European Commission 2010). For businesses, it is the performance dimension on which they will compete more intensely in order to remain competitive in the world markets in presence of low-wage, high-growth nations such as China and India. Newly emerged economic powers such as China and India also view innovation strategically as one of the means to increase - if not maintain - the growth rate of their economies (Wooldridge 2010). Meanwhile, the concept of innovation itself is undergoing changes in its interpretation and implementation. Many recent research and popular articles and books have been written on these changes in the conceptualization of innovation e.g., disruptive, frugal and reverse innovations (Wooldridge, 2010; Christensen, 1997; Christensen and Raynor, 2003; Inmelt et al., 2009).

When it comes to any discussion on innovation one has to first carefully define the meaning of the term. A major confusion is between innovation and invention. The term innovation as used in the paper can be defined as the creation of new and/or changes in product, process, way of doing business that adds economic value to the consumer, the firm, other stakeholders of the firm and the economy. As such it is quite different from an invention which can and often leads to innovations. What distinguishes innovation from inventions and creative ideas is that it creates economic value. For instance, Leonardo da Vinci was far ahead of his time in terms of
ideas. His sketches show concepts for flying machines (Flying Machines 2014). But they remained as ideas and the conditions for turning them into innovations did not exist until a century ago. While there is a greater supply of inventions and ideas - as the number of patents would indicate for instance - innovations are much harder to come by.

This paper is organized as follows. Section II provides a review of the literature on open or networked innovation and co-creation. In section III, the different business models for implementing innovation and co-creation of value are discussed with illustrative examples. In section IV, the key sector-specific drivers of open innovation are presented and discussed. In section V, analytical models that relate the intensity level of open innovation to the drivers are specified. Null hypotheses for empirical testing of the model are also specified. Conclusions follow in section VI.

II. LITERATURE REVIEW

In recent years there have been major changes in the modalities of implementing innovations. Increasingly, innovations are generated and implemented through user-centered, collaborative and open modalities (von Hippel, 2009; Huston and Sakkab, 2006; Chesbrough, 2009). An observed trend is for organizations to look outside for innovation ideas (see Chart 1). The corporate model of R&D is giving way to decentralized R&D which in case of multinational firms is often dispersed around the globe. An advantage of this external collaboration is that innovation takes place not inside of a hierarchy but in a network. With network innovation a company is able to leverage the ideas of thousands of scientists and technologists with diverse backgrounds who are not its full-time employees. The chances of finding good ideas are increased by casting the net far and wide. And thanks to the Internet, reaching so many people has never been easier. But, for this collaboration to work, organizations have to learn to leverage effectively and efficiently the — wisdom of the crowds. Partnerships now play a vital role in technology commercialization (see Chart 1). Such partnerships while creating new opportunities also create new challenges in terms of partner selection and protection of proprietary knowledge.
In Germany, initiatives such as the Kompetenznetze or network competence cluster involving: financial institutions; universities and research institutes; large enterprises and small and medium enterprises (SMEs) focus on portfolios such as biotechnology; micro/nano/opto segments; new materials and chemistry; aviation and space; health and medical science; energy and environment; information and communications technologies; and production and engineering (Kompetenznetze Deutschland Initiative, 2011). The objective of the cluster is to facilitate: internationalization; cross-mapping networks of innovation; and network-based competency development and financing. The constituency in network competence clusters comprises mostly of SMEs having about 50% stake; followed by large enterprises having a 10% stake; and 30% stake comprising research universities and institutes (Kompetenznetze Deutschland Initiative, 2008).

In the U.S., the last three decades have witnessed the passage of legislation designed to encourage technology commercialization. For example, the National Competitiveness Technology Transfer Act of 1989 has enabled private firms access to the technologies and research facilities of the national laboratories through cooperative research and development agreements (CRADAs). The same act has also altered the mission of the national laboratories. The transfer and commercialization of their technologies is an important part of their mission.

Open Innovation and Co-Creation

Firms are moving away from the paradigm of closed innovation involving vertically integrated processes of research and development within closed architectures that primarily focus on in-sourcing of commercializing the concepts. There are several factors that have contributed to the erosion of the closed innovation model. Some of these factors include growing organizational mobility of highly skilled professionals who are aware of options outside their organization to commercialize their ideas; availability of private venture capital to back start-ups which commercialize research; reduced shelf life of technologies; and availability of new technologies such as the internet that enable collaboration in new ways. Chesbrough (2003) proposes the concept of open innovation where firms harness internal and external ideas and leverage their research and development (R&D) portfolio beyond the boundaries of the firm. This creates new opportunities for enhancing the value of the intellectual property of the firm. An organization can integrate the external sources of innovation to create additional value for internal innovations through the licensing of R&D portfolio or spin-offs (see Figure 1).
Open innovation is not to be confused with outsourcing of R&D. In the latter, part or whole of R&D work is transferred to outside providers. But in the case of open innovation, ideas from outside are evaluated and channeled through the internal R&D department. The internal pathway for moving projects from research through development to the market need not be used only for ideas generated internally. In open innovation, projects originating from outside can also use this pathway. Conversely, internal projects may find an external pathway for commercialization (see Figure 1).

Open innovation is now able to facilitate additional value creation along with (Regional Innovation Systems) RIS by involving the regional clusters. Unlike the closed innovation models, open innovation models takes into consideration the increasing complexity in innovation processes such as: R&D units that are increasingly becoming dynamic in collaborations involving advanced technology segments; growing availability and demand for knowledge workers (Kogut and Almeida, 1999; Chesbrough, 2003; Kramer, 2011); converging industries (Choi and Valikangas, 2001; Kramer, 2011); and the need for private venture capital markets and diversification in supplier partnerships (Christopherson et al., 2008; Chesbrough, 2009; Steinle and Scheile, 2008; Kramer, 2011).

The challenge of open innovation paradigm is in bringing B2B and B2C interactions across network infrastructures within a common framework as existing architectures and processes to develop products, services and create value follow the closed innovation paradigm. One implication of open innovation is that participating businesses, suppliers and customers get involved at various stages of project management. For this to happen effectively and efficiently, properly designed and structured processes that transcend the boundaries of the firm are necessary.
A related concept that has gained currency in the business literature is co-creation of value. Its relationship to open innovation needs to be clarified. Prahalad and Ramaswamy (2004) have stated “The meaning of value and the process of value creation are rapidly shifting from a product and firm-centric view to personalized customer experiences. Informed, networked, empowered, and active customers are increasingly co-creating value with the firm.” Customers, businesses and other entities are increasingly co-creating value in the area of social computing; internet and electronic commerce. The difference between open innovation and co-creation is that the latter focuses on involving the customer directly into the development of products, services or value with the firm. The concept of innovation as used in this paper has the inherent property of value creation. Thus open innovation when it involves customers and/or lead users (von Hippel, 2009) is essentially the same as co-creation of value.

A review of the literature suggests that research on open innovation and co-creation is primarily conceptual and descriptive involving frameworks, case studies and examples (Bell and Loane, 2010; Ramaswamy and Gouillart, 2010; Agarwal et al., 2008). This paper makes a contribution to the literature by proposing empirically testable analytical models. This approach will help in generating insights for understanding the phenomenon of open innovation in a more rigorous way. A distinguishing feature of these models is that they are tailored to different sectors, and avoid the one-size-fits-all approach.

III. BUSINESS MODELS FOR INNOVATION

Companies have used a variety of business models for realizing the value of innovation. The business models range from closed to open and can broadly be classified as 1) Closed; 2) Cooperative; 3) Collaborative; 4) Co-creative (see Figure 2)

![Figure 2: Business Models for Innovation](image-url)
Open innovation model is not suited for any company – “although a trend toward open innovation is observed open innovation is not an imperative for every company and every innovator” (Gassman, 2006). It is more relevant for companies that are seeking breakthrough innovations. If strong execution is the key component of a company’s strategy (e.g., General Electric which has promoted the practice of Six Sigma on a large scale), protection of intellectual property is a critical issue, and the company is doing unique things that others may not be able to contribute to, then a process for open innovation is not necessary. Sometimes, client expectations play a role. For instance, in professional and financial services conservative, risk averse behavior is expected. Being more open to be more innovative may not be the right thing to do in that culture. Chart 2 shows that though open innovation is becoming increasingly important, internal R&D continues to be more prevalent across all sectors than externally sourced R&D and external knowledge (Golightly et al., 2012).

**Chart 2: Innovation Sources**

![Innovation sources across different sectors](image)

ICT – Information and Communication Technologies; FMCG – Fast Moving Consumer Goods
Source: Golightly et al. 2012.

Toyota applies co-opetition as a knowledge co-creation strategy for multi-technological innovation. This involves integration of processes related to the development, manufacturing and production within the company along with the integration of activities of supplier-networks (Wilhem and Kohlbacher, 2011). This has helped Toyota develop an approach that is close to incremental innovation. Co-opetition requires both cooperation and competition during the knowledge sharing activities and knowledge creation activities of the carmaker and its supplier-
networks. Knowledge sharing is related to enhancing the intellectual competency of the firm over its existing knowledge and knowledge creation is related to exploration that helps the firm develop new knowledge portfolios in the area of expertise. Cooperation is related to the knowledge sharing activities between the firm and the supplier-networks while competition is related to knowledge creation that is encouraged among competing suppliers. Toyota does not apply open innovation to its multi-technological innovation method in the automotive sector but is applying it in the Toyota Heart Project that develops humanoid robots. Toyota has been able to develop the required co-competitive tension required to develop joint ventures for multi-technological innovation.

The co-competition strategy depends upon a greater degree of network governance from the carmaker that is able to encourage the process management of suppliers. The keiretsu or the corporate governance system within automakers in Japan competes with the supplier network rather than with the market. The notion of competition and cooperation is specific to the Japanese automotive industry and may vary in other countries. However, Toyota has been able to initiate joint ventures with European companies specifically governing its own development, manufacturing and production portfolios along with the integration of European procurement portfolio into its production and operations management.

Procter and Gamble (P&G) gets more than 30% of its ideas for new products and services through R&D in which outsiders participate. P&G had designed a network to implement its “connect and develop” model of open innovation. It consists of key suppliers and technology entrepreneurs worldwide who form a proprietary network and technology intermediaries like Ninesigma and Innocentive who are part of an open network. Innocentive facilitates open innovation of needs-based concepts and ideas on the internet by inviting participants from across the globe. Through trial and error P&G has developed a process to manage this network (Huston and Sakkab, 2006) thereby increasing its research productivity by more than 60% and more than doubling its innovation success rate.

Open innovation has brought about cooperation between businesses that allows for agreements for sharing basic research such as those between IBM, AT&T Bell Laboratories and Cisco, Intel Corporation and Microsoft. These firms are able to create additional value by incorporating concepts that are both internal and external to the firm. Intel Corporation has been able to set up R&D units in close proximity to university research groups facilitating the exchange of knowledge through cooperative agreements. Firms are entering into research partnerships with technology entrepreneurs and smaller firms and cooperative research and development agreements (CRADAs) with national labs and universities in the U.S. European telephone makers were able to create a pool of GSM patents at an affordable cost through cooperative agreements. This provided a cost advantage for firms accessing the patents.

Collaborations between businesses such as Dell, Fujitsu, Hitachi, HP, IBM, NEC and Sun in open source development of operating systems in computing have brought down costs. This approach has been used by telecommunications service providers such as Alcatel, Cisco, Ericsson, NEC, Nokia, NTT and Toshiba. The microprocessor industry has also benefited from collaborations in open source development for businesses like AMD, Intel and Transmeta. They make use of complementary R&D portfolios, licensing and spin-offs. Apple Incorporated’s collaboration with news media companies, its iTunes platform and app pages signifies another approach to open innovation.

Nike’s NikeID page allows customers to co-create designs of sneakers in real time before purchase. In electronic commerce, Amazon.com is an example of a business to business (B2B)
and business to customer (B2C) framework for collaboration, cooperation and co-creation. IKEA follows the model of co-creation by involving the customer in co-assembling products after design selection of furniture and its purchase.

An example of applying co-creation to the field of education involved students in a graduate school at Kyoto University in Japan collaborating with a manufacturing firm. In a live project demonstrating the usefulness of information systems design in developing a new product, the students were able to define the effectiveness of the co-creation system in project management (Ohara, 2008).

In the non-business social sphere, open source software development has led to great advances in social computing and social networking. Apache servers; the Eclipse platform for Java software developers; the Linux operating system; Web browsers; the MySQL Open source database and Mailing Software are all examples of open source software development that have been successful and are offered free to customers.

IV. DRIVERS OF OPEN INNOVATION

There are many technological factors, motivations (e.g., economic, social and intellectual) and developments (e.g., social networking) that are driving the level and intensity of open innovation. Technology platforms for businesses; size of the firm; rate of technological change; disruptive technologies; resources of firms; competitive environment and costs; core competencies; R&D portfolios; development of operating systems software; social computing; social networking; electronic commerce; internet and microprocessing are all drivers of open innovation and co-creation (Chesbrough et al., 2006; Grover and Kohli, 2012; Rai et al., 2012; Messinger et al., 2009; Shang et al., 2011; Wagner and Majchrzak, 2007; Riedel et al., 2013).

The list of drivers given above is too broad for an analytical explanation of the phenomenon of open innovation. For this a sector/industry specific approach is necessary. A one-size fits all approach will not be useful as different sectors are at different stages of maturity with respect to innovation and the drivers of open innovation are not all the same. A study done at the Big Innovation Centre in the U.K. (Golightly et al., 2012) focuses on the market characteristics of the different sectors. Based on data gathered through interviews and surveys the study identifies key drivers that affect the degree of open innovation in each sector. For instance, information and Communications Technology (ICT) sector is characterized by rapidly growing demand, disruptive technologies, short lifecycle of technologies where scaling up quickly is possible. Very different set of factors are at play in the pharmaceutical industry which is R&D intensive and where the very survival of the firms depend on innovation for developing new drugs and drug making processes. Long lead times, complex regulations and high R&D costs make this sector quite distinct from the ICT sector. Advanced manufacturing is similar to pharmaceutical sector in that R&D costs are high and time-to-market is long. The demand in this sector is sensitive to public spending as traditionally it has depended on defense and public procurements, at least in the U.K. The firms face competitive pressures from emerging economies. Whereas in the FMCG (Fast Moving Consumer Goods) sector there is rapid consumer-led product innovation of incremental type and speed-to-market is important. Companies such as Unilever and P&G have been the earliest adopters of open innovation with globally dispersed R&D centers that incorporate knowledge about needs and requirements of local markets. In the Energy and Utilities sector environmental concerns and related regulations have driven innovations to reduce carbon emissions and develop clean and renewable energy sources. Technologies such as mobile banking and its integration for use of Big Data and analytics have driven innovation in the financial services industry. The entire media industry has been greatly disrupted by digital
technologies for producing and distributing news and services. The print media sales have declined rapidly. Using the digital media to create new businesses with archived content and reach new customers is driving innovation in this sector. Table 1 summarizes the status of open innovation, the drivers and characteristics of the various sectors.

### Table 1: Open Innovation in Sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Status of Open Innovation</th>
<th>Drivers of Open Innovation</th>
<th>Sector Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT</td>
<td>OI maturity is high. Innovation in products and processes is usually very high, and moves quickly.</td>
<td>Rapid growth of start-ups, disruption of business and technology, mobile computing.</td>
<td>Very high customer demand, technology innovation by SMEs and start-ups.</td>
</tr>
<tr>
<td>Pharmaceutical</td>
<td>Shift from the ‘chemical paradigm’ to the search for innovative therapies requiring mixed disciplines and integration of technologies.</td>
<td>Regulatory pressure, time pressure to bring drug to market, and cost reduction are other drivers for innovation.</td>
<td>Driven by incremental and radical innovation where the product and process innovation takes more time than other market sectors.</td>
</tr>
<tr>
<td>Advanced Manufacturing</td>
<td>OI still an emerging concept and the key challenge is to balance ‘openness’ with ‘security’. Cultural challenges prevalent.</td>
<td>Dynamic markets, huge R&amp;D costs reduction, shrinking public sector budgets, competition from emerging economies.</td>
<td>Partnerships common, however traditional supply chain management approaches often used. Innovation in SMEs prominent, particularly in growing, tech-enabled, security market.</td>
</tr>
<tr>
<td>Sector</td>
<td>Open Innovation Maturity</td>
<td>Competition and Market Characteristics</td>
<td>Consumer Demand Characteristics</td>
</tr>
<tr>
<td>-------------------------</td>
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</tr>
<tr>
<td>FMCG</td>
<td>Ol maturity is high due to continuous incremental innovation.</td>
<td>Competition is high and the market is very demanding. Short life of products, rapidly moving market and, customer needs.</td>
<td>Consumer demand is high. Markets move very quickly, hence product innovation is very high.</td>
</tr>
<tr>
<td>Energy and Utilities</td>
<td>Ol maturity is low as the R&amp;D in Energy sector is complex. Due to the huge role of different players (state, large and small firms) the process of innovation is convoluted.</td>
<td>Increase in energy requirements and tighter carbon regulations. Emerging technologies and shift to renewable and sustainable energy.</td>
<td>A number of collaborations in UK supported by govt. bodies has enabled significant R&amp;D and innovation. New technologies are in pipeline to support the renewable energy targets and companies are exploring OI to achieve it.</td>
</tr>
<tr>
<td>Business &amp; Financial Services</td>
<td>Firms have followed traditional routes of innovation but are now experimenting with new approaches.</td>
<td>Advances in (mobile) technology, changing markets and a difficult economic climate are pushing new business models.</td>
<td>Traditional markets, low risk taking ability in innovation process. Lack of IP protection for processes or investment models limits desire for openness.</td>
</tr>
<tr>
<td>Media</td>
<td>Transformation from print to digital media. More digital platforms are being created through product innovation. Open Innovation is being embraced to preserve incumbents’ market share.</td>
<td>The digital revolution has challenged traditional print and broadcasting, particularly mobile technology. New players and business models have emerged.</td>
<td>Fast moving market, enabling new platforms and better reachability to customers.</td>
</tr>
</tbody>
</table>

ICT – Information and Communication Technologies; FMCG – Fast Moving Consumer Goods
Source: 2012 report on *Realising the Value of Open Innovation* by the Big Innovation Centre.
V. ANALYTICAL MODELS FOR OPEN INNOVATION

The sector-specific drivers of open innovation summarized in Table 1 suggest and form the basis for the following analytical models for explaining the level of open innovation taking place in a particular sector.

The general model can be specified as $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_iX_i + \ldots + i = 1, 2, 3, \ldots, n$ where $Y$ = intensity or level of open innovation and co-creation measured by monetary value of open innovation co-creation projects. This is measured by amount invested in open innovation projects. It is the sum total of open innovation project * amount invested in each project. The independent variables $X_i, i = 1, 2, 3, \ldots, n$, for each sector are derived from the drivers of open innovation given in Table 1.

The sector-specific models are given in the following Table 2. Each null hypothesis is to be interpreted as follows. If it is hypothesized that increases in $X_i$ will lead to $Y$ then this implies that slope coefficient $b_i$ in the multiple regression model is positive/negative. For example, if we hypothesize that increases in the level of competition in a sector is likely to increase the level of open innovation, then, for empirical testing purposes, it is equivalent to the hypothesis that slope coefficient associated with the independent variable Herfindahl-Hirschman Index (which is a measure of competition, smaller the value of this index greater the competition) is negative.
### Table 2: Multiple Regression Models for Intensity Level of Open Innovation

<table>
<thead>
<tr>
<th>Sector</th>
<th>Drivers</th>
<th>Null Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT</td>
<td>$x_1 = \text{Growth rate of start ups (last five years)}$</td>
<td>$b_1 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_2 = \text{Number of new disruptive technologies (last five years)}$</td>
<td>$b_2 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_3 = \text{Index of mobile computing use}$</td>
<td>$b_3 &gt; 0$</td>
</tr>
<tr>
<td>Pharmaceutical</td>
<td>$x_1 = \text{Number of regulations that affect growth (last five years)}$</td>
<td>$b_1 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_2 = \text{Number of new drugs introduced in the market (industry average for last five years)}$</td>
<td>$b_2 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_3 = \text{Cost index (industry average for last five years)}$</td>
<td>$b_3 &gt; 0$</td>
</tr>
<tr>
<td>Advanced Manufacturing</td>
<td>$x_1 = \text{R&amp;D cost index (industry average)}$</td>
<td>$b_1 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_2 = \text{Public sector budgets}$</td>
<td>$b_2 &lt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_3 = \text{Competition in industry (measured by Herfindahl-Hirschman index)}$</td>
<td>$b_3 &lt; 0$</td>
</tr>
<tr>
<td>FMCG</td>
<td>$x_1 = \text{Competition in industry (measured by Herfindahl-Hirschman index)}$</td>
<td>$b_1 &lt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_2 = \text{Shelf life of products (industry average)}$</td>
<td>$b_2 &lt; 0$</td>
</tr>
<tr>
<td>Energy and Utilities</td>
<td>$x_1 = \text{Energy demand}$</td>
<td>$b_1 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_2 = \text{Number of carbon related regulations}$</td>
<td>$b_2 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_3 = \text{Number of new energy technologies}$</td>
<td>$b_3 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_4 = \text{Kwh of energy used from renewable and sustainable sources}$</td>
<td>$b_4 &gt; 0$</td>
</tr>
<tr>
<td>Business and Financial Services</td>
<td>$x_1 = \text{Mobile technology advances}$</td>
<td>$b_1 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_2 = \text{Number of customers from new markets}$</td>
<td>$b_2 &gt; 0$</td>
</tr>
<tr>
<td>Media</td>
<td>$x_1 = \text{Penetration of mobile technology (measured by readership via mobile technology)}$</td>
<td>$b_1 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_2 = \text{Number of new players in industry (measured by Herfindahl-Hirschman index)}$</td>
<td>$b_2 &gt; 0$</td>
</tr>
<tr>
<td></td>
<td>$x_3 = \text{Number of new business models}$</td>
<td>$b_3 &gt; 0$</td>
</tr>
</tbody>
</table>

See References section for note on Herfindahl–Hirschman Index.

These models are useful at the sector level for understanding the level of open innovation. They can be adapted for a firm’s use by including in the model, firm-specific factors such as size, spending on R&D, and the level of competition faced by the firm.

### VI. CONCLUSIONS

Research studies of open innovation and value co-creation have been mainly descriptive in nature. This paper provides an analytical framework that relates the level of open innovation in an industry to the factors that drive the open innovation phenomenon in the same industry. These models can be empirically tested. It should be noted that these models do not explain the
benefits accruing to the firm that engages in open innovation. For that purpose, a different analytical model, one that relates the performance metrics for open innovation to the enablers of open innovation is necessary.

REFERENCES


"The term “HHI” means the Herfindahl–Hirschman Index, a commonly accepted measure of market concentration. The HHI is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. For example, for a market consisting of four firms with shares of 30, 30, 20, and 20 percent, the HHI is 2,600 (30^2 + 30^2 + 20^2 + 20^2 = 2,600). The HHI takes into account the relative size distribution of the firms in a market. It approaches zero when a market is occupied by a large number of firms of relatively equal size and reaches its maximum of 10,000 points when a market is controlled by a single firm. The HHI increases both as the number of firms in the market decreases and as the disparity in size between those firms increases."