02-20-AP04-4866

SUSTAINABILITY OF PROPRIETARY TECHNOLOGY CONCEPTS, PLATFORMS AND ECOSYSTEMS

DR. DHRUPAD MATHUR[1]

ABSTRACT

This research is aimed at identifying and enlisting various diverse factors that lead up to the sustainability of technology concepts, platforms and ecosystems. This would potentially pave the way for systemising such factors and subsequently help in developing various combinations of business strategies and practices to enhance the sustainability of technology concept platforms and ecosystems, and also show a path for possible transformation. This paper recognises various prominent factors, such as: user preference, non-substitutable nature, rareness, inimitable, valuable, sales, pricing, profitability, communicating with the market, strategic signals, flexibility of firms, community, organisation and human capacity, knowledge, innovation, interdependent relationships among multiple technologies, perceived uncertainties, competitiveness, early action, industry standards etc. It also argues that the types of market and the nature of industry in which the technology concept operates also plays an important role in determining the sustainability or scope of possible tech transformation.

Keywords: proprietary technologies, tech sustainability framework, technology transformation

INTRODUCTION

This working paper serves as a foundation for an intended case study that would attempt to identify and analyse various factors leading up to the emergence, evolution, sustainability and extinction of various proprietary technology concepts, platforms and ecosystems. As per the definition by Financial Times, "[t]echnology ecosystems are product platforms defined by core components made by the platform owner and complemented by applications made by autonomous companies in the periphery. These ecosystems offer solutions comprising a larger system of use than the original platform owner created and solve important technical problems within in an industry." In the last two decades, various proprietary technology concepts and platforms have emerged both in the consumer technology and industrial engineering domains. Some of these technology platforms have emerged and survived while some have not.

The Gartner's Hype Cycle model, which is a graphical depiction of a common pattern that arises with each new technology or innovation, explains how technology triggers inflated expectations. However, when new technology concepts and platforms emerge, their route to commercialisation and mainstream adoption is quite uncertain. There are a number of examples of new technology concepts that have emerged and vanished – from "pagers" to "push to talk" technologies, and from "magnetic discs" to "optical storage". These have all been through their period of struggle only to have outlived their utility or useful life. In the wake of the evolution of new technology platforms, it is interesting to explore how market forces behave, how consumers behave, how the consumption patterns change, and what type of business environment dynamics lead to the success or failure of new concepts. This research and the proposed case study aims to bring out a range of pertinent examples from consumer and industrial technologies to establish the path taken by such technology concepts from inception to maturity. It would also attempt to identify the patterns of successful evolution against the background of technology landscape across diverse business ecosystems. One of the key

[1] Associate Professor – IT Mgt. and Assistant Dean – Executive MBA, SP Jain School of Global Management, Dubai, United Arab Emirates. Email: dhrupad.mathur@spjain.org

outcomes of the case study would be to discover major strategic manoeuvres undertaken by successful proprietary technology platform companies that ensure their sustenance and rapid growth. Further, it will also unravel areas of possible tech transformations.

PROBLEM IDENTIFICATION

Adomavicius et al. (2007) argued that the technology ecosystem is a system of interrelated technologies that influence each other's evolution and development, and that a specific technology ecosystem view is defined around a focal technology in a given context.

Amidst the complex dynamics of technology markets, a discussion on proprietary technology sustainability is particularly pertinent today. Over the last few decades, there have been major developments in consumer market technologies as well industrial technologies. Most of these developments have been steered by some pioneering companies (or individuals) who have invested in the related R&D and brought new concepts to market, leading to the development of new market opportunities and enhanced user experience. Advances in semiconductor technologies and the rapid emergence of very large-scale integration has certainly fostered this phenomenon. In the last decade, this pace has increased dramatically due to major technological innovations, and the reducing cost of processing, connectivity and storage etc. Therefore, the tech innovators as well as the technology adopters are faced with an ever-standing challenge of constantly reviewing and evaluating a wide range of new technological concepts and solutions and working towards their mainstream adoption. On one side, there is a constant stream of emerging technologies hitting almost every industry ecosystem, while on the other side there are mature technologies being phased out or that have outlived their useful life.

In the banking industry, for instance, a wide range of scenarios depicting the impact of technology emergence and obsolescence can be observed. While the last few years have added technologies such as e-payments, mobile payments, secured credit cards, near field communication, biometrics etc. to the payment processing portfolio, on one hand, on the other hand the recent situation around the Windows XP discontinuation by Microsoft impacting most ATMs (Automated Teller Machines) is a good example of what can go wrong when even mature technologies in established business ecosystems undergo obsolescence. And in this case the impact of obsolescence could have been quite severe – a CNN report mentions that banks everywhere are in a race against time to upgrade their ATMs before they become hot targets for hackers (Paglirey, 2014).

Dao and Zmud (2015) concluded that to increase the likelihoods of success, innovating firms use strategic signals to communicate with market participants to reduce participants' perceived uncertainties associated with their innovative products. They examined that during a standards war involving a technology-based product, the influence of technology -, market- and standards-related strategic signals on the stock price of one of the technology leaders. (A technology leader is defined as a firm that develops and promotes its proprietary product design to become the industry standard.) Using event study methodology, the authors found that a technology leader's market- and standards-related signals have significant positive influences on this leader's stock price. However, to what extent this market leadership position could be sustained continues to be a persistent question.

RESEARCH PROBLEM

Waite (2006), in his study of the sustainability of the performance of technology innovator firms on business environments exhibiting turbulence, claimed that the combination of business strategies and practices that tends to enhance the sustainability of performance has been the subject of only a modest number of scholarly studies, but has been at the forefront of corporate agendas for decades. He also mentioned that dramatic shifts in performance and

industry standing occur frequently among firms that develop technology products and services, the "technology innovators", in part because these firms operate in external business environments that tend to be turbulent. The literature does not offer a formal definition of sustainability of performance, nor a method for determining the level of sustainability.

While a lot of work has been done to gauge the acceptance of technology by various stakeholders across industries, the question of the sustainability of technology concepts and platforms, which is very significant from a business performance point of view, has not been adequately addressed in the academic literature. Davis (1989) postulated a popular framework for technology acceptance called the Technology Acceptance Model. However, there are no specific frameworks addressing the business sustainability of technology concepts or platforms.

Kelly and Rice (2002) concluded that in dynamic, technology-dependent environments, firms can take action to protect their unique technologies from imitation, but they cannot protect these technologies from obsolescence. Their strategic decisions must take into account the complex array of technologies that are needed to maintain competitiveness in technology-based industries and the short window through which a particular technology can maintain its value. New firms may need to take action – early on – to maximise the value of their unique technologies.

The business sustainability of technology concepts, platforms and ecosystems is an intricate affair and there are no straightforward approaches to gauging the sustainability of a technology concept. Hence, this pertinent issue of the sustainability of technology concepts is therefore the key research problem being investigated here.

OBJECTIVES OF THE RESEARCH

The objectives of this research are to identify and enlist various diverse factors that lead to the sustainability of technology concepts. This would potentially pave the way for systemising these factors and later help in developing various combinations of business strategies and practices that will enhance the sustainability of technology concepts and platforms. In future, this research can be extended to develop strategic frameworks or models based on the factors identified by the means of the proposed business case-based approach.

SCOPE OF THE STUDY

Looking at the vast expanse of the technology landscape and the myriad possible combinations of factors leading up to sustainability, this study in its present form would entail an extensive exploratory study through qualitative research to identify the key factors across various industries utilising technology. The research therefore would be focused on identifying and enlisting such factors based on leading academic papers and various industry examples.

SURVEY OF LITERATURE

Business sustainability is closely related to competitive advantage; however, it goes beyond competitive advantage in terms of its impact through its continuous derivation of value for all stakeholders and by providing sustained growth and opportunities for technology businesses. The million-dollar question in today's business environment is how to sustain a technology that has attained competitive advantage or market leadership over time.

Vonderembse and Ragu-Nathan (2013) described that when barriers to entry are limited, technologies often contribute little to a firm's long-term competitive advantage. Their research argues that a manufacturing firm's proprietary technologies can overcome this limitation because they are rare, inimitable, valuable and non-substitutable. Technologies, which are dedicated by suppliers to meet a manufacturer's needs, are also a part of a firm's strategic assets. Based on 201 responses from senior managers and executives at US manufacturers,

their results show that proprietary technologies positively influence suppliers' dedicated technologies. In addition, these two types of technology influence in different ways a manufacturing firm's flexibility and its competitive advantage. Proprietary technologies indirectly impact flexibility and directly impact competitive advantage, while suppliers' dedicated technologies directly impact flexibility and indirectly impact competitive advantage. The combination of the two technology resources creates the overall success for the manufacturer.

Economides and Katsamakas (2006) elucidated that technology platforms, such as Microsoft Windows, are the hubs of technology industries. They compared industry structures based on a proprietary platform (such as Windows) with those based on an open source platform (such as Linux), and analysed the structure of competition and industry implications in terms of pricing, sales, profitability and social welfare. They found that when the platform is proprietary, the equilibrium prices for the platform, the applications and the platform access fee for applications may be below marginal cost, and they characterised demand conditions that lead to this.

They further explained that the proprietary applications sector of an industry based on an open source platform may be more profitable than the total profits of a proprietary platform industry. When users have a strong preference for application variety, the total profits of the proprietary industry are larger than the total profits of an industry based on an open source platform. The variety of applications is larger when the platform is open source. When a system based on an open source platform with an independent proprietary application competes with a proprietary system, the proprietary system is likely to dominate the open source platform industry both in terms of market share and profitability. This may explain the dominance of Microsoft in the market for PC operating systems.

Adomavicius et al. (2007) proposed a new conceptual model for understanding technology evolution that highlights dynamic and highly interdependent relationships among multiple technologies. They argued that, instead of considering technologies in isolation, technology evolution is best viewed as a dynamic system or ecosystem that includes a variety of interrelated technologies. By considering the interdependent nature of technology evolution, they identified three roles that technologies play within a technology ecosystem: components; products and applications; and support and infrastructure. Technologies within an ecosystem interact through these roles and impact each other's evolution. They also classified types of interactions between technology roles, which they termed "paths of influence". They demonstrated the use of their proposed model through examples of wireless networking (Wi-Fi) technologies and a business mini-case on the digital music industry.

Coeurderoy and Durand (2004) emphasised that turning a proprietary technology into a competitive advantage is a critical challenge for pioneers, and it should be defined thoroughly and related to the chosen strategic orientation. In particular, they have shown that pioneers should move carefully towards cost leadership strategies, even if they see these at first glance as the best way of dominating the business. A second stream of research would determine the consequences of both order of entry and proprietary technologies on a firm's overall performance. Pioneer effect has always been related to market share. However, its long-term effect on performance is still unclear.

Kauffman and Mohtadi (2004) in their study of proprietary platform procurement systems mentioned that proprietary platform procurement systems involve traditional electronic data interchange technologies and that open platform procurement systems are associated with e-market web technologies. Hybrid platforms involve elements of both. They mentioned that results explain the coexistence of both proprietary and open platforms, showing that larger firms tend to adopt costlier procurement technology solutions, such as proprietary electronic data interchange, which provides greater supply certainty. Smaller firms adopt less

costly procurement technologies that entail greater supply uncertainties, such as open platform procurement systems. Two guidelines emerge for practitioners: (1) the adoption of standard e-procurement platforms needs to be understood in terms of the controllable risk trade-offs that are offered to small and large firms; and (2) gauging the business value impacts of exogenous shocks is critical to decision-making.

Chengalur-Smith, Nevo and Demertzoglou (2010) discovered that organisations are increasingly interested in exploring Free/Libre Open Source Software-based technologies as viable alternatives to proprietary or commercial solutions, but research on the business value of such technologies is lacking. However, their findings suggest that in order to realise the benefits from open source infrastructure technologies, organisations should have the human and technological capacities to absorb and utilise them as well as the ability to establish, maintain and leverage ties with the technologies' communities of developers and users.

Gawer and Cusumano (2008) described that an industry platform involves not only one company's technology or service but also an ecosystem of complements to it that are usually produced by a variety of businesses. As a result, becoming a platform leader requires different business and technology strategies than those needed to launch a successful stand-alone product. Companies should decide early on whether they want to pursue a platform or a product strategy. The authors describe two fundamental approaches to building platform leadership, which they call "coring" and "tipping". Coring is using a set of techniques to create a platform by making a technology core to a particular technological system and market. When pursuing a coring strategy, would-be platform leaders should think about issues such as how to make it easy for third parties to provide add-ons to the technology and how to encourage third-party companies to create complementary innovations. Tipping is the set of activities that helps a company tip a market toward its platform rather than some other potential one. Another tipping strategy is for a company to bundle features from an adjacent market into its existing platform; the authors call this "tipping across markets".

Lichtenthaler, Ernst and Conley (2011) identified the difficulty in profiting from proprietary technology. They emphasised that in today's challenging economy, many industrial companies are trying to capture additional value from their technologies by licensing their intellectual property to other organisations, including direct competitors. By licensing their proprietary technology, companies attempt to achieve a sufficient return on R&D, and licensing often goes beyond a marginal activity involving residual technology. To identify organisational success factors for technology licensing, they conducted a benchmarking study in medium-sized and large industrial European companies. After analysing the academic and managerial literature on technology licensing, they carried out exploratory interviews with 35 experts in 25 companies to gain a detailed understanding of organising for technology licensing. The findings from this study underscore that strategic intent alone is insufficient for profiting from licensing.

Rong et al. (2013) studied how the technological ecosystem extension facilitates technology substitution in an emerging industry. The paper focuses on: (1) the technological ecosystem with an expanded scope, including supply, demand and intermediaries; (2) two types of ecosystem extension – the bottom-up and top-down ecosystem extension; and (3) the determinants of sustaining the ecosystem extension. They conducted in-depth interviews in the Chinese low-speed electric vehicle industry, which adopted a bottom-up ecosystem extension compared with the traditional car industry with a top-down ecosystem extension to the emerging electric vehicle industry. The paper also offers managerial implications for the focal firms and policy-makers to capture the emerging opportunities within an ecosystem. This study proposed a new product development model that aims to improve the effectiveness of innovative new product development in the medical devices field. By adopting open innovation theory and applying an in-depth investigation methodology, the paper proposed a knowledge

cluster that improves the integration of interdisciplinary human resources and enhances the acquirement of innovative technologies. A knowledge cluster approach helps gather, organise, synthesise and accumulate knowledge in order to create the impetus for innovation.

RESEARCH METHODOLOGY

Information for research to explore sustainability of technology concepts has been gathered from different sources of secondary data. Various online papers were obtained through popular authentic sources such as ProQuest, EBSCO, Google Scholar etc.

Based on the inputs from secondary data, the research frame work is developed on the sustainability of technology concepts, platforms and ecosystems, as shown in Figure 1.

RESEARCH FRAMEWORK

Based on a wide survey of literature and industry illustrations, the following factors have been identified as potential factors impacting the sustainability of technology concepts, platforms and ecosystems:

1. User preference
2. Non-substitutable nature
3. Rareness
4. Inimitable
5. Valuable
6. Sales
7. Pricing
8. Profitability
9. Communicating with market
10. Strategic signals
11. Flexibility of firms
12. Community
13. Organisation and human capacity
14. Knowledge
15. Innovation
16. Interdependent relationships among multiple technologies
17. Perceived uncertainties
18. Competitiveness
19. Early action
20. Industry standards

These factors can be grouped into two broad categories, namely: Tech Firm Dependent or Internal Factors, and Market Dependent or External Factors, thereby producing the following basic framework:

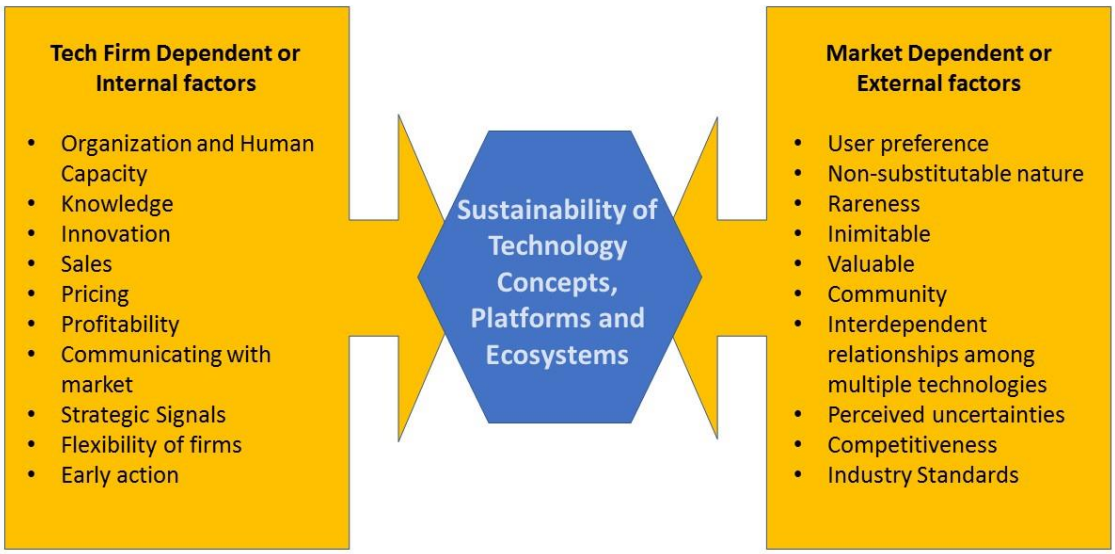

Figure 1. Framework on Sustainability of Technology Concepts, Platforms and Ecosystems

DISCUSSION, ANALYSIS AND FINDINGS

From the perusal of the above framework it is evident that the factors enlisted are very diverse; they range from intricate matters of business strategy to the undercurrents of market behaviour. So while the sustainability of technology concepts is a major area of concern for businesses across all domains, it is difficult to gauge explicitly what set of factors would eventually lead to its sustainability. Clearly there is no single path to success. However, there are a range of different possibilities and if an understanding of potential behaviour of market and technology forces vis-à-vis the listed factors can be elucidated then a capability of optimal decision-making can be developed.

In order to develop a comprehensive case study which can elaborate and substantiate the proposed research framework, it would be useful to observe various companies over a period of time and to review the paths taken by them in terms of the introduction of new technology concepts, their evolution, maturity and obsolescence. It would also be pertinent to see various technology concepts and ecosystems through the same lens.

For example, when IBM introduced its Magnetic Disk in 1956, it was a rare and innovative product offering tremendous value; it later went on to become an "industry standard". The dominance of this company in the computing space was such that all personal computers were made "IBM compatible". After a series of progressive changes, today the company operates in cloud computing, IT infrastructure, the Internet of Things, and analytics etc. However, if one looks at what happened in the storage media market, we see a range of different form factors evolving in last few decades such as optical media and semiconductor media etc. From a technology concept standpoint, all these form factors are fundamentally different from each other in terms of the underlying technology. This implies that the same or better service functionality can be offered by various unrelated technology form factors. The same phenomenon can be observed in technology platforms, ecosystems and technology-driven businesses at large.

On the same spectrum are companies such as Cisco, Microsoft, Google, Apple etc. Cisco continues its leadership position in networking hardware and telecommunications equipment and other high-tech services consistently over last few decades, having pioneered the relevant

technology form factors. Microsoft has dominated the PC desktop and office software business for several decades.

Google and Apple have differentiated and maintained leadership positions in what they continue to do. However, if one looks at their competitors, such as Yahoo, RIM Blackberry etc., there are serious lessons to be learnt. Both Apple iPhone and RIM Blackberry are good examples of the evolution of proprietary technology ecosystems. However, the path taken and their fate is radically different due to the different play of the factors listed.

In the consumer markets, a number of companies such as Nokia, Motorola, Sony, Dell, Huawei, Lenovo, Samsung, HP etc. can be reviewed from the perspective of the proposed research framework and the paths taken by each of them will provide valuable insights. However, it is important to note that in today's era most companies offer products and solutions based on a combinations of industry standard and/or proprietary technology.

Though technology sustainability can primarily be considered as a function of the robustness of the technology concept itself, various business cases and industry examples demonstrate that it also depends on the nature of industry and the type of market. For example, the story in the institutional markets is quite different; there we have companies like GE, Siemens, SAP, Oracle, Intel, AMD etc. reaping long-term gains out of their proprietary technology platforms. Siemens, for instance, has developed a range of successful proprietary products in healthcare technology. This reinforces again that there are various possible paths to success in the technology space.

There are furthermore complexities to deal with. Describing the new concepts of "value transposition" and "value extraction", Mathur (2016) postulated that some non-market (completely unrelated) entities that are not even initially recognised on the business environment landscape and are certainly not "on the radar" using traditional competition strategies can, however, seize the entire value preposition of the pre-existing markets and cause a serious dissolution of existing industry ecosystems or portions through value transposition and value extraction, which can happen with services as well as products. He illustrates this point by recognizing that m-Pesa is not a bank, Zomato is not a restaurant, Uber owns no taxis, AirBnB owns no hotels, Kindle is not a book and Bitcoin is not a monetary authority, but that all these entities have disrupted the pre-existing markets or traditional business environments.

Another extreme example is Walt Disney World, which has created a complete proprietary ecosystem around its business concepts, all powered through its proprietary robotics, instrumentations, intelligence and high-tech applications, leading up to an unparalleled and immersive user experience, a universe of its own. Universal Studios and Legoland are also in the same league.

An altogether new generation of emerging technologies such as the Internet of Things implementations, wearable devices, autopilot cars, hyperloop transport system etc. are already on the horizon and each one of them will soon go through their cycle of maturity and then the quest for sustainability. The research framework and its proposed substantiation through business cases will go a long way towards helping the innovating firms solve this perpetual puzzle of sustainability.

Applicability of the proposed framework

The proposed framework on the Sustainability of Technology Concepts, Platforms and Ecosystems therefore must be applied at a concept or platform level and all the listed factors can be gauged as high, medium or low through empirical observations within a business situation. This will project an integrated view of possible sustainability and highlight the tech concepts and firms that are in an advantageous situation. The framework can also be refined further to suit specific industries or market types.

LIMITATIONS

Survey of literature has shown that the wide and high-level nature of this topic has prevented researchers from coming forward with a conclusive framework to address the puzzle of sustainability. The same applies to this research paper as well. It will also need several refinements adequately supported with business cases to make the proposed framework more practical, realistic and action-oriented. However, here we have taken the first step towards creating a preliminary structure around this ambiguous problem and demonstrated that is has diverse issues, actors and divides.

CONCLUSIONS

Towards the main question of sustainability of technology concepts, this paper concludes with the identification of two broad categories of impacting factors: tech firm-dependent and market-dependent. Both the clusters offer a wide range of identified factors captured in the research framework. Further work on this research will be instrumental to substantiating the factors and putting them in the perspective of diverse business situations depicting the evolution and sustainably of technologies. This paper hence serves as a foundation to develop a management framework or tool for decision-making through further observation-based exploratory research.

REFERENCES:

Adomavicius, G. et al. (2007) Technology roles and paths of influence in an ecosystem model of technology evolution. *Information Technology and Management*, 8(2), 185–202.

Andersen, B. et al. (2013) Are there "Institutional Failures" in Intellectual Property Marketplaces? Evidence from Information and Communication Technology Firms. *International Journal of Management*, 30(2), 723–739.

Baumol, W.J. (1999) Licensing proprietary technology is a profit opportunity, not a threat. *Research Technology Management*, 42(6), 10–11.

Chengalur-Smith, I., Nevo, S. and Demertzoglou, P. (2010) An Empirical Analysis of the Business Value of Open Source Infrastructure Technologies. *Journal of the Association for Information Systems*, 11(11), 708–729.

Coeurderoy, R. and Durand, R. (2004) Leveraging the advantage of early entry: proprietary technologies versus cost leadership. *Journal of business research*, 57(6), 583–590.

Contractor, F.J. and Sagafi-Nejad, T. (1981) International Technology Transfer: Major Issues and Policy Responses. *Journal of International Business Studies*, 12(2), 113.

Dao, V.T. and Zmud, B. (2015) The Influence of Technology-Related, Market-Related, and Standards-Related Strategic Signaling During a Standards War. *IEEE Transactions on Engineering Management*, 62(3), 300.

Davis, F. D. (1989) Perceived usefulness, perceived ease of use, and user acceptance of Information. *MIS Quarterly* 13(3), 319–340.

Economides, N. and Katsamakas, E. (2006) Two-sided competition of proprietary vs. open source technology platforms and the implications for the software industry. *Management science*, 52(7), 1057–1071.

Eisenmann, T.R. (2008) Managing proprietary and shared platforms. *California management review*, 50(4), 31–53.

Fitzpatrick, W.M. (2003) Uncovering trade secrets: The legal and ethical conundrum of creative competitive intelligence. *S.A.M. Advanced Management Journal*, 68(3), 4–13.

Gawer, A. and Cusumano, M.A. (2008) How Companies Become Platform Leaders. *MIT Sloan Management Review*, 49(2), 28–35.

Hirsch, R.L. (1996) Technology for a competitive industry. *The Electricity Journal*, 9(4), 80-81, 80.

Jin, Y., Vonderembse, M. and Ragu-Nathan, T. (2013) Proprietary technologies: building a manufacturer's flexibility and competitive advantage. *International Journal of Production Research*, 511(9), 5711.

Kauffman, R.J. and Mohtadi, H. (2004) Proprietary and Open Systems Adoption in E-Procurement: A Risk-Augmented Transaction Cost Perspective. *Journal of Management Information Systems*, 21(1), 137–166.

Kelley, D.J. and Rice, M.P. (2002) Leveraging the value of proprietary technologies. *Journal of Small Business Management*, 40(1), 1–16.

Kelly, D.J. and Rice, M.P. (2001) Technology-based strategic actions in new firms: The influence of founding technology resources. *Entrepreneurship Theory and Practice*, 26(1), 55–73.

Korkeamäki, T. and Takalo, T. (2013) Valuation of innovation and intellectual property: the case of iPhone. *European management review*, 10(4), 197–210.

Lichtenthaler, U., Ernst, H. and Conley, J.G. (2011) How to Develop a Successful Technology Licensing Program. *MIT Sloan Management Review*, 52(2), 17–19.

Li-Hua, R. and Lu, L. (2013) Technology strategy and sustainability of business. *Journal of Technology Management in China*, 8(2), 62–82.

Mathur, D. (2016) Segmentosaurs and the rise of new non-market entities. *Forbes Middle East*, April.

Paglirey, J. (2014) 95% of bank ATMs face end of security support. *CNN Money*, March.

Persidis, A. (2001) Strategies of biotechnology firms towards new, platform technologies. *International Journal of Biotechnology*, 3(1), 23–32.

Reilly, R.F. (1998) The valuation of proprietary technology. *Management Accounting*, 79(7), 45–49.

Rong, K. et al. (2013) Business ecosystem extension: facilitating the technology substitution. *International Journal of Technology Management*, 63(3), 268–294.

Tassey, G. (2005) The disaggregated technology production function: A new model of university and corporate research. *Research Policy*, 34(3), 287–303.

Tassey, G. (2016) The technology element model, path-dependent growth, and innovation policy. *Economics of Innovation and New Technology*, 25(6), 594–612.

Valkokari, K. (2015) Business, Innovation, and Knowledge Ecosystems: How They Differ and How to Survive and Thrive within Them. *Technology Innovation Management Review*, 5(8), 17–24.

Waite, C. J. W. (2006) *Sustainability of performance of technology innovator firms in business environments exhibiting turbulence*. PhD, The George Washington University.