Digital Transformation and Its Influence on Platform Business

by

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ABSTRACT

Platform business model is increasingly gaining popularity among academics and practitioners. New start-ups to established incumbent companies have all shifted or are adjusting their business model from traditional linear to platform-based approach. Platform is a business model that creates value by connecting multiple interdependent participants and facilitating exchanges among these participants. Digital technologies such as connectivity, cloud computing, big data analytics, machine learning, and artificial intelligence play important role in making these multi-party connections and exchanges possible. There is considerable amount of literature published on platform business and digital transformation. Platform business literature often discusses the strategies of platform business and various methods of designing and setting up platform business. The digital transformation literature often discusses various digital technologies and ways of using those technologies to improve efficiency and performance. The main purpose of this study is to empirically analyze relationship between degree of digital transformation and platform business model and contribute to literature with insights gained from the results of the analysis.

This study analyzes 753 USA based active public nonfinancial firms from 16 industries existed on year 2018. The degree of digitalization measured as number of digital technologies involved in operations and products was related to existence of platform business. Analysis was done for both product platform and industry platform. This study finds that degree of digital transformation is significantly positively related to the likelihood of existence of both product platform and platform business. The study also finds that out of 16 industries studied, six industries are more likely to have platform business. This study also related other company characteristics with platform business. The findings include: Platformization is positively related to firms' size and number of complementors a firm has. Firm's age is negatively related to platformization. Digitalization of value chain has positive relationship with product platform while no relationship with industry platform. And, R&D spending does not influence platformization.

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DEDICATIONS

To all my Teachers

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I INTRODUCTION

In today's hyper connected digital world, the digital transformation has become a survival strategy for businesses of all types and sizes. Digital transformation is a process of collective deployment of various digital technologies in various business functions (Universit, 2018). With the advent of digitalization technologies, platformization of businesses and products has become valuable business model and operation strategy. Digital transformation involving technologies such as Connectivity (Internet, 5G), Artificial Intelligence (AI), Machine Learning (ML), Big Data management, Internet of Things (IoT), Block chain, Cloud and AR/VR (Augmented/Virtual Reality) enable platformization of products, business operations and business models. Existing recent business literature, suggests the business of platforms to be the business model of the companies of future (Cusumano, Gawer, & Yoffie, 2019b; Hagel, 2015). The platform business model achieves success through network effects. The digital technologies increase the growth of the network effects. However, as Cusumano et al., indicate not all products or industries are platformizable (2019b). Since not all products or businesses are platformizable the digital transformation strategy will enable platformization for some industries and will not enable for other industries. Platform business model and digital transformation strategy are relatively new and therefore research on platformization or business platform in multi-industry setting is limited or non-existent. Understanding the industry and company factors, especially related to the digitalization strategy, that act for or against the platformization would be valuable addition to the existing literature on business platforms. This research would be one of the firsts in identifying few industry and firm factors that may influence the platformization. This will help further research on what we can do with those factors to use or not to use platformization strategy for a given industry or business.

Given the research context, the following research questions are posed. (1) What are the digitalization factors that significantly influence platformization? (2) What are other industry and company factors that significantly influence platformization? (3) In what industries digital transformation strategy is more likely to heighten or increase the use of the platform model?

The reasons for these research questions are as follows. As mentioned before, platform business model may not be possible in all industries. As seen in literature on platform business (Cusumano et al., 2019b; Cusumano, Gawer, & Yoffie, 2019a) all 43 sample companies from Forbes Global 2000 list, identified as platform businesses are in just five distinct non-financial industries. All industries are more digitally oriented. This shows that digitalization or digital transformation may be playing a role in strategy of platform business. Also, the limited number of platform businesses in top 2000 global firms list suggests two possibilities. Either companies form different industries are not fully into the digital transformation strategy to achieve expected success or digitalization may not always lead to platform business. According to Venkatraman, we are only at starting of the digital transformation. In the future all the companies, irrespective of what industries they are from, will transform to digitalization (Venkatraman, 2017). So, this may just be matter of time that we do not see the platformization yet or for those different industries the digital transformation strategy is not adequate to realize the platformization. Or there might be some other firm specific or industry specific factors that have not enabled these organizations to use digital transformation strategy to realize the platformization. This research is an attempt to find evidence about this influence of the digital transformation in enabling the platformization.

In addition to digitalization strategy, other firm level and industry level factors also play role in forming platform business model. Firm level factors may include firm size, age, and research and development investment. Industry characteristics may include need for collaboration, and presence of enough number of third-party complementors. This research also involves analysis of relationship between platformization and various firm level characteristics and industry effects.

Contribution of this study is organized in seven chapters including this introductory chapter. Chapter II begins with theories of platforms including the different types of platforms such as business platforms and product platforms. Followed by this platform literature is a review of studies on digital transformation and their link to business models. Literature review and hypotheses for research questions concerning relationship between digital transformation and platformization follow this in Chapter III. Chapter IV is discussion about the methodology used for this study that includes discussion of models, statistical procedures and descriptions of data and sample. Chapter V presents results of estimation of various models followed by Chapter VI where discussions of these results are presented. Finally, conclusion in chapter VII gives brief summary of this research, implications of the findings and identification of areas of future research.

II LITERATURE REVIEW

PLATFORM BUSINESS

A. *WHAT IS PLATFORM BUSINESS?*

Platform business model is a new business model that we see in new generation high technology companies such as Google (Alphabet – the parent company), Facebook, Uber, Airbnb and so on. The fundamental idea behind the platform business is to setup an environment to connect two or more parties of a business and to enable them to interact among themselves independently (Hagiu, 2009). The term platform in a broader sense means "bringing or joining together". Historically the term "platform" was associated with product platforms which are used as efficiency management approach. A product platform will have base product or structure on which a company builds multiple product lines or versions of products. In product platform, different product lines, subsystems and components are grouped together on a common structure. For example, the leading automobile maker Honda uses same suspension and power train, chassis sub systems for multiple models. The company's popular Honda Element and Honda CR-V are two different car models targeting two different customer segments. These models are based on same basis chassis, power steering gearbox and power train subsystems (Meyer, 2008). In other words, these two models share the same platform. In product platforms, reusability is the objective.

Nowadays, the term "platform" is related to the business model powered by digital technologies to connect people, organizations and resources to create and exchange value (in Gatautis, 2017). Technically speaking as Schwarz (2017) says, these platforms are digital infrastructures. Different applications can be run on them for some finite, clearly defined set of uses such as connecting platform participants and facilitating transactions among them. The participants can be users, developers, producers and other industry complementors.

This industry platform is also a common base like the product platform that provides a common foundation that a company can develop more products on it. However, unlike product platform the industry platform can bring in components from parties outside the company from the same industry or from different industry. In that sense, the industry platforms are technology systems whose elements can be in-house or outside the company (Cusumano, 2010)

Business platforms are subsets of industry platforms, which will have either a base technology made open to multiple independent parties. These independent parties bring in their innovations and applications on this base platform. This business platform is innovation platform (Cusumano et al., 2019b, 2019a). For example, Google's Android operating system is a platform open to a larger community of developers. Another variation of the business platform is transaction platform, in which the platform is a facilitating environment. Multiple independent parties conduct business transactions in this facilitating environment. For example, Airbnb and eBay merely connect buyer and seller. These do not produce or sell any products. In business platforms, connecting and facilitating interactions are the objectives. In the business platforms depending on number of parties taking part in the platform, there can be two-sided platform or multi-sided platform.

Platform business is not entirely new. As stated in (Cusumano, 2010), even though the literature on the platforms is relative new, the key ideas of the platforms, especially the industry platforms, such as network effects, switching costs are already there. There has been business of platforms in the past such as Credit card payments and communication networks such as old telephone networks and even those traditional physical marketplaces like farmer markets are business platforms. All these connected multiple sides – consumers and service providers. But their reach and visibility are not as proliferating as those we see in new platform businesses such as Apple, Twitter, Google, Facebook and so on. The extraordinary reach and growth of the business experienced by these firms are due to network effects enabled by the digital technologies. An important striking feature of today's business platform is the network effect. By network effect, product or service value to a user increases as more number of users use the product or service (Cusumano et al., 2019b; Gatautis, 2017). The network effects can be "direct" network effects where adding participants in one side benefits participants from the same side. Or it can be "indirect" network effects where adding participants in a side, say buyer side, increases benefits to different other sides such as producers.

Platforms can be a simple platform of just two sides or can be a more complex platform with more than four sides. These multi-sided platforms are newer types of platforms. For example, the platform involving social media networking such as Facebook, computational platforms such as Google, and Microsoft compete for end users, developers, and for advertisers

(Cusumano, 2010). As Pagani (2013) says, the multisided platforms are results of collision of innovations in multiple technological areas such as computing, networks, value chain clock speed, content control, and consumer experience. The multisided platforms can also be seen as complex socio-technical systems with independently interacting elements such as customers and complementors (Staykova & Damsgaard, 2018). The number of sides in the multisided platform can vary from two sides as evidenced from eBay and Visa to more than three sides as seen in Microsoft and Google. Balancing interests of all the sides and choosing which sides to target can have huge impact on the success of multisided platforms (Pagani, 2013)

The multisided platforms create a new interconnected market where the end users, the platform providers and developers all communicate and collaborate and together improve the platform for betterment of all parties. One of the studies on multisided platform says these multisided platform businesses occur whenever two or more different groups of parties that need each other are brought together to a commonplace. The upcoming of multisided platforms represent new form of market (Eisenmann, Parker, & Alstyne, 2016)

There are different types of platforms depending on the utility gained from the platforms (Kenney & Zysman, 2016). Retail platforms such as Amazon, eBay that are online retail stores connect the producers and consumers. Service platforms such as Airbnb, Uber and Lyft connect ride service providers and riders. Work mediating platforms such as LinkedIn and Amazon Mechanical Turk connect various job seekers to right employers either for long-term or for short-term employment. Innovation and digital tool platforms enable creation of other platforms. And there are platforms for platforms such as Internet service providers that provide connectivity to multiple platforms.

B. VALUE CREATION IN PLATFORMS

As Gatautis (2017) says, platforms are not just selling channels anymore but they act as value creation orchestrators enabling cooperation between different market players. The success of business platform will happen only if all parties in the platform benefit in some way. Value creation occurs in platform through cost decrease in distribution and transactions and revenue generation through nonlinear growth of network of platform users (Cusumano et al., 2019b; Pagani, 2013). Network effects leads to non-linear growth of platform participants. This is because joining one more added participant to the platform increases the value experienced by all participants of the platform (Evans & Schmalensee, 2017, 2018; Kazan, Tan, Lim, & Damsgaard, 2018). The platforms create value for the whole ecosystem through transparency improvement and enhancement of agility and flexibility (Benlian & Kettinger, 2018).

The communication infrastructure providers generate revenue by providing connectivity services to these platforms. For users and consumers, the platforms provide values in the form of new way of collaboration, information security, integrity and authenticity and customer services and support on real-time basis. As Pagani (2013) says, consumers can be part of large social networks, consume contents on demand – the content pull, and can also publish contents like advertisements – the content push. Businesses also get value through platform businesses. Businesses can experience increased business agility. For example, companies can field test their new ideas and product features by rapid field tests. Platforms create value ecologically also (Benlian & Kettinger, 2018). For example, digital infrastructure helps realization of platforms. Move to digital infrastructure is inherently green and environmentally friendly.

C. PLATFORM BUSINESS MODEL

The platform business model is carrying out business activities on platforms (Gatautis, 2017; Kim, 2014, 2016) to create value. These business activities include activities such as product development activities including R&D and manufacturing, delivering product to end users, marketing and promotions, services and support to end users, managing partners and suppliers. Value creation and value capturing are basis of composition of platform business model. In platform business model, the value chain is not to the left or to the right as is in traditional value chain. In platform business model, all sides create value. The basis of platform business model is decided based on the target side of the platform. The platform business model that targets the customer side creates values through improving customer experience and network effects on the demand side. The value capture in this model is by revenue generation through this non-linear network effect. The platform business model that targets the complementor side of the platform creates value through bringing in more complementary innovative products and applications to the platform. The value capture occurs through revenue generation by fees for participation of developers or for transactions. In this model the platform provider facilitates the participations and transactions. In any platform business model, the cost and revenue occur on all sides of the platform. All sides of platform incur costs to support the platform. Revenue generation can occur from all sides or from one or two sides while subsidizing other sides.

DIGITAL TRANSFORMATION

As stated before, digital infrastructure drives the platformization and continuing operation of platform business. Digital strategy is about deciding about what technologies need to be setup in what part of the value chain. Those decisions are to create extraordinary value experience to the parties of the platform including to improve the quality of platform. The following sections briefly review the literature on the digital transformation and its relationship to platformization of businesses.

A. DIGITAL TRANSFORMATION STRATEGY

One of the requirements for a successful platform business is a well-executed digital strategy. Recent literature on the industry platforms can assert this (Cusumano et al., 2019b, 2019a; Gatautis, 2017; Kenney & Zysman, 2016; Pagani, 2013; Sia & Soh, 2016). Companies like Google, Microsoft, Amazon and Apple successfully do the platform business because their businesses run on digital. Traditional incumbent industrial companies or new companies increasingly use digital technologies to capture consumer's attention and develop long-lasting relations (Gatautis, 2017). Kenney and Zysman (2016) say that digital platform economy encompasses growing number of digitally enabled activities in business, politics and social interactions. They also point out the algorithmic revolution and cloud computing are the foundations of platform economy. Venkatraman (2017) in his best-selling book firmly says the digital technology is a critical for every business in every industry now and in the future.

According to Pagani (2013) digital strategy involves coordination across firms along product, process, and service domains there by creating complex dynamic ecosystems. Literature on digital transformation present information about what the digital strategy really is (Hess, Benlian, Matt, & Wiesböck, 2016; Main, Lamm, & Mccormack, 2018; Sebastian, Ross, & Beath, 2017; Universit, 2018; Venkatraman, 2017). Digital strategy is not just upgrading the company infrastructure with better connectivity or with better servers or with adding computer with high computation power. It is not just about improving efficiency through automation and process improvements through digital infrastructure. The digital strategy should holistically transform the way how business creates value to customer. It should aim to add value in every part of the value creating activities. From being in touch with customers through real-time data collection to get more accurate customer persona to product design, manufacturing and providing post sale customer support and service. Simply saying, every aspect of the business activity in solving customer problem should use full potential of suitable digital technologies.

B. WHAT IS DIGITAL TRANSFORMATION?

Digital transformation is not only about the technologies. Digital transformation is that combines business strategy and synchronous adoption of multiple digital technologies (Universit, 2018). Digital transformation is about how the business would compete better using technology. It is about creating winning future (Main et al., 2018). Digital transformation is concerned with transformations or changes that digital technologies can bring in the business model of companies (Hess et al., 2016). It is incorporating company's business strategy into its Information Technology (IT) strategy. IT strategy is about bringing in new digital technologies to improve the digital infrastructure of the company with objective of productivity improvement. But the business strategy is about designing and setting up or upgrading the business models and formulating tactics for executing the strategic actions. The digital strategy is combination of both and involves a company-wide holistically addressing opportunities and risks of digital technologies (Singh & Hess, 2017). In short, digital strategy involves continuously upgrading IT digital infrastructure for business model innovations.

C. DIGITAL STRATEGY AND PLATFORMIZATION

Digital transformation is to bring changes in whole organization by adopting to multiple digital technologies simultaneously to have business model improvement to achieve superior competitive advantage. Since this study focuses on platform business model, here we present summary of how digitalization is necessary condition for platformization. Platformization is designing and implementing a business platform that brings multiple parties together to conduct business transaction while creating value. Platformization is also about designing and architecting products and services and a common ecosystem environment such that they are open and inviting complementary components and innovations from outside third-parties. Openness and interaction among participants of the platform play crucial role in setting up and achieving success of the platform. To setup a business platform or to do platform business of an existing business with such openness and heightened interactions, the business must be digital. For a business to become digitally transformed, several technologies must be used together. There is recent vast literature supporting the link between the digital strategy and platformization.

Venkatraman (2017) suggests the business is digital if: (1) Big data, analytics and artificial intelligence affect the business process and business decision making. (2) Product and service delivery to individual customers and customer experience are improved through social network applications, mobile applications and cloud computing. (3) Internet of things (IoT) links all the products. (4) Supply chain is evaluated through robots, drones and 3D printing and (5) Machine learning algorithms and robotics influence future business designs. A Gartner survey and analysts reports on digital platform report that digital technologies such as enterprise service bus (ESB), IoT, API Management, integration platform as a service (iPaaS) and event stream processing are the most popular technologies being used in digital platforms. Artificial Intelligence and data and analytics are also some of the main components that digital technology platforms use (Swanton, 2018; Swanton & Golluscio, 2018). The study of transformative impact of cloud computing technology on value creation shows that platformization is one of the three mechanisms of transformative value creation (Benlian & Kettinger, 2018).

III HYPOTHESIS DEVELOPMENT

One of the main objectives of this study is to find relationship between digitalization maturity and its influence on the platform business. This study also attempts to find the industries which are more likely to have digital strategy enabling business platforms. Using the literature review we derive the hypotheses presented below. First, we develop the primary hypotheses for relationship between the digitalization maturity and platformization. Next, we present several secondary hypotheses for various firm specific characteristics that may influence platformization. The secondary hypotheses are for controlling effects of industry membership and other firm specific characteristics on platformization. This is to identify industries that have significant relationship between digitalization maturity and platformization. The industries identified to show significant relationship with platformization are classified as platform industries and rest of the industries are classified as non-platform industries. In the follow up analysis, the digitalization characteristics of platform industries are compared with that of non-platform industries. Digitalization characteristics means firms' involvement in different digital technologies used in digital transformation. This comparison is to determine industries that are mostly likely to have significant relationship between digitalization and platformization. Evidence for likelihood of having platform business in an industry is obtained by the variance analysis between groups of platform industries and non-platform industries.

The review of literature on platform business and the digitalization point out that digitalization is the key driver of the platform business. Without enough digital infrastructure platformization will not exist and be successful. As seen in the review of literature, the digital technologies that drive the business platform include communication technologies, IoT, big data analytics, machine learning and AI, cloud computing, ESB, Public APIs and iPaaS.

Communications technologies include high speed communication infrastructure made up of optical networks and 5G wireless communications. The communication infrastructure powers the Internet and connectivity of all the computing machines and resources and different parties of platforms. A research on platform companies Google, Flickr and Salesforce.com suggests that connectivity is one of five interdependent dimensions that platform leadership depends on (Lee, Kim, Noh, & Lee, 2010). Since the Internet is considered as the platform for platforms (Kenney & Zysman, 2016), the connectivity to the Internet with recent advanced technologies is critical for digital maturity. Therefore, when there is connectivity infrastructure with high level of maturity we can expect to have high level of digitalization in the organization.

A Gartner report says that a coherent IoT strategy is key to the success of digital strategy (Hung, 2018). Internet of Things is interconnection of devices and objects found around us. It is the network of physical devices, vehicles and other items embedded with electronics to support connectivity and manageability (Hung, 2018; Hung, Friedman, Ganguli, Heidt, & Tsai, 2017). IoT is a term collectively used for the connectivity of devices, various connectivity and sensor technologies used in IoT and processes and procedures used in connecting those devices. Essentially IoT creates an ecosystem of connected elements that interact with each other. From technology perspective business platforms or business ecosystems are bunch of building blocks connected to each other (Muegge, 2013). The connectivity powers technologies like IoT. In one sense IoT by itself is a business ecosystem forming a business platform (Westerlund, Leminen,

& Rajahonka, 2014). IoT connects digital part of the business with the physical world. This connectivity with the physical world can be in the form of data collection to understand stakeholders. It can be in the form of gathering customers view on product and services use. Or it can be in the form of real-time interaction with various parties of the platform business (Swanton & Golluscio, 2018; Venkatraman, 2017). Since IoT is one of the main communication technologies, higher deployment of the IoT in a company would indicate higher digitalization maturity.

Big data analytics is another component of digital strategies. Data and analytics accelerate the digital strategy (Laney et al., 2019). This is the algorithmic way of analysis of complete information as opposed to the sample-based statistical analysis. In this approach the complete data is analyzed to learn changes and patterns and algorithmically arrive at conclusions. Sophisticated machine learning, and artificial intelligence algorithms use massive data collected, say through IoT, from various elements of the business ecosystem to create models of business. These models help to get better understanding of customers, products and services, suppliers, technological trends and so on. For a business platform, collecting massive information about all parties of the platform and analysis on the data to decide on efficiency improvement and business model adjustment, big data analytics becomes a critical component. Therefore, a digital strategy involving big data analytics methods shows a higher level of maturity of digital strategy.

Cloud computing is having computing infrastructure in a "centralized powerful network of computing resources" – the cloud. The computing cloud can be private to a company or public form where a company gets the computing as service from the cloud service provider. The term "computing" can mean as simple as running a software application for a company's need or having the complete IT infrastructure provisioned on the cloud through virtualized services. Cloud computing is evolution of computing technology to have IT infrastructure, components and applications on shared collection of powerful computing resource cluster. Cloud computing enables companies to have access to IT infrastructure, on-demand, for any platform or device. Platformization is one of the three transformative values of Cloud technology (Benlian & Kettinger, 2018). Through cloud computing, a company can achieve an efficient IT infrastructure that drives the platformization. Therefore, having a higher involvement in Cloud infrastructure shows higher digital maturity in an organization.

Companies deploy different software applications for conducting business. The applications range from R&D to Marketing and Sales, from supplier management to quality management systems. These applications are either locally placed or run from cloud. Integrating these enterprise applications enable a company improve efficiency and productivity. A study on enterprise architecture also suggest that implementing integrated business processes and IT infrastructure increases productivity and efficiency over time (Zayati, Biennier, Moalla, & Badr, 2012). Enterprise Service Bus (ESB), a technology that creates an integrating environment to connect all applications becomes critical for a company (Martínez-Carreras, García Jimenez, & Gómez Skarmeta, 2015). ESB is a backbone for connecting and integrating a company's applications and services. All applications and services connected through ESB share data and communicate with each other. So, using ESB for application integration becomes part of the digital strategy. Therefore, presence of ESB in a company's digital transformation strategy suggests another increase in the level of digital maturity

In summary, with all or some of these digital technologies as part of digital transformation strategy, a company can have different degrees of digital maturity which would define its platformization likelihood. For instance, a digitally transformed company has high speed optical wireline and Giga bit wireless communication infrastructure through which it communicates externally and internally with workers, partners, suppliers and so on. The company collects massive data on products and services, movement of inventory etc., using the sensors, robots, drones and other devices linked through IoT. The company uses Big data analytics with machine learning and artificial intelligence algorithms to analyze information to decide business strategies. The company efficiently sources computing resources and IT infrastructure from cloud service providers. The company has linked those sourced applications and all its local applications through ESB technology to improve productivity and efficiency. All or some of the company's value creation is through services or products that have digital components. Such a digitally mature company will be a good candidate for platformization business. Therefore, companies with higher maturity of digitalization are highly likely to have business platform now or in the future. The companies that have lower degree of digital maturity would not have business platforms or even product platform.

Hypothesis 1

The existence of business platform or industry platform in a firm is positively related to level of maturity of digitalization

Hypothesis 2

The existence of product platform in a firm is positively related to level of maturity of digitalization

As previously noted in the literature review not all companies would have the opportunity to platformize their business due to their nature of offering and value creation activities. For instance, the book on platform business by Cusumano et al (2019b), identifies nearly 43 companies as platform companies. These companies have offerings in some way related to digital. From this we can infer that businesses offering products and services more into digital will have more chance of platform-based business. The digitalization should enable transformation of value chain into value ecosystems. Venkatraman (2017) points out that just converting IT infrastructure with all the digital technologies alone will not lead to success of digital strategy. The digitalization should also be fully complementary to all or some of main value creating activities. Venkatraman further says that digitalization should be part of value creation activities in a way to help companies take maximum advantage of scale, scope and speed together. Therefore, the companies that have services and products that enable digitalization of higher level of value creation activities will have higher likelihood of getting into business platform. In other words, companies having more digitized products and services will have more chance of platformization and vice versa. And the companies that have deployed the digital strategy in more value creating activities will have higher chance of business platformization and vice versa. Therefore, *the existence of business platform in a firm is expected to be positively related to digitality of the offering. And similarly, the existence of business* *platform in a firm is expected to have positive relationship with the level of value creating activities transformed to digital.*

Besides factors discussed above, several company specific and industry specific characteristics would also influence platformization of business. The companies invested in digital transformation technologies early enough and operating with partially transformed or fully transformed digitalization value chain are more likely to have business platformization. The level of transformation – partial or full shows proportion of value chain transformed to digital. More experience the companies have in using digital technologies, more digital the infrastructure would have been setup. This would enable them to connect multiple parties of their business better than companies that have less experience in digital technologies. Therefore, the digital experience will be a driving factor of the business platform. More the digital technology experience more likely the company to have platformization and vice versa. In contrast, even with the higher level of digital experience, it will be difficult for entrenched incumbent companies to change their business model to platform business. Higher level of digitalization will be on efficiency improvement and business development and not necessarily on platformization. Therefore, *the existence of business platform in firm is expected to be positively or negatively related to firm's level of experience of digital technologies.*

Firm's investment power is another factor that would influence the platformization. To have a successful business platform, companies should be able to manage multiple sides of the business platform. They may have to subsidize one or more sides using value created from other sides on which the company focuses. To have the cross subsidization, the company should have the investment capacity to drive the platform side management. Bigger the company's investment ability better chance of surviving platform business. Gawer & Cusumano (2012) suggest that even though size of the company may not influence platform leadership always, sometimes the company size matters for the platform businesses. Therefore, larger companies with better financial strengths will have more chance of having business platform and financially smaller companies will have less chance of business platform. Therefore, we *expect to see evidence for positive relationship between firm size and existence of platform business.*

The firms that invest in research and development at higher levels will have more innovations in products and services. With higher levels of innovations, companies need better, efficient and productive IT infrastructure for efficient operations. This will normally result in quicker implementation of new business models. Generally firms, at first experiment with new technologies, then change the core business models as they find success in experimentation or due to competitive pressure (Venkatraman, 2017). For the experimentation phase of transformation, firms need more research and development initiatives. Firms that spend more on research and development will pass the experimentation phase quicker and are more likely to have successful business platform. There is also other literature evidence for link between innovation ability and platform development (Lee et al., 2010). It states that platform leadership in companies like Google depends on innovation ability as well as other factors such as connectivity, complementarities, efficiency, and network effects. Since platform development needs designing right architecture - decoupling and interfaces, standards development and industry cooperation (Gawer & Cusumano, 2012), firms' R&D strength shows well architected products and services that enable platformization. Therefore, *the existence of business platform in firm is expected to be positively related to R&D strength of the firm.*

Nature of the company also plays an important role in being or becoming platform business. Venkatraman (2017), while presenting digital transformation methods, lists three sets of firms. Those are the industry incumbents which are historical companies, technology entrepreneurs which are "born digital" companies and digital giants which are big players whose business is inherently digital. Out of these categories, for industry incumbents, depending on the nature of the products and services offering, the digital transformation may or may not lead them to become platform business. The companies that are "born digital" already have their value creation on the digital. For these companies, becoming digital platformization is relatively easier when compared to industry incumbent. For the digital giants, since they are already digital with experience with digital technologies, these are also more likely to have business platform. At first these might not have been platform businesses. But through digitalization over period of time their business model would have changed to platform business. Therefore, from platform business view there is not much difference between born digital and digital giants. Both types are more likely to have business platforms (Daugherty, Carrel-Billiard, & Bil, 2016). Therefore, we expect to see *the existence of business platform in firm is more likely for born digital and technology giant companies and less likely for industry incumbent companies*

Companies build business platforms to enable other third-party companies build their products over the platform. Other companies are complementors of the platform business ecosystem. Businesses need complementors to emerge as platform businesses and survive as platform leaders. The business platform firms and complementors mutually benefit and therefore business platform thrives. If business platform cannot attract, incentivize and keep the complementors, platform business will lose the platform battle and lose its competitive advantage as the business platform (Gawer & Cusumano, 2012). Therefore, the presence of complementors in the industry will increase the likelihood of a firm emerging as business platform provider. We expect that *existence of business platform in firm will have positive relationship to the number of complementors the business has.*

IV RESEARCH METHODOLOGY

The research aims to address the following research questions: (1) What are the digitalization factors that significantly influence platformization? (2) What are other industry and company characteristics that significantly influence platformization? (3) In what industries digital transformation strategy is more likely to improve or increase the use of the platform model? The research is quantitative empirical research involving logistic regression and multivariate analysis. First part of the research is to find evidence for significant relationship between degree of digitalization or digitalization maturity and existence of platform business. As a side analysis of this part, we find evidence for relationship between other company specific and industry specific characteristics and existence of platform business. In this part we conduct logistic regression with fixed effects for various industries. This part of the analysis results in evidence for the research questions (1) and (2). Second part of the research aims to address the research question (3). In the second part of the research, using the results from the first part, we identify reference platform industries which are positively significantly related to platformization. We compare the platformization influencing characteristics – digitalization characteristics – of the reference platform industries collectively with that of other industries to find evidence for significant difference. We conduct one-way multivariate analysis of variance (MANOVA) for comparison of these characteristics among the industries. In this approach of using MANOVA, we avoid conducting many individual regressions for every digitalization characteristics for every industry separately. Also, unlike regression, MANOVA has the advantage of testing differences across all the industries for all the linear combinations of the characteristics.

MEASURES AND MODEL

A. DEPENDENT VARIABLE: Platformization

Business Platform

For the first part of the research, we use multivariate logistic regression statistical procedure. The dependent variable is *I_PLATFORM*. This is a binary variable with values of YES or NO marking existence or non-existence of platform business model (Multi-sided or Ecosystem) in a company. We deduce the existence of business platform in a company by following three different ways.

(1) Revenue based: Existence of the network effect. The effect of network effect will be realized on the firm's revenue generation capability. For example, as suggested in (Cusumano et al., 2019a) a company has business platform, if firm's revenue raised through network effects is at least roughly 20 percent of the firm's total revenue. Identifying the portion of revenue due to business growth by network effects can be done subjectively and hence the platform companies can be identified subjectively. In the research sample, we include 19 USA firms of the 43 platform companies listed in (Cusumano et al., 2019a, 2019b).

(2) Business model based: Platform Type 1: Transaction platform. As discussed in literature (Cusumano et al., 2019a), the transaction platform is a platform business that connects

buyers and producers. The platform makes it possible to make a larger number of buyers buy goods and services form many sellers who offer or share information about goods and services. This is different from ordinary on-line store. The buyers and sellers take part and create a multi-sided transaction platform in a way that more participants join the platform, more benefits to all the parties. Identification of the transaction platform is done by analyzing firms' business model from publicly available source of information. Firms that have business model like business model of companies such as Amazon Marketplace, eBay are identified as platform business.

(3) Business model based: Platform Type 2: Business Ecosystem. This is discussed in Cusumano et al.,(2019a) as innovation platform. These are the firms that make and own platform with common technology building blocks so multiple external third parties can build complementary building blocks to this platform. Firm's platform with all building blocks collectively benefits all participants of the platform. Thus, in Type 2 platform, the firm creates a platform that is an ecosystem of multiple businesses comprising of partners, third-party developers and other complementors. The complementors benefit from offering complementary products and services. As more complementors add components to the platform, more valuable the platform to users and other market players. When platform value increases, more complementors and innovations are added to the platform. This creates a positive network effect. Identification of the ecosystem platform or innovation platform is done by analyzing firms' business model from publicly available source of information. Firms that have business model equivalent to the business model of companies like Microsoft, Intel, Google (Android) are identified as platform business.

$$I\_PLATFORM = \left\{\mathbb{I}(REV_{NwE} > 0.2) \bigvee \mathbb{I}[f(PF_{Type\ 1})] \bigvee \mathbb{I}[f(PF_{Type\ 2})]\right\}$$

(Eq. 1)

where,

$I\_PLATFORM$ – Dependent variable for Industry platform, which is derived based on network effect revenue or business model (platform type 1, and platform type 2)

$\mathbb{I}$ – Indicator function that takes value 1 if the function is true and takes value 0 otherwise.

$\vee$ – Logical OR

REV_{NwE} – Revenue of the firm due to network effects

$PF_{Type\ 1}$ – The firm has transaction platform business. A binary value. Takes value 1 if the firm has transaction platform or 0 otherwise.

$PF_{Type\ 2}$ – The firm has innovation platform business. A binary value. Takes value 1 if the firm has innovation platform or 0 otherwise.

Product Platform

Existence of product platform in a company is determined by the product architecture and relationship between different lines of offerings of the company. The product platform is determined if a firm has common architecture and related lines of products. The existence of product platform in a firm is identified by analyzing business model, products and services offering using publicly available source of information. The firms that has stream of derivative products, family of products or set of new features developed over existing products are identified as firm with product platform.

$$P\_PLATFORM = \mathbb{I}\left(COMM\_ARCH \bigwedge PLINE\right)$$

(Eq. 2)

where,

$P\_PLATFORM$ – Dependent variable for product platform, which is derived based on existence of common product architecture and family of products or derivative products

$\mathbb{I}$ – Indicator function that takes value 1 if the function is true and takes value 0 otherwise.

$COMM\_ARCH$ – A binary variable with value 1 or 0 indicting presence of common product architecture. A value 1 indicates that common architecture is used in the firm and value 0 indicates otherwise.

$\wedge$– Logical AND

$PLINE = f(Family\ of\ Products, Derivative\ Products)$ – A binary variable with value 1 or 0 indicting presence of link among different product lines. A value 1 suggests there is link among different product versions value 0 suggests otherwise.

B. *INDEPENDENT VARIABLES: Predictor*

The hypotheses *Hypothesis 1* and *Hypothesis 2* relate the level of digitalization of a firm with existence of business platform or product platform. For this model, the predictor independent variable is degree of digitalization of a firm. The degree of digitalization is an aggregate measure that covers all the digitalization technologies involved in the digitalization. As stated in the literature review, the digital technologies that drive the business platform include communication technologies that provide connectivity, IoT, big data analytics, Machine learning and AI, Cloud computing, ESB and Public APIs. For this research we consider six broader level technologies namely (i) Communication, (ii) IoT, (iii) Big data analytics, (iv) Machine Learning and AI, (v) Cloud computing, and (vi) ESB and public APIs to measure the degree of digitalization of a firm. The level of digitalization is derived based on the model given below

$$DIGITAL\_LEVEL = f(\,DT \in \{ICT, IOT, BDA, ML\_AI, CC, ESB\_API\})$$

(Eq. 3)

$$DIGITAL\_LEVEL = \sum_{DT \in \left\{\begin{matrix} ICT, \\ IOT, \\ BDA, \\ ML\_AI, \\ CC, \\ ESB\_API \end{matrix}\right\}} DT\_PRESENT_{DT}$$

(Eq. 4)

where,

$DIGITAL\_LEVEL$ –The level of digitalization derived as the number of digital technologies a firm uses. This is calculated using equation *(Eq. 4)*. A larger value of $DIGITAL\_LEVEL$ will indicate higher level of maturity of digitalization of a firm.

DT – Set of digital technologies that would be enabling platformization such that

$DT \in \{ICT, IOT, BDA, ML\_API, CC, ESB\_API\}$, where,

ICT – Label for Internet and communication technology

IOT – Label for Internet of things technology

BDA – Label for Big data analytics technology

ML_AI – Label for Machine Learning and Artificial Intelligent technologies

CC – Label for Cloud computing technology

ESB_API – Label for enterprise service bus and public API technologies

$DT\_PRESENT_{DT}$ – A binary YES or NO value indicating whether a firm uses the technology DT or not. A value of 1 indicates presence of the technology in the firm's IT infrastructure and value 0 indicates otherwise.

C. INDEPENDENT VARIABLES: Controls

The hypothesis development section also describes other firm specific and industry specific determinants of platform in a firm. These determinants also represent the control variables for the estimation model. The measure of digitality of a company's offering is firm specific determinant. It is a binary dummy variable denoted as $DIGITAL\_OFFER$. This is measured as YES with value 1 if the product is a digital product and or delivered through digital channels. This is measured as NO with value 0 if the offering is not digital and not delivered through digital channels.

The measure of the level of value creating activities transformed to digital is a firm specific determinant. This indicates what level of value chain is digitalized in a firm. Even though the digitalization level is firm specific, the value chain of business platform may be common to all firms in the same industry. This is measured as the number of value-creating activities digitized and denoted as $DIGITAL\_VAL\_ACT$. This variable is an aggregate measure made up of digitalization in outbound logistics (product delivery) and digitalization in marketing and sales efforts such as social media presence.

$$DIGITAL\_VAL\_ACT = f(\, DVC \in \{VC\_OBL, VC\_MKT\})$$

(Eq. 5)

$$DIGITAL\_VAL\_ACT \; = \sum_{DVC \in \left\{ \substack{VC\_OBL \\ VC\_MKT} \right\}} DVC\_PRESENT_{DVC}$$

(Eq. 6)

where,

$DIGITAL\_VAL\_ACT$ – Number of digitalized value chain activities of a firm calculated using equation *(Eq. 6)*.

DVC – Set of digitalized value chain activities

$DVC \in \{VC\_OBL, VC\_MKT\}$ where,

VC_OBL – Label for outbound value chain activities.

VC_MKT – Label for marketing activities

$DVC\_PRESENT_{DVC}$ – A binary YES or NO value indicating whether a value chain activity is digitalized or not. A value of 1 indicates that value chain activity is digitalized and value 0 indicates otherwise.

The measure of the digital experience is a firm specific determinant. This indicates how long, in years, has a firm been using digital technologies in its IT infrastructure and business operations. This independent variable is denoted as $DIGITAL\_EXP$. And we use the age of the firm as the proxy to measure digital experience of the firm. To normalize the determinants against different firms in the sample we need a control based on firm size. Since we use dummy variables for other factors of determination of platformization, we use firm size as additional separate independent variable in the model instead of normalizing other factors as proportions of firm size. As stated in hypothesis before, firms' investment capability is one of the determinants of platformization. Firm size, besides being a normalization control, it is also a proxy for investment capability of the firm. Total Assets of the firm is used as a measure for firm size independent variable $FIRM\_SIZE$. Strength of research and development that indicates innovation capability for a firm is another control determinant of platformization. Firm's R&D spending is a good measure of firms' innovation capability. Strength of research and development capability of a firm is measured as annual R&D expense as a percent of total sales. The R&D strength is denoted by the variable RND. The number of complementary sides for a business is one of good determinants of platformization. It is a company specific determinant but depends on nature of industry. This is a count of business partners and complementors that firm is doing business with. This variable is denoted as $NCOMP$.

The measure of type of the firm $FIRM\_TYPE$ shows whether a firm is "born digital" or not. It is a binary dummy variable with value 1 if the company is "born digital" company and value 0 if the company is not "born digital". In line with the description of "born digital" firms by Gartner Analysts (Raskino & Waller, 2016), we consider a firm as born digital, if it was established after year 1995 and if it has digital offering. That is,

$$FIRM\_TYPE = \left\{\mathbb{I}(Firm\ age < 23) \bigwedge DIGITAL\_OFFER\right\}$$

(Eq. 7)

where,

$\mathbb{I}$ – Indicator function that takes value 1 if the function is true and takes value 0 otherwise.

Λ – Logical AND

With the variables discussed above, the estimation is done with industry dummy variables. This is a cross-section analysis involving data from companies from different industries as of year 2018. The estimation model specification of logistic regression for testing the research hypotheses of first part of the research is given as follows:

$$
\begin{aligned}
PLATFORM_i = \delta_0 + \delta_1\, DIGITAL\_LEVEL_i + \\
\delta_2\, DIGITAL\_OFFER_i + \\
\delta_3\, DIGITAL\_VAL\_ACT_i + \\
\delta_4\, DIGITAL\_EXP_i + \\
\delta_5\, FIRM\_SIZE_i + \\
\delta_6\, RND_i + \\
\delta_7\, NCOMP_i + \\
\delta_8\, FIRM\_TYPE_i + \\
\textstyle\sum_{j=1}^{n-1} \delta_{8+j}\, I\_DUMMY_{j,i} + \epsilon_i
\end{aligned}
$$

(Eq. 8)

where,

$PLATFORM \in \{I\_PLATFORM,\ P\_PLATFORM\}$

i – Index of firm

n – Number of industries

I_DUMMY_j – Dummy variable representing industry j

Above stated specification is for testing link between the digitalization strategies of the firm to the likelihood of platformization of its business. As stated in research question (3), one of the other objectives of this research is to empirically identify the industries whose digitalization strategies would result in business platform. To do this we first identify the "platform industries" by testing model specification given above in equation *(Eq. 8)* for hypotheses *Hypothesis 1* and *Hypothesis 2*. Platform industries are industries whose dummy variables have positive significant relationship with the platformization. Digitalization characteristics of group of companies from platform industries are collectively compared with group of companies from other non-platform industries. The group of companies that is not significantly different from the group of companies from platform industries is more likely to have digital strategies resulting in business platforms. For example, an industry which does not have higher proportions of companies involving cloud computing or IOT technologies will be significantly different from industry that shows significant relationship between digitalization and business platformization.

The digitalization characteristics are set of variables representing presence of digitalization technologies constituting independent variable DIGITAL_LEVEL and set of variables representing digitalization of value chain activities constituting DIGITAL_VAL_ACT.

$$Digitalization\ Characteristics \leftarrow \begin{Bmatrix} DT \in \{ICT, IOT, BDA, ML\_AI, CC, ESB\_API\} \\ DVC \in \{VC\_OBL, VC\_MKT\} \end{Bmatrix}$$

(Eq. 9)

First the comparison is done across all industries for all the linear combinations of the digitalization characteristics collectively. One-way MANOVA analysis is used for this comparison. The factor of analysis is the industry variable $FIRM\_IND$ to which the firm belongs. The level of the factor $FIRM\_IND$ is an integer which takes value 1 through number of industries in the full sample. Firms from a given industry have same value for $FIRM\_IND$. The dependent variables are variables representing use of digital technologies in a firm. Since not all industries are expected to have same digital technological characteristics, we expect to see all 16 industries are significantly different in proportions of companies using the digital transformation technologies. Once this is confirmed, a second stage of comparison analysis followed by the one-way MANOVA is conducted to determine the industry that is significantly different from the reference group – the platform industry. This second stage comparison is a follow-up pair-wise comparison with reference group for the digitalization characteristics. By this second stage comparison we get evidence for industry similar to reference group is more likely to have the digitalization strategy leading to platformization.

DATA AND SAMPLE

The data for this research is cross-sectional data for a sample of 753 companies from 16 different industries. Data for the cross-sectional analysis is collected for the year 2018.

Data for the analysis were collected from multiple sources, including Compustat database, Mergent Online, SEC filings, Company archives and websites. The sample includes only USA based active public industrial companies. All the financial information for the sample companies is retrieved from Compustat North America company database. Numerical data retrieved include: (1) Total Net Sales (2) Research and Development expense and (3) Total Assets. Descriptive data retrieved include (1) Company status about whether the firm is active or not (2) MSCI Global Industry Classification Standard (GICS) industry code for industry to which the firm belongs. First, year 2018 financial data for all available industry USA public companies were retrieved. This early sample size was 5063 industrial companies. The financial and non-industry companies are not considered for this research. This sample is reduced to 1299 companies after filtering out the companies that do not have information about R&D expenses, Total Assets and Total Net Sales. This reduced sample has 64 MSCI GICS industries. Out of these 64 industries 16 industries that had more than 37 companies or that had some platform companies as identified in (Cusumano et al., 2019a, 2019b) were selected for this research. The size of the resultant sample is 769 firms. After cleaning up the data for the outliers, the sample size reduced to 760 firms. SEC filings of year 2018 annual report (10-K) for these firms were retrieved from SEC EDGAR database. These data were collected for the digitalization strategy and business description information retrieval. Seven of 760 firms did not have filings in EDGAR database. After removing those companies, the resultant sample size is 753 firms. The following table gives the list of industries and the number of sample firms considered in each industry.

NO	**GICS Code**	**Industry**	**Number of companies**
I01	151010	Chemicals	42
I02	201040	Electrical Equipment	20
I03	201060	Machinery	73
I04	255020	Internet & Catalog Retail	14
I05	255040	Specialty Retail	43
I06	351010	Health Care Equipment & Supplies	77
I07	351020	Health Care Providers & Services	37
I08	352010	Biotechnology	100
I09	352020	Pharmaceuticals	38
I10	451020	IT Services	23
I11	451030	Software	106
I12	452010	Communications Equipment	35
I13	452020	Computers & Peripherals	16
I14	452030	Electronic Equipment Instruments & Components Industry	52
I15	453010	Semiconductors & Semiconductor Equipment	61
I16	502030	Interactive Media & Services	16
		Total	**753**

Table 1 Industry list and firm count

Firms' Annual reports were analyzed to identify the platform companies and digitalization strategies. Nineteen USA companies that were identified as platform companies in (Cusumano et al., 2019a) are considered as platform companies. For remaining companies, analysis was done on business description, business model and growth strategies as given in the annual report. This is to check for business models similar to the business models of companies such as Amazon Marketplace and eBay. The companies having business models similar to these companies were classified as platform companies (Type 1 platform). Analysis was also done to check for business ecosystem with third-party collaborators, growth by network effects, enablers of component technologies, innovative solution provider for industry wide problem, and other aspects of innovation platform. These aspects are as suggested by innovation platform definition given in (Cusumano et al., 2019a). The companies having business models similar to the business models of companies such as Microsoft and Qualcomm were also classified as platform companies (Type 2 platform). If a firm is classified as platform company the variable I_PLATFORM is set to 1 otherwise it is set to 0. For those companies that have platforms but do not suggest business model that generates revenue through network effects and that do not have transaction platform and business ecosystem, presence of common architecture, derivative products and family of products is assumed. These companies are considered to have product platform and P_PLATFORM is set to 1. All I_PLATFORM companies are also considered to have product platforms.

To derive degree of digitalization, analysis on annual reports was done to check for mentioning of digital technologies in the business description or management discussion and analysis sections of the annual report. Mentioning of digital technologies such as Big data analytics, Machine Learning and Artificial Intelligence, Cloud computing and Internet of Things suggests the following. The firms are either developing products or adjusting their business operations or building capabilities along the line of digital transformation. Therefore, we set 1 to corresponding technology variable when there is discussion of these technologies. For example, when a firm discusses about big data and analytics support for their customers, we set BDA to 1 and so on. Since Internet and communication technologies and enterprise service bus technologies are minimum technologies that all companies in the digital era have we consider this as one technology. Therefore, the DIGITAL_LEVEL default value is set to 1 for all companies. For every added digital technology the company discusses, DIGITAL_LEVEL is incremented. By this since having DIGITAL_LEVEL not bound to 0 and since the DIGITAL_LEVEL values are evenly spaced, we can assume this variable as a continuous variable in the model (Pasta, 2009). According to this coding method, the variable DIGITAL_LEVEL takes value between 1 and 5, inclusive. That is, $\text{DIGITAL\_LEVEL} \in [1, 5]$.

Similarly, for number of digitalized value chain activities, we assume minimum one value chain activity is digitalized. Therefore DIGITAL_VAL_ACT is initialized to 1 for all companies. Further analysis of annual report is done to check for discussion of digital delivery such as cloud-based offering and marketing via social media. If a firm has content delivery through on-line, the variable VC_OBL is set to 1. This is to mark that firm's outbound logistic is digitalized by web-based offer delivery such as online-shopping. The variable VC_OBL is set to 2 to indicate that the firm's outbound logistic is digitalized through cloud-based delivery. If a firm has social media presence we set VC_MKT to 1 to indicate that marketing value chain activity has higher digital maturity. According to this coding method, the DIGITAL_VAL_ACT takes value between 1 and 4, inclusive. i.e., DIGITAL_VAL_ACT $\in [1, 4]$

To identify the digital content offering, the annual report was analyzed for digital content-based product or service offering. If a firm discusses digital content or digital offering such as software product or digital service, we set the variable DIGITAL_OFFER to 1. The following table shows the list of topics used for analyzing public source of information and the corresponding variables set to 1

Variable	**Topics analysis**	**Variable Set to 1**
DIGITAL_LEVEL	Internet of Things, IOT, Internet of Everything	IOT
	Big Data, Analytics	BDA
	Machine Learning, Deep Learning, Artificial Intelligence	ML_AI
	Cloud Computing, Cloud	CC
DIGITAL_OFFER	Internet offering, Digital content, Digital offering, Digital service, Software	DIGITAL_OFFER
DIGITAL_VAL_ACT	E-commerce, on-line store, online offering, internet shopping, online shopping, cloud-based offering, SaaS	VC_OBL
	Social Media	VC_MKT
I_PLATFORM	Third-party developers, collaborators, complementors, ecosystem of partners, network effect, complementary technology	I_PLATFORM
P_PLATFORM	Platform	P_PLATFORM

Table 2 Topics of analysis in Annual Report

Mergent online data were retrieved for each of the sample firms to get information about company strategies. Information on strategic partners and year of incorporation were retrieved from Mergent online database. The NCOMP for a firm is set to sum of the number of strategic partners who have “collaboration” or “licensing” or “integrated product offering” relationship with the firm. Strategic partners of these relationships are more likely to provide complementary support. Therefore, the number of these relationships the firm has is considered for number of complementors variable. An important note about the variable NCOMP is that it may be a partial count of the complementors. It counts only the strategic partners as stated by the company. The company may not state all third-party developers that develop complementary components as strategic partners. For example, for companies like Google, many third-party developers make applications on Android platform. Even though these are complementors, Google may not list these as its strategic partners. Therefore, the variable NCOMP may not include the complementors equivalent to these third-party participants of the platform.

The age of the firm acts as proxy for the digital experience of a firm. The age of the firm is the number of years after incorporation as of year 2018.

$$DIGITAL\_EXP = 2018 - Year\ of\ Incorporation \quad (Eq.\ 10)$$

V RESULTS

DATA DESCRIPTIONS

The research uses both continuous and discrete data for the analysis. Table 3 and Table 4 given below summarize data of sample used in models that use industry platform and product platform as dependent variables. The sample data consists of continuous numerical data such as firms' financial data including research and development expense as ratio of total sales, and total assets as proxy for firm size. The continuous data also includes the firms' age, number of complementors, level of digitalization, and number of digitalized value chain activities. The sample's discrete data includes data for binary value variable representing business platform, product platform and digital offering.

Table 3

Sample Description: Variables with Continuous values (Interval and Ratios)

This table shows descriptive statistics of continuous variable data of sample used in this study. The descriptive statistics are given for the sample used for analysis of link between digitalization level and existence of industry and product platform. The sample for the model consists of 753 observations of information for USA based industry firms (non-financial firms) from 16 industries. RND is the ratio of research and development spending to total sales, FIRM_SIZE is represented by the total assets, DIGITAL_EXP is represented by the number of years of incorporation and NCOMP is the number of complementors which is equal to the number of firms' strategic partners with collaboration or licensing or integrated product offering relationship. DIGITAL_LEVEL is the number of digital technologies the firm uses in its operations and offering. DIGITAL_VAL_ACT is the number of value chain activities that have been digitalized by the firm.

	Mean	Median	Maximum	Minimum	Std. Dev.	Shapiro-Wilk W	Prob.	N
RND	0.764460	0.099270	46.04963	0.000000	3.285306	0.220000	0.000000	753
FIRM_SIZE	7526.500	977.8000	365725.0	0.200000	27241.16	0.270040	0.000000	753
DIGITAL_EXP	34.96000	25.00000	175.0000	1.000000	31.29129	0.793470	0.000000	753
NCOMP	3.854000	0.000000	68.00000	0.000000	8.360553	0.516440	0.000000	753
DIGITAL_LEVEL	2.325000	2.000000	5.000000	1.000000	1.276467	0.855560	0.000000	753
DIGITAL_VAL_ACT	1.756000	1.000000	4.000000	1.000000	0.898461	0.774130	0.000000	753

Table 3 Sample Description: Continuous variables

The sample has firms with mean age of 35 years, median age of 25 years. The sample includes firms with age as young as one year and as old as 175 years. The sample includes firms of almost all ages within age range of one year and 175 years with 80% of the firms less than 50 years old. The sample firms spent, on average 76.45% of their total revenue for research and development during in year 2018. The minimum R&D spending is zero percent of total revenue and maximum R&D spending is 4604.96% of total revenue. On average, in the year 2018, the sample firms had average total assets of USA$ 7526.5 million and the total assets of all the firms ranging between USA$ 977.8 million and USA$ 365725.0 million. Eighty percent of the sample firms had less than USA$ 5000 million total assets. On average, the sample firms had 4 complementors. The number of complementors of the sample firms ranged from no complementors to maximum 68 complementors.

This study considers the count of digital technologies that a firm uses as the level of digitalization. On average, in year 2018, the sample firms use at least 3 digital technologies in their operations or in their product offering. That is, on average, from this study's perspective, the sample firms are in digitalization level 3. Since all firms are assumed to have minimum the ICT and API technologies in their operations, all firms have minimum digitalization level of 1. The sample firms, on average had 2 value chain activities digitalized.

Table 4
Sample Description: Discrete Variables

This table shows description of discrete variables data of sample used in this study. The descriptions of discrete variables are given for the sample used for analysis of link between digitalization level and existence of industry and product platform. The sample for the model consists of 753 observations of information for USA based industry firms (non-financial firms) from 16 industries. I_PLATFORM is a binary variable indicating whether the firm is an industry platform or not. P_PLATFORM is a binary variable indicating whether the firm has product platform or not. DIGITAL_OFFER is a binary variable indicating whether the firms' offerings are digital. The variables are described in terms of proportion of the binary values as percent of sample size.

	% YES	% NO	N
I_PLATFORM	5.843293	94.15671	753
P_PLATFORM	83.53254	16.46746	753
DIGITAL_OFFER	33.86454	66.13546	753

Table 4 Sample Description: Discrete Variables

Based on this study's coding method to identify the industry platform firms, the sample has 44 industry platform companies. This is roughly six percent of the sample. Similarly, according to this study's coding method to identify the product platform firms 84% of the sample is product platform firms. Out of these 753 sample firms, 34% of the firms offer digitalized products or services.

SPECIFICATION STABILITY AND ROBUSTNESS

Correlation analysis of independent variables revealed that variable FIRM_TYPE, which indicates whether the firm is "born digital" or not is highly correlated with variable DIGITAL_OFFER. Therefore, this variable was omitted from the model specification and the modified model specification is as given below

$$
\begin{aligned}
PLATFORM_i = \delta_0 + \delta_1\, DIGITAL\_LEVEL_i &+ \\
\delta_2\, DIGITAL\_OFFER_i &+ \\
\delta_3\, DIGITAL\_VAL\_ACT_i &+ \\
\delta_4\, DIGITAL\_EXP_i &+ \\
\delta_5\, FIRM\_SIZE_i &+ \\
\delta_6\, RND_i &+ \\
\delta_7\, NCOMP_i &+ \\
\sum_{j=1}^{n-1} \delta_{7+j}\, I\_DUMMY_{j,i} + \epsilon_i
\end{aligned}
$$

(Eq. 11)

where,

$PLATFORM \in \{I\_PLATFORM,\ P\_PLATFORM\}$

i – Index of firm

n – Number of industries

I_DUMMY_j – Dummy variable representing industry j

The correlation matrix of the independent variables is given in the Table A3 of Appendix A. We do not see any high correlation among independent variables. The models in equation *(Eq. 11)* were validated for specification error and robustness tested for over-all fitness, reliability of coefficients and residuals. For these modified specifications, Ramsey's RESET (Regression Specification Error Test) test of specification correctness was conducted. For all models, with three terms of powers of regressors, this test results suggest no potential specification errors. Appendix A, Table A1 shows the results of Ramsey's RESET test for all the models. Tests for multicollinearity among independent variables were conducted. The tests suggest no severe multicollinearity exists among independent variables for all models. Appendix A, Table A2 presents Variance Inflation Factors (VIF) for all variables from all models. The models were also validated for serial correlation and heteroskedasticity. The Durbin-Watson *d* test (DW Test) statistics for all models show there is no significant positive serial correlation exists for all models. Appendix A, Table A4 lists the DW *d* test statistics for all the models. Heteroskedasticity tests conducted on cross-sectional data used for all models also suggest there is no evidence for significant heteroskedasticity. Appendix A, Table A5 shows the results of Breusch-Pagan test for heteroskedasticity. The variables DIGITAL_LEVEL, DIGITAL_VAL_ACT and NCOMP are potential endogenous variables. These variables and the dependent variables I_PLATFORM and P_PLATFORM may be jointly determined. Test for endogeneity due to omitted variables or simultaneity was conducted for these potential endogenous variables using instrumental variables method. Residuals of reduced form equations of these three potential endogenous variables were used as instrumental variables. The results show there is no endogeneity due to omitted variable or simultaneity in both industry platform and product platform models.

ESTIMATION RESULTS

Binomial Logistic regression procedures were conducted to analyze relationship between the chance of existence of platform and level of digitalization. Bayes Generalized Linear Model (GLM) Maximum Likelihood (ML) iterative estimation method was employed for the binomial logit regression. Regression was run for both industry platform and product platform existence as dependent variables. The results of these multivariate binomial logistic regressions conducted for the hypothesis testing are shown in Table 5 and Table 6. These tables show regression results for the analysis done for hypotheses *Hypothesis 1* and *Hypothesis 2*. Table 5 and Table 6 show intercepts and slope coefficients of the independent variables used in various analyses. Table 5 and Table 6 also show statistics for over-all fitness of specification for each model. The fitness measure $\bar{R}_p^2$ is a goodness of fit measure specially calculated for probabilistic regression such as linear probability model or binomial logit model. It is calculated as average of percent of one's explained correctly and percent of zeroes explained correctly (Studenmund, 2017). The coefficients of the independent variables are log of the odds of existence of industry platform for unit change in the corresponding independent variable. Since this study's main interest is in the directionality of relationship between dependent and independent variables and since accuracy of the coefficients is not critical for this study, we use an approximation of coefficients. As recommended in (Studenmund, 2017) we take 25% of the coefficients to approximate the change in the probability that the dependent variable equals 1.

Table 5 shows binomial logit regression result for the industry platform model. In this model the dependent variable indicates the existence of the industry platform in a firm as of year 2018. In the Table 5, the first and third columns show the independent variables. Second and fourth columns show the corresponding estimates of coefficients of the independent variables.

Table 5

Binomial Logit Regression Results for Industry Platform specification

This table shows the results of multivariate maximum likelihood logistic regression that estimates relationship between level of digitalization and existence of industry platform in a firm. The existence of transaction platform or innovation platform is used as the measure of industry platform for analysis of relationship between level of digitalization and existence of industry platform. I_PLATFORM is the dependent variable and is analyzed for level of digitalization along with other control variables. To analyze about the industry in which the industry platform business is more likely to exist, industry dummy variables I01 - I16 for 16 industries with industry I01 (Chemicals) as reference industry are used. Industry names corresponding to these industry dummy variables and Standard Errors for the coefficients are given in parentheses.

Variable	Estimate	Variable	Estimate
Intercept	-5.380000*** (1.026000)	I05 (Specialty Retail)	-0.510000 (1.811000)
DIGITAL_LEVEL	0.348700** (0.201200)	I06 (Health Care Equipment & Supplies)	-0.787600 (1.661000)
DIGITAL_OFFER	0.828300* (0.572200)	I07 (Health Care Providers & Services)	-1.257000 (1.617000)
DIGITAL_VAL_ACT	-0.017950 (0.220400)	I08 (Biotechnology)	-1.159000 (1.628000)
DIGITAL_EXP	-0.037090*** (0.013620)	I09 (Pharmaceuticals)	-0.697100 (1.731000)
FIRM_SIZE	0.000027*** (0.000007)	I10 (IT Services)	2.668000*** (0.874100)
RND	0.064260 (0.083280)	I11 (Software)	1.970000*** (0.816300)
NCOMP	0.026230** (0.014540)	I12 (Communications Equipment)	0.686100 (1.003000)
I02 (Electrical Equipment)	-0.330200 (1.963000)	I13 (Computers & Peripherals)	-1.367000 (1.561000)
I03 (Machinery)	-0.558800 (1.767000)	I14 (Electronic Equipment, Instruments & Components Industry)	0.729200 (1.136000)
I04 (Internet & Catalog Retail)	3.783000*** (0.943500)	I15 (Semiconductor & Semiconductor Equipment)	1.890000** (0.881600)
		I16 (Interactive Media & Services)	3.045000*** (0.935500)
$\bar{R}_p^2$	0.567477		
Null Deviance, df	335.29, 752		
Residual Deviance, df	184.30, 730		
AIC	230.3		

Note:

*** Significant at p-value < 0.01 ** Significant at p-value < 0.05

* Significant at p-value < 0.1

Table 5 Binomial Logit regression results for industry platform specification

The results show that the estimated model exhibits a good fit. The adjusted R-squared for probabilistic model $\bar{R}_p^2$ has value of 0.57 which indicates that more than 50% of variations in the dependent variable are correctly predicted by the estimator. The difference between the Bayes GLM Null deviance and Residual deviance is also in the lower range of 151. This suggests that deviation in the prediction capability of the estimator is not far away from ideal estimator. Hypothesis *Hypothesis 1* says that higher level of digitalization is positively related to the existence of industry platform. The table 5 shows results of estimation used for testing this hypothesis. The results show that the independent variable DIGITAL_LEVEL which indicates the level of digitalization, is positively significantly related to the chance of existence of business platform at five percent level of significance. This conforms to hypothesis *Hypothesis 1.* That is, there is statistical evidence that on average when there is higher level of digitalization, there is higher chance of presence of industry platform, while all other influencing factors stay same among firms. Average probability of existence of industry platform increases by nearly 8.7% when one more another digital technology is introduced in the digitalization, while keeping constant other independent variables constant.

The variable DIGITAL_OFFER, which represents whether a firm has digital based offering or not, is positively, significantly related to the chance of existence of business platform at 10% level of significance. This result conforms to expectation according to hypothesis. The average probability of existence of industry platform increases by approximately 20.7% when the firms have digital products or services while keeping other independent variables constant. The variable DIGITAL_EXP, which indicates firms' level of experience in digitalization, is negatively significantly related to the industry platform at one percent level of significance. This conforms to negative half side of hypothesis. According to this double-sided hypothesis, we expect firms' number of years of experience in digitalization to be positively related to industry platform. Or with consideration of firms age as proxy for digitalization experience we expect a negative relationship due to firms' inertia. Older incumbent companies may face inertia in strategy adjustment for digital transformation or platformization of operations and offerings. Therefore, being an older firm would in fact delay digitalization and therefore the chance of existence of platform business among older firms will be lower. The variable FIRM_SIZE is positively significantly related to the industry platform at one percent level of significance. This result conforms to expectation as hypothesized. On average, the likelihood of existence of industry platform increases by nearly 0.001% for unit increase of FIRM_SIZE. Similarly, the variable NCOMP – the number of complementors the firm has – is positively significantly related to existence of industry platform at one percent level of significance with all other independent variables not changing across firms. This conforms to the stated hypothesis of positive relationship between number of complementors and existence of industry platform. Other independent variables namely, DIGITAL_VAL_ACT and RND show no significant relationship with chance of existence of industry platform.

The regression results show that the chance of existence of industry platform increases for firms from certain industries. The results show that the industry dummy variables representing "Internet & Catalog Retail", "IT Services", "Software", and "Interactive Media & Services" industries are positively significantly related to existence of industry platform. These results are significant at one percent level of significance. The results also show that the relationship between industry dummy variable representing "Semiconductors & Semiconductor

Equipment" industry and chance of existence of industry platform is significant and positive at five percent level of significance.

Table 6 shows binomial logit regression result for the product platform model. In this model the dependent variable indicates the existence of product platform in a firm as of year 2018. Similar to Table 5, in the Table 6 also, the first and third columns show the independent variables. Second and fourth columns show the corresponding estimates of coefficients of the independent variables.

The results in Table 6 show that the estimator of product platform model exhibits a good fit. The adjusted R-squared for probabilistic model $\bar{R}_p^2$ has value of 0.63. This suggests that more than 50% of variations in the dependent variable are correctly predicted by the estimator. The difference between the Bayes GLM Null deviance and Residual deviance is also in the lower range of 166. This shows that deviation in the prediction capability of the estimator is not far away from ideal estimator. Results of Table 6 are for Hypothesis *Hypothesis 2.* According to Hypothesis *Hypothesis 2* there is positive relationship between level of digitalization and existence of product platform. The table 6 shows results of estimation used for testing this hypothesis. The results show that the independent variable DIGITAL_LEVEL, which indicates the level of digitalization, is positively significantly related to the chance of existence of product platform at one percent level of significance. This conforms to hypothesis *Hypothesis 2.* That is, there is statistical evidence that on average when there is higher level of digitalization, there is higher chance of presence of product platform, while all other influencing factors stay same among firms. Average probability of existence of product platform increases by around 17%

when one more another digital technology is introduced in the digitalization, while keeping constant other independent variables.

Similar to the industry platform model the relationship between variable DIGITAL_OFFER, which represents firms' digitality of offering and chance of existence of product platform is also positive and significant at one percent level of significance. This result also conforms to expectation as hypothesized. The average probability of existence of product platform increases by nearly 38.4% when the firms have digital products or services while keeping other independent variables constant. All else equal, the independent variable DIGITAL_VAL_ACT, which represents the level of digitalization of value chain, is found to be positively related to existence of product platform. This relationship is significant at one percent level of significance. The level of digitalization of value chain is measured as number value chain activities employing digital technologies. Therefore, the estimation of coefficient of DIGITAL_VAL_ACT suggests the chance of existence of product platform would increase by approximately 15.8% when one more value chain activity is digitalized while there is no change in other influencing factors. Unlike industry platform model, this relationship between DIGITAL_VAL_ACT and existence of product platform conforms to the hypothesis. Like it was observed in the industry platform model, in product platform model also, the variable NCOMP – the number of complementors the firm has – is positively related to existence of product platform at five percent level of significance while all other independent variables not changing across firms. This conforms to the stated hypothesis of positive relationship between number of complementors and existence of product platform.

Table 6

Binomial Logit Regression Results for Product Platform specification

This table shows the results of multivariate binomial logistic regression that estimates relationship between level of digitalization and existence of product platform in a firm. The existence of common product architecture, derivative products or family of products is used as the measure of product platform for analysis of relationship between level of digitalization and existence of product platform. P_PLATFORM is the dependent variable and is analyzed for level of digitalization along with other control variables. To analyze about the industry in which the product platform is more likely to exist, industry dummy variables I01 - I16 for 16 industries with industry I01 (Chemicals) as reference industry are used. Industry names corresponding to these industry dummy variables and Standard Errors for the coefficients are given in parentheses.

Variable	Estimate	Variable	Estimate
Intercept	-0.620300* (0.481800)	I05 (Specialty Retail)	0.459600 (0.693400)
DIGITAL_LEVEL	0.676300*** (0.158600)	I06 (Health Care Equipment & Supplies)	0.257800 (0.422900)
DIGITAL_OFFER	1.536000*** (0.543900)	I07 (Health Care Providers & Services)	-0.045050 (0.524400)
DIGITAL_VAL_ACT	0.630300*** (0.233300)	I08 (Biotechnology)	-0.134100 (0.448700)
DIGITAL_EXP	-0.004192 (0.003496)	I09 (Pharmaceuticals)	0.151900 (0.524200)
FIRM_SIZE	-0.000007 (0.000006)	I10 (IT Services)	0.991200 (1.587000)
RND	0.046060 (0.045240)	I11 (Software)	0.124600 (0.985200)
NCOMP	0.072880** (0.032170)	I12 (Communications Equipment)	0.078520 (0.772800)
I02 (Electrical Equipment)	-1.651000*** (0.583200)	I13 (Computers & Peripherals)	1.423000 (1.528000)
I03 (Machinery)	-0.426700 (0.391700)	I14 (Electronic Equipment, Instruments & Components Industry)	-0.418200 (0.461500)
I04 (Internet & Catalog Retail)	-0.813400 (1.077000)	I15 (Semiconductor & Semiconductor Equipment)	-0.271600 (0.489400)
		I16 (Interactive Media & Services)	0.608200 (1.753000)
$\bar{R}_p^2$	0.630346		
Null Deviance, df	673.70, 752		
Residual Deviance, df	508.01, 730		
AIC	554.01		

Note:

*** Significant at p-value < 0.01 ** Significant at p-value < 0.05

* Significant at p-value < 0.1

Table 6 Binomial Logit regression results for product platform specification

Other independent variables namely, DIGITAL_EXP which represents firms' number of years of experience in digitalization, FIRM_SIZE and RND show no signification relationship with chance of existence of product platform.

Unlike industry platform model, except the industry dummy variable representing "Electrical Equipment" industry, all other dummy variables representing other industries do not show significant relationship with existence of product platform. The result show unexpected negative change in the probability of existence of product platform for being in "Electrical Equipment" industry when compared to being in the reference industry "Chemicals" industry.

As well as estimating the model using logistic regression using maximum likelihood method, models' estimations were done with linear probability method also. The results of the linear probability method analysis conducted on industry platform and product platform specifications are given Table A6 and Table A7 in Appendix A. After ignoring differences due to numerical rounding and accuracy, we observe that the results of linear probability model are close to the results of the binomial logistic regression model.

VI DISCUSSION

This research set out with the main objective of discovering relationship between industrial firms' level of digitalization and presence of platform business model in those firms. Level of digitalization in a firm is inferred from the number of digital technologies companies are involved with. Firms use the digital technologies such as Internet of Things, Big data analytics, Machine Learning and Artificial Intelligence, and Cloud Computing in operations, infrastructure or in the product and service offerings. Presence of platformization of business model is inferred from existence of product platforms and industry platforms. Industry platform exists if there is a business model to derive revenue using an ecosystem of businesses or to derive revenue by facilitating an environment to bring buyers and sellers together. The relationship between degree of digitalization and platformization was analyzed on a sample of 753 USA based non-financial industry firms. Other objective of the study is to identify with high confidence, the industries that have significant relationship with platformization. The sample was chosen to include 16 industries. Dummy variables representing each of these industries were used to determine effect of industry membership on platformization. Objectives of this study also include finding industries which are more likely to have platformization. Finding these industries is based on firms' involvement in various digital technologies. Comparison of level of use of digital technologies in platform industries and non-platform industries is done. This is to assess the relationship between digital technological characteristics of industries and platformization.

We hypothesized that, all other things equal, the chance of platform business is positively related to level of digitalization. The results of research using year 2018 data suggest conformance to this hypothesis. Table 7 given below presents summary of findings of analysis for the main hypotheses.

Table 7
Summary of estimation results of main hypotheses
This table gives the description of results of estimations for relationship between level of digitalization and platform business.

	Industry Platform	Product Platform
Level of Digitalization	Higher level of digitalization increases chance of platform business	Higher level of digitalization increases chance of product platform
Digital Offering	Presence of digital offering increases chance of platform business	Presence of digital offering increases chance of product platform
Number of digitized Value chain activities	Change in number of digitized value chain activities does not influence chance of platform business	Higher the number of digitized value chain activities higher the chance of product platform
Number of complementors	Higher the number of complementors more the chance of platform business	Higher the number of complementors more the chance of product platform

Table 7 Summary of Estimation results

The results of analysis of relationship between level of digitalization and platform business show there is significant positive relationship between the level of digitalization and platformization. We observe that there is significant evidence for this relationship for both the platform business model and product and service platforms. The sample has 44 industry platform companies which make up approximately six percent of the sample and 84% of sample is product platform. All the industry platform companies from the sample are also product platform companies. All else equal, when there is higher level of digital transformation in a firm there is high chance of existence of platform business. On average, all else equal, when the firms' digital level goes up by one level by using any digital technology, the likelihood of platform business goes up by 8.7%. Also, having a digital content-based offering increases this chance by 20.7%

when compared to having non-digital content product. Even though this statistical evidence suggests firms having higher level of digitalization is more likely to have industry platform, it is not evidence for the cause. However, there are notable amount of literature from managers and practitioners which suggest the platform business can be result of digital technologies (Bossert & Desmet, 2019; Gens, 2013; Moazed, 2017; Rosen, 2019; Zambrano, 2016). The digital technologies being precondition for formation of platform business or the platform business model designed as part of digital transformation process confirm the statistical evidence.

Like any other businesses, industry platform business can be considered as interconnected social-technical-economical system (socio-technomical system) of buyers and producers (Staykova & Damsgaard, 2018). The system can be as simple as a transaction mechanism to facilitate connecting the buyers and sellers. Or it can be as complex as connecting various producer participants that make complementary parts of single simple product or a complex solution to a problem common to more than one industry. The system is social as it interconnects people for various transactions for the benefit of people and society as whole. The system is economical system since its main basic emergent behavior is economic value creation. The system is technical as it uses various technological forms to connect the elements of systems and run the business functions. From digitalization perspective, core mechanisms binding industry platform business include interconnecting participants from multiple sides, collecting information, gaining insight about needs and wants and various other characteristics of participants, and deciding and acting up on the insights gained. The digital transformation technologies are essential to these interconnections (Rosen, 2019). Modern industry platforms are built on foundations of various digital technologies such as cloud computing, high speed wired and wireless communications, social media, big data analytics using machine learning and artificial intelligence (Gens, 2013). Communications technologies involving high speed and mobility enable connections of participants and platform growth (Venkatraman, 2017). Cloud computing and APIs strengthen collaboration and resource sharing. Technologies of machine learning, artificial intelligence and big data analytics play role in data collection and gaining deep understanding about the users, collaborators and other market expectations. This strong dependence on the digital technologies for the success of the platform is a good reason for observing statistically shown positive relationship between degree of digitalization and platform business.

The results indicate that the number of value chain activities digitized does not have influence on industry platform. However, it has positive significant relationship with product platform. In this research to measure the number of value chain activities digitized, we followed a linear value chain model as introduced by Porter (Porter, 1985). Based on this model, generally, the primary value chain activities include inbound logistics, production, outbound logistics, sales and marketing, and customer support. The support activities of value chain include research and development, procurement, infrastructure, and human resources. Portion or all the value chain activities can be digitized depending on the industry. For example, generally speaking, for software industry, the outbound logistic can be digitalized by offering the software on cloud. For semiconductor industry the outbound logistics may be hard to digitalize since in general, the distribution of semiconductor products may need physical channels and partners. Because of several advantages of digitization, digitization of linear value creation activities improves product development efficiency. This results in modular architecture of products for reusing components and formation of product platforms. Therefore, higher level of digitization of linear value chain activities is positively related to the product platform as hypothesized. The result shows that on average when the companies digitize one more additional value chain activity, the chance of product platform increases by 15.8%.

On the other hand, in platform businesses, value creation occurs by network of value creating activities that augment the linear value chain activities. There may also be an arrangement where, whole value network itself can make up the business model of industry platform. Value creation occurs by collaboration from different external third-party participants in distributed manner. These external value creating activities of the value network can be additions to existing value chain activities internal to the firm. Moreover, platforms mostly stem based on product architecture and interconnection of the participants of the business for collaboration that make up the value network. Irrespective of whether the internal linear value chain activities are digitalized or not, the platform business as external value network may still exist. It depends upon the product architecture, need for collaboration from third-party businesses and producer or developer community. Therefore, digitalization of value chain activities which are internal to the firm may not have influence on formation of platform business model.

Number of complementors is another company characteristic which is positively significantly related to platform business. Complementors are external third-party producer participants that produce components to a platform company's offering such that both the producer participants and the platform company mutually benefit. The analysis results show that on average, all else equal, when the number of complementors increases by one there will be 0.66% higher chance of platform business. Platform businesses connect multiple sides. In transaction platforms buyers and producers are connected. In innovation platforms, buyers, producers and various other producer participants that make complementary components to the products and services are connected. The producer participants – the complementors make up the industry platform. When a firm needs collaboration with other industry players for sourcing technologies and complementary components or for standardization of technologies for components compatibility, industry platform evolves. The need for collaboration arises when firms take on to solve an industry wide problem or produce offerings that more than one industry needs. Regardless of reason for need for collaboration, platform evolves if a firm has to collaborate with more than one complementor. When an industry has greater number of complementors, a firm from that industry will have higher chance of forming industry platform.

Size of the firms represented by monetary value of total assets is an indication of company's investment power and over-all attractiveness of the firm for other industry players to collaborate with. Total value of assets is also a sign of firms' long-term viability which assures the buyers, sellers and other industry participants to transact with the company. Larger companies' investment capability would also result in investments in digital technologies and quicker digital transformation. Larger firms with their market power would also be able to exercise power in technology standardization. This would enable larger firms to create industry platform relatively easier when compared to smaller firms. Therefore, firms of larger size are expected to have industry platforms with higher chance.

When we consider the age of the company with the platformization, we get evidence for a negative relationship between age of the firm and platform business. According to results, more aged the firms are, less likely would they have industry platform business. This could be mainly due to the old incumbent firms' inability to break the trap of success to adopt quickly to the digital technologies. Digital transformation requires faster and dramatic changes which may revise product architecture and so the product roadmaps. It may require upgrades of existing processes and operations methods. It may require reconfiguration of dependency on partners and collaborators. For older companies, these changes are harder and time consuming and may even lead to negative effects. For relatively younger companies this risk is relatively lower. Therefore, we may expect to see lower level of digitalization in older companies and as a result in older companies, the chance of platformization may be lower. Results related to relationship between research and development spending and platform is not as hypothesized. Firms' spending on R&D does not have significant relationship with platform business model. As it is discussed before, platform business model design and implementation are through investment in digital transformation. But the R&D spending accounts for the spending on research for the product development. So, the R&D spending does not directly influence the platformization.

Industry platforms are not new. Platform business model has been in use since from several decades ago in businesses such as telephone networks and auction houses. However, the platform business model is not seen in all industries. In some industries, such as software industry, the nature of product offering and flexibility in the value chain arrangements readily present environment and means of evolution of industry platforms. Some industry's product offering, and market structure enable the firms to create industry platform with some technological augmentation. For example, auto mobile industry with technologies related to connectivity and high computation power could create platforms for buyer-producer transactions and component producers' collaboration. In some industries like pharmaceuticals and healthcare, due to criticality of information protection, intellectual property protection and various other closed environment needs, creation or evolution of platform may be limited. The results of analysis on a sample of firms from 16 distinct industries show that firms from five industries have higher chance of having industry platform. The five industries are: "Internet & Catalog Retail", "IT Services", "Software", "Interactive Media & Services" and "Semiconductors & Semiconductor Equipment". Further analysis of the firms from these five industries shows that all of these industries have commonality in level of use of various digital technologies in member firms. The Table 8 shows proportion of firms involved in various digital technologies. For technologies relevant for those five industries which are significantly related to the platform business, the proportion of the firms involved in the technology is comparatively similar across these platform industries. For example, when compared to other industries, all of these platform industries have more than 40% of firms that use big data analytics. All of these industries have more than 30% of the firms that involve machine learning and artificial intelligence technologies. Among all industries, more than 80% of firms are platform industry firms that use cloud computing technologies. Firms from these platform industries also have other common characteristics. Following are some of visible characteristics. (1) Ability to digitize some or all part of products and service offerings. (2) Willingness to relax protection of IPR and therefore ability to share technology secrets among complementors for collaboration. (3) Ability to adopt digital transformation to the advantage of connecting partners, users and complementors and so to improve the efficiency of product development and market access.

Table 8
Digital technologies in different industries

This table shows the level of digital technologies used in industries chosen for this study. The column "N" shows the number of sample firms in each industry. IOT - Internet of Things; BDA - Big Data Analytics; ML_AI - Machine Learning and Artificial Intelligence; CC - Cloud computing. The communication technologies such as high-speed internet connection (both wired and wireless) and API technologies are assumed to have been adopted by all firms in all industries. The columns headed by different technologies show the proportion of firms involved in that particular technology for a given industry.

Industry	N	IOT	BDA	ML_AI	CC
Biotechnology	100	0.00	0.12	0.02	0.21
Chemicals	42	0.00	0.07	0.02	0.48
Communications Equipment	35	0.57	0.51	0.29	0.80
Computers & Peripherals	16	0.50	0.69	0.44	0.81
Electrical Equipment	20	0.40	0.15	0.05	0.55
Electronic Equipment, Instruments & Components Industry	52	0.27	0.27	0.15	0.50
Health Care Equipment & Supplies	77	0.01	0.23	0.10	0.39
Health Care Providers & Services	37	0.00	0.51	0.14	0.49
Interactive Media & Services	16	0.00	0.87	0.31	0.81
Internet & Catalog Retail	14	0.00	0.64	0.43	0.86
IT Services	23	0.26	0.83	0.30	0.91
Machinery	73	0.12	0.18	0.08	0.38
Pharmaceuticals	38	0.00	0.24	0.00	0.21
Semiconductors & Semiconductor Equipment	61	0.54	0.44	0.43	0.62
Software	106	0.26	0.85	0.65	0.97
Specialty Retail	43	0.02	0.37	0.12	0.44

Table 8 Digital Technology usage level in various industries

Comparison of firms from platform industries with firms from non-platform industries using technological characteristics show that among all these 16 industries, only one industry: "Computers & Peripherals" is comparable to two of the platform industries. Multivariable comparison analysis using MANOVA with variables indicating firms' involvement of various digital technologies was conducted to identify industries that are more likely to have platform companies. Linear combinations of proportions of firms using different digital technologies from non-platform industry and platform industry are compared. Based on the technological characteristics commonality discussed above, if the mentioned proportion of firms from a given non-platform industry is not significantly different from the proportion of firms from at least one platform industry, then the given non-platform industry is considered more likely to have platform business in the future. The Table A8 given in Appendix A shows the results of the MANOVA analysis for comparison of combinations of proportions of firms using different digital technologies from different industries with platform industries. The results show that the null hypothesis of, proportions of firms using different digital technologies from "Computers & Peripherals" industry are same as that from platform industries "IT services" and "Semiconductor & Semiconductor Equipment", cannot be rejected below 10% level of significance. Therefore, since on average, firms from "Computers & Peripherals" industry have similar level of digital transformation as the firms from platform industry, all things equal, "Computers & Peripherals" industry is also more likely to have platform companies in the future.

Overall the research results conform to the main hypotheses and majority of the secondary hypotheses. The results show evidence for significant positive relationship between digitalization and platformization. The Table 9 shows the summary of results of hypothesis testing using results of estimation of product platform model and industry platform model.

Table 9
Summary of results of hypothesis testing

Hypothesis	Support: Industry Platform	Support: Product Platform
Platformization is positively related to degree of digitalization	Yes	Yes
Platformization is positively related to digitization of products and service offering	Yes	Yes
Platformization is positively related to number of digitized value chain activities	No	Yes
Platformization is positively related to number of complementors and partners	Yes	Yes
Platformization is positively related to size of the firm	Yes	No
Platformization is significantly related to age of the firm	Yes	No
Platformization is positively related to R&D spending	No	No

Table 9 Summary of results of hypothesis testing

VII SUMMARY AND CONCLUSIONS

The primary research objective was to discover the relationship between digital transformation and platform business model. The other research objectives were also to discover other firm level factors that influence platformization and to identify industries that are more likely to have platform business model. For this objective, the research was conducted on firms from 16 non-financial industries. This study used data on USA based firms. Theories of platform business, digital transformation, value networks and concepts on various digital technologies were used to support the framework of analysis and to hypothesize relationship between level of digitalization and likelihood of existence of platform. The research findings include the following:

(1) Degree of digitalization has significant positive influence on likelihood of existence of both product platform and industry platform

(2) Company characteristics such as size and number of partners and complementors have significant positive influence on platformization while company age has negative relationship with platformization

(3) Out of 16 industries considered in analysis the industries "Internet & Catalog Retail", "IT Services", "Software", "Interactive Media & Services", "Semiconductors & Semiconductor Equipment", and "Computers & Peripherals" are more likely to have platform business model.

The significant statistical evidence of these results gives following messages for managers and practitioners: It appears that digital transformation can be a catalyst for platformization. Through digital transformation process with focus on certain digital technologies applicable to the business needs, a firm can design and implement platform business model. If a firm has an innovation that requires standardization and collaboration from other industry players or if the firm has a core product whose value will be increased by complementary products or services from third-party companies, the firm can potentially design and implement an industry platform. If a firm can generate relatively higher levels of revenue by offering products and services through subscription and licensing rather than out-right selling, the firm can potentially design and implement a transaction platform. From the common characteristics of industry platforms identified in this research, we see that Cloud Computing and Big data analytics are more powerful enhancers of platform business when compared to other digital technologies. Sixty to 90% of platform companies use these Cloud Computing and Big data analytics. Digital offering and delivery through cloud or Internet are pre-requisites for platform business. Connectivity and ESB/APIs are default and therefore these are minimum requirements for the platform businesses. In today's digital world all business should be already using these. Virtual Reality and Augmented Reality and Internet of Things technologies are business specific and these are not specific to platform companies only. These technologies are used both in platform and non-platform companies equally depending on business need. Even if the companies have digitally transformed at higher level in operations, value chain, and product offerings, platformization may not be feasible in some industries. Some of these industries include pharmaceuticals and healthcare where collaboration and open sourcing are competition sensitive. Collaboration and opening up the platform to complementors and so to increase the number of complementors is beneficial to the platform business.

This research comes with some assumptions and limitations. To encode measures of the level of digitalization and platformization the research employs some subjectivity. For these measures, business description is analyzed and existence of platform business model is subjectively determined using definitions of platform business taken from the platform business literature (Cusumano et al., 2019a). Firm's business description is subjectively compared with business description of companies identified as platform companies in literature. Similarly, for the measure of the level of digitalization, when firms describe themselves as being involved in various digital technologies, the research assumes the firms actually deploy those digital technologies as part of digital transformation of product offering or operations or infrastructure. Even though the research uses acceptable size of sample for analysis, the proportion of the firms identified as industry platform is only roughly six percent of the sample. That is, only roughly six percent of the whole sample influences the value to mark existence of industry platforms. The conclusions for the likelihood of existence of industry platform are based on this small proportion which may be a concern for logistic regression method. However, in this research, even if the sample is adjusted to have evenly chosen proportions of industry platform firms and non-industry platform firms the results are not like to be largely different. We observed during our analysis that all industry platform firms heavily use digitalization. Therefore, adjusting the sample to increase the proportion of industry platform firms or to decrease the proportion of non-industry platform firms is likely to improve logistic regression fit.

Future extension of this research can address some of these limitations. This research uses only 16 industries for the analysis of relationship between industry membership and likelihood of platform business. The six industries identified as more likely to have platform business are results of comparison among these 16 industries of this sample only. The research sample can be further expanded with greater number of industries including private companies. This research uses publicly available secondary data such as financial statements and website information. A possible improvement could be to use primary data. Information about the platformization and nature and use of digital technologies can be obtained directly from managers and practitioners through interviews and surveys and so subjectivity in the encoding of variables can be reduced.

Possibilities for other future research can be explored along the following lines: This research only gives evidence for the directionality of relationship between the digital transformation and existence of platformization. The research can be extended to understand how the digital transformation actually influences design and implementation of the industry platform. This would give valuable information about specific technologies required for platformization. Also, we would get insight about whether there are any specific set of approaches or specific combination of digital technologies in digital transformation process that significantly influence success of platformization. The platform literature defines various types of platforms. At a higher level there are transaction platforms, innovation platform and hybrid platform (Cusumano et al., 2019b, 2019a). From application perspective there can be technology platforms, computing platforms, utility platforms, market places and so on. A useful research similar to this research can be done on relationship between the type of platform and digital transformation and other firm level characteristics. Further extension of this research could be analysis of influence of various industry characteristics such as barrier to entry, market size, industry type such as high tech or low tech on platformization. Not all platform businesses are successful. From firm performance perspective we find platform business companies in two extremes. Some platform companies are very successful, and some platform companies are failures. A study on performances of platform business with various firm characteristics and investment on digital transformation would provide valuable insights. Specifically, one can compare the platformization performance and firm characteristics across industries and firms. This research has potential to give information about the extremes of performances of platform companies.

BIBLIOGRAPHY

Andersson Schwarz, J. (2017). Platform Logic: An Interdisciplinary Approach to the Platform-Based Economy. *Policy and Internet*, *9*(4), 374–394.

Benlian, A., & Kettinger, W. J. (2018). Special Section : The Transformative Value of Cloud Computing : A Decoupling , Platformization , and Recombination Theoretical Framework. *Journal of Management Infomation Systems*, *35*(3), 719–739.

Bossert, O., & Desmet, D. (2019). The platform play: How to operate like a tech company. *McKinsey Digital*. Retrieved from McKinsey Digital Database.

Cusumano, M. A. (2010). The evolution of platform thinking. *Communications of the ACM*, *53*(1), 32–34.

Cusumano, M. A., Gawer, A., & Yoffie, D. B. (2019a). 3.4 Platform versus Non-Platform Company Performance : Some Exploratory Data Analysis , 1995-2015. *Software Business, Platforms, and Ecosystems: Fundamentals of Software Production Research*, 171.

Cusumano, M. A., Gawer, A., & Yoffie, D. B. (2019b). *The Business of Platforms: Strategy in the Age of Digital Competition, Innovation, and Power*. New York: Harper Business.

Daugherty, P., Carrel-Billiard, M., & Bil, M. J. (2016). Platform Economy : business model innovation from the outside in. *Technology Vision*. Retrieved from Accenture.

Eisenmann, T., Parker, G., & Alstyne, M. W. A. (2016). Strategies for Two Sided Markets. *Harvard Business Review*, *84*(10), 92–101.

Evans, D. S., & Schmalensee, R. (2017). Network Effects: March to the Evidence, Not to the Slogans. *Ssrn*, (August), 1–10.

Evans, D. S., & Schmalensee, R. (2018). Debunking the 'network effects' bogeyman. *Regulation*, *40*, 36–39.

Gatautis, R. (2017). The rise of the platforms: Business model innovation perspectives. *Engineering Economics*, *28*(5), 585–591.

Gawer, A., & Cusumano, M. A. (2012). How companies become platform leaders. *MIT/Sloan Management Review*, *49*(2).

Gens, F. (2013). *The 3rd Platform : Enabling Digital Transformation. IDC White Paper*. Retrieved from IDC.

Hagel, J. (2015). The power of platforms. *Deloitte University Press*, 1–14.

Hagiu, A. (2009). Multi-Sided Platforms: From Microfoundations to Design and Expansion Strategies. *Harvard Business School Strategy Unit Working Paper*, *9*(115), 1–25.

Hess, T., Benlian, A., Matt, C., & Wiesböck, F. (2016). Options for Formulating a Digital Transformation Strategy. *MIS Quarterly Executive*, *15*(2), 123–139.

Hung, M. (2018). IoT Implementation and Management — From the Edge to the Cloud: A Gartner Trend Insight Report (ID: G00350392). Retrieved from Gartner Database.

Hung, M., Friedman, T., Ganguli, S., Heidt, E. T., & Tsai, T. (2017). Internet of Things Primer for 2017 (ID: G00318562). Retrieved from Gartner Database.

Kazan, E., Tan, C., Lim, E. T. K., & Damsgaard, J. A. N. (2018). Disentangling Digital Platform Competition : The Case of UK Mobile Payment Platforms. *Journal of Management Infomation Systems*, *35*(1), 180–219.

Kenney, M., & Zysman, J. (2016). The rise of the platform economy. *Issues in Science and Technology*, *32*(3), 62–69.

Kim, J. (2014). Platform business and network strategy. *STI Policy Review*, *5*(1), 57–74.

Kim, J. (2016). The Platform Business Model and Strategy: A Dynamic Analysis of the Value

Chain and Platform Business. The University of Manchester (United Kingdom).
Laney, D., Howson, C., Buytendijk, F., Waller, G., Schulte, W. R., Logan, V., … White, A. (2019). Predicts 2019 : Data and Analytics Strategy (ID: G00374107). Retrieved from Gartner Database.
Lee, S. M., Kim, T., Noh, Y., & Lee, B. (2010). Success factors of platform leadership in web 2.0 service business. *Service Business*, *4*(2), 89–103.
Main, B. A., Lamm, B., & Mccormack, D. (2018). What Boards Need to Know About Digital Transformation. *Corporate Governance Advisor*, *26*(1), 18–22.
Martínez-Carreras, M. A., García Jimenez, F. J., & Gómez Skarmeta, A. F. (2015). Building integrated business environments: analysing open-source ESB. *Enterprise Information Systems*, *9*(4), 401–435.
Meyer, M. H. (2008). Perspective: How Honda innovates. *Journal of Product Innovation Management*, *25*(3), 261–271.
Moazed, A. (2017). The Value of Digital Transformation: How Investors Evaluate "Tech." Retrieved June 8, 2019, from https://www.applicoinc.com/blog/value-digital-transformation-isnt-tech/
Muegge, S. (2013). Platforms, Communities, and Business Ecosystems: Lessons Learned about Technology Entrepreneurship in an Interconnected World. *Technology Review Review*, (February), 5–15.
Pagani, M. (2013). Digital Business Strategy and Value Creation : Framing The Dynamic Cycle of Control Points. *MIS Quarterly*, *37*(2), 617–632.
Pasta, D. J. (2009). Learning When to Be Discrete: Continuous vs. Categorical Predictors. *Statistics and Data Analysis*, 1–10.
Porter, M. E. (1985). The value chain and competitive advantage. In *Competitive Advantage: Creating and Sustaining Superior Performance: With a New Introduction* (pp. 33–61). New York: The Free Press.
Raskino, M., & Waller, G. (2016). Ten Basic Management Ideas to Import From Born-Digital Companies. Retrieved from Gartner Database.
Rosen, M. (2019). Platform Business Model of the Digital Economy. *BPTrends Column*. Retrieved from www.bptrends.com.
Sebastian, I. M., Ross, J. W., & Beath, C. (2017). How Big Old Companies Navigate Digital Transformation. *MIS Quarterly Executive*, *16*(3), 197–214.
Sia, S. K., & Soh, C. (2016). How DBS Bank Pursued a Digital Business. *MIS Quarterly Executive*, *2016*(June), 105–122.
Singh, A., & Hess, T. (2017). How Chief Digital Officers Promote the Digital Transformation of their Companies. *MIS Quarterly Executive*, *16*(1), 1–17.
Staykova, K. S., & Damsgaard, J. (2018). Introducing Platform Interactions Model for Studying Multi-Sided Platforms. In *Hawaii International Conference on System Sciences* (pp. 5024–5033).
Studenmund, A. H. (2017). *Using Econometrics: A Practical Guide* (7th ed.). Pearson.
Swanton, B. (2018). Getting to the Details of the Digital Platform : A Gartner Theme Insight Report (ID: G00373873). Retrieved from Gartner Database.
Swanton, B., & Golluscio, E. (2018). Survey Analysis : Building a Digital Business Technology Platform Requires New Technologies and Methods (ID: G00374016). Retrieved from Gartner Database.
Universit, M. (2018). Digital Transformation: What is New If Anything? *Academy of*

Management Discoveries, *4*(3), 378–387.
Venkatraman, V. (2017). *The Digital Matrix: New Rules for Business Transformation Through Technology*. Greystone Books.
Westerlund, M., Leminen, S., & Rajahonka, M. (2014). Designing Business Models for the Internet of Things. *Technology Innovation Management Review*, *4*(7), 5–14.
Zambrano, E. (2016). Platform Innovation is the Best Type of Digital Transformation. Retrieved June 8, 2019, from https://www.applicoinc.com/blog/platform-digital-transformation/
Zayati, A., Biennier, F., Moalla, M., & Badr, Y. (2012). Towards lean service bus architecture for industrial integration infrastructure and pull manufacturing strategies. *Journal of Intelligent Manufacturing*, *23*(1), 125–139.

APPENDIX A

Table A 1 Specification correctness Tests: Ramsey's RESET tests for industry platform and product platform models

Table A1

Specification Correctness Tests: Ramsey's RESET test for industry platform and product platform models

This table shows summary of results of Ramsey's RESET test for industry platform and product platform models with quadratic terms of regressors. F-statistic, degrees of freedom and significance of F-statistic are shown for models linking existence of industry platform and product platform with level of digitalization and industry dummies. The results suggest null hypothesis that the concerned equation and alternative equation are same cannot be rejected at 5% level of significance.

Model	F-Statistic	df	Prob.
Industry Platform Model	0.300230	(22, 708)	0.999300
Product Platform Model	0.964020	(22, 708)	0.509000

Table A 2 Coefficient Tests: Variance Inflation Factors (VIF) for industry platform and product platform model

Table A2

Variance Inflation Factors (VIF) for industry platform and product platform models

This table shows the variance inflation factor for each variable used in industry platform and product platform models of this study. The results show that for all independent variables, VIF < 5.0, indicating no significant correlation exists among independent variables.

Variable	VIF
DIGITAL_LEVEL	1.754432
DIGITAL_OFFER	1.742576
DIGITAL_VAL_ACT	1.385324
DIGITAL_EXP	1.119688
FIRM_SIZE	1.066859
RND	1.038998
NCOMP	1.087006

Table A 3 Correlation Matrix for independent variables

Table A3

Correlation Matrix for Independent variables

This table shows the correlation among the independent variables of the model.

	DIGITAL_LEVEL	DIGITAL_OFFER	DIGITAL_VAL_ACT	DIGITAL_EXP	FIRM_SIZE	RND	NCOMP
DIGITAL_LEVEL	1.000000						
DIGITAL_OFFER	0.600631	1.000000					
DIGITAL_VAL_ACT	0.472925	0.457279	1.000000				
DIGITAL_EXP	-0.107299	-0.230496	-0.161853	1.000000			
FIRM_SIZE	0.129123	0.079279	0.068779	0.148533	1.000000		
RND	-0.100684	-0.097930	-0.088556	-0.119441	-0.054023	1.000000	
NCOMP	0.234980	0.190857	0.094202	-0.002867	0.162137	0.010022	1.000000

Table A 4 Residual Tests: Serial Correlation test (DW test)

Table A4

Residual Tests (Serial correlation) for industry platform and product platform models

This table shows Durbin-Watson statistics and p-value of Durbin-Watson statistics of industry platform and product platform models. The results show that for both models d-statistic is not significant at 5% level of significance. This suggests that the null hypothesis of no positive serial correlation cannot be rejected.

Model	DW d-stat	(k, N)	Prob.
Industry Platform Model	2.138900	(23, 753)	0.915900
Product Platform Model	2.091900	(23, 753)	0.767700

Table A 5 Residual Tests: Heteroskedasticity test for Industry Platform and Product Platform Models

Table A5

Residual Tests (Heteroskedasticity) for Industry platform and product platform models

This table shows Breusch-Pagan test statistics (sample size times the coefficient of determination), degrees of freedom and Chi-squared critical value for regression equation with residual-squared as regressand and all other independent variables as regressors. The results show that for all models, the test statistic is lesser than Chi-squared critical value at 5% level of significance, suggesting that the null hypothesis of homoskedasticity cannot be rejected.

Model	**NR^2**	**df**	**5% Sig. Critical χ^2**
Industry Platform Model	18.39564	22	33.92444
Product Platform Model	24.12857	22	33.92444

Table A 6 Linear probability estimation (OLS) results for industry platform specification

Table A6

Linear probability Estimation Results for Industry Platform Model

This table shows the results of multivariate linear probability (OLS) regression that estimates relationship between level of digitalization and existence of industry platform in a firm. The existence of transaction platform or innovation platform is used as the measure of industry platform for analysis of relationship between level of digitalization and existence of industry platform. I_PLATFORM is the dependent variable and is analyzed for level of digitalization along with other control variables. To analyze about the industry in which the industry platform business is more likely to exist, industry dummy variables I01 - I16 for 16 industries with industry I01 (Chemicals) as reference industry are used. Industry names corresponding to these industry dummy variables and Standard Errors for the coefficients are given in parentheses.

Variable	Estimate	Variable	Estimate
Intercept	0.004898 (0.038660)	I05 (Specialty Retail)	0.013790 (0.048760)
DIGITAL_LEVEL	0.010880" (0.008590)	I06 (Health Care Equipment & Supplies)	-0.005779 (0.040060)
DIGITAL_OFFER	0.022470 (0.024440)	I07 (Health Care Providers & Services)	-0.042480 (0.047270)
DIGITAL_VAL_ACT	-0.009600 (0.011630)	I08 (Biotechnology)	-0.021290 (0.040970)
DIGITAL_EXP	-0.000652*** (0.000279)	I09 (Pharmaceuticals)	-0.034010 (0.047210)
FIRM_SIZE	0.000002*** (0.000000)	I10 (IT Services)	0.198800*** (0.057780)
RND	0.001564 (0.002486)	I11 (Software)	0.106300** (0.046430)
NCOMP	0.002129** (0.000991)	I12 (Communications Equipment)	0.007899 (0.050900)
I02 (Electrical Equipment)	0.000823 (0.056180)	I13 (Computers & Peripherals)	-0.056720 (0.063670)
I03 (Machinery)	0.017040 (0.040040)	I14 (Electronic Equipment, Instruments & Components Industry)	0.014620 (0.043800)
I04 (Internet & Catalog Retail)	0.381400*** (0.067900)	I15 (Semiconductor & Semiconductor Equipment)	0.046610" (0.043370)
		I16 (Interactive Media & Services)	0.298900*** (0.066200)
R^2	0.256400		
$\bar{R}^2_p$	0.568182		
F-Statistic	11.44000***		

Note:

*** Significant at p-value < 0.01 ** Significant at p-value < 0.05

* Significant at p-value < 0.1 " Significant at p-value < 0.15

Table A 7 Linear probability estimation (OLS) results for product platform specification

Table A7

Linear probability Estimation Results for Product Platform Model

This table shows the results of multivariate linear probability (OLS) regression that estimates relationship between level of digitalization and existence of product platform in a firm. The existence of common product architecture, derivative products or family of products is used as the measure of product platform for analysis of relationship between level of digitalization and existence of product platform. P_PLATFORM is the dependent variable and is analyzed for level of digitalization along with other control variables. To analyze about the industry in which the product platform business is more likely to exist, industry dummy variables I01 - I16 for 16 industries with industry I01 as reference industry (Chemicals) are used. Industry names corresponding to these industry dummy variables and Standard Errors for the coefficients are given in parentheses.

Variable	Estimate	Variable	Estimate
Intercept	0.602200*** (0.064590)	I05 (Specialty Retail)	0.108000* (0.081450)
DIGITAL_LEVEL	0.061300*** (0.014350)	I06 (Health Care Equipment & Supplies)	0.053200 (0.066920)
DIGITAL_OFFER	0.101500*** (0.040840)	I07 (Health Care Providers & Services)	0.018760 (0.078960)
DIGITAL_VAL_ACT	0.041680** (0.019430)	I08 (Biotechnology)	0.048850 (0.068450)
DIGITAL_EXP	-0.000613* (0.000466)	I09 (Pharmaceuticals)	0.078370 (0.078870)
FIRM_SIZE	0.000000 (0.000000)	I10 (IT Services)	0.024630 (0.096520)
RND	0.003030 (0.004152)	I11 (Software)	-0.046710 (0.077560)
NCOMP	0.001642 (0.001656)	I12 (Communications Equipment)	0.002156 (0.085030)
I02 (Electrical Equipment)	-0.280500*** (0.093860)	I13 (Computers & Peripherals)	0.059010 (0.106400)
I03 (Machinery)	-0.086080* (0.066890)	I14 (Electronic Equipment, Instruments & Components Industry)	-0.053510 (0.073170)
I04 (Internet & Catalog Retail)	-0.029120 (0.113400)	I15 (Semiconductor & Semiconductor Equipment)	-0.011300 (0.072450)
		I16 (Interactive Media & Services)	0.014320 (0.110600)
R^2	0.169900		
$\bar{R}_p^2$	0.525841		
F-Statistic	6.794000***		

Note:

*** Significant at p-value < 0.01 ** Significant at p-value < 0.05

* Significant at p-value < 0.1

Table A 8 Results of One-Way Multivariate Analysis of Variance (MANOVA)

Table A8

One-Way Multivariate Analysis of Variance Results

This table shows the results of One-Way Multivariate Analysis of Variance (MANOVA) to compare the digital technological characteristics of platform industries with non-platform industries. The proportions of companies using different digital technologies from an industry that is not significantly related to platformization are collectively compared with the proportions of the companies using corresponding same digital technologies from industries that are significantly related to platformization. The column "Platform Industry" lists the industry that is significantly related to the platformization. The column "Non-Platform Industry" lists the industries that are not significantly related to platformization. The columns "Pillai's Trace" and "F" show the test statistic of multivariate comparison of two industries. Each row of the results shows two industries that are compared, test statistics and probability of significance for the null hypothesis that proportion of the firms of the two industries using digital technologies are statistically same.

Platform Industry	Non-Platform Industry	Pillai's Trace	F	Prob.
Internet & Catalog Retail	Health Care Providers & Services	0.192896	3.744289	0.017124
	Electronic Equipment, Instruments & Components Industry	0.340907	7.887874	0.000034
	Biotechnology	0.503070	37.11968	0.000000
	Health Care Equipment & Supplies	0.226145	6.282977	0.000175
	Machinery	0.449571	16.74365	0.000000
	Chemicals	0.550810	21.25462	0.000000
	Pharmaceuticals	0.524414	17.64273	0.000000
	Communications Equipment	0.384656	6.876182	0.000217
	Electrical Equipment	0.568095	9.536115	0.000048
	Computers & Peripherals	0.327925	3.049562	0.035498
	Specialty Retail	0.221994	3.709386	0.009914
IT Services	Health Care Providers & Services	0.321857	6.525972	0.000226
	Electronic Equipment, Instruments & Components Industry	0.329529	8.601064	0.000011
	Biotechnology	0.592483	42.88956	0.000000
	Health Care Equipment & Supplies	0.358061	13.24729	0.000000
	Machinery	0.456662	19.12079	0.000000
	Chemicals	0.628885	25.41874	0.000000
	Pharmaceuticals	0.573903	18.85640	0.000000
	Communications Equipment	0.259135	4.634494	0.002779
	Electrical Equipment	0.537113	11.02336	0.000005
	Computers & Peripherals	**0.122851**	**1.190486**	**0.332652**
	Specialty Retail	0.323614	7.296290	0.000072
Software	Health Care Providers & Services	0.460646	29.46544	0.000000
	Electronic Equipment, Instruments & Components Industry	0.500205	38.28144	0.000000
	Biotechnology	0.761465	160.4105	0.000000
	Health Care Equipment & Supplies	0.564925	57.78125	0.000000
	Machinery	0.625664	72.70564	0.000000
	Chemicals	0.660064	69.41700	0.000000

	Pharmaceuticals	0.695846	79.50124	0.000000
	Communications Equipment	0.295689	14.27414	0.000000
	Electrical Equipment	0.492231	29.32434	0.000000
	Computers & Peripherals	0.113979	3.762778	0.006459
	Specialty Retail	0.496806	35.54299	0.000000
Interactive Media & Services	Health Care Providers & Services	0.189756	3.825208	0.015362
	Electronic Equipment, Instruments & Components Industry	0.396688	10.35590	0.000002
	Biotechnology	0.524595	41.19613	0.000000
	Health Care Equipment & Supplies	0.291698	9.060186	0.000004
	Machinery	0.569037	27.72811	0.000000
	Chemicals	0.650223	33.46135	0.000000
	Pharmaceuticals	0.504951	17.00002	0.000000
	Communications Equipment	0.467479	10.09539	0.000006
	Electrical Equipment	0.631909	13.30457	0.000002
	Computers & Peripherals	0.398635	4.474459	0.006657
	Specialty Retail	0.268329	4.950905	0.001789
Semiconductors & Semiconductor Equipment	Health Care Providers & Services	0.329325	11.41659	0.000000
	Electronic Equipment, Instruments & Components Industry	0.115428	3.523242	0.009614
	Biotechnology	0.458630	33.03944	0.000000
	Health Care Equipment & Supplies	0.373201	19.79729	0.000000
	Machinery	0.237747	10.05880	0.000000
	Chemicals	0.371848	14.50332	0.000000
	Pharmaceuticals	0.345407	12.40015	0.000000
	Communications Equipment	0.085481	2.126471	0.083853
	Electrical Equipment	0.143067	3.172097	0.018224
	Computers & Peripherals	**0.065508**	**1.261792**	**0.292985**
	Specialty Retail	0.303072	10.76301	0.000000

APPENDIX B

Figure B 1 Binomial Logistic Regression Plots for Industry Platform Model

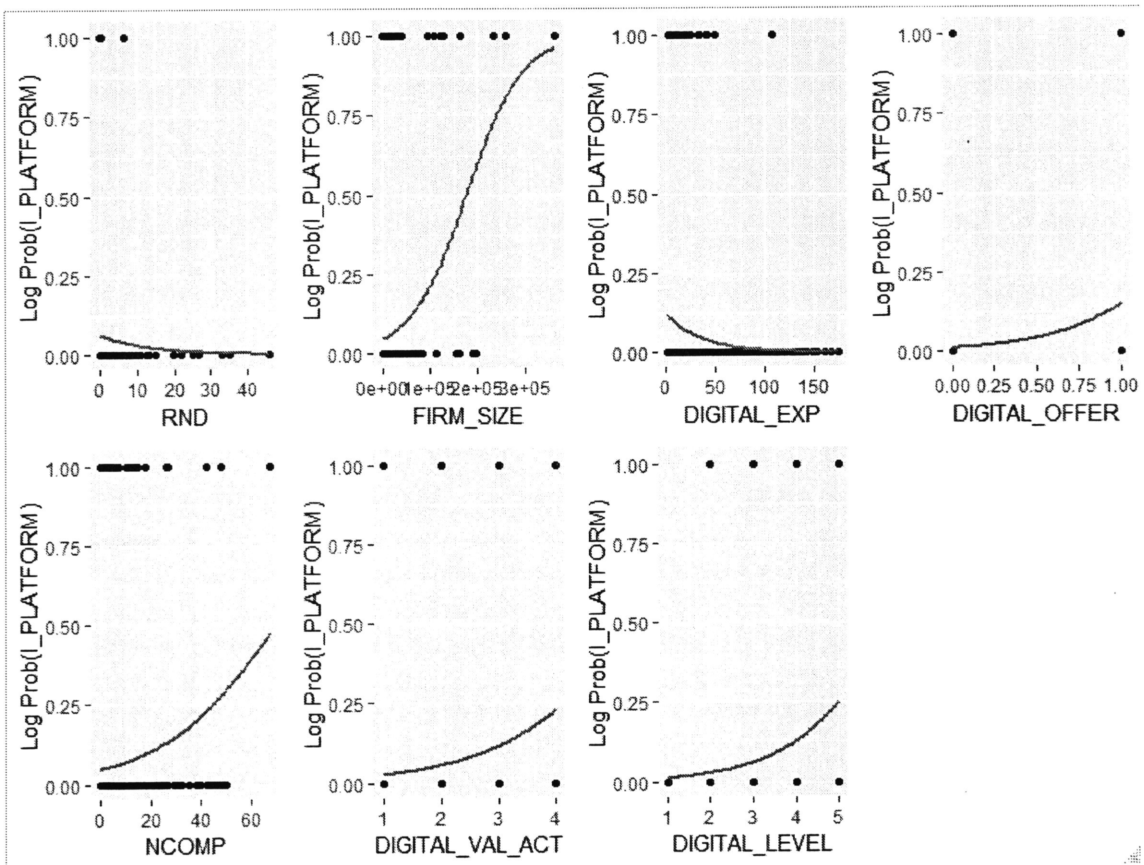

Figure B 2 Binomial Logistic Regression Plots for Product Platform Model

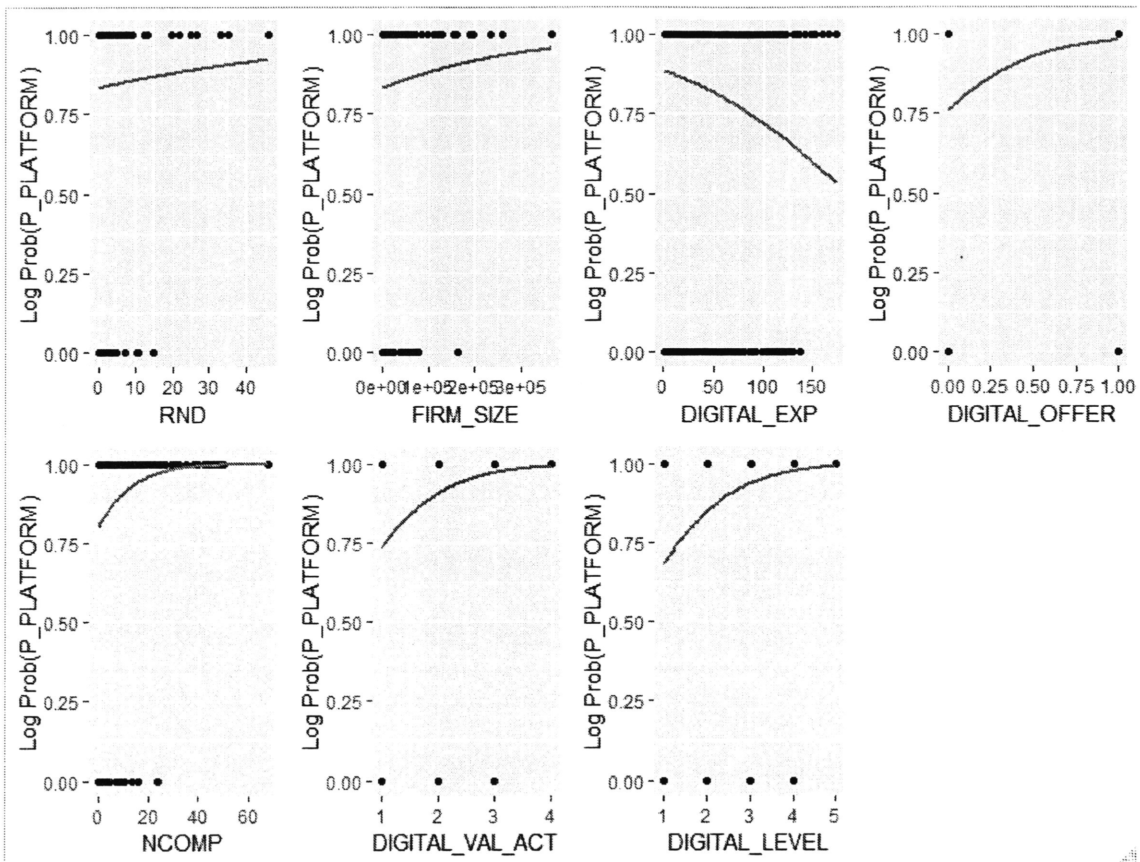

Figure B 3 Linear Probability Regression Plots for Industry Platform Model

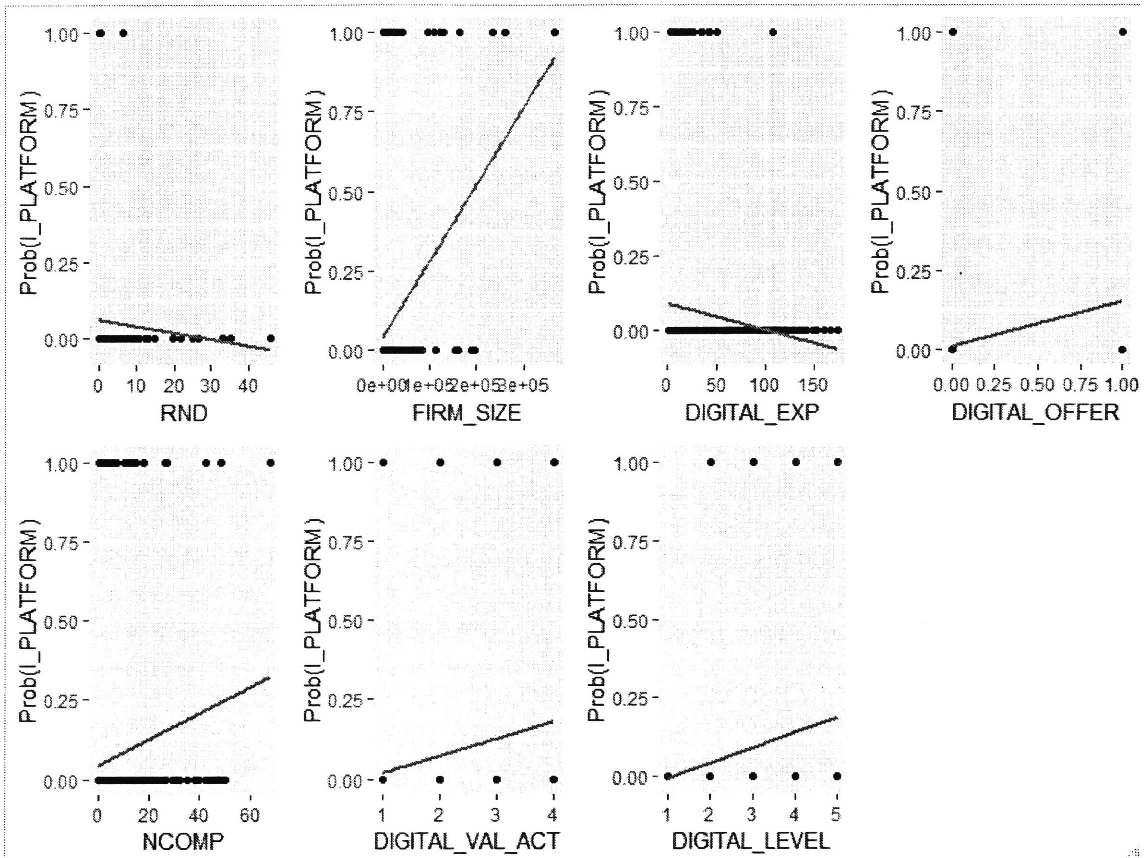

Figure B 4 Linear Probability Regression Plots for Product Platform Model