Business Model Cohesiveness Scorecard: Implications of Digitization for Business Model Innovation

Chander Velu

Institute for Manufacturing

Department of Engineering

17 Charles Babbage Road

University of Cambridge

Cambridge CB3 0FS

United Kingdom

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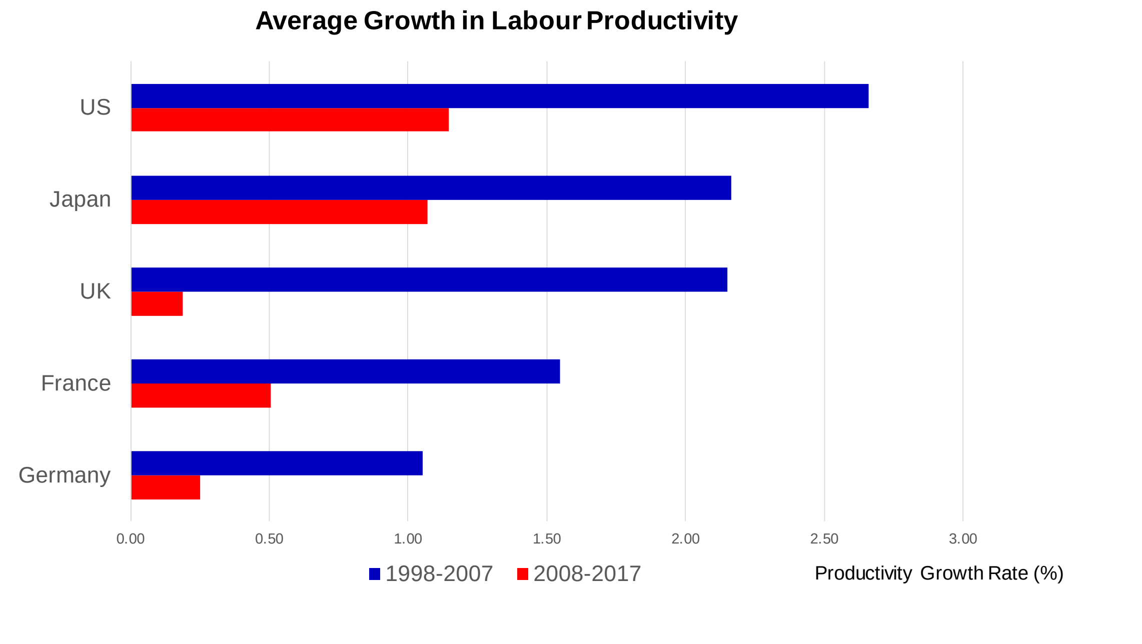
Introduction

Productivity growth in major economies has slowed down in the last decade despite the prevalence of digital technologies. This phenomenon is widely known as the productivity paradox and is illustrated in Figure 1 (below) among several G7 countries (Syverson, 2011). Moreover, industries that are the most intensive users of information and communication technologies (ICT)[1] appear to have contributed most to the slowdown in productivity (Van Ark, 2016). This chapter puts forward the thesis that the productivity paradox might be due to the lack of business model innovation as a result of inadequate management information on the effectiveness of the business model following the adoption of digital technologies. The chapter proposes a scorecard-based framework to measure the effectiveness of the business model to enable senior management to identify business model innovation opportunities following the adoption of digital technologies.

Figure 1: Average Growth in Labour Productivity



Source: Conference Board Total Economy Data, 2018

[1] Measured by purchases of ICT assets and services relative to GDP.

There are several possible reasons for the productivity paradox, such as the skills mismatch due to changes in product market structures driven by digitalization, the slowdown in technological diffusion between firms at the front of the technological frontier and others, and the legacy of the financial crisis causing the dislocation of markets and mismeasurement as a result of the digital economy providing significant propositions for free. However, studies on the history of new technologies have shown that productivity improvements might be hampered by the limited redesign of business models following the adoption of new technologies by firms. Business models are complex activity systems that summarize the architecture and logic of a business and define the organization's value proposition and its approach to value creation and capture (Velu, 2017). Therefore, one of the possible explanations for the productivity decline, which has been under-emphasized, is the lack of business model innovation following the adoption of new digital technologies. Moreover, it is well known that incumbent firms are often slow at recognising and implementing business model innovation following the advent of new technologies (Velu, 2016). Such a phenomenon is likely to be even more prevalent as firms adopt digital technologies. Recent studies have emphasised the importance of understanding the process of where strategy comes from and hence being able to influence the development of new business models (Brandenburger, 2017).

Digital technologies display properties of data homogeneity and reprogrammability (Yoo, Boland, Lyytinen, Majchrzak, & Majchrzak, 2012). Digital technologies can reduce the costs of economic activities[2] as well as enable new value propositions (Goldfarb & Tucker, 2019). Digital technologies enable closer integration of processes horizontally and vertically both within and across firms. In addition, digital technologies enable the collection and analysis

[2] Costs can be divided into five broad types, namely, search, replication, transportation, tracking and verification.

of data on the state of physical and non-physical resources. Moreover, digital technology based platforms display layered modular architecture or sometimes referred to as ‘the stack’, consisting of hardware, network, content and service layers (Yoo, Henfridsson, & Lyytinen, 2010). Such layered modular architecture enables the recombination of the layers both vertically and horizontally in order to design business models that are able to create new customer value propositions as well as to better deliver existing propositions. The recombination of the layers could happen across multiple industries that might reshape industry architectures. Hence, business models based on digital technologies often consists of constellation of core and complementary assets within an ecosystem in order to create and capture value (Jacobides, 2018; Teece, 2018). This poses an increasing challenge for firms adopting digital technologies to decide which resources to control and how to enable other complementary assets in order to create and sustain competitive advantage (Satish Nambisan, Lyytinen, Majchrzak, & Song, 2017).

The challenge of business model innovation following the adoption of digital technologies might be exacerbated due to the primary focus of management information systems[3] in firms that emphasize profitability as the key decision criteria. Profitability is based on matching revenues and costs during a reporting period. Profitability reports do not provide adequate information to management on the interactions of the activity system that constitutes the business model and therefore the dynamic consistency of the components of the business model. Such a measure of the interactions of the activity system that identifies both the enhancing and mitigating effects of a change of activity following the adoption of digital technologies is essential in order to help identify opportunities for business model innovation. Studies have emphasised that managing linkages across the value chain, business models and

[3] We use the term management information systems broadly to encompass business information systems that provide financial and non-financial information for senior management decision making.

ecosystems is a complex task and is a major source of competitive advantage (Demil & Lecocq, 2010; Porter, 1985). Therefore, we posit that the profitability reports need to be complemented with a Business Model Cohesiveness Scorecard (BMCS) that provides information on interlinkages both within and across the value chain of firms in order to enable senior management to identify opportunities for business model innovation.

Business Models as Complex Systems

Business models are a form of activity system that connects the internal aspects of the firm, such as resources and routines, with the external stakeholders, for example, suppliers and customers, and therefore articulates how the firm goes to market to implement the strategy (Baden-Fuller & Haefliger, 2013; Zott & Amit, 2010; Zott, Amit, & Massa, 2011). The business model as an activity system has three key design parameters, namely, *content*, *structure* and *governance*. Content outlines which activities are part of the business model. Structure is about how these activities are interlinked. Governance relates to who has the right to make decisions about them. A business model can be viewed as a complex system with components that connect the customer value proposition, how value is created, the means of value capture and the partners in the value network (Velu, 2017). Hence, the business model is the 'architecture' that provides the bridge between value created for customers and the value captured by the business in terms of profit.[4]

Studies have shown that the systems perspective is a helpful framework to understand how the mechanisms for value creation and capture function and evolve as an integral part of the business model. The systems perspective of a business model tends to conceptualize the difference between the components with reference to the whole and its constituent parts, the relationship between components and the possible viewpoint of the agents who are part of the

[4] This includes a holistic perspective covering value for all stakeholders.

system[5] (Cabrera, Cabrera, & Powers, 2015; Midgley & Wilby, 2015). Management's objective is to manage the *dynamic consistency* by maintaining cohesiveness between the components of the business model in order to ensure efficiency of the existing model while enabling innovation of the business model (Demil & Lecocq, 2010). Therefore, a systems perspective of business models would be beneficial when new digital technologies are implemented to enhance the efficiency, as well as effectiveness, of the business model.

New technologies alter the congruence between components and cause reverse salience where the components are not consistent with one another, which provides the stimulus for business model innovation[6]. Business model innovation can occur when there are changes to the interdependencies between components, or changes in the components themselves, in order to provide a proposition to an existing market or a new market (Amit & Zott, 2012; Casadesus-Masanell & Zhu, 2013). Such business model innovation might require, among other types of change, *reactivating* – changing the set of activities; *relinking* – changing the linkage between activities; *repartitioning* – changing the boundaries of the focal firm; or *relocating* – changing the location in which activities are performed[7] (Foss, Saebi, & Santos, 2015). From a systems perspective, such decisions need to be made to maintain congruence between the different components of the business model in order to ensure that the positive feedback is harvested while managing the conflicts arising from the negative feedback. Firms adopting digital

[5] There are similarities between these concepts of systems thinking and the content, structure and governance. In the case of systems thinking, the notion of viewpoints is broader than decision rights with reference to governance, as the former encompasses the subjective beliefs held by agents, which can then influence the evolution of the system.
[6] Reverse salience is where the sub-component is not fully aligned with the other components and hence hampers the potential development of the collective system.
[7] This concept is similar to thickening – the reinforcing of existing core elements with new elaborating elements, patching – the creation of new core and elaborating elements, coasting – no new additions to the core elements, and trimming – removal of the core and elaborating elements (Siggelkow, 2011).

technologies are likely to face such a challenge of maintaining the congruence of the business model.

Business Model Innovation, Digital Technologies and Ecosystems

Digitization involves the encoding of analog information into a digital format (Yoo et al., 2010; Youngjin Yoo et al., 2012). The encoding of information in digital formats provides the basis for unique properties of digital technologies[8] such as reprogrammable functionality (due to the Von Neumann architecture) and data homogenization (due to the representation of data in bits of 0 and 1)[9]. This provides the basis for technologies to display *convergence* in terms of user experiences between digital and non-digital objects.

Digital technologies enable a product to be servitized and combined with other offerings to provide radically new propositions. Consider a simple example, where a tractor is connected with sensors (Porter & Heppelmann, 2014). Initially, the tractor becomes a smart product. However, over time the smart tractor can be connected to other farm equipment, weather data, irrigation systems and seed optimisation systems. The interconnected system of systems enables radically new customer value propositions which contributes to significant improvement in farm productivity. Therefore, digital technologies enable a more connected and networked world which calls for an ecosystem of core and complementary resources to come together in creating and capturing value. The complementary assets within an ecosystem typically are non-generic which might also be supermodular[10] (Jacobides, 2018; Teece, 2018).

[8] Digital technologies include the Internet, sensors, actuators, storage- and communication-based technologies among others. The emergence of digital technologies enables a wider set of activities and processes to be automated.
[9] These properties of digitalization enables two key separations: between form and function (via reprogrammability) and between content and medium (data homogenization).
[10] Non-generic complementary assets are unique to the core assets in order to create value. Supermodular complementary assets imply that more of one input makes the other input more valuable.

From a supplier perspective, non-generic complementary assets require production to be coordinated across producers or adherence to a standard in modular systems.

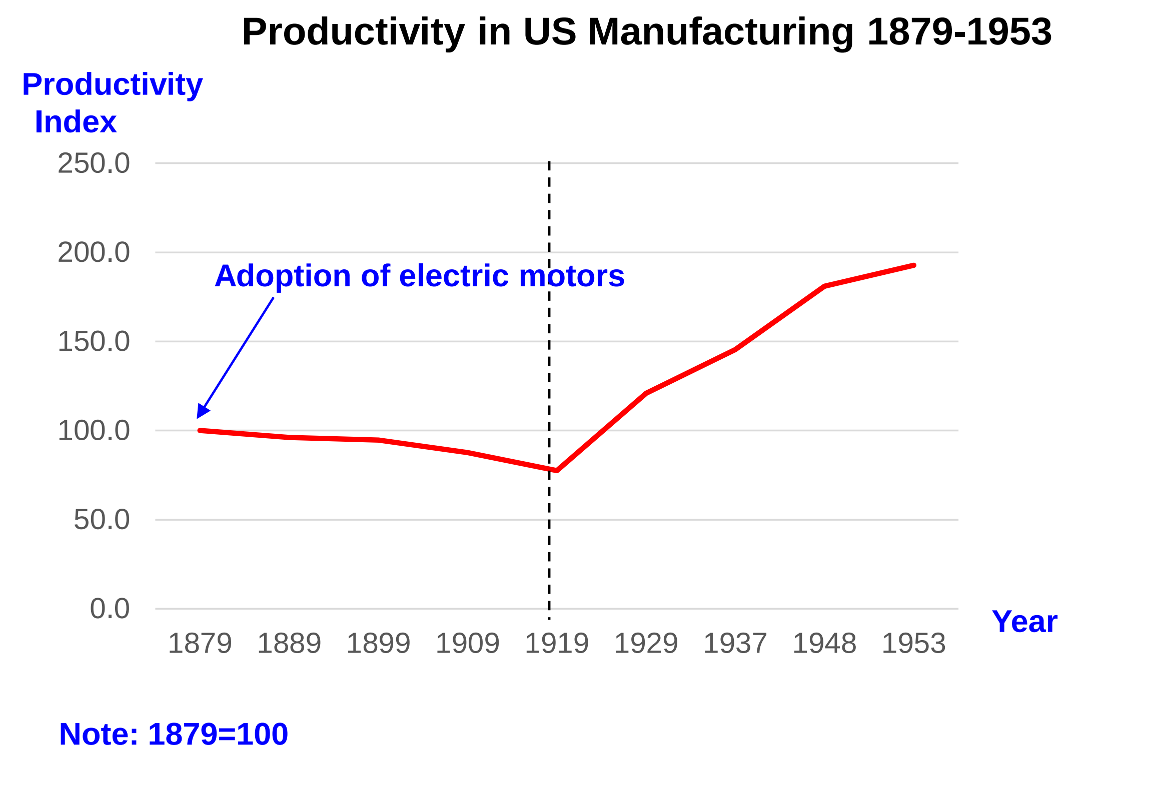
Moreover, the layered modular architecture of the digital technologies enables recombination across the four loosely coupled layers of hardware, network, content and service which could reorganise the traditional industrial boundaries. Moreover, such recombination is the source of *generativity,* which is the capacity to produce unprompted change and innovation from uncoordinated and heterogeneous audiences. Scholars have argued that value co-creation in ecosystems comes about through combining resources from the supply side, demand side as well as through generativity (Autio & Llewellyn, 2019). Therefore, the formation and subsequent evolution in the scope of the firms that bring together the relevant complementary assets within an ecosystem is a major source of business model innovation. We posit that maintaining the congruence between the different components of the ecosystem in order to ensure that the positive feedbacks are harvested while managing the conflicts arising from the negative feedbacks is a means of enabling business model innovation.

New Technologies and the Piecemeal Syndrome

The adoption of new technologies to improve a sub-process within an organization often helps with the efficiency improvements of that process (Skinner, 1986). However, such new technology adoption often alters the congruence between components, which causes reverse salience. Reverse salience is the concept whereby components of the system are no longer fully in alignment with one another, as there are opportunities for improvement, because the efficiency of the process improvements enabled by the new technology is either creating conflicts with adjacent processes or providing opportunities for process redesign as a result of new value propositions to the customer. Managers often adopt new technologies for process improvements with less emphasis on the opportunities to redesign the whole system. This is called the ‘piecemeal syndrome’ (Den Hertog, 1978; Skinner, 1986). Although previous scholars have primarily addressed the 'piecemeal syndrome' at the factory or organizational change level, it could equally be applied to business model innovation.

In order to illustrate the impact of new technologies on productivity it would be instructive to look at a historical example. In particular, we examine productivity changes following the adoption of electric motors to replace steam engines in US manufacturing (David, 1990; Devine, 1983). As can be seen in Figure 2, electric motors were introduced around 1879 to replace steam engines in the US, but there were few productivity gains for the first 30 years. Factories with steam engines were built across two floors with steam rising from the ground floor to move a single-line shaft system through pulleys and belts on the first floor. When electric motors started replacing steam engines, the factories replaced the steam engines with a single electric motor but kept everything else the same, including the two-floor system in the factories.

Figure 2: Productivity in US Manufacturing 1879–1953

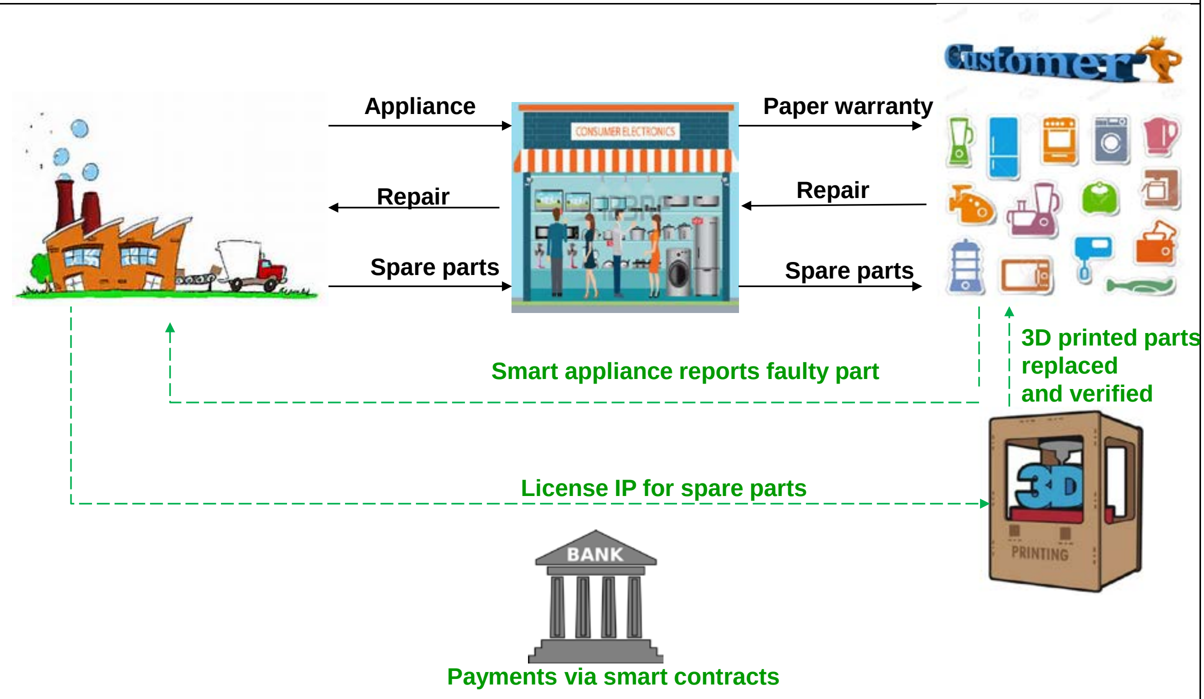


Source: Adapted from Devine, W. (1983), 'From Shafts to Wires: Historical Perspective on Electrification', *Journal of Economic History*, **XLIII** (2), 347–371.
David, P. A. (1990), 'The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox', *American Economic Review Papers and Proceedings*, **80** (2), 355–361.

As shown on the right-hand side of Figure 2, productivity only improved when new business models emerged from around the 1920s. The new business models involved having multiple electric motors where the work needed to be done and leasing these multiple motors from external specialist firms that provided a full spectrum of services to support them. The new business models enabled productivity improvements in terms of lower energy consumption and improved production flows. In particular, the unit drive system with a single motor where the work needed to be done enabled improved workflow design in the factories. In addition to contributing to workflow improvements, the unit drive system also meant that when a particular machine broke down the remaining motors could still function and not disrupt the production process, which was the case with a single shaft system. This contributed to lower energy consumption. Moreover, improved lighting meant fewer accidents, which also contributed to productivity improvements.

A more contemporary example could be envisioned from the adoption of digital technologies such as additive manufacturing, the Internet of things (IoT) and distributed ledger technologies (DLT). Let us consider an application to the consumer appliance industry, as shown in Figure 3. Today, if a part in a consumer appliance such as a washing machine were to become faulty, the consumer would have to wait between two days and six weeks to get the part in from the manufacturer. The manufacturer, in turn, has to hold a large number of spare parts. In the future, it is highly likely that many consumer appliances will be embedded with sensors that are capable of checking their own quality and integrity. Imagine, if such a smart washing machine were able to predict when a key part is likely to fail and the part communicates with the manufacturer directly. The manufacturer would lend its intellectual property to a third-party firm closer to the customer, which would then use 3D printing (additive manufacturing technology) to print and replace it. Once the parts had been replaced, payments would automatically be triggered via the bank to the relevant parties through a smart contract. This entire process would be managed using a distributed ledger so that parties could record and inspect the origins, supply, repair and operation of spare parts through the recorded transactions and smart contracts. Such an industrial system requires new business models from the retailer, manufacturer and in the form of new third-party 3D printers. These types of new business model could increase productivity significantly. First, the manufacturer no longer needs to hold a large quantity of spare parts, while reducing the time it takes to deliver the parts to the consumer. Second, the retailer could have a much-improved warranty management process. Third, the 3D printing company could print on demand to meet the customer's urgent requirements. Moreover, such an industrial system would help reduce waste through better repair and recycling. However, if the incumbent firms were merely to adopt the technologies to improve existing processes within the confines of the existing business models, such as the 3D printing of parts and holding them in stock, we could face the 'piecemeal syndrome' without the benefits that business model innovation would bring about through a change in the industrial architecture.

Figure 3: Distributed Manufacturing in Consumer Appliances



Limitations of the Current Management Information

Most management information systems are geared towards reporting the profitability of products or organizational units. Such profitability reporting involves the principles of matching costs with the revenues earned for a particular period in time. These costs and revenues are matched with little emphasis on understanding the activities and processes (Hergert & Morris, 1989). Management would need information about the degree of dynamic consistency of the business model as they adopt new digital technologies in order to identify business model innovation opportunities.

There is a growing consensus that business models are complex activity systems. Therefore, understanding business models from the perspective of value chains and key activities is critical when creating competitive advantage. However, scholars have argued that traditional accounting systems are not only unhelpful but can also get in the way of value-chain analysis (Porter, 1985). There are two principal reasons for this that are relevant to the analysis here (Hergert & Morris, 1989). First, critical activities that form the basis of creating competitive advantage are not normally recognized within the accounting systems[11]. These critical activities might cut across functions and hence might not map to the functional responsibilities. Second, most accounting systems assume the independence of sub-units. Therefore, the accounting systems rarely collect information for the purposes of coordinating and optimizing across different activities and, when they do, they tend to use fairly rudimentary methods.

The role of critical activities and interdependencies in business model innovation can be illustrated with an example in the design of low-cost airline business models (Charterjtee, 2005). Southwest Airlines disrupted the airline industry by not adopting the traditional hub and spoke model but a point-to-point model which requires aircrafts to be turned around fast. Moreover, Southwest had to have high utilization of its assets as a result of being short of cash to lease new aircrafts. In order to achieve such high utilization rates, it needed to have activities that ensured planes were available at short notice. Southwest needed to standardize and simplify boarding, as well as having pilots who could fly all planes. In order to achieve this objective Southwest decided to have the same aircraft type, Boeing 737. Southwest also decided to have its own maintenance fleet in order to ensure rigorous maintenance. Therefore, the core objectives of Southwest had implications for selecting the critical activity and understanding the interdependencies of the critical activity on other activities and processes across the value chain.

[11] Critical activities are the activities that provide the firm with a differentiated and unique offering that is valuable for the customers compared to actual or potential competitors.

Towards a Framework for the Business Model Cohesiveness Scorecard

Scholars have argued that the interdependencies of activities are central to the concept of activity systems and provide insights into how business models evolve over time as the external market or technologies change. Therefore, understanding the architecture of the business model in terms of content, structure and governance of the activity system would be essential in enabling business model innovation. Scholars have proposed improvements to the focus of management information systems on financially focused reporting. One of the well-established propositions is the balanced scorecard (Kaplan & Norton, 2006). The balanced scorecard enhances the focus on financial reports by including other key aspects such as the customer, the internal process and learning and growth perspectives. The customer measures emphasize the approach to creating value for customers. The internal process measures ask what processes the firms must excel in to satisfy customers and shareholders. Finally, the learning and growth measures focus on how to align intangible assets such as people, systems and culture to improve the critical processes. The balanced management of these measures would contribute to superior financial outcomes. More recently, scholars have extended the notion of the balanced scorecard by emphasizing the importance of alignment in order to capture synergies across the measures (Kaplan & Norton, 2006). Such alignment needs to include the strategy formulation process, both within and outside the boundary of the firm with external stakeholders. Scholars have also argued that the financial measures that are reported by firms are generally backward-looking and need to be enhanced by a strategic resources and consequences report (Lev & Gu, 2016), which would capture the essential assets that drive the performance of the business model and its execution. For example, the fundamental indicator might include new-customer and churn rates for telecoms firms, accident severity and frequency and policy-renewal rates for car insurance firms, and clinical trial results for biotech firms[12]. Although the above approaches represent an improvement on the financial focus of most management information systems, we argue that it does not provide management with the fundamental information needed to understand and manage the evolution of the business model.

A systems dynamics approach enables the interdependencies of the activity system of the business model to be better captured (Sterman, 1984, 1997). Systems dynamics modelling is a framework with which to analyse the behaviours of the system as a whole instead of analysing the separate parts on a piecemeal basis. Systems dynamics explicitly models the positive and negative feedback loops between the interdependent components of the system. Such feedback analysis illuminates the cause and effect relationships. Therefore, when a new digital technology is implemented with a view to enhancing a sub-process or activity system, such a systems dynamic analysis of the positive and negative feedback would provide the information to senior management about the opportunities for architectural-level changes to the systems, which would act as the foundation for business model innovation. We refer to such feedback analysis as the Business Model Cohesiveness Scorecard (BMCS), as it aims to measure the degree of alignment between components of the business model in order to effectively and efficiently achieve the overall core objective of the firm. The BMCS contributes to highlighting the major opportunities for *reactivating*, *relinking*, *repartitioning* or *relocating* as the basis for business model innovation. It is necessary to ensure the proper alignment of people, systems and culture in order for the business model to achieve cohesiveness. We propose four perspectives that need to be considered to measure the degree of cohesiveness:

(1) *Physical flow* – Are the raw materials and finished products and services delivered at the right time and place?

[12] Some firms such as AstraZeneca have more recently been reporting results of clinical trials in their annual reports.

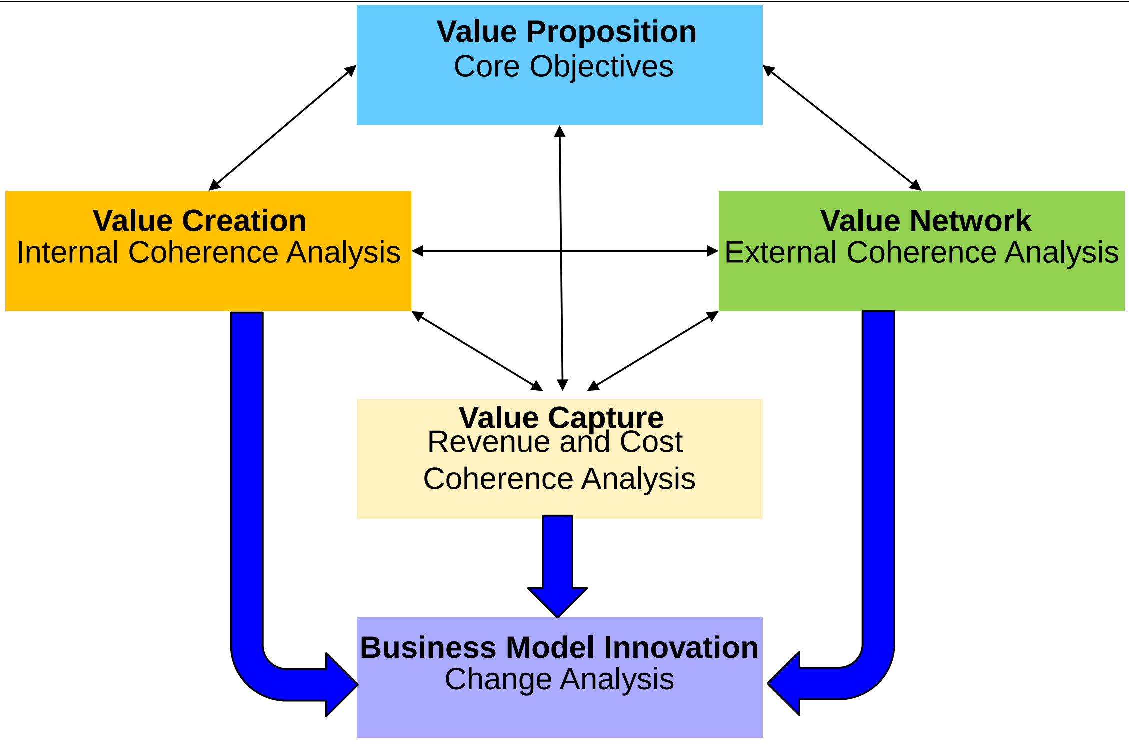
(2) *Information flow* – Is the information for decision-making delivered to the right individuals or systems to enable efficient decision-making?

(3) *Decision rights* – Is the authority to make decisions given to the right individuals or systems?

(4) *Incentives system* – Are the incentives appropriately aligned across stakeholders for timely and cohesive decision-making?

These four perspectives need to be examined across the business model components based on the core objectives and processes in order to ensure that the customer value propositions are delivered while making a suitable return for the firm. This is illustrated in Figure 4 (below).

Figure 4: Business Model Cohesive Scorecard Framework



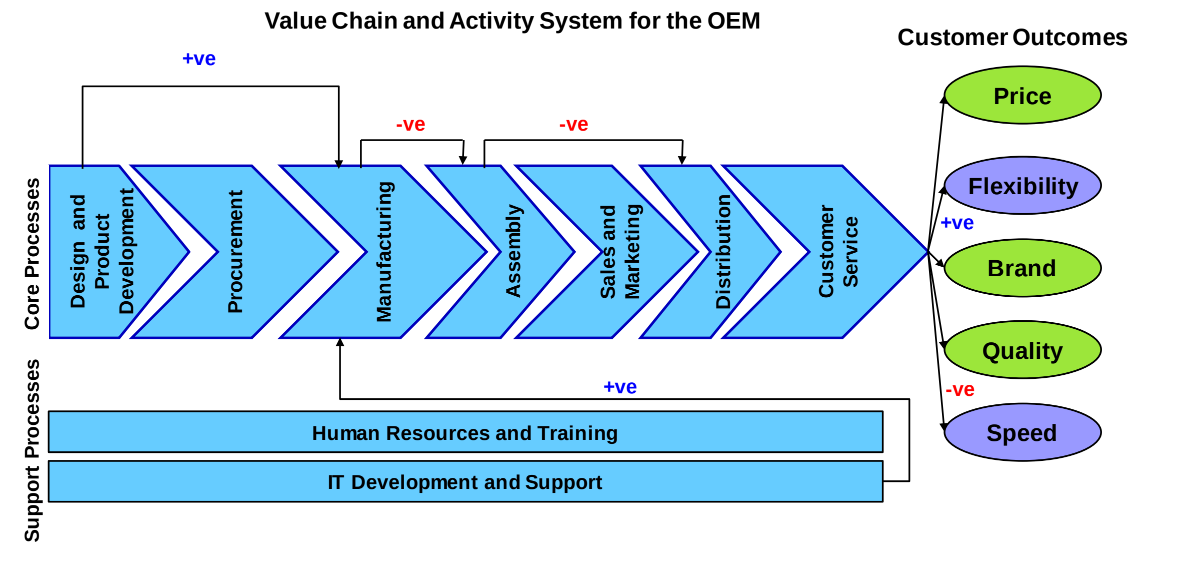
Illustrative Case Vignette

Let us revisit the case of distributed manufacturing in the consumer appliance industry, as discussed earlier. For illustrative purposes, we show the analysis at the value-chain level. A similar BMCS analysis could be performed for digital-technology-based ecosystems with a layered modular architecture and its potential recombination as a source of business model innovation (Yoo et al., 2010). The value chain and activity systems for the original equipment manufacturer (OEM) are illustrated in Figure 5 (below). Let us assume that the IT support team has been able to identify and procure a suitable additive manufacturing (AM) machine for printing key spare parts for the branded washing machine. The technology team has made an assessment to evaluate the feasibility of adopting the machine as part of the spare parts manufacturing and reported that it is technologically feasible and would also reduce costs, as the OEM does not need to hold a large inventory of spare parts. The spare parts will be printed as soon as the IoT device on the customer's washing machine orders it. A simple analysis of the enhancing and mitigating impacts of the adoption of AM for the spare parts might reveal the following:

(1) IT support and responsiveness for the AM machine could be better, as it is new and more modular than a more integrated existing manufacturing system.
(2) The AM machine could enable new types of spare part to be produced with improved material physical properties that might have a positive effect on design and product development.
(3) The new product development might enable flexibility to be introduced to the customers in designing a replacement part that suits the customer use profile better; for example, customers that use the machine for heavy loads of washing might require a different type of spare part than customers who use the washing machine for light loads. Such a use profile could have been collected by the IoT device in the machine.
(4) The AM machine is typically slow at printing the spare parts, and the added complexity of customized ordering of parts might result in slower delivery times for the customer. Therefore, there is a mitigating impact of the feedback on the assembly function.

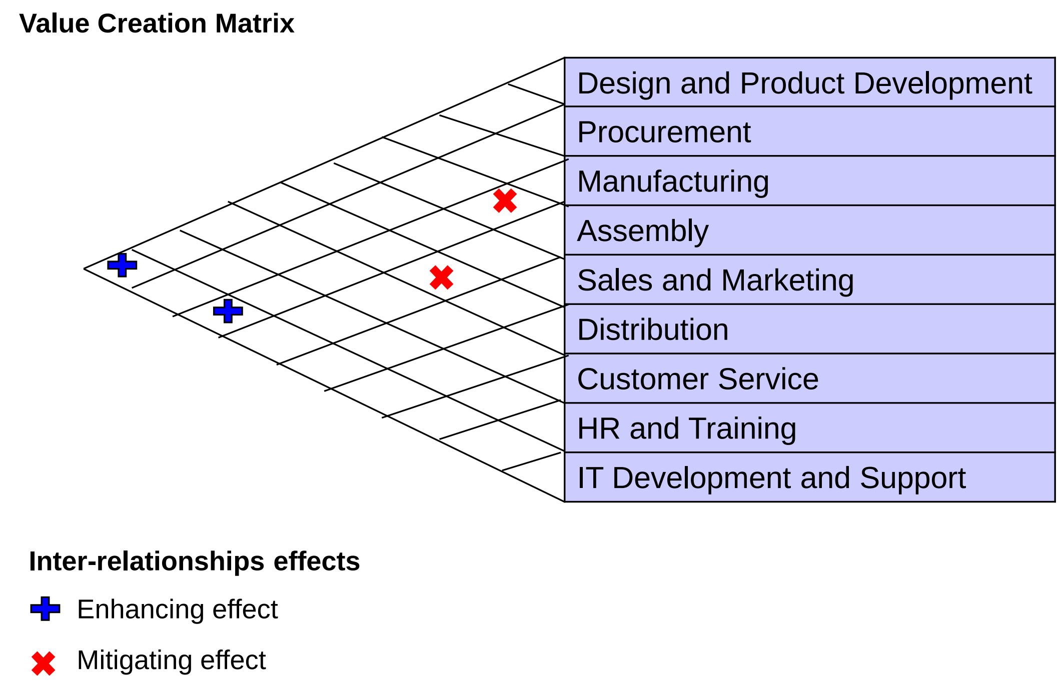
(5) The mitigating impact on the assembly function will, in turn, affect the distribution function and, hence, there might be slower delivery outcomes for the customer.

Figure 5: Value Chain and Activity System



The above analysis could be done at different levels of aggregation or disaggregation. For example, the value-chain analysis could be further decoupled into processes or activity level. The level of disaggregation needs to be chosen appropriately, as it is useful to identify the key enhancing and mitigating effects that might be relevant to managing business model innovation opportunities. The enhancing and mitigating effects across the firm's value chain could be represented as an internal coherence analysis as part of the BMCS framework, as shown in Figure 4. This internal coherence analysis is shown in Figure 6 (below).

Figure 6: Internal Coherence Analysis



A similar coherence analysis could be carried out for the value network by analysing positive and negative effects across firms within the ecosystem. A simple analysis of the positive and negative impacts of the adoption of AM for the spare parts might reveal the following, which is represented as the external coherence analysis in Figure 6:

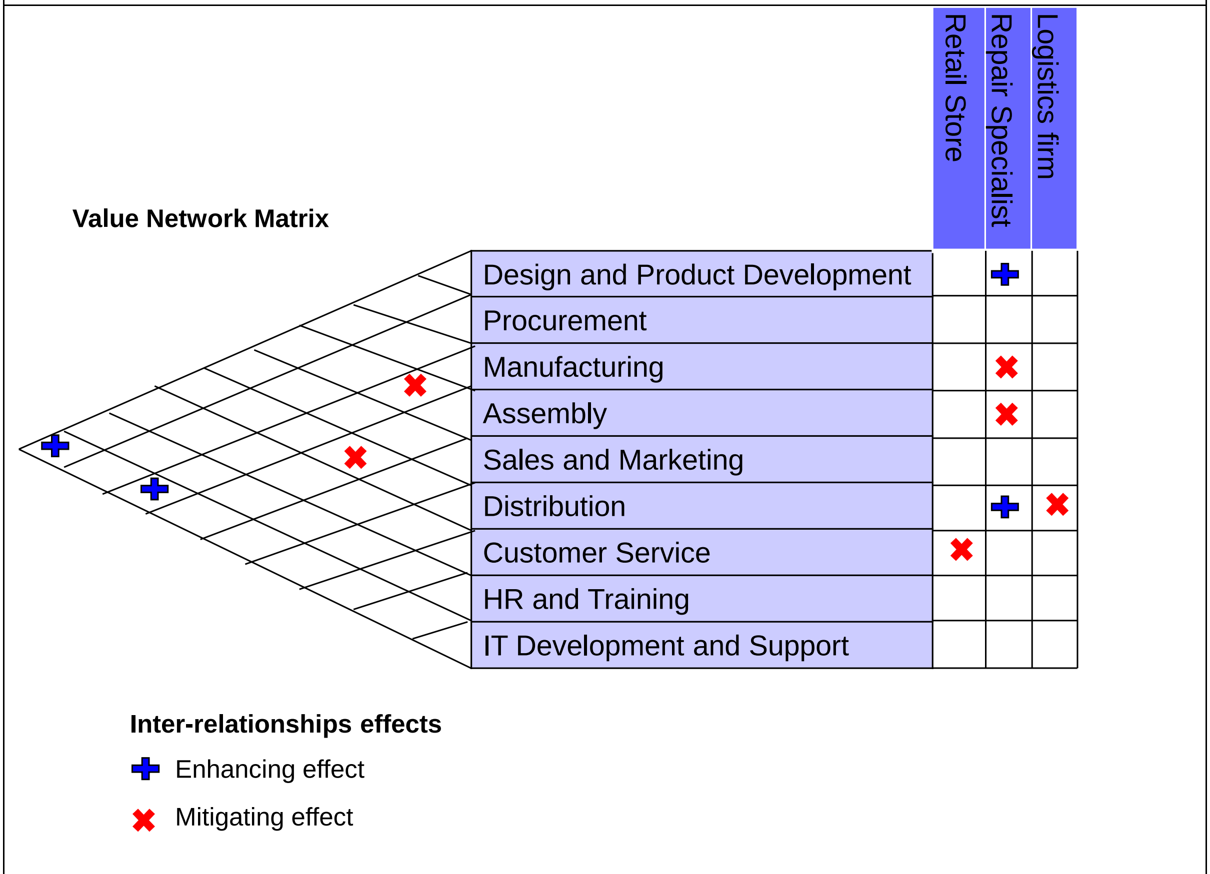
(1) The printing of spare parts by the equipment manufacturer on demand, and then supplying them to the retailer, would add further time to the repair process for the customer. Hence, this is a mitigating effect.

(2) Moreover, the uncertainty in terms of when the spare parts can be printed by the equipment manufacturer could add further time to the repair process as a result of the availability schedule of the logistics firm and the repair firm. Hence, this is a mitigating effect.

(3) However, the ability to print the spare parts based on the requirement of the customer and for the specialist repair firm to fit the parts accordingly would enhance the value for the customer. Hence, this is an enhancing effect.

(4) The logistics firm might face uncertainty in terms of when the parts might be ready and incur extra scheduling costs. Hence, this is a mitigating effect.

Figure 7: External Coherence Analysis



The next stage involves analysis of the value-capture mechanism and how it affects the coherence of the business model following the adoption of the digital technology. In particular, the analysis would involve understanding how the revenue and cost architecture affects the efficacy of the business model in delivering the customer value proposition while earning a profitable return for the other stakeholders. The resource velocity measures the extent to which the assets are turned over to make a profit. Typically, for high-margin products the resource velocity is low, whereas for lower-margin products it is high (Johnson, 2010). For example, the value-capture coherence analysis could include the following, which is displayed in Figure 8 (below):

(1) The revenue architecture would depend on the value proposition delivered to the customer. On the one hand, the increased flexibility in product design could increase revenues. On the other hand, the potential increase in delivery times could negate the benefits to the customer and hence decrease revenues.

(2) The cost architecture would vary depending on whether it were for the manufacturer (value-creation) or the other firms within the ecosystem (value network). For the manufacturer the reduced inventory could lower costs, while the uncertainty involved in printing on demand means that costs could increase. For other firms in the ecosystem, such as the repair specialist or the retailer, the costs could increase as a result of the costs of planning based on the uncertainty in the delivery times.

(3) In the case of the spare parts being printed by the manufacturer, the resource velocity could be higher or lower depending on the net effect of flexibility and time to deliver for the customer.

(4) Finally, the combination of the revenues, costs and resource velocity would have an impact on margins and profits. The margins and profits for the manufacturer could potentially increase depending on the net effect of revenue, costs and velocity. For the firms in the value network, such as the retailer and the repair specialist, the profits/margins could decrease as a result of the higher costs and the impact of revenue and resource velocity.

Figure 8: Revenue and Cost Coherence Analysis

	Value Creation	Value Network
Revenue/Value Proposition	↑ increased flexibility ↓ increased time to delivery	
Cost	↓ reduced inventory ↑ uncertainty from printing on demand	↑ due to uncertainty from printing on demand
Resource Velocity	↓↑ Could increase or decrease depending on the net effect of flexibility and time to deliver for the customer	
Margins/Profits	↑ Potentially increased margins/profits depending on the trade-off between revenue and costs and resource velocity	↓ Potentially decreased margins/profits from higher costs depending on impact of revenue and resource velocity

Finally, the business model change analysis could be done by considering how the physical flow, information flow, decision rights and incentives affect the overall coherence of the business model and areas for possible innovation. The combination of the internal and external coherence analysis, together with the revenue and cost coherence analysis, might open up a discussion on the possibility of moving the printing of the parts nearer to where the customer is located, which could be done by the retailer, the retailer's repair firm or a new third-party repair firm. Moreover, such a discussion could be the 'catalyst' to reorganise the industrial architecture to embrace a new digital ecosystem. This could have implications for the value-capture mechanism, as follows:

(1) Let us assume that the existing arrangements for the spare parts are based on the customer either paying for the part through a repair warranty programme or paying for the repair on a part-by-part basis. The payment is not based on the performance in terms of the speed of repair, which the customer values significantly.

(2) The emergence of printing the part to order provides the opportunity to price the repair based on the outcome in terms of the speed of repair that the customer demands. The price could be more closely aligned to the cost of printing on demand, as well as the speed of repair.

The BMCS provides the relevant information for management to discuss the cohesiveness of the system and therefore an evaluation of the effectiveness of the business model as new digital technologies are adopted. For example, such an evaluation might provide the basis for a target new business model and its roadmap that leverages the benefits of distributed manufacturing afforded by the combination of IoT, distributed ledger and additive manufacturing. The business model would involve the original equipment manufacturer lending the IP to a third-party firm closer to the customer to print the spare parts. All of these could be logged onto the distributed ledger for appropriate IP payment to the manufacturer.

Discussion

Studies have highlighted the need for coordination when there are supermodular complementarities whereby the addition of one element makes the increase in another related element more valuable (Milgrom & Roberts, 1995). It can be argued that the implementation of digital technologies has the properties of supermodular complements with respect to changes in business models. In other words, in order to fully obtain the benefits of adopting digital technologies, other related changes need to be made to the activity system within the firm and the ecosystem in order to make the business model efficient and effective, which contributes to superior performance. The BMCS is a framework that provides senior management with the information and opportunities for continuous dialogue about such coordinated changes to the business model. However, such a change to the business model requires changes to the approach to leadership and inter-firm coordination activities, as well as the design of the information systems. We discuss these challenges in turn.

Leadership

Studies have highlighted that senior management need to display three principle qualities in order to identify and implement business model innovation (Doz & Kosonen, 2010). These are *strategic sensitivity* – sharpness of perception to strategic developments; *leadership unity* – the ability to make bold and fast decisions; and *resource fluidity* – reconfiguring capabilities and redeploying resources. All of these leadership qualities require a sense of ownership of the business model in order to enable the business model change process. However, one of the major challenges that firms face as they grow larger is leadership by functional lines in order to drive efficiency. Often the focus on efficiency, which entails a focus of productivity improvements at the process level, blinds senior management to the need for coordinated change of the business model. This is primarily because functional leadership creates a culture whereby no one in the firm owns the business model. We call this the business model leadership void. Such a business model leadership void results in each functional leader taking tactical decisions to maximize the efficiency and productivity of their own functions and under-emphasizing the implications and actions of other functions. We know from simple game theory that optimal response by each unit, without coordination, when there are strategic interactions, results in sub-optimal overall outcome for the system. Therefore, to overcome this challenge, it is imperative for senior management to wear two hats simultaneously. The first step is to optimize the business functions and the second is to own the business model in order to identify potential innovation opportunities and coordinate changes required across other functional lines of the business. First, identifying business model innovation opportunities requires information across the functions of the business, as well as across the other firms within the ecosystem. Second, as business models are complex systems, implementing changes to the business model would require coordination of the different functions across the business, as well as third-party firms within the ecosystem. The BMCS framework enables senior management to manage these leadership tasks effectively, as it identifies interrelationships and the implications for the business model. Moreover, the BMCS framework might contribute to the call to better understand the sources of effective strategy formulation and hence contribute to business model innovation by embedding systems level thinking within senior management (Brandenburger, 2017).

Information Systems Design

The BMCS could initially be developed as a qualitative scorecard using a combination of interviews or workshops with senior management and data from various systems on a periodic basis. Such qualitative reports would provide the initial impetus and culture change necessary to embed systems thinking within the organization and also highlight the importance of business model roadmapping as part of the technology management process. Once the qualitative BMCS has been routinized, the firm could start implementing systems to partially automate the analysis required using data from the various systems. Many of the information systems within firms are built to serve a particular task or functional requirements. For example, the manufacturing support system (MSS) supports production and logistics processes, the enterprise resource planning (ERP) system manages various resources such as cash, raw material and production capacity, the customer relationship management systems (CRM) manage customer data, and accounting systems provide financial and cost information. However, often these systems are not built to report the interlinkages of the activities across functions. In order to do so, firms need to build an appropriate middleware that takes data feeds from various information systems in order to analyse where and how these interlinkages might affect performance. It is possible that management has formed certain hypotheses about such interrelationships and hence the data extraction and analysis could be done to measure and provide quantification of such relationships. However, as the business grows larger and the interrelationships become complex it might be not be obvious where the interrelationships occur and there could be second-order or even third-order effects of certain activity changes on other activities within the organization. In such circumstances, it is possible to use machine-learning techniques that find the interrelationships from the data without the predefined programmed relationships.

Inter-firm coordination

The interrelationships of the business model extend across the firm boundary to other firms within the ecosystem, as was the case with the example of the distributed manufacturing of spare parts. Digital ecosystems which consists of non-generic complementary assets which could be supermodular require firms to coordinate to co-create value. Firms within the ecosystem will need to develop the BMCS in order to ensure coherence between the constellation of core and complementary assets that co-create value. Such a coherence analysis would need to consider the physical flow, information flow, decision rights and incentives across the ecosystem of firms. This is particularly challenging as generativity which is a key feature of digital ecosystem requires optimal level of coordination so as to have sufficient direction whilst embracing impromptu change. Therefore, firms need to have organizational processes to create and manage the BMCS inter-firm metrics. These could take the form of an inter-firm business model coordination committee that meets periodically to review the BMCS reports and discuss how best to enhance the benefits arising from complementary practices, while managing the competing processes following the adoption of digital technologies by the various firms within the ecosystem. Firms could develop cloud-based architecture that provides relevant data from their respective systems to analyse the impact of their interlinkages across the ecosystem in order to populate the BMCS. For example, some CRM and ERP systems already allow for data sharing across firms, which could be used as the foundation to further build inter-firm BMCS metrics. Such initiatives must aim not to compromise the strategic proprietary information that provides strategic competitive benefits to the firms, while being useful for understanding the interrelationships of processes across firms to enable business model innovation in order to improve the productivity of these firms.

Limitations

The BMCS framework proposed here has several limitations. First, the BMCS assumes interlinkages are key to identifying and implementing business model innovation. However, digital technologies enable very radical shifts in business models from combining multiple activities and processes across different ecosystems in order to create revolutionary offerings. Such situations might require continuous testing and validation where interlinkages might be ambiguous or not obvious. The BMCS might need to be extended to incorporate an outside in perspective that could challenge the status quo and highlight the potential ineffectiveness of the existing business model. Such an outside in perspective could provide the basis for evaluating whether a radically new business model needs to be nurtured as opposed to organically morphing the existing business model.

Second, the BMCS framework does not emphasise the importance of the appropriateness of the information flows and hence governance arrangements that could be a source of enhancing and mitigating effects. It is important that the right part of the ecosystem has the relevant information in order to be able to make appropriate decisions. This will also ensure flexibility of the system to reconfigure appropriately as needed. The BMCS might need to be further supplemented with a map of information flows across the firms and its ecosystem to address this shortcoming.

Third, the BMCS only examines the first order enhancing and mitigating effects. Further development of BMCS needs to explore the higher order effects to have a more comprehensive picture of the business model innovation opportunities.

Conclusion

The productivity paradox exists among many major economies despite the prevalence of digital technologies. We argue that the productivity puzzle might be due, in part, to the lack of business model innovation following the adoption of digital technologies in firms. We posit that this is because firms have a tendency to focus on efficiency improvements at a process level, as opposed to efficacy of the business model. One of the issues regarding the lack of focus on the business model is a result of inadequate management information that focuses on profitability. We propose complementary information called a Business Model Coherence Scorecard (BMCS) that emphasizes the interrelationships between key activities, both within and across firms, in order to deliver the key customer value outcomes. We believe that such a BMCS would enhance the dialogue of senior management to highlight the importance of ownership of the business model and to identify business model innovation following the adoption of digital technologies. The BMCS would initially need to be developed qualitatively and subsequently populated by data from within and across the network of firms in the value ecosystem. Such integrated management reporting systems would contribute to lifting productivity and enhancing economic growth.

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