

Framework for Analyzing the Competitiveness of Advanced Technology Manufacturing Firms

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Abstract

This paper presents a framework that can be used to analyze the competitiveness of advanced technology durable goods manufacturing firms. The four main factors of competition for advanced technology firms identified by the authors are (1) production and delivery capabilities, (2) production and delivery costs, (3) operational capacity, and (4) innovation and product differentiation. Within each of these factors are four to six subfactors of competition, such as labor, financial capacity, and research and development. Each of the four factors and many of the subfactors are linked, with competitiveness on one factor influencing a firm's ability to compete on another factor. These factors and subfactors provide a basis for the analysis of firm-level competition that can be applied across advanced technology industries, regardless of the type of good produced by the firm.

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Introduction

The ability of manufacturing firms to compete in advanced technology industries is increasingly driven by a broad range of competencies, some of which were only minor considerations a generation ago. As with all manufacturing firms, low production costs are important for a firm to gain and maintain competitiveness in its industry. Modern technology-driven firms, however, also need to supply value-added services, provide effective cybersecurity, use advanced data analytics, and generate innovative products and processes in order to be competitive. In order to assess the relative competitiveness of these advanced technology firms in relation to each other, it is helpful to have a comprehensive outline of the factors needed to compete in advanced technology industries. This paper, therefore, provides a framework to analyze competition among advanced technology durable goods manufacturing firms, laying out the major factors that need to be considered in an analysis of firm competitiveness.

The framework in this paper is designed to assess the competitiveness of advanced technology *firms*, rather than advanced technology *industries*. This paper uses firm activities, assets (e.g., intellectual property), and capabilities as the basis for a competitiveness framework, which are referred to as factors and subfactors of competition. The specific factors were selected based on an extensive review of the academic literature, media reports, business literature, etc. The authors also reviewed factors of competition that firms self-identified, including through a review of company financial reports. Finally, the authors reviewed competitiveness factors identified for advanced technology industries and firms in U.S. International Trade Commission (Commission) studies.

The next section of the paper will define advanced technology firms, and the following section will provide an overview of the research that provides the theoretical foundation for the framework. The main focus of the paper is the subsequent sections, which introduce the framework and discuss each factor and subfactor of competition in more detail.

Definition of Advanced Technology Firms

The purpose of this paper is to develop a framework that applies to advanced technology durable goods manufacturing firms. Examining widely used definitions from the Bureau of Labor Statistics (BLS), International Trade Administration (ITA), and Brookings Institution, four durable goods North American Industry Classification System (NAICS) manufacturing subsectors are identified as containing high-tech or advanced industries by all sources: (1) machinery manufacturing (NAICS 333); (2) computer and electronic product manufacturing (334); (3) electrical equipment, appliance, and component manufacturing (335); and (4) transportation equipment manufacturing (336).¹ The framework in this paper is designed to apply to these four subsectors as well as miscellaneous manufacturing (337)

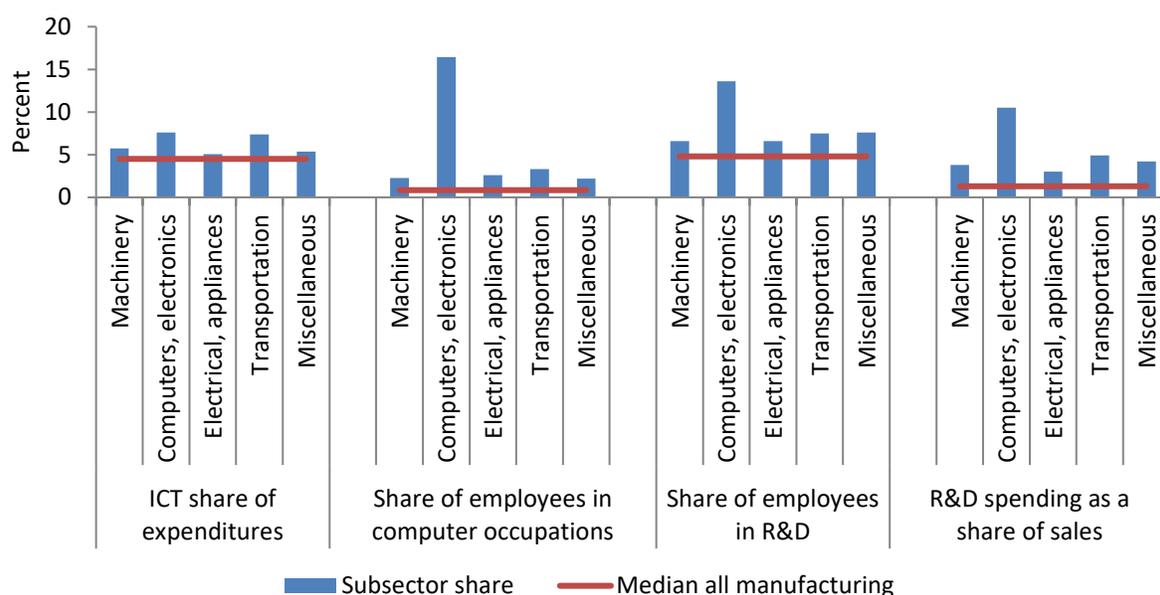
¹ BLS and Brookings define the industries at the NAICS 4-digit (industry group) level. Each of the 3-digit NAICS included here has at least one 4-digit NAICS on the BLS and Brookings List. The ITA list is at the three-digit (subsector) level. The industries covered in this paper (which is not a detailed analysis of individual industries) are at the 3-digit subsector level. Wolf and Terrell, "The High-Tech Industry," May 2016; USDOC, ITA, "High-Tech Industries," 2017, 3; Muro et al., *America's Advanced Industries*, February 2015, 21.

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Appendix A).² Miscellaneous manufacturing is included here (though not in all definitions of advanced manufacturing) as it includes medical devices not covered by the other NAICS subheadings.

The five subsectors covered here are research and development (R&D) and information and communications technology (ICT) intensive, as would be expected from advanced technology industries (figure 1).³ These industries are also heavy users of advanced production technology. The automotive industry, for example, is the largest user of industrial robots per 1,000 workers, and the aerospace and automotive industries contain the largest share of firms that expect to use 3D printing.⁴

Figure 1 ICT and R&D intensity of advanced technology durable goods subsectors



Source: DOL, BLSs, “May 2017 National Industry-Specific Occupational,” March 30, 2018; Census Bureau, “Annual Survey of Manufactures,” December 15, 2017; NSF, “Business Research and Development,” March 12, 2018, tables 17 and 47. Notes: The ICT share of expenditures are capital and other expenditures (based on the Annual Survey of Manufactures) on computers and software equipment and services as a share of all capital and other expenditures. The share of employees in computer occupations are the share of workers defined as “computer and information systems managers” (occupational code 11-3021), “computer occupations” (15-1100), and “computer hardware engineers” (17-2060). The share of employees in R&D is global employment by respondents to the National Science Foundation’s (NSF) survey. R&D spending is domestic R&D spending paid for by the company and others as a share of domestic net sales.

As this is a firm-level framework, and goods and services are inextricably tied together in many of these firms, this framework does not separate goods and services provided by firms within the five covered

² This framework can be applied to analyze the competitiveness of firms at any level (such as the subsector, industry group, or industry level). For example, it could be used to analyze the competitiveness of all agricultural equipment manufacturers or those that specifically produce lawn and garden equipment.

³ This methodology for ICT intensity is adapted from USITC, *Digital Trade*, July 2013, 3-2-3-4.

⁴ Acemoglu and Restrepo, “Robots and Jobs,” March 2017, A-14; Ernst and Young, *EY’s Global 3D Printing*, 2016, 19.

subsectors. As will be discussed below, many advanced technology firms offer embedded or related services that enhance the value of products and may increase firm competitiveness and profitability.

Activities, Assets, and Capabilities as the Foundation of Competitive Advantage

The framework proposed for this analysis builds on the work of Michael Porter, who proposed that a firm’s activities are the basis for its competitive advantage.⁵ A firm, according to Porter, performs a set of activities that include all of the steps in producing and delivering a product to customers, as well as related support activities such as technology development and procurement. A firm can develop a competitive advantage if it is able to combine these activities or perform them in a unique way that leads to either lower costs or a differentiated product that provides more value to customers and can sell at a higher price. While there are hundreds of possible activities, Porter divides them into nine categories, and then further into general areas of primary activities—which are all activities related to producing and delivering the product to customers—and support activities that are not explicitly part of the primary activity, but may impact all of the primary activities.⁶ While described separately, the activities are linked and improvements in one area may contribute to competitive advantage in another area.⁷

Chris Zook and James Allen state that competitive advantage derives from a firm’s ability to differentiate itself from its competitors.⁸ According to Zook and Allen, firms can differentiate themselves via “superior cost economics, unique product features, or control over a key position in a larger economic system.”⁹ They identify more than 250 types of differentiation, which they group into 15 “clusters” in three categories: management systems, operating capabilities, and assets.¹⁰ For the purposes of this paper, the key addition to Porter’s work is the inclusion of assets as a source of competitive advantage.

Deloitte indicates that it is the capabilities of manufacturers that differentiate them and provide them with a competitive advantage.¹¹ According to Deloitte, these “capabilities, when coupled together, are

⁵ Michael Porter’s framework applies to all firms, and not just the advanced technology durable goods manufacturing firms covered in this paper.

⁶ Primary activities are inbound logistics, operations, outbound logistics, marketing and sales, and after-sales service. Support activities are firm infrastructure, human resources management, technology development, and procurement. Porter, “Competitive Advantage: Enduring Ideas and New Opportunities,” June 22, 2012, 6.

⁷ Porter, “What is Strategy?” 2008, 38; Porter and Millar, “How Information Gives You Competitive Advantage,” 2008, 75–77.

⁸ Zook and Allen, *Repeatability*, 44–45.

⁹ An example of this last type of differentiation would be Intel’s position in supplying processors for personal computers. Zook and Allen, *Repeatability*, 45–46.

¹⁰ Management systems include portfolio management and finance; mergers and acquisitions, joint ventures, and partnering; regulatory management; business unit strategy and driving priorities; and human resources management and culture. Operating capabilities include supply chain and logistics; production and operations; development and innovation; go-to-market; and customer relationships. Assets include tangible assets; scale; technology and intellectual property; brand; and tied customer network. Zook and Allen, *Repeatability*, 47–49.

¹¹ Deloitte Center for Industry Insights, *High-performing Manufacturers*, 2016, 1.

difficult for their competitors to replicate, and when executed well, they create long-term competitive advantage by generating greater customer loyalty, higher market share, and superior profitability.”¹² Further, certain “capabilities will enable the organization to create unique value and consistently deliver that value to customers in a way that is distinct from competitors’ offerings.”¹³

Proposed Advanced Technology Competitiveness Framework

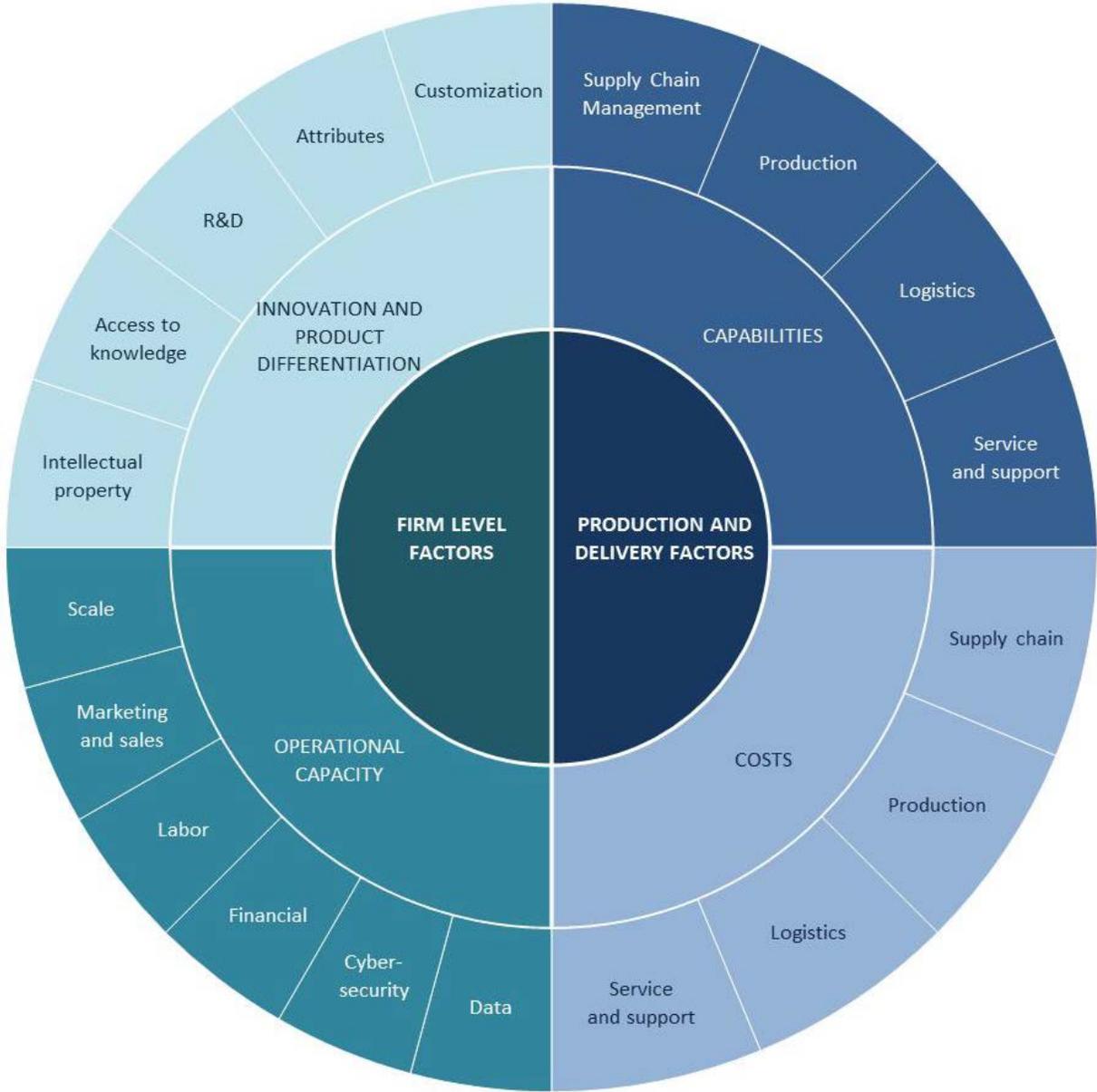
Overview

The four main factors of competition for advanced technology firms are (1) production and delivery capabilities, (2) production and delivery costs, (3) operational capacity, and (4) innovation and product differentiation (figure 2). Production and delivery capabilities and costs are all the activities and costs associated with producing goods (and related services) and delivering them to customers. Operational capacity and innovation and product differentiation capture other relevant firm characteristics. Within each of these factors are four to six subfactors of competition, such as labor, financial capacity, and research and development. Each of the four factors and many of the subfactors are interconnected, with competitiveness on one factor influencing a firm's ability to compete on another factor. For example, innovation can result in new production processes, which can improve production capabilities and lower costs. While not explicitly included in the framework, costs also apply to operational capacity and innovation and product differentiation, and lowering these costs can be an important priority for firms. Factors such as price that are often associated with competitiveness are not included in the framework as they are the result of factors discussed here rather than factors themselves (see appendix B).

¹² Deloitte Center for Industry Insights, *High-performing Manufacturers*, 2016, 1.

¹³ Deloitte divides the capabilities into four areas, depending on whether companies have current or future advantages. High-performing manufacturers have both current and future advantages, for example, in areas such as brand strength; a skilled workforce; global sales, marketing, distribution, and logistics; a strong balance sheet; cybersecurity; and the protection of intellectual property. Deloitte Center for Industry Insights, *High-performing Manufacturers*, 2016, 3, 6.

Figure 2 Factors of competition for advanced technology firms



Source: Staff research.

The relative importance of the factors in the framework varies by industry, and even within an industry firms may compete on different factors. For example, firms in some industries may compete primarily by differentiating their products, while in other industries there may be little opportunity for firms to differentiate products and production costs may be more critical. In the smartphone industry, for example, some firms primarily supply differentiated products (e.g., Apple), while others may compete by supplying low-cost products. Other companies compete with both differentiated and low-cost

products.¹⁴ When all firms in an industry compete primarily on a single element, such as cost, this can drive down overall industry profitability.¹⁵ However, when firms within a particular industry compete on different elements, this can increase overall industry profitability because firms provide product and price mixes that compete for different customers.¹⁶ When applying the framework to specific industries, all of the factors may not be relevant or it may be appropriate to combine certain factors (such as production capabilities and costs) into a single analysis.

Production and Delivery Capabilities

Production and delivery capabilities are all activities associated with manufacturing a good and providing it to customers. The most competitive firms are able to produce innovative products, at high quality, that can be delivered to customers in a timely manner. The key capabilities are (1) supply chain management, (2) production, (3) logistics, and (4) service and support.

Supply chain management

Firm-level competitiveness can be heavily influenced by effective supply chain management. The supply chain includes all of the raw materials, parts, and other inputs that go into producing a good, as well as associated logistics (including inventory management). The management of a supply chain involves a number of considerations (in addition to costs, which are discussed below), such as ensuring an adequate supply of inputs, making certain that inputs meet quality requirements, maintaining the appropriate inventory level, monitoring the financial condition of suppliers, and ensuring that the supply chain is resilient enough to withstand any potential disruptions (e.g. shortage of raw materials arising from natural disasters, currency fluctuations, etc.).¹⁷

Supply chain resilience is especially critical for advanced technology manufacturing sectors, because the production of these goods tends to occur in numerous countries. Semiconductor manufacturing, for example, is fragmented across multiple countries.¹⁸ In response to severe droughts in Taiwan, a Taiwanese firm (Taiwan Semiconductor Manufacturing Co.) and a U.S. firm (United Microelectronics Corporation) jointly developed a water recycling program to mitigate supply chain risks and ensure consistent production.¹⁹ In sectors such as machinery, motor vehicles, and aerospace, firms rely on

¹⁴ Duberstein, “Xiaomi IPO,” June 29, 2018; Hruska, “Apple Gained Market,” July 26, 2018; Tao, “Huawei Leads,” July 26, 2018; Ismail, “Moto Now Owns,” April 19, 2018; Fieldhack, “Overall Q1 US Smartphone,” May 22, 2018.

¹⁵ Porter, “The Five Competitive Forces that Shape Strategy,” January 2008, 32–33.

¹⁶ Porter, “The Five Competitive Forces that Shape Strategy,” January 2008, 32–33.

¹⁷ Sheffi, “Preparing for Disruptions Through Early Detection,” Fall 2015; Deere & Company, Form 10-K, December 18, 2017, 7; Caterpillar, Form 10-K, February 15, 2018, 6; Apple Inc., Form 10-K, November 3, 2017, 65; Bain & Company, “Inventory Management,” July 6, 2011; Dobbs et al, *Playing to Win*, September 2015, 78.

¹⁸ SIA, “The Global Semiconductor Supply Chain,” 2014.

¹⁹ Bollinger, “Managing Risk,” April 20, 2015.

global suppliers for key components and any delays in deliveries by these suppliers can slow production.²⁰

Another competitive supply chain management strategy is to demonstrate sustainability. This has become especially critical as the advent of international accords, the introduction of manufacturing standards, and mounting consumer preferences for products with a minimal environmental impact have placed pressure on firms to work with their suppliers to reduce carbon emissions and limit environmental waste.²¹ A 2014 survey by Accenture revealed that 81 percent of CEOs believed in demonstrating the sustainability of their production, in part, to satisfy customer demands.²²

Production capabilities

The ability of high tech firms to produce innovative, high quality products is critical to firm competitiveness, as is the ability to quickly bring new products to market, to rapidly switch between products as technology changes, and to offer customized products. In the semiconductor industry, for example, manufacturers can differentiate themselves from competitors by offering chips with the most advanced technologies.²³ One survey of manufacturers found that “quality management systems” was the top ranked of “potential technology advancements to improve business performance in the next five years.”²⁴ Firms in consumer oriented industries, such as consumer electronics and automobiles, are able to increase product customization and lower time to market by implementing new production techniques, such as artificial intelligence, robotics, and additive manufacturing.²⁵

Strategic use of technology is another important way in which advanced technology firms are able to improve their production capabilities. For example, advanced production capabilities, such as “smart manufacturing systems,” allow firms to incorporate new technologies that provide real-time data to decision makers, while also providing predictive maintenance and failure preventing capabilities.²⁶ Improving production capabilities, whether through adopting new technologies or streamlining processes that increase productivity or create differentiation in capabilities, is one way in which firms are able to become more competitive. Firms with greater production capabilities will manufacture products with additional added value.²⁷ When competitors are unable to make similar production capability upgrades, the more competitive firms are able to capture higher market shares, create customer loyalty, and improve profitability.²⁸

²⁰ Wall and Cameron, “Boeing, Airbus Strain to Deliver,” July 15, 2018; Aeppel and Singh, “Why Caterpillar Can't Keep Up,” May 23, 2018; Ruda, “Biggest Risks,” August 8, 2017.

²¹ DNV-GL, *Viewpoint Report*, February 2018; Naden, “You Are What You Buy,” April 21, 2017.

²² Accenture, “CEOs and Consumers Disconnected,” July 15, 2014.

²³ TSMC, *TSMC Annual Report 2017*, March 12, 2018, 14; Morris, “Inside GlobalFoundries’ Long Road,” March 13, 2018.

²⁴ *IndustryWeek*, Custom Research, and Kronos Inc., “The Future of Manufacturing: 2020 and Beyond,” 2016, 7.

²⁵ World Economic Forum, “Technology and Innovation,” March 2017, 4, 10.

²⁶ Jung et al., “Mapping Strategic Goals,” 2015, 184-185.

²⁷ World Economic Forum, “The Future of Manufacturing,” November 2014, 8.

²⁸ Deloitte Center for Industry Insights, *High-performing Manufacturers*, November 29, 2016.

Logistics capabilities

Outbound logistics, which is the “process related to the movement and storage of products from the end of the production line to the end user,”²⁹ is a significant aspect of firm competitiveness. It is important for firms to deliver products to customers efficiently and on-time. Customers increasingly demand shorter delivery time frames, and there may be financial penalties for firms that do not deliver products on time.³⁰ Global logistics capabilities are important for firms that want to compete beyond the domestic market.³¹

Access to transportation infrastructure is an important consideration in plant location selection decisions, demonstrating the importance of logistics.³² For example, wind turbines are large, difficult to transport products and important considerations when locating a wind turbine manufacturing plant include the availability of multiple shipping options and proximity to customers.³³ Similarly, business jet manufacturers need sufficient land at their plant for a runway and a location to hold aircraft until they are delivered.³⁴

Service and support capabilities

Services are an increasingly important component of product offerings and include not just after sales service, but also additional products that can increase the value of the original product for the customer, while also providing benefits to the firm.³⁵ In the business jet industry, where firms need to provide 24 hour service near aircraft locations, the quality of the services provided by business jet sellers is a key factor in jet sales. After sale business jet services include repair and maintenance, parts distribution, equipment and software upgrades, as well as other services that can lower customer operating costs and affect purchasing decisions.³⁶ Aircraft manufacturers are also using after-sales services, such as replacement parts and repairs, to compete against other aircraft service and parts manufacturers to capture a larger share of the market and increase profit margins.³⁷ Wind turbine manufacturers expanded their operations and maintenance, design, and installation service offerings as “a potentially strong revenue stream to supplement equipment sales” in “an increasingly competitive equipment market.”³⁸

²⁹ CSCMP, *Supply Chain Management Terms and Glossary*, August 2013, 139.

³⁰ JDA, *JDA 2018 Intelligent Manufacturing Survey*, 2018, 3.

³¹ Deloitte Center for Industry Insights, *High-performing Manufacturers*, 2016, 6.

³² Gambale, “32nd Annual Corporate,” Q1 2018; *Automotive Logistics*, “Plant Locations,” June 10, 2016; David, *Wind Turbines*, June 2009, 14–16; Torsekar, “China Climbs the Global Value Chain,” March 2018, 8.

³³ David, *Wind Turbines*, June 2009, 14–16.

³⁴ USITC, *Business Jet*, April 2012, 2-11.

³⁵ Huang et al., “How Customer Service,” January 16, 2018; Porter and Heppelmann, “How Smart Connected Products are Transforming Companies,” October 2015, 18; Oxford Economics, *Manufacturing Transformation*, June 9, 2013, 9.

³⁶ USITC, *Business Jet*, April 2012, 2-13.

³⁷ Scott, “Boeing Takes on Peers,” October 24, 2016; *The Straits Times*, “Airbus, Boeing Chase,” May 14, 2018.

³⁸ USITC, *Renewable Energy and Related Services*, August 2013, 4-12.

Connected products have necessitated a shift in strategy from targeting one-time sales opportunities to emphasizing prolonged customer service.³⁹ For example, preventative monitoring and services reduce the necessity of in-person support, adding value to customers via after-sales services and lowering repair costs for firms.⁴⁰ Aircraft engine manufacturers use preventative monitoring to identify when a specific part will need to be replaced before it becomes ineffective, reducing flight delays for aircraft operators.⁴¹ Firms offering complementary services through extended customer support are also able to collect additional data used to improve customer experience and lower company costs.⁴² In addition to preventative monitoring, aircraft engine manufacturers analyze in-flight data to increase fuel efficiency to lower costs for aircraft operators.⁴³

Production and Delivery Costs

Lower production and delivery costs enable firms to increase profitability and employ a variety of pricing strategies. Further, firms that are able to optimize processes or lower prices through economies of scale create a barrier to entry for new firms. Four production and delivery costs are discussed below: (1) supply chain costs, (2) production costs, (3) logistics costs, and (4) service and support costs.

Supply chain costs

Lowering supply chain costs (especially material and input costs) is important for manufacturers,⁴⁴ and can impact firm competitiveness. Material and input costs alone accounted for 37 to 65 percent of the value of U.S. shipments in 2016 for the five advanced technology NAICS subsectors covered in this report.⁴⁵ Volatility in materials and input prices is also a significant concern for many firms.⁴⁶ Raw materials such as steel and aluminum, for example, account for a significant portion of vehicle production costs, and an increase in these costs can have a significant impact on firm profitability.⁴⁷ Firms can lower their supply chain costs or the risk of price volatility in a number of ways, such as diversifying their supplier base, fostering close collaboration with suppliers, and hedging the risk of price increases.⁴⁸

³⁹ Porter and Heppelmann, “How Smart Connected Products are Transforming Companies,” October 2015, 18.

⁴⁰ Porter and Heppelmann, “How Smart Connected Products are Transforming Companies,” October 2015, 19-20;

Porter and Heppelmann, “How Smart Connected Products are Transforming Companies,” December 2015, 6.

⁴¹ RTInsights, “How Rolls-Royce Maintains Jet Engines,” October 11, 2016.

⁴² Porter and Heppelmann, “How Smart, Connected Products are Transforming Competition,” November 2014, 15;

Porter and Heppelmann, “How Smart Connected Products are Transforming Companies,” December 2015, 6.

⁴³ RTInsights, “How Rolls-Royce Maintains Jet Engines,” October 11, 2016.

⁴⁴ One survey found that “material costs” were the second highest ranked market challenge for firms.

IndustryWeek, Custom Research, and Kronos Inc., “The Future of Manufacturing: 2020 and Beyond,” 2016, 2.

⁴⁵ Includes the value of receipts for services. U.S. Census Bureau, “2016 Annual Survey of Manufactures,” accessed July 17, 2018.

⁴⁶ Deere & Company, Form 10-K, December 18, 2017, 13; Caterpillar, Form 10-K, February 15, 2018, 10; Apple Inc., Form 10-K, November 3, 2017, 65; Ford, Form 10-K, February 8, 2018, 13.

⁴⁷ Carey, “Ford Complains Rising Metals Costs,” January 24, 2018; Kallstrom, “Raw Materials,” February 10, 2015.

⁴⁸ Noor, “The Power of Successful Supplier Collaboration,” February 2013; Ford, Form 10-K, February 8, 2018, 94.

At the same time, advanced technology industries have leveraged newer technologies to lower input (and hence, supply chain) costs.⁴⁹ For example, GE has used additive (3D) manufacturing to produce fuel nozzles for its LEAP aircraft engine, replacing the 20 inputs that are traditionally made across a number of countries with a single manufacturing process that is made in a single location.⁵⁰ Further, within the electronic products sector, 3D manufacturing has been used to produce a variety of components, such as electronic circuits and electronic insulators.⁵¹ The use of this technology has enabled these firms to shorten production cycles and become less reliant on imported parts.

Production costs

Two main ways in which firms are able to boost competitiveness in the area of production capabilities are through lowering production costs and boosting productivity. Manufacturing firms that are able to lower costs, such as through increased efficiency associated with production capabilities, will be more competitive than other firms with higher costs. Firms able to reduce production costs may lower prices or increase profits.⁵² In instances where the good or service is not differentiated from a competitor's product, firms will compete on price and low costs are important for a firm to remain profitable.⁵³

Low costs are also a barrier to other firms entering the industry, as established firms may have economies of scale or other advantages, such as production efficiencies or experience, that make it difficult for new firms to enter the market.⁵⁴ On the other hand, advanced technology firms with disruptive technologies may have lower costs that enable them to create new markets by targeting a new group of consumers and eventually challenge traditional providers of a good or service.⁵⁵ Additive manufacturing and robotics are examples of technologies that lower production costs for manufacturers. Additive manufacturing allows firms to create prototypes and product molds quicker, in smaller quantities, and at lower costs versus traditional, subtractive manufacturing. Manufacturing firms, in certain circumstances, can also rely on robotics instead of more expensive labor.⁵⁶

Logistics costs

Outbound logistics costs are a significant part of a firm's overall costs, and manufacturing firms that can reduce these costs while still meeting performance requirements can improve their competitiveness. One study found that firms (of which 83 percent were manufacturing firms) spend an average of 4.7 percent of revenue on distribution, and the highest spending group of firms spent an average of 7.9

⁴⁹ Dobbs et al., *Playing to Win*, September 2015, 76.

⁵⁰ Manyika et al., *Digital Globalization*, February 2016.

⁵¹ Walter, "Researchers Find New Way to 3D Print Electronic Circuits," November 9, 2017.

⁵² Raynor and Ahmed, "Three Rules for Making a Company Truly Great," April 2013; Dobbs et al., *Playing to Win*, September 2015, 76.

⁵³ Accion, "Pricing Your SaaS Product," March 23, 2015, 7, 18; Porter, "How Competitive Forces Shape Strategy," March 1979.

⁵⁴ Accion, "Pricing Your SaaS Product," March 23, 2015, 7, 20; Porter, "The Five Competitive Forces that Shape Strategy," January 2008, 27; Porter, "How Competitive Forces Shape Strategy," March 1979.

⁵⁵ Dobbs et al., *Playing to Win*, September 2015, 10–12.

⁵⁶ Hagel et al. "The Future of Manufacturing," March 31, 2015.

percent of revenue on transportation.⁵⁷ A USITC survey of domestic producers of remanufactured goods found that transportation costs was the factor most commonly cited by firms as extremely important in their ability to compete in foreign markets.⁵⁸ Outbound logistics costs can be reduced in a number of ways, such as siting factories in locations with low shipping costs, redesigning products and packaging, and increasing the amount of products sent in each shipment.⁵⁹ With high costs and the volatility of certain inputs to transportation and delivery costs, such as fuel costs, firms that are able to more efficiently transport and deliver products to customers can lower costs and have a competitive advantage over firms relying on traditional approaches.⁶⁰

Service and support costs

After-sales service and support can be a significant cost for companies. In the business jet industry, for example, costs for providing services 24 hours a day at geographically distant locations are substantial.⁶¹ Manufacturing firms that optimize after-sales and support services, such as through data collection (discussed below) and measuring the performance of products, without increasing costs, will be more competitive in the market.⁶² Customer retention, product design improvements, and short-term profits are all examples of benefits manufacturing firms can achieve through after sales services that can be maximized by lowering costs.⁶³ For example, customer retention and the potential for follow-up sales, is often less costly than finding new customers.⁶⁴ Additionally, advanced manufacturing firms that export products face additional costs associated with service and support. Firms that must recall certain products, especially from abroad, will incur high costs associated with both transportation and customer satisfaction. Samsung's recall of its Galaxy Note 7 phone, for example, is estimated to have cost \$5 billion, and damaged customers' perception of the brand.⁶⁵ Firms are able to work with local partners to lower service and support costs.⁶⁶

Operational Capacity

Operational capacity encompasses a range of firm capabilities. These capabilities are interconnected with the production and delivery factors, and may impact multiple subfactors in these areas. For example, a firm's financial capacity impacts its ability to invest in production capabilities and logistics.

⁵⁷ Liberatore and Miller, "Outbound Logistics Performance," 2016, 5–6.

⁵⁸ USITC, *Remanufactured Goods*, October 2012, 2-22.

⁵⁹ Russel et al. "The Real Impact of High Transportation Costs," Quarter 1, 2014; O'Byrne, "Is Nearshoring the Solution?" July 29, 2015; Girrback, "How Cisco's Packaging Diet," March 10, 2010.

⁶⁰ Russel et al. "The Real Impact of High Transportation Costs," Quarter 1, 2014.

⁶¹ USITC, *Business Jet*, April 2012, 2-13.

⁶² Sacanni, "The Role and Performance Measurement," 2006, 277.

⁶³ Sacanni, "The Role and Performance Measurement," 2006, 277.

⁶⁴ Cohen, Agrawal, and Agrawal, "Winning in the Aftermarket," May 2006.

⁶⁵ Price, "Samsung's Reputation has Crashed," February 21, 2017; Rahim, "Samsung's Reputation has Gone," February 21, 2017.

⁶⁶ USDOC, ITA, "After-Sales Service," October 20, 2016.

Operational capacity includes (1) data, (2) cybersecurity, (3) financial capacity, (4) labor, (5) marketing and sales, and (6) scale.

Data

The generation, storage, analytics, and protection of data are increasingly important determinants of competitiveness for advanced technology firms. Data in this context, refers to the vast collection of information that companies accumulate, which can be derived internally or externally (e.g., from customers, suppliers, and the larger market) and can be both structured (e.g., customer sales data) and unstructured (e.g., internet search results). Analytics refers to the statistical methods, algorithms, and software-enabled tools that facilitate the interpretation of these data.⁶⁷ Robust data collection and analytical capabilities enable firms to refine the products and services offered to meet the needs of their customers, and can be used to improve business processes and practices.⁶⁸

A key for companies to adapt and expand into new markets or remain competitive in current markets is their ability to generate and use data from those markets, which better enables them to adapt to changing conditions or address unique market needs. Firms gather data on customer preferences in potential markets to confirm that the offered product or service will be competitive or even in demand. Determining customer familiarity with a product or service, on top of market demand, allows firms to better customize educational and advertising strategies to compete in the market.⁶⁹ For example, one appliance manufacturer increased sales by updating its advertising strategy after analyzing market data that indicated customers made purchasing decisions based off retailer websites, not manufacturer websites or print and television advertisements.⁷⁰ Data gathered about local culture and customs is incorporated into those strategies as well.⁷¹ Firms that gather information about specific markets, and customize their products and services accordingly, will be more competitive.

A NewVantage Partners (NVP) survey of global Fortune 1000 companies found that for firms that had started big data initiatives, the majority had achieved benefits such as increased or new sources of revenue and lower expenses.⁷² A McKinsey study found that these investments tend to yield increases in operating profits and value-added productivity.⁷³ At the same time, many firms are struggling to achieve the benefits of investments in big data. The NVP survey found that a substantial minority of firms had not yet achieved benefits in some categories, such as increasing revenue.⁷⁴ And the McKinsey study found that investments in big data have less impact on certain metrics, such as revenue for consumer

⁶⁷ *Harvard Business Review*, "The Explainer," August 24, 2014.

⁶⁸ *Financial Times* "The Digital Divide Over Consumer Data," July 26, 2017; *Financial Times*, "Consumers Win a Victory," August 7, 2017; Dobbs et al., *Playing to Win*, September 2015, 79.

⁶⁹ Entrepreneur, "How to Take Your Company Global," n.d. (accessed on March 9, 2018); Ramaswamy et al., *Making it in America*, November 2017, 38.

⁷⁰ Bhandari et al. "Using Marketing Analytics to Drive Superior Growth," June 2014, 40.

⁷¹ BDC, "3 Essential Steps for Entering a Foreign Market," n.d. (accessed on March 9, 2018).

⁷² NVP, *Big Data Executive Survey 2017*, 2017, 8.

⁷³ Bughin, "Big Data," February 2016.

⁷⁴ NVP, *Big Data Executive Survey 2017*, 2017, 8.

companies and costs for business to business companies.⁷⁵ Companies that invest more than they need to in big data may not achieve expected financial returns.⁷⁶

One of the major cost drivers and impediments to generating value is low quality data, such as incomplete data sets or data containing errors, and firms that address this issue will be more competitive.⁷⁷ One survey found that data scientists spend half their time “collecting, labeling, cleaning, and organizing data.”⁷⁸ Even internal company data are often stored in different locations and systems throughout the company, and bringing together this data involves significant costs.⁷⁹ Newly created data also contains many errors, however, and can significantly increase costs for companies.⁸⁰ IBM estimates lower quality data costs in the United States totaled \$3.1 trillion in 2016 due to efficiency losses associated with time spent to reduce and correct data errors, as well as business and customer impacts.⁸¹

Cybersecurity management

Cybersecurity management, a firm's ability to protect customer and company data and provide secure software, platforms, and products, is a potential distinguishing factor in the market, and the inability to protect information can damage a company's reputation, lead to the loss of customers, and result in significant costs.⁸² As firms collect more data from users, the firm's ability to protect the data and the overall reputation for security become potential differentiators and sources of value.⁸³ Different industries face different costs associated with cybersecurity and data breaches. For example, the healthcare and financial services industries face, on average, higher costs than the technology and communication industries due to different regulations and needs.⁸⁴ As a firm's data becomes increasingly sensitive and valuable, the costs of cybersecurity breaches also increase.⁸⁵ This includes its own data and intellectual property (IP). IP, in particular, provides value to firms, and protecting that proprietary information is important in retaining competitiveness.⁸⁶

⁷⁵ Bughin, “Big Data,” February 2016.

⁷⁶ Visibelli, “How Big Data Can Mean Big Money,” n.d. (accessed March 21, 2018).

⁷⁷ Redman, “4 Business Models for the Data Age,” May 20, 2015; Wilder-James, “Breaking Down Data Silos,” December 5, 2016.

⁷⁸ CrowdFlower, *2017 Data Scientist Report*, 2017, 5.

⁷⁹ Wilder-James, “Breaking Down Data Silos,” December 5, 2016.

⁸⁰ Nagle, Redman, and Sammon, “Only 3% of Companies' Data,” September 11, 2017.

⁸¹ Redman, “Bad Data Costs the U.S. \$3 Trillion Per Year,” September 22, 2016.

⁸² Chacko, Sekeris, and Herbolzheimer, “Can You Put a Dollar Amount,” October 5, 2016; IBM Security and Ponemon Institute, *2017 Cost of Data Breach Study*, June 2017, 1; Accenture and Ponemon Institute, *2017 Cost of Cyber Crime Study*, 2017, 12, 29; Deloitte Center for Industry Insights, *High-performing Manufacturers*, 2016, 6.

⁸³ Porter and Heppelmann, “How Smart, Connected Products are Transforming Companies,” October 2015, 21.

⁸⁴ IBM Security and Ponemon Institute, *2017 Cost of Data Breach Study*, June 2017, 13.

⁸⁵ USITC, *Global Digital Trade 1*, August 2017.

⁸⁶ Thomas, *The Role of Trade Secrets*, January 15, 2015, 2.

Underinvestment in cybersecurity could result in data breaches that lead to additional costs and undermine other aspects of competitiveness.⁸⁷ According to an Accenture/Ponemon study, the average cost to a company of a cybercrime was \$11.7 million in fiscal year (FY) 2017, with the highest incident costing a company \$77.1 million.⁸⁸ A RAND Corporation study using 2004–15 data found that the average cost was \$7.8 million, but the median cost was 250,000.⁸⁹

At the same time, cybersecurity budgets remain a cost for companies, with an average global company information technology budget of \$5.1 million in 2016 and organizations worldwide spending an estimated \$81.6 billion on information security in 2016.⁹⁰ Firms need to invest in cybersecurity cost-effectively to ensure that spending remains manageable. Simply spending more does not necessarily ensure higher quality outcomes.⁹¹

Financial capacity

Financial capacity (cash reserves and ability to generate revenue, attract venture capital and equity investments, and borrow money on favorable terms) is important for all types of firms, from early start-ups to mature market leaders. Strong financial capacity enables a firm to invest in new business strategies, research and development, the commercialization of new technologies, and advertising.⁹² Research and development and up-front advertising, for example, take place before a product or service has been monetized, thus requiring a company to rely on its pre-revenue finances to cover costs and creating a barrier for other firms without adequate financial capacity.⁹³ The ability to attract initial funding from investors is especially important for advanced manufacturing start-ups, which may focus on growth and remain unprofitable for years, due in part to high fixed asset costs.⁹⁴ Even some established companies reinvest substantial revenue into further expanding business operations, thus limiting profitability.⁹⁵

⁸⁷ Chacko, Sekeris, and Herbolzheimer, “Can You Put a Dollar Amount,” October 5, 2016; Gordon et al., “Empirical Evidence,” 2018, 142–143, 150.

⁸⁸ This study includes direct, indirect costs, and opportunity costs for companies of a cybercrime. It is broader than some studies that examine only the cost of data breaches, a subset of cybercrimes. An IBM/Ponemon Institute study found that the average cost of a data breach was \$3.6 million in FY 2017. Accenture and Ponemon Institute, *2017 Cost of Cyber Crime Study*, 2017, 12; IBM Security and Ponemon Institute, *2017 Cost of Data Breach Study*, June 2017, 1.

⁸⁹ The RAND study does not include costs such as lost sales and the impact on the company's brand. The study found that the mean cost of a data breach was \$5.9 million, and the median was \$170,000. Romanosky, “Examining the Costs and Causes of Cyber Incidents,” 2016, 129

⁹⁰ PwC, *Key Findings*, 2017, 2; Sinn, “Moving Forward with Cybersecurity and Privacy,” December 2016, 10; Gartner data cited in Cloudmask, “The Cost of Data Security,” n.d. (accessed July 20, 2018).

⁹¹ Choi et al., “Hit or Myth?” 2017, 2–4; Morgan Stanley, “Cybersecurity: Time for a Paradigm Shift,” June 15, 2016.

⁹² Porter, “The Five Competitive Forces That Shape Strategy,” January 2008, 27; USITC, *Medical Devices and Equipment*, March 2007, 2-5; Deloitte Center for Industry Insights, *High-performing Manufacturers*, 2016, 6.

⁹³ Porter, “The Five Competitive Forces That Shape Strategy,” January 2008, 27.

⁹⁴ Graham, Suster, and Fried, “Should Your Startup Prioritize Profits or Growth?” July 8, 2017; McCue, “Advanced Manufacturing Expertise,” July 30, 2014; NIST, “Connecting Small Manufacturers,” November 2011, 20.

⁹⁵ Alba, “No, Amazon isn't Going to Quit,” July 28, 2016.

Financial capacity also enables firms to respond to new entrants (or deter new entrants), the emergence of competing products, or other market changes.⁹⁶ A financially secure firm is also more capable of responding to competitors through purchasing complementary or competing technology or assets.⁹⁷ Cisco, for example, which offers videoconferencing services, purchased Acano, a videoconferencing startup, to increase the interoperability of its products with Skype for Business, a competing videoconferencing service.⁹⁸ Firms often make acquisitions to acquire new technologies or intellectual property.⁹⁹

Labor

Access to workers with diverse skillsets (such as knowledge in engineering, regulatory affairs, user interface design, data analytics, systems integration, cloud competency, and software development) is critical to the competitiveness of advanced technology firms.¹⁰⁰ Firms which are able to employ and retain talented individuals, especially in IT and engineering departments, will be more efficient at implementing new business strategies and creating new product features aimed at boosting competitiveness. A lack of access to skilled employees can be a barrier in accomplishing a firm's strategies.¹⁰¹ Additionally, increased demand for software engineers, has led advanced technology firms, such as Airbus and Danaher, to compete for skilled labor by locating offices in clusters where advanced manufacturing and academia interact.¹⁰²

As technology progresses, so do the skills required by production workers in advanced manufacturing environments. Firms that improve production equipment to boost competitiveness, as discussed in the production capabilities section above, will also need to focus on more effective and skilled factory labor.¹⁰³ One common method manufacturing firms use is "upskilling" current employees by offering in-house training for new skills.¹⁰⁴ In other cases, manufacturing firms fund high-school programs to improve skills in robotics, CNC machinery, and 3D printing so production labor becomes more efficient and available.¹⁰⁵ Additional emerging skillsets for advanced manufacturing workers include virtual and augmented reality knowledge, as well as other data visualization tools.¹⁰⁶

⁹⁶ Porter, "The Five Competitive Forces That Shape Strategy," January 2008, 27; Laurent, "Cash Reserves: Both Safety and Strategy!" October 15, 2009.

⁹⁷ Goedhart, Koller, and Wessels, "The Six Types of Successful Acquisitions," May 2017.

⁹⁸ Bort, "Why Cisco Paid \$700 Million for this Guy's Company," November 20, 2015; Cisco, "Cisco has Acquired Acano Limited," (accessed March 5, 2018).

⁹⁹ Dobbs et al., *Playing to Win*, September 2015, 74.

¹⁰⁰ Porter and Heppelmann, "How Smart, Connected Products are Transforming Competition," November 2014, 15; Porter and Heppelmann, "How Smart Connected Products are Transforming Companies," October 2015, 22-23; USITC, *Medical Devices and Equipment*, March 2007, 2-6-7.

¹⁰¹ Benavides et al., "CPG Manufacturers Need," 2016, 12-13.

¹⁰² Porter and Heppelmann, "How Smart Connected Products are Transforming Companies," October 2015, pp. 10, 23.

¹⁰³ Karren, "The Smart Factory is Only as Smart as its Workers," June 15, 2016.

¹⁰⁴ Karren, "The Smart Factory is Only as Smart as its Workers," June 15, 2016.

¹⁰⁵ McCue, "Advanced Manufacturing Expertise Key to Future," July 30, 2014.

¹⁰⁶ Burke, Laaper, and Sniderman, "The Smart Factory," August 31, 2017.

Marketing and sales

The effectiveness of firms in selling products to customers is an important factor in firm competitiveness.¹⁰⁷ Effective sales involve everything from traditional sales techniques to using technology to optimize offerings and tailor or bundle products.¹⁰⁸ Firms can bundle together multiple products, yielding an offering that attracts new customers and enhances existing demand among current consumers.¹⁰⁹ For example, GE Healthcare added value to its diagnostic technologies by pairing these devices with enterprise-wide software that enables purchasers to monitor inventories of other GE issued medical equipment, arrange servicing appointments, and track regulatory requirements to ensure compliance.¹¹⁰ In addition to offering more and targeted value to its customers, bundled products and services also raise switching costs of moving to a rival firm and improve customers' brand loyalty.¹¹¹

Access to distribution channels can also provide a firm with a competitive advantage and serve as a barrier to entry to other firms, though new entrants that find untapped distribution channels can use these as a way to ease market entry.¹¹² In the medical device industry, for example, firms that want to sell in the Japanese market need relationships "with experienced and well-connected dealers who maintain effective distribution networks and access to hospitals and who may assist manufacturers to develop long-term supply relationships."¹¹³ Similarly, Chinese medical device manufacturers' access to distribution channels has been one of the reasons that these firms have been able to increase their domestic market share.¹¹⁴

Firms benefit from being able to sell in foreign markets and not just their home markets. Firms that are able to sell beyond their home market can benefit from significant additional demand and rapid growth in developing countries, all of which can improve profits.¹¹⁵

Scale

Scale provides firms with a number of advantages (in addition to economies of scale in production described above), such as brand recognition, production experience, proprietary technology, and

¹⁰⁷ Porter and Heppelmann, "How Smart, Connected Products are Transforming Competition," November 2014, 14–15; Davcik, and Sharma. "Marketing Resources," 2016, 1–2.

¹⁰⁸ Greene, "How Oracle Engineered," August 16, 2017; Porter and Heppelmann, "How Smart, Connected Products are Transforming Competition," November 2014, 15.

¹⁰⁹ Consumers may benefit from lower transaction costs, purchasing bundled products instead of several individual ones. Shankar, "A Practical Guide to Combining Products and Services," November, 2009; Porter, *Competitive Strategy*, 1980, 427; Evans, "Part 5: Software Platforms," 2011, 389.

¹¹⁰ GE Healthcare, "AssetPlus," n.d. (accessed on July 31, 2018).

¹¹¹ Shankar, "A Practical Guide to Combining Products and Services," November, 2009.

¹¹² Magretta, *Understanding Michael Porter*, 2012, 40; Porter, "The Five Competitive Forces that Shape Strategy," January 2008, 28.

¹¹³ USITC, *Medical Devices and Equipment*, March 2007, 2-6.

¹¹⁴ Torsekar, "China's Changing Medical Device Exports," January 2018, 6.

¹¹⁵ Dobbs et al., *Playing to Win*, September 2015, 73–74; Deloitte Center for Industry Insights, *High-performing Manufacturers*, 2016, 6.

avored geographic location.¹¹⁶ These advantages present barriers to entry for market challengers and inherently give an incumbent a competitive advantage. For example, a large firm may be able to use its position and market leverage to enter into exclusivity arrangements with other actors within the market.¹¹⁷ Larger, incumbent companies are also able to use established customer bases, and the valuable data contained therein, as a tool to scale quickly, enter new markets (potentially disrupting conventional industries), limit customer poaching from market challengers, and ultimately remain more competitive.¹¹⁸ One study noted that large firms are more likely to create new, innovative technologies due to their position of strength in the market over smaller, less established firms.¹¹⁹ Conversely, some smaller firms are able to take advantage of network effects and lower costs to be more efficient at scaling their business in the face of new technology than larger, more established firms.¹²⁰

Innovation and Product Differentiation

The generation of new ideas, development of new products and processes, and protection of these innovations underpin the competitiveness of advanced technology firms. Innovation enables firms to develop unique products and achieve higher profits. In certain instances, IP can also serve as a barrier to entry for rival firms unable to access these technologies, while in other instances innovation can ease market entry, allowing new or smaller firms to challenge existing companies. Innovation may also raise switching costs by creating new products or services that can't be readily exchanged for products provided by another firm.¹²¹ Innovation is particularly important for advanced technology firms, where robust investments in R&D are often necessary to help firms remain ahead in the development of technology.¹²²

Innovation also contributes to firms' ability to differentiate their products, affording them a competitive advantage¹²³ over their competitors, particularly in ways that are not easily replicated.¹²⁴ Firms that differentiate their products are able to charge higher prices and increase profitability, as well as potentially increase demand.¹²⁵ Differentiation also increases customer loyalty, which makes price less

¹¹⁶ Porter, "The Five Competitive Forces that Shape Strategy," 27; Dobbs et al., *Playing to Win*, September 2015, 74.

¹¹⁷ OECD, "Competition and Barriers to Entry," OECD Observer, 2007, 3-4

¹¹⁸ MacMillan and Selden, "The Incumbent's Advantage," October 2008; Iansiti, "Managing Our Hub Economy," September-October 2017.

¹¹⁹ Eggers and Kaul, "When Big Firms Are Most Likely to Innovate," October 19, 2016.

¹²⁰ Hirt and Willmott, "Strategic Principles for Competing in the Digital Age," May 2015, 2.

¹²¹ Magretta, *Understanding Michael Porter*, 2012, 28–31; Porter, "The Five Competitive Forces that Shape Strategy," January 2008, 27; Pisano, "Profiting from Innovation," 2006, 1126; Christensen, Raynor, and McDonald, "Disruptive Innovation," December 2015, 46, 51–52; Dobbs et al., *Playing to Win*, September 2015, 74.

¹²² Hirt, "Strategic Principles," May 2014.

¹²³ This section will refer specifically to products and ways they are offered to customers. Differentiation in terms of production costs, operational execution, etc. are covered in other factors.

¹²⁴ Porter, *Competitive Strategy*, 1980, 38; Porter, "What is Strategy," November–December 1996, 5; Porter, "The Five Competitive Forces that Shape Strategy," January 2008, 32–33.

¹²⁵ Porter, "What is Strategy," November–December 1996, 5; Porter, "The Five Competitive Forces that Shape Strategy," January 2008, 32–33.

of a consideration in purchasing decisions and raises switching costs.¹²⁶ Five elements of innovation and product differentiation are discussed below: (1) intellectual property, (2) access to knowledge, (3) R&D; (4) attributes, and (5) customization.

Intellectual property (IP)

The granting and protection of IP, including patents, copyrights, trademarks, and trade secrets, provides a foundation for companies to obtain benefits from their R&D and innovation. Without IP protection, the first firm to invest time and money in a new product or service would always be at a disadvantage to later entrants who could simply copy and market products without having to recoup sunk costs.¹²⁷ IP, such as patents, may impact the ability of new firms to enter the market, though new entrants with existing IP¹²⁸ assets may find it easier to enter the market than those without such IP. In the highly competitive advanced technology industries, firms have traditionally relied heavily on IP protections.¹²⁹ Advanced technology firms, especially within the computers and electronics sector, are among the world leaders in IP-related activities, accounting for the greatest share of global patent and trademark applications in 2016 and driving the substantial global expansion of R&D investments in recent years.¹³⁰

Access to knowledge

Firms increasingly need to access ideas and knowledge outside of the firm, and may adopt business models that encourage collaboration and facilitate the development of technology over which they don't have full control. Open source software, for example, is being used by many firms, including established firms that are integrating it into product offerings.¹³¹ Firms have also adopted open innovation, which is “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively.”¹³² As part of open innovation, firms may also involve users or outside contributors in the innovation process to provide new ideas, designs, and products.¹³³ IP partnerships, which enable firms to access each other's knowledge and new technologies, develop new capabilities, and supply new markets, are becoming

¹²⁶ Porter, *Competitive Strategy*, 1980, 38.

¹²⁷ Dobbs et al., *Playing to Win*, September 2015; U.S. Dept. of Commerce, *Intellectual Property and the U.S. Economy*, March 2012, v.

¹²⁸ Cockburn and MacGarvie, “Entry and Patenting in the Software Industry,” May 2011, 915–916, 931.

¹²⁹ Womack, “Oracle Plans,” April 24, 2017. For example, a 2012 report found that many of the subsectors covered in this report ranked among the most “patent intensive” manufacturing sectors. USDOC, *Intellectual Property and the U.S. Economy*, March 2012, 33.

¹³⁰ WIPO, “Record Year,” March 15, 2017.

¹³¹ OECD, *Data Driven Innovation*, 79–80.

¹³² Chesbrough, “Everything You Need to Know About Open Innovation,” March 23, 2011.

¹³³ Dobbs et al., *Playing to Win*, September 2015, 79; Kapoor, Nolan, and Venkatakrisnan, “How GE Appliances,” July 21, 2017; Wilson, “GE Appliances’ Plan,” January 10, 2018; Oxford Economics, *Manufacturing Transformation*, June 9, 2013, 13.

more common.¹³⁴ These IP arrangements can help firms address shared problems, while benefiting all participants. For example, Cisco has initiated partnerships with a broad range of firms (including Airbus, DHL, and Caterpillar) to help resolve the common challenges associated with supply chain digitization.¹³⁵

Firms located in clusters, “geographic concentrations of companies, suppliers, related industries, and specialized institutions such as academic programs,” benefit from their proximity to these other organizations.¹³⁶ In the area of R&D, firms’ innovative capacity is enhanced by their increased access to capital, knowledge, expertise, suppliers, and skilled labor. Clusters also enable firms to scale their innovations more quickly and allow new firms to enter the market as they are able to more readily access the range of resources described above.¹³⁷ Firms may also benefit from national-level research and development activities. In the U.S. medical device industry, for example, firms benefit from research conducted by the National Institutes of Health and other organizations.¹³⁸

Research and development

A firm’s R&D activities create long-term value for the company through the improvement or new development of goods, services, knowledge, and processes.¹³⁹ Advanced technology firms are among the world’s leading investors in R&D, reflecting the priorities placed on building innovative capacity.¹⁴⁰ For example, in 2017, two of the top three spenders on R&D, by industry, were computing and electronics and automobiles, with companies such as Intel, Samsung, and Volkswagen among the top five spenders globally. Six of the top fifteen companies were automobile companies.¹⁴¹ Medical device firms commonly spend an average of 7 percent of revenues on R&D,¹⁴² in contrast to the global industry average of 4.2 percent.¹⁴³

A firm derives a competitive advantage from effective R&D, not from the level of spending alone. Factors such as organizational capabilities and whether investment is sustained over time also influence

¹³⁴ These partnerships may include: 1) licensing (the granting of legal rights for the use of patents, copyrights, trademarks, or trade secrets); 2) technology purchases and sales; 3) IP-based component business arrangements, in which the licensee is permitted to use IP for components; 4) contract R&D (contracting out designs or other IP that can be tailored to local market preferences); and 5) joint ventures that provide for the licensing of patents, trademarks, and other IP assets to local partners. Michael, “Developing Effective Intellectual Property Partnerships,” June 16, 2015; Chesbrough, “A Better Way to Innovate,” July 2003.

¹³⁵ Furr, “Managing Multiparty Innovation,” November 2016.

¹³⁶ Magretta, *Understanding Michael Porter*, 2012, 145; European Commission, *Innovation Clusters in Europe*, n.d. (accessed March 28, 2017), 3.

¹³⁷ Gambardella, *Building High-Tech Clusters*, 2004, 1; Shih, “What to Know,” Fall 2015; Porter, “Clusters and the New Economics of Competition,” 83–84; OECD, *Clusters, Innovation and Entrepreneurship*, 2009, 30–31.

¹³⁸ USITC, *Medical Devices and Equipment*, March 2007, 2-5.

¹³⁹ Incremental Innovation, “The Importance of R&D,” 2012.

¹⁴⁰ Jaruzelski, “Software-as-a-Catalyst,” October 25, 2016.

¹⁴¹ Jaruzelski, Staack, and Chwalik, “Will Stronger Borders Weaken Innovation?” October 24, 2017.

¹⁴² Eisenhart, “Emergo Survey,” July 17, 2017.

¹⁴³ PwC, “2016 Global Innovation 1000,” October 2016.

whether companies derive an advantage from R&D.¹⁴⁴ Firms with financial capacity often acquire smaller firms to get access to their research and innovations.¹⁴⁵ For example, traditional vehicle manufacturers, their suppliers, and other technology firms are making significant acquisitions of firms developing new technologies, such as those for autonomous vehicles and in-vehicle entertainment and information.¹⁴⁶

R&D investments are made in technological and business model innovations with the intention of creating value for customers, either by inducing them to pay more for an improved product or service, or reducing the cost of the product/service.¹⁴⁷ Many of the innovations resulting from R&D are incremental, leading to improvements to a current product or process. Other innovations, however, result in entirely new business models or products. These types of innovations, depending on the structure of the industry, may create opportunities for new firms to enter the market and challenge incumbent firms or may result in entirely new markets for products.¹⁴⁸

Product attributes

One way that firms can distinguish themselves is by employing their resources to develop and market the various attributes of their products. Attributes refer to the qualities that distinguish a firm's products and services. Successful firms are able to provide multiple attributes that are appealing to customers.¹⁴⁹ Examples that are important to firm competitiveness include product performance, quality, durability, ease of use, flexibility, energy efficiency, safety, connectivity, noise, size, weight, and environmental impact.¹⁵⁰ In the passenger vehicle industry, for example, attributes that consumers consider when purchasing a vehicle include fuel efficiency, reliability, technology (e.g., back-up cameras, Bluetooth integration), appearance, utility (e.g., cargo space), and safety.¹⁵¹ Some of these attributes are a baseline that a company must maintain in order to compete in a market, while others can form the basis of a differentiation strategy that can add value for customers.¹⁵²

¹⁴⁴ Jaruzelski, Schwartz, and Staack, "Innovation's New World Order," October 27, 2015; Barton et. al, "Measuring the Economic Impact of Short-termism," February 2017, 6–7; Pisano, "You Need an Innovation Strategy," June 2015.

¹⁴⁵ Luckerson, "How Google Perfected the Silicon Valley Acquisition," April 15, 2015; Christensen, Raynor, and McDonald, "Disruptive Innovation," December 2015, 51; Dobbs et al., *Playing to Win*, September 2015, 79.

¹⁴⁶ Dawson, "Big Tech Reshaping Auto Supply Chain," March 14, 2017; Dawson and Higgins, "Delphi to Buy," October 24, 2017; Hammerschmidt, "Automotive Infotainment," April 24, 2017.

¹⁴⁷ Pisano, "You Need an Innovation Strategy," June 2015.

¹⁴⁸ Christensen, Raynor, and McDonald, "Disruptive Innovation," December 2015, 46, 49, 51–52; Christensen and van Bever, "The Capitalist's Dilemma," June 2014, 62–63; Pisano, "Profiting from Innovation," 2006, 1126; Pisano, "You Need an Innovation Strategy," June 2015.

¹⁴⁹ Zook, "The Great Repeatable Business Model," November 2011; Allen, "Living Differentiation," March 21, 2012.

¹⁵⁰ Compiled from company financial reports.

¹⁵¹ Coffin, *Passenger Vehicles*, May 2013, 37.

¹⁵² Porter and Heppelmann, "How Smart, Connected Products are Transforming Competition," November 2014, 14–16.

Customization

One major shift for manufacturers is the increasing need to provide more product varieties and customized products, often with shorter life cycles.¹⁵³ A recent survey found that more than half of manufacturing firms expect the share of orders that are “configure or assemble to order” to increase in the next five years, and that almost half expect the “engineer to order” share to increase during this time period.¹⁵⁴ This shift is being driven by a number of factors, including the greater availability of customer data (enabling firms to better tailor products for the needs of individual customers), growing demand in developing countries, and purchaser demands for more customized products.¹⁵⁵

Customization enables firms to deepen brand loyalty (which raises switching costs) and establish prices that better reflect the value from the product, all of which improves a firm's competitive standing against rivals.¹⁵⁶

Conclusion

The four main factors of competition for advanced technology firms are (1) production and delivery capabilities, (2) production and delivery costs, (3) operational capacity, and (4) innovation and product differentiation. These factors are closely related and linked, and while the relative importance of factors may vary by industry, assessing a firm's strengths and weaknesses in each of these areas is crucial to understanding the relative competitive position of the firm. The framework, however, is specific to competition among firms and cannot be directly applied to an analysis of the competition of national industries. Subsequent research will examine modifications to the framework needed to assess competition at the industry level.

¹⁵³ Ramaswamy et al., *Making it in America*, November 2017, 35–36; Malik, Niemeyer, and Ruwadi, “Building the Supply Chain,” January 2011.

¹⁵⁴ *IndustryWeek*, Custom Research, and Kronos Inc., “The Future of Manufacturing: 2020 and Beyond,” 2016, 5.

¹⁵⁵ Porter, “How Smart Connected Firms Are Transforming Companies,” October 2015; Ramaswamy et al., *Making it in America*, November 2017, 35–38.

¹⁵⁶ Porter, “How Smart, Connected Firms Are Transforming Competition,” November 2014.

Appendix A

The industry groups within each of the subsectors covered by this framework are listed in table 1.

Table 1: Subsectors covered by this competitiveness framework

Subsector		Industry groups
Code	Description	
333	Machinery manufacturing	Agriculture, construction, and mining machinery manufacturing (NAICS 3331) Industrial machinery manufacturing (NAICS 3332) Commercial and service industry machinery manufacturing (NAICS 3333) Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing (NAICS 3334) Metalworking machinery manufacturing (NAICS 3335) Engine, turbine, and power transmission equipment manufacturing (NAICS 3336) Other general purpose machinery manufacturing (NAICS 3339)
334	Computer and electronic product manufacturing	Computer and peripheral equipment manufacturing (NAICS 3341) Communications equipment manufacturing (NAICS 3342) Audio and video equipment manufacturing (NAICS 3343) Semiconductor and other electronic component manufacturing (NAICS 3344) Navigational, measuring, electromedical, and control instruments manufacturing (NAICS 3345) Manufacturing and reproducing magnetic and optical media (NAICS 3346)
335	Electrical equipment, appliance, and component manufacturing	Electric lighting equipment manufacturing (NAICS 3351) Household appliance manufacturing (NAICS 3352) Electrical equipment manufacturing (NAICS 3353) Other electrical equipment and component manufacturing (NAICS 3359)
336	Transportation equipment manufacturing	Motor vehicle manufacturing (NAICS 3361) Motor vehicle body and trailer manufacturing (NAICS 3362) Motor vehicle parts manufacturing (NAICS 3363) Aerospace product and parts manufacturing (NAICS 3364) Railroad rolling stock manufacturing (NAICS 3365) Ship and boat building (NAICS 3366) Other transportation equipment manufacturing (NAICS 3369)
339	Miscellaneous manufacturing	Medical equipment and supplies manufacturing (NAICS 3391) Other miscellaneous manufacturing (NAICS 3399)

Source: NAICS codes and descriptions from DOL, BLS Website, https://www.bls.gov/iag/tgs/iag_index_naics.htm (accessed July 17, 2018).

Appendix B: Outcomes and Influences not Included in the Framework

The competitiveness of firms is derived from their strengths in each of the factors of competition discussed in this framework. Other elements that may influence customer purchasing decisions or that are often perceived as elements of competition are not included in the framework because they are outcomes of the factors discussed above. Price, for example, is not included in the framework, though it is a factor on which customers base purchasing decisions. Price is an outcome of other factors in the framework, such as the cost of production and the extent to which products are differentiated from competitors' goods. Similarly, total cost of ownership (which includes the purchase price and other costs/attributes, such as repair costs, reliability, and fuel efficiency) is an important factor in customer purchasing decisions. As with price, however, total cost of ownership is a result of many other factors of competition, such as production capability, production costs, and product attributes.

Similarly, competitive advantage is not derived from a single best timing of entry for all firms (such as a first mover advantage). Instead, the factors in the framework (e.g., innovation, financial capacity) influence the best entry timing for each firm. The extent to which firms gain an advantage from moving first, for example, depends on factors such as the rate of market growth, speed of technology change, and attributes of the firm.¹⁵⁷ There are also advantages to firms for moving later (e.g., benefits from market development or technology improvement by first movers), and even within the same market firms can have different ideal entry timing.¹⁵⁸ For large firms, it can be advantageous to wait until a market develops and then use their resources to enter the market.¹⁵⁹

Other elements, such as regulations and government policies, may impact individual factors of competition in the framework, but are not themselves factors of competition. For example, a government policy that provides loan guarantees would impact a firm's financial capacity. Similarly, a government policy that provided for manufacturing equipment purchases would impact the recipient firm's production capabilities. Tariffs can impact a firm's logistics costs.

The factors included here are the capabilities required for firms to compete, but the framework does not specify whether all of these capabilities need to be in-house or whether they can be contracted out to other firms. Industries will have different optimal arrangements of in-house and contracted capabilities, and even within an industry the best approach may vary by firm. In the business jet industry, for example, a firm needs advanced manufacturing plants, with a runway, ramp space, access to good transportation infrastructure, and a reliable utilities infrastructure.¹⁶⁰ In the semiconductor

¹⁵⁷ Lieberman and Montgomery, "Conundra and Progress," 2013, 321–322; Suarez and Lanzolla, "The Half-Truth of First-Mover Advantage," April 2005; Lieberman and Montgomery, "First-Mover Advantages," 1988, 52.

¹⁵⁸ Lieberman and Montgomery, "Conundra and Progress," 2013, 317; Lieberman and Montgomery, "First-Mover Advantages," 1988, 47–49.

¹⁵⁹ Lieberman and Montgomery, "Conundra and Progress," 2013, 321–322; Suarez and Lanzolla, "The Half-Truth of First-Mover Advantage," April 2005.

¹⁶⁰ USITC, *Business Jet*, April 2012, 2-11.

industry, integrated device manufacturers (e.g., Intel, Samsung) handle all major steps in the value chain internally, while fabless firms (e.g., Qualcomm, NVidia) do the research and design in-house, and contract out the manufacturing.¹⁶¹ There are a number of trade-offs between performing an activity in-house or outsourcing it, however, and these have implications on the factors of competition in this framework, such as costs, intellectual property protection, knowledge, production flexibility, and financial capacity.¹⁶²

¹⁶¹ Barbe, Kim, and Riker, "Trade and Labor in the U.S. Semiconductor Industry," July 2018, 3.

¹⁶² ATKearney, *Make vs Buy Revisited*, 2010, 1; Boston Consulting Group, "Rethinking Asset-Light," n.d. (accessed July 13, 2018); Kachaner and Whybrew, "When 'Asset-Light' is Right," September 30, 2014.

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