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Unveiling the Determinants of IT Business Value: An Industry-Level Analysis on the Role of the Information-Based Nature of the Product

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Abstract—**Despite predictions that information technology (IT) investments would have a transformative effect on industry structures, little empirical research has compared the value generated by IT investments across sectors. This study theorizes and tests which component of value—output growth or input reduction—prevails at the industry level by analyzing the effects of IT investments on labor productivity. Results for 231 industries between 2008 and 2019 show that IT investments affect labor productivity growth. However, this effect has different drivers, depending on the industry. IT investments in industries specialized in information goods lead to output growth but to a reduction in labor input and output in other sectors. Taken together, the results confirm that industry is a relevant variable in IT business value research and raise policy implications about the structural divergence that IT investments are creating between sectors.**

Index Terms—**Digital products and services, industry-level studies, information goods, information technology (IT) business value, IT capability, strategic role of IT.**

I. Introduction

THE importance of industry type in determining the impact of information technology (IT) investments on competitive dynamics and structural change [1] is well articulated in the information systems (IS) literature since the contribution of Chiasson and Davidson [2]. However, despite the broad consensus on the transformational effects of IT on industry structures [3], empirical research conducted so far has not identified any idiosyncratic industry characteristics that can model the association between IT and business value.

This gap in the academic literature is due to an uneven coverage of the range of industries considered in previous research examining the IT business value at the industry level [4]. To bridge this gap, several studies on the IS discipline have started looking at the IT business value at the industry level, responding to Chiasson and Davidson's [23] call for more studies on the macroeconomic impacts of IT using data from reliable sources that applied economics studies had carefully screened out (e.g., [5], [6], [7], [8], [9], [10], [11], [12]). However, the difficulty of constructing large datasets that correlate granular industry variables over an adequate time span [13] explains why many industry-level studies on the IT business value have considered a small number of industries or a large number of industries limited to a single International Standard Industrial Classification (ISIC) code.[1] Furthermore, considering the multifaceted role that modern IT technologies can play in organizations—i.e., automate, inform, transform [14], [15]—recent literature reviews on the business value of IT point out that we still know little about whether the value generated by IT investments essentially consists of a growth in output at the aggregate level (due to its potential to transform products, services and value chains) or whether it enables a reduction in labor input (due to its potential to automate work or manage information more effectively) [4], [16].

This study contributes to bridging this gap in the IT business value literature by isolating the determinants—output growth or input reduction—through which labor productivity growth occurs, due to IT investments, following different trajectories, depending on the type of industry. To empirically validate such theoretical understanding, an industry-level study was conducted using detailed data from the Italian National Institute of Statistics (Istat) about 231 three-digit industries operating between 2008 and 2019. There are two main reasons why Italy is a relevant empirical context for the type of research undertaken in this study. First, Italy can be considered a representative context of the average situation of the most industrialized European countries. Second, the data collected by Istat at industry level can be considered unique at European level as they allow to correlate IT investments data with labor productivity data by covering the entire population of firms within each industry, thus overcoming the difficulty of constructing such large datasets over an appropriate time span [13].

Consistent with the literature, the results show that IT investments affect labor productivity growth. However, the longitudinal approach of the study made it possible to capture how and why such an effect has different drivers, depending on the type of industry. IT investments in industries in which the nature of

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1.For example, Chatterjee et al. [14] analyzed 42 industries; Mittal and Nault [5] 20 industries; Ren and Dewan [9] 59 industries; Chae et al. [11] 63 industries; Han et al. [7] 92 three-digit code industries; and Acemoglu et al. [10] 387 four-digit code industries in the manufacturing sector.

products and services essentially consists of information (henceforth "information goods") lead to value-added (output) growth. On the other hand, they lead to a reduction in both labor input and the output (value-added) in other sectors. This result indicates that sectors outside the information goods industry that invested more in IT experienced a loss in their ability to capture economic value. Furthermore, the results indicate that industries that are not specialized in information goods benefited from a reduction in employment as a result of IT investments. Conversely, the information goods industry did not show any visible effect on employment reduction, as a result of IT investments; in fact, quite the contrary.

Overall, the results provide solid empirical evidence that sheds new light on how between-industry divides are due to the extent the structural traits of industries affect the IT business value creation process. The gray area pertains to the understanding of whether the IT business value consists in favoring output growth or input reduction. We have here contributed to bridging this gap in the IS value literature by isolating the determinants through which labor productivity growth due to IT investments follows different trajectories, which depend on industry-related technological, economic, and managerial factors. Furthermore, by highlighting the structural gaps and divergences that IT investments are creating across sectors, the study provides important implications for scholars, practitioners, and policymakers to reframe the promise of digital transformation associated with technological discontinuities, such as artificial intelligence, into a more realistic perspective. The results are robust across different estimation methods and specifications, and the theoretical development indicates that these effects could persist in the future and occur in other developed countries.

II. Theoretical Background

In order to organize previous research and identify gaps for future efforts, this section is organized as follows. I begin by defining the key terms of this study: labor productivity, IT investment, and IT business value. Section II-A introduces the drivers of the IT business value, focusing on the strategic role of IT to investigate the interdependencies between the IT business value and the characteristics of an industry. Section II-B presents the different types of industries and why the IT business value creation process can vary between them.

Labor productivity—which in economic studies is intended as the economic value of the output created by a firm divided by the amount of labor input that such a firm uses in the production process—is the most frequently discussed process performance measure in the IT investment context [4], [16]. It in fact represents the primary lens through which the prevalence of effects of economic growth (more output) or input reduction (less labor) can be discerned [17], [18]. The idea that IT can "automate" or "informate" equates to saying that IT investments can impact labor productivity by reducing the amount of labor input devoted to routine operational or informational tasks [15] or by increasing the volume of output produced with the same quantity of input [19]. The role of transformation attributed to IT involves increasing the economic value of output by creating

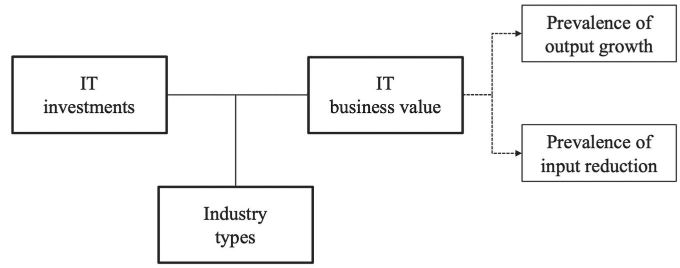

Fig. 1. Toward an integrating framework.

new products and services, or adding new features to existing ones, where the value lies in capturing and treating the information in new ways. Under these circumstances, the prevalent approach in the IS literature is to attribute a role of business transformation to IT in industries where the core products and processes are inherently information intensive [20], [21], [22], [23], [24]. However, our knowledge on whether the components of productivity growth due to output growth or input reduction prevail as a result of industry-level factors is still at an initial stage [4], [11].

The way industry influences the relationship between IT investments and the creation of IT business value is depicted in Fig. 1 and reviewed in two distinct parts of this section.

A. *Drivers of the IT Business Value*

IS researchers have used different approaches to investigate the interdependencies between the IT business value and the characteristics of an industry. The first approach, which is taken from the strategy literature [25], investigates how variables of the competitive industry environment, such as dynamism, munificence, and complexity, contribute to codetermining the returns of IT investments, but it does not consider how IT investments affect the value creation process considering the idiosyncratic characteristics of the focal product or service of an industry [26].

The second approach, which is taken from the IS literature, uses the construct of the information intensity of an industry—which is typically measured considering the percentage of IT investments over sales revenue—as the key variable that influences the returns on IT investments [5], [23], [27], [28]. The authors in [5] and [23] studied how the information intensity of an industry influences its productivity. Han et al. [7] studied how information intensity influences IT outsourcing and IT spillovers. Neirotti and Pesce [29] investigated how the information intensity of an industry is associated with within-industry divides, thus highlighting how the diffusion of IT capabilities that lead to value creation and capture can also be slow in industries that are theoretically more oriented toward IT investments. However, the construct of the information intensity does not explain how or why the characteristics of an industry that justify the intensity of firms investing in IT shape the IT value creation process [16], [26].

The third approach is based on the strategic role of IT [15]. It categorizes the role of IT for an industry as the capacity of “Automating,” “Informating,” and “Transforming” [14]. Automating consists in replacing human labor with software and algorithms. Informating consists in providing data and information to empower management and employees. The “automate” and “informate” logics can both lead firms to redesign their business processes in order to “do the same things with less (input)” [30]. In other words, the automation and information type of IT use is triggered by the adoption of such enterprise systems as enterprise resource planning (ERP), which supports production planning and control, inventory management, invoicing, asset maintenance, collaboration, as well as data sharing and integration with supply chain partners to manage demand and material flows. Being related to such “standardized software packages” as ERP systems, the input reduction that stems from this type of IT investments may require limited implementation costs and involve a large number of firms [31].

The “transform” ontology linked to the strategic role of IT refers to how IT can support firms in “doing new things” [14], [15]. The role of IT in some industries is to transform traditional ways of doing business by redefining business processes and improving their external orientation toward customers—including the development of new business logics such as e-commerce and servitization (i.e., selling an integrated combination of products and services). Companies that are able to enact the “transform” strategic role for IT investments are often able to introduce radical business models that disrupt “industry recipes” [32] and create new market structures [11]. Although the use of IT to “do the same things with less” is aimed at reducing operational expenses and at protecting a firm’s profit margin from competitive pressure on prices, the “transform” role in IT allows a firm “to do new things” aimed at its output growth, at finding more munificent and high-growth market segments, and at increasing a customer’s willingness to pay, thanks to benefit differentiation, customization, additional products, and jointly provided services. However, not all the firms in an industry are capable of realizing such a type of business value [11]. In other words, the effective use of IT in a transform strategic role requires a high entrepreneurial orientation of the top management team, extensive learning in the organization and management of IT resources, the precursory adoption of interrelated IT resources, and investments in human and organizational capital to be effectively incorporated into the business processes [33].

B. Industry Types

There are many reasons why the IT business value creation process can vary from industry to industry. First, IT capabilities can vary at the industry level as a result of how resources and capabilities shape a firm’s competitive conduct [11], [34], [35]. Prior research has conceptualized IT capabilities over three dimensions [35] as follows: 1) the ability to manage an IT infrastructure; 2) the ability to use IT resources to reach strategic goals; 3) the ability to explore new ways of using already existing or new IT resources. Superior IT infrastructure capabilities enable the value-added role of IT by shaping “a firm’s capacity to launch frequent and varied competitive actions” [33, p. 256] and by increasing the quality of a firm’s overall IT landscape [36]. Furthermore, superior IT infrastructure capabilities allow firms to speed up their innovation processes [34], rapidly detect newly emerging opportunities for innovation [33], and effectively generate digital options and business concepts to allow them to compete in the digital economy [33]. IT capabilities also allow managers to envision how to exploit IT investments for strategic purposes that are significant for their firms to leverage on IT for superior performance and to shape their strategic conduct over time [33], [34]. Correspondingly, IT capabilities allow a firm to achieve agility and a proactive stance to meet new business model opportunities and ideas based on IT, thus reflecting its ability to use existing or new competencies, technologies, and knowledge [36].

Second, the level of IT investments is an essential element of IT capabilities [33]. IT investments have a significant and positive effect on the performance of a firm [37]. However, IT capabilities can vary at the industry level [38], [39] as a result of how the governance framework of IT investments is designed [40], of the usage frequency of the IT tool [41], and of the extent to which IT supports a firm’s operations and management practices [35]. Such differences in capabilities at the industry level denote a superior endowment that some industries can exhibit for such factors as human capital, the vendors’ supply of standardized IT solutions, regulatory frameworks, institutional factors, professional norms, and social forces that require a more extensive use of IT and more persistent IT investment patterns [34]. The different endowment of capabilities that exists at the industry level may also be due to the fact that the opportunities of value creation through IT are inherently linked to the nature of the core processes and information processing needs [42]. For example, IT plays a critical role in such industries as the media because of its strategic potential to transform the industry itself [11]. In other industries, such as the retail industry or utilities, the role of IT is to automate business processes and operations [11]. Thus, having superior IT capabilities may not be as strategically important as having other resources.

Third, the aggregate spending of a sector on IT can be considered a proxy of an industry’s IT capabilities [7]. In this regard, prior studies used the notion of IT intensity to “indicate industries’ different propensities to invest in IT” [7, p. 119]. The positive association between IT spending and IT capabilities has been confirmed in several studies. One of the reasons for the positive association between IT spending and IT capabilities in the IT business value creation process is that it usually exhibits certain time persistence. Such persistence leads to intangible asset accumulation dynamics [43], which can explain the increasing marginal returns from the stock of IT investments. This may imply that industries that spend more on IT—after achieving productivity growth from automation and information of the internal processes—may shift their focus on IT investment initiatives toward endeavors that have an external orientation, which in turn may lead to output growth [1].

Fourth, industries have different competition intensity levels, which can accelerate both IT investments and the search for new IT capabilities linked to the innovative use of IT [7], [44], [45]. However, there can be yet another effect of competition intensity at the industry level on the effects manifested in an industry due to IT investments. This point is extremely relevant in the current scenario, where industries specialized in handling information can intermediate in—and thus extract value from—more mature and less information intensive industries through the adoption of digital platform-based business models. This is how the sharing economy and digital platforms extract value from such sectors as transportation, logistics, hospitality, restaurants, and retail [46], [47]. Prospectively, the same case of increasing value capture from industries and firms handling "bits" and data rather than "atoms" [20] might also be observed in manufacturing industries, where the provider of IT solutions for operation management (e.g., Oracle, SAP, or Salesforce) and system integrators (e.g., General Electric with the Predix platform, Siemens) try to extract value from their manufacturing clients through centralized approaches to data management enabled by IoT and AI [48].

III. Hypotheses

Based on what was discussed in the previous section and depicted in Fig. 1, this study argues that IT investments have a greater effect on labor productivity in sectors where the nature of products and services consists essentially of information. Information is defined as "anything that can be digitized, that is, represented as a stream of bits" [50, p. 3]—as a result of how the technological and economic forces in such sectors set the conditions for the development of superior IT capabilities and a broader repertoire of competitive actions and digital options [33].

Existing taxonomies in IS research, including industry taxonomies related to the rate of information intensity (from Porat and Rubin [24] to Calvino et al. [50]) and industry taxonomies related to the strategic value of IT (from Chatterjee's taxonomy [14] to its most recent updates, e.g., that of Chae et al. [11]), have been systematically examined. On the one hand, it is worth noting that industrial taxonomies relating to information intensity rate do not take different industries or their distinctive aspects into consideration [16], [26]. On the other hand, industry taxonomies related to the strategic value of IT risk are becoming obsolete as a result of the ongoing acceleration of technology development, which implies a progressive convergence between the physical and digital worlds that is increasingly blurred [51]. Therefore, the three Automate, Informate, and Transform categories may not be adequate to capture the role of IT in the industry context [11].

To overcome these shortcomings, this study relies exclusively on the ISIC of all economic activities, focusing on Section J of the "Information and Communication" industries (ISIC Rev. 4 and NACE Rev. 2), which represents all products and services as a stream of bits [52]. A dummy variable was created to discriminate the industries from Section J of "Information and Communication"—whose core product or service was information goods—from all the other sectors using the dichotomy of industries specialized in "information goods" versus sectors that are not specialized in information goods.

A. *Output Growth Mechanisms and the Type of Industry*

Information goods, such as software, content creation, publishing, information services, IT services, and media activities, are products or services whose economic value depends on the information they contain. "Information is by nature a heterogeneous commodity" [24]: computer processing differs from data communication, and television is completely different from books. However, the Internet has provided these industries with new ways of combining and distributing these services at a global level through an industrialized approach [20], thereby increasing the operational and strategic flexibility of the firms in these sectors [51] as well as the cost efficiency that results from combining product customization with a broader reach of customers [22]. The strategic role of IT and the development of superior IT capabilities in the information goods industry can explain the superior capacity of certain firms to capitalize on IT investments to achieve growth of the economic value.

The first reason why such industries can obtain higher returns is due to the fact that when the carrier of information is no longer physical, and is instead digital, i.e., scalability and economies of scales as well as networking become possible [53]. Evans and Wuster [22], for example, showed that when the carrier of information is no longer material-based, and is instead Internet-based, the tradeoff between richness (in the way information can be managed and transmitted) and reach is mitigated, and such mitigation enables a mass customization. Thus, achieving output growth and a global operational scale becomes possible without the degree of inertia and bureaucracy historically associated with larger firms (Brynjolfsson and McAfee [53] labeled these dynamics as "scale without mass").

Second, the extant studies and market outlooks depict a situation of higher IT investments in the information goods industry [54], which is a result of its role in transforming externally oriented activities [55] and of the greater opportunities available to these firms to achieve competitive differentiation [56]. The greater financial resources allocated to IT investments (OECD citations) and the greater operational risks stemming from IT use (e.g., technical glitches, obsolescence, service outages, unreliable vendors or partners, security breaches, and privacy issues) have led firms in the information goods industry to develop more complex IT capabilities for data management/protection purposes [34], [36], [57], [58], [59] and to guide the planning, strategizing, and control of their IT investments [34], [58], [60], [61]. These types of IT capabilities also lead to time compression diseconomies and asset mass efficiencies in the development of the IT portfolio [61], [62], [63], thus reducing decision-making difficulties in the efficient and effective use of IT assets [64]. Taken together, such factors act as a possible isolation mechanism that can hinder noninformation goods industries from pursuing output growth opportunities to the same extent as their information goods counterparts.

A third reason why IT capabilities create more output growth in the information goods industry is the way the broader presence of digital options in such sectors leads managers to become increasingly specialized in redesigning operations, products and business models around new IT and digital technologies [33],

[35]. This eventually tends to make capabilities in operations, strategy-making, and entrepreneurial orientations more deeply cospecialized with IT investments [65], [66].

Fourth, the higher strategic dependence that firms in the information goods industry have on IT [52], [67] leads such firms to broaden their repertoire of competitive actions by seizing the right opportunities offered by new IT technologies [33]. The creation process of new businesses through IT and digital technologies can occur by aligning the needs of new clients and the interests of a wide range of stakeholders with the creation of new ecosystems [47], [68], [69]. The implementation of such ecosystems involves a high level of social complexity [70] due to the necessity of integrating internal IS with those of the supply chain partners and entails a higher level of pre-existing IT capabilities at the industry level. The way Amazon and Google reapplied their core competencies by entering a multitude of markets as platform orchestrators [71] is evidence of how coordination costs are becoming extremely low, which not only allows an ease of searching and product comparison but also enhances the ability to recombine digital products to create new value [51].

A related argument is that of product flexibility, due to an easier codifiability [3], [72] and a faster clock speed of innovation for information goods compared to physical ones [51], [73]. In general, speed in the life cycle of a product/service is an important property that reflects the inherent dynamics of sectors specialized in information goods. The "clock speed" of software development is generally much faster than that of traditional manufacturing firms that produce physical products, thus new avenues for digital options are created [33]. In this regard, recent studies [38], [51], [73], [74] have underlined that when manufacturing firms add digitally enabled features or services to their legacy product, they are obliged to follow a more rigid clock speed of innovation, even when the digital technologies provide new avenues to add new features or to digitize some others.

Finally, as conceptualized by the authors in [22] and [49], the production function in the information goods industry follows different economics from the other information intensive industries. On the one hand, the fixed costs of producing information goods are dramatically higher, due to the human costs of developing intellectual capital rather than plants and equipment [33]. On the other hand, the zero marginal cost associated with information and the fact that information exhibits the feature of nonrival goods imply that firms specialized in information goods can expand their output base with little effort [33]. In the same way, Evans and Wurster [22] argued that the use of the Internet as a distribution channel mitigates the tradeoff between the richness of the information being exchanged and its reach (i.e., the number of possible recipients), and this enables more tailored digital goods/services to be delivered to the consumer in a more interactive way. This dramatically increases the economic value of the digital product being exchanged and leads us to expect that the overall impact of IT investments on IT business value could be that of an output growth rather than an employment reduction. In short, several preconditions related to IT capabilities and industry types that indicate IT investments have a more salient impact on output growth in industries that produce information goods than in other sectors. This leads to the formulation of the following hypothesis.

H1. The effects of IT investments on labor productivity, due to output growth, are greater in industries specialized in information goods than in other sectors.

B. Input Reduction Mechanisms and the Type of Industry

The multitude of arguments related to the IT capabilities at play outside the information goods industry suggests that, in these settings, productivity growth driven by IT investments may be due more to input reduction mechanisms in the employment structure than to economic growth.

Several empirical research results [5], [7], [23] and market outlooks [52], [54], [67] have shown that firms outside the information goods industry tend to systematically invest fewer resources in IT capabilities and governance frameworks to plan their IT investments and to allocate decision-making power to such initiatives. This tendency is due to the fact that IT has never been a critical mission for operations [56] because their key production (or service delivery) processes involve the handling of "atoms" rather than "bits" [20]. The lack of governance frameworks for IT investments and the shortage of IT capabilities have produced asset redundancies, a lack of interoperable systems, and lower economies of scale in IT procurement, thus making the IT conversion process into business value more difficult [64]. Furthermore, fewer IT capabilities and a lower persistence in the accumulation of IT assets can lead firms in industries not specialized in information goods to focus their investments on simpler domains, oriented toward improving efficiency and labor use rather than pursuing more complex innovating product or service initiatives through IT [11], [35]. Hence, it is possible to hypothesize that the relationship between IT investments and labor productivity is less prominent and is prevalently focused on reducing the input in industries where IT capabilities and IT assets are not codeveloped or cospecialized with operations and strategy [75].

A second reason why IT investments in sectors not specialized in information goods can have less effect on output growth may be due to the lower codifiability of the operational processes [3] that are based more on operators' judgment and tacit knowledge than on data-driven approaches [72], [76]. In this regard, Brynjolfsson and Hitt [76] showed that data-driven decision making in managing operations leads firms to achieve superior productivity and asset utilization. Hence, the fact that outside information goods industry decision-making may be less codified in production and engineering processes can explain why it is difficult for IT investments to lead to a growth in output due to a better use of the available productivity capacity or higher sales from product innovation.

Third, infomediation and platform-based business models may favor the disintermediation of some industries not specialized in information goods, such as the retail, hospitality, tourism, and automotive industries, thereby resulting in a reduction in their value capture capability. Espousing the new business logics introduced by modern IT technologies in such industries has been a strategic necessity [77] and may have increased IT spending. However, the ultimate effect has been that firms in these industries have limited IT capabilities for turning their increased IT spending into IT business value [16] and output growth [4]. Furthermore, platform-based models and the sharing economy have led to some of these industries, e.g., hotels, restaurants (through online food delivery platforms such as Just Eat or Deliveroo), private transportation (through mobility platforms such as Uber or Lyft), looking for an employment structure that is based on a tier of self-employed and lowly paid workers [78]. This would seem to be an argument in favor of the idea that the increased IT spending witnessed in these industries, due to the shift in IT toward a strategic necessity, has led to input reduction mechanisms. Moreover, the disintermediation suffered by these industries may have led firms to search for efficiency changes in their internal production models (and therefore in their employment and unit labor costs) as a result of the pressure on prices and the growth in the external costs.

A final point in favor of the prevalence of input reduction mechanisms over output growth for industries not specialized in information goods pertains to the fact that the IT investments may have been focused on "automate" or "informate" logics [11], [14], [15] and may have involved cutting down on the middle managers in the bottom part of the hierarchy and administrative employees [79], [80]. Furthermore, IT investments on the shop floor may go hand in hand with technology and organizational innovation, such as robotics and lean production methods, to reduce the amount of labor involved in the intensive and non-value-added routine tasks for which low skilled workers are required [81], [82], [83].

In short, investments in IT can be concentrated on systems with a limited level of novelty and organizational complexity [35] that reduce the number of employees needed in low-skilled positions [81]. In addition, investments in emerging IT technologies are simply less diffused [54], [67] and, when they occur, they do not generate job creation for middle or high-skilled positions. Such considerations and the lower endowment of IT capabilities in sectors not specialized in information goods lead us to expect that the prevailing impact of IT investments on labor productivity could be that of an employment reduction rather than an output growth. This leads to the formulation of the following hypothesis.

H2. The effects of IT investments on value-added productivity, due to an employment reduction, are more visible in industries not specialized in information goods.

IV. Methodology

A. Empirical Setting

The data from this analysis refer to 231 three-digit industries in Italy and are available in "I.Stat," the warehouse of statistics currently produced by the Istat. There are two main reasons why Italy is a relevant empirical setting for the type of research undertaken in this study.

First, Italy may be considered a representative setting of the average situation of the most industrialized European countries. On the one hand, Italy has a low percentage of IT investments—11.3% of the total nonresidential gross fixed capital formation—as opposed to 32.14% in the USA and 25% in certain European countries, such as the U.K. and Sweden, which show a high tendency toward IT investments [84]. On the other hand, Italy shows a comparable IT adoption rate for several types of IS, such as ERP, SCM and CRM, with the U.K., Sweden, Germany, and France [85].

Second, the data collected by the Istat at the industry level can be considered unique at the European level. Indeed, this dataset allows data about IT investments (available since 2008) to be correlated with data on labor productivity, investments in tangible assets, and the composition of industries—at the three-digit level of the ISIC of all Economic Activities—which cover the whole private economic sector and the entire population of firms within each industry. As already mentioned in Section I, the difficulty of constructing this type of database in a time series explains why similar industry-level studies on the IT business value have considered a small number of industries or a large number of industries limited to a single ISIC code. As a result of the aforementioned features of the Istat industry-level database, it was possible to consider 231 industries for which complete data on the key variables of interest were available from 2008 to 2019. Appendix A provides the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2) and the corresponding references to the International Classification (ISIC) for the 231 industries considered in this study.

B. Variables

1) Dependent Variables:

a) Value-added labor productivity: Value-added labor productivity is defined as the ratio of value-added to the number of employees, and it reflects the productivity of the labor production factor [86]. Value-added takes into account the sales revenues minus the external costs for raw material and service costs. The values were deflated to the 2008-year values. Compared with labor productivity based on gross output, the growth rate of value-added productivity is "less dependent on any change in the ratio between intermediate inputs and labor, or on the degree of vertical integration" [88, p. 27]. Moreover, value-added-based labor productivity measures tend to be less sensitive to processes of substitution between materials plus services and labor than gross-output based measures. The OECD [87] recommends using value-added productivity to analyze micromacrolinks, such as the industry contribution to economy-wide labor productivity and economic growth.

b) Value-added labor productivity growth: This variable takes into account the logarithmic annual growth rate of the labor productivity of an industry. Deflated value-added values were used.

c) Output growth: This variable was operationalized as the logarithmic annual growth rate of value-added between 2008 and 2019. Deflated values were used.

d) Employment reduction: This variable was operationalized as the logarithmic growth rate of the number of workers employed at the industry level.

2) Independent Variables:

a) IT investments: Early studies operationalized IT investments using highly aggregated measures, such as IT expenditures (for hardware, software, personnel), technical IT assets (e.g., the number of PCs and servers), or human IT assets (e.g., the number of IT employees). However, it has widely been argued in the literature that gaining further insights into how and why IT creates business value requires the conceptual and empirical disaggregation of IT investments [34], [44], [58], [88], [89], [90], [91]. Recent literature reviews have pointed out deficiencies in the knowledge of how specific IT investments contribute to various types of economic performance [4], [16], [92]. Schryen [4, p. 148] highlighted that "better insights into the way IS investments induce superior business performance require a breakdown of IT investments into single IT assets." Becchetti et al. [93] revealed that when IT investments were decomposed into software, hardware, and telecommunications, only software investments exhibited a significant effect on labor productivity. Therefore, although some types of IT investment may lead to productivity increases, others may add value to different areas or even no value at all. Empirical studies on IT business value have only recently started to look at investments through more disaggregated measures and specific IT assets [4], [16]. IT investments in ERP systems are the most frequently studied IT assets [75]. Mangin et al. [94], in their literature review, found that most studies reported a positive postimplementation impact of ERP systems on firm performance, especially for large companies over a long period. Moreover, positive performance impacts have been found for CRM systems [95], [96], SCM systems [30], [95], and knowledge management systems [97].

Therefore, this study focuses conceptually and empirically on the capital expenditure (over industry sales revenue) for software, which may include system and infrastructure software (e.g., for servers and network management), business intelligence and business analytics software (e.g., knowledge management systems for data visualization, data warehousing, dashboards, and reporting to retrieve, analyze, and transform data into business insights), enterprise application software (e.g., ERP systems such as SAP and SCM, CRM systems and other extended modules and applications), and programing software (e.g., compilers used to translate and combine computer program source codes and libraries into executable programs). This operationalization reflects the choice made by other scholars who analyzed the impact of expenditures on investments in software and production-oriented software (cf., [4], [92], [94]).

b) Information goods industry: To overcome the shortcomings of the existing taxonomies highlighted in Section II, this study relies exclusively on Section J of the "Information and Communication" industries (ISIC Rev. 4 and NACE Rev. 2), which includes all the products and services as a stream of bits [52]. This section in particular includes the production and distribution of information and cultural products, the provision of the means to transmit or distribute these products, as well as data or communications, IT activities, and the processing of data and other information service activities. This section was introduced into the fourth version of ISIC published by the United Nations in 2008 (and, consistently, in the second version of the statistical classification of economic activities in the European Community, which is abbreviated as NACE) to better reflect the current economic phenomena and to be more in line with the modern trends dictated by the information economy (ISIC, Rev. 4; p. iii).

TABLE I
INFORMATION GOODS INDUSTRY

	ISIC Rev. 4 / NACE Rev. 2 Code	Description	(1) $\frac{VA_{IG_{2019}}}{VA_{ALL_{2019}}}$	(4) $\frac{IT_{IG_{2019}}}{IT_{ALL_{2019}}}$
Section J - Information and Communication	581	Publishing of books, periodicals and other publishing activities	0.36%	1.42%
	582	Software publishing	0.03%	0.08%
	591	Motion picture, video, and television program activities	0.28%	0.07%
	592	Sound recording and music publishing activities	0.02%	0.00%
	601	Radio broadcasting	0.02%	0.01%
	602	Television programing and broadcasting activities	0.22%	0.17%
	611	Wired telecommunications activities	1.55%	4.15%
	612	Wireless telecommunications activities	0.82%	9.33%
	613	Satellite telecommunications activities	0.01%	0.02%
	619	Other telecommunications activities	0.13%	0.93%
	620	Computer programing, consultancy, and related activities	2.67%	14.85%
	631	Data processing, hosting and related activities; web portals	0.69%	3.18%
	639	Other information service activities	0.04%	0.02%
		TOTAL	**6.84%**	**34.23%**

Table I illustrates a list of the 12 three-digit industries belonging to Section J of "Information and Communication" (ISIC Rev. 4 and NACE Rev. 2). The main components of this section are publishing activities, including software publishing (ISIC Code and NACE Division - 58), motion picture and sound recording activities (ISIC Code and NACE Division - 59), radio and TV broadcasting and programing activities (ISIC Code and NACE Division - 60), telecommunication activities (ISIC Code and NACE Division - 61), IT activities (ISIC Code and NACE Division - 62), and other information service activities, such as data processing, hosting and relating activities, web portals, and news agency activities (ISIC Code and NACE Division - 63). Table I also reports some descriptive statistics related to the Italian industries in the ISIC code and NACE division of section J of "Information and Communication," considering 2019 as the reference year. Overall, these industries account for 6.84% of the total of the values added to the entire sample (Column 1). According to OECD [52], although these industries account for a relatively small share of the OECD business sector GDP, they may contribute significantly to growth and the productivity performance if the latter grows more rapidly than the rest of the economy. On the whole, these industries account for 34.23% of the total IT investments in the sample (Column 2). It is worth noting that the total capital expenditure on IT (over the industry sales revenue) in 2019 made by these industries was 13× higher than that of all the other industries in the sample. A dummy variable was created to discriminate the industries from Section

J of "Information and Communication"—whose core product or service was information goods—from all the other sectors, using the dichotomy of industries specialized in "information goods" versus sectors that are not specialized in information goods.

3) Control Variables: In order to avoid omission biases and unobserved heterogeneity when estimating the effects of IT spending on labor productivity, the presence of other variables that could affect the analyzed dependent variables was checked. First, the year variables were used to take into account the economic cycle and, in particular, the economic recessions that occurred in 2008 and 2012. Second, the number of firms in the industry was considered, as this number is expected to influence the IT diffusion process. The diffusion of IT-based solutions in industries with a high number of enterprises may take longer to involve the late majority [98] since there are a high number of enterprises that have to be "infected" by the diffusion process and—as firms in this sector are on average smaller—this can negatively affect the diffusion process. As such, the number of firms may negatively affect the productivity growth component that can be attributed to IT investments.

The third type of control refers to the availability of qualified human capital, measured as the personnel cost per capita. An extensive amount of empirical literature on the IT business value argues that IT needs human capital investments to develop its full potential [99]. Industries with a larger availability of qualified human capital are usually more productive and require a limited amount of low qualified labor [100]. The personnel costs include the costs borne by firms for wages and training activities. Industries with higher personnel costs typically employ workers with higher educational attainment, a condition that goes hand in hand with higher budgets for employer-provided training [14], [88].

Finally, it was controlled for the industry capital intensity level, measured as both the capital expenditure (over the industry sales revenue) on tangible fixed assets and the ratio of tangible fixed assets per employee. The reason for this dual control is that labor productivity generally increases as the amount of fixed investment per employee increases [101]. Capital intensive industries usually show a high degree of automation in their production processes, and they employ a restricted tier of qualified human capital in the programing, control, and inspection/maintenance of the production assets. The annual measure of tangible fixed assets was adjusted to account for inflation. Instead, for the amount of fixed investment per employee, the annual deflated measure of tangible fixed assets was divided by the total number of employees at the industry level.

C. Econometric Approach

Coherently with the extant studies that link IT investments with firm performance (e.g., [1], [70], [102], [103]), the econometric approach used here to test the hypotheses considered once-lagged values of IT spending on labor productivity. This approach allows the changes in industry-level practices needed to produce visible economic effects to be taken into account. Furthermore, the approach allows the potential endogeneity of the IT spending variable to be considered and mitigated [104]. Huber-White robust standard errors were taken into account to avoid any potential heteroskedasticity and autocorrelation in all models. Finally, lagged variables were included in all models to test for time lags in the effect of IT investments on labor productivity and its growth component, i.e., output growth and input reduction. The large number of observations in the panel dataset made it possible to use time lags without experiencing a substantial reduction in the statistical power of the regression models, thus overcoming an important limitation of previous industry-level studies (cf., [28]).

The econometric estimates were drawn up according to three analysis steps described as follows.

1) *Baseline models*: First, a baseline regression that estimates the first-order effect of IT spending on labor productivity and its two components (output growth and input reduction) was estimated using ordinary least squares (see Table III, Models 1_{FE}–4_{FE}). The econometric approach was based on panel regression models with a fixed effects estimator. In general, fixed effects allow any omitted variable bias due to time-invariant unobservable factors to be eliminated [105]. In our specific case, this bias may have been related to the competitive forces and the institutional conditions at play in each sector. The appropriateness of the specifications with fixed and random effects was tested. The Hausman test was used to check the orthogonality of the industry-specific error with the explanatory variables. The results, which are reported in Appendix B, suggest that the fixed effects model is the appropriate one. For completeness, a random effects model was also estimated (see Appendix C, Models 1_{RE}–4_{RE}), which assumes that industry effects are characterized by a time-invariant component of the composite error term. Such a component is a random disturbance that characterizes each industry, and it is constant over time [107, p. 150]. A random effects approach is consistent with the objective of drawing general inferences about IT investments and industry-level productivity in economically advanced countries other than Italy. However, it should be pointed out that on the basis of guidelines from the econometric literature [106], the results of the fixed effects model were considered of primary importance.
2) *The moderating role of the type of industry*: The second step was aimed at estimating the second-order effect due to IT spending and to the type of industry, i.e., the information goods industry versus all other industries (see Table III, Models 5_{FE}–8_{FE}). Furthermore, a random effects model was estimated (see Appendix C, Models 5_{RE}–8_{RE}).
3) *Extensions*: Although industry and time fixed effects were considered, once-lagged values of IT spending on labor productivity, and Huber-White robust standard errors for potential heteroskedasticity and autocorrelation in all models, another potential deviation from modeling assumptions includes endogenous explanatory variables. In other words, one way in which assumptions can be violated is if the causality is reversed; instead of increases in IT investments leading to a higher output, an

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TABLE II
DESCRIPTIVE STATISTICS

		Descriptive Statistics			**Analysis of Variance**			
	Industry types	Mean	Standard Deviation	Frequency	Between group sum of squares	Within group sum of squares	F-statistics (p-value)	Bonferroni (p-value)
IT investments over revenues *(deflated values, 2008 = base year)*	Information goods	0.014	0.018	143	0.02	0.01	433.43 (0.000)	0.01 (0.000)
	All the other industries	0.001	0.004	2,398				
Employment *(log values)*	Information goods	9.272	1.791	143	44.53	4877.72	18.59 (0.000)	- 0.64 (0.000)
	All the other industries	9.908	1.532	2,398				
Number of firms *(log values)*	Information goods	7.116	2.241	143	78.71	10472.41	15.31 (0.000)	-0.84 (0.000)
	All the other industries	7.961	2.269	2,398				
Average firm size *(log values)*	Information goods	2.156	1.956	143	5.02	6204.56	1.65 (0.199)	0.21 (0.200)
	All the other industries	1.943	1.732	2,398				
Value Added *(log deflated values, 2008 = base year)*	Information goods	21.899	1.507	143	41.62	4769.23	1.96 (0.002)	0.20 (0.002)
	All the other industries	20.695	1.929	2,398				
Revenues *(log deflated values, 2008 = base year)*	Information goods	21.688	1.798	143	26.70	5604.225	9.70 (0.002)	- 0.49 (0.002)
	All the other industries	22.179	1.649	2,398				
Value Added per employees *(log deflated values, 2008 = base year)*	Information goods	11.422	0.555	143	20.50	626.04	66.05 (0.000)	0.43 (0.000)
	All the other industries	10.992	0.557	2,398				
Value Added over revenues *(deflated values, 2008 = base year)*	Information goods	0.386	0.105	143	0.39	54.47	14.40 (0.000)	0.06 (0.0000)
	All the other industries	0.327	0.167	2,398				
Tangible and fixed-assets investments over revenues *(log deflated values, 2008 = base year*	Information goods	0.041	0.041	143	0.00	6.18	0.10 (0.754)	-0.00 (0.754)
	All the other industries	0.043	0.056	2,398				
Tangible fixed assets per employees *(log deflated values, 2008 = base year)*	Information goods	8.608	1.209	143	1.40	2818.32	1.01 (0.3155)	-0.11 (0.315)
	All the other industries	8.796	1.175	2,398				
Personnel costs *(log deflated values, 2008 = base year)*	Information goods	10.729	0.261	143	9.88	232.02	86.62 (0.000)	0.30 (0.000)
	All the other industries	10.430	0.342	2,398				

TABLE III
FIXED EFFECTS MODEL SPECIFICATIONS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Value-added labor productivity		Output growth	Input Reduction	Value-added labor productivity		Output Growth	Input Reduction
	Value added per employee [log deflated values]	**Value added per employee** annual growth rate [log deflated values]	**Value Added** annual growth rate [log deflated values]	**Employment** annual growth rate [log deflated values]	**Value added per employee** [log deflated values]	**Value added per employee** annual growth rate [log deflated values]	**Value Added** annual growth rate [log deflated values]	**Employment** annual growth rate [log deflated values]
Year Dummies	included	Included	Included	Included	Included	included	included	included
L. IT spending deflated values	1.5638*** (0.62)	1.2213** (0.62)	0.6781 (0.63)	-1.9606*** (0.39)				
L. IT spending x Information Goods deflated values					2.5262*** (1.03)	2.4243*** (1.02)	2.8507*** (1.03)	0.3171 (0.62)
L. IT spending x All other industries deflated values					1.0201 (0.77)	0.5325 (0.77)	-0.6297* (0.80)	-3.3300*** (0.48)
L. Growth Dependent Variables log deflated values		-0.8869*** (0.02)	-0.8409*** (0.02)	-0.5299*** (0.02)		-0.8850*** (0.02)	-0.8343*** (0.02)	-0.5179*** (0.02)
Number of firms log deflated values	-0.1564*** (0.03)	-0.1415*** (0.03)	0.0420 (0.03)	0.0507*** (0.02)	-0.1580*** (0.03)	-0.1431*** (0.03)	0.0371 (0.03)	0.0446** (0.02)
Tangible fixed assets per employee log deflated values	0.0377*** (0.01)	0.0346*** (0.01)	-0.0032 (0.01)	-0.0295*** (0.01)	0.0378*** (0.01)	0.0347*** (0.01)	-0.0031 (0.01)	-0.0291*** (0.01)
Personnel costs log deflated values	0.8218*** (0.06)	0.7552*** (0.06)	0.2170*** (0.06)	-0.3133*** (0.04)	0.8217*** (0.06)	0.7539*** (0.06)	0.2175*** (0.06)	-0.3048*** (0.04)
Revenues log deflated values	0.1647*** (0.02)	0.1543*** (0.03)	0.6513*** (0.02)	0.3758*** (0.02)	0.1635*** (0.02)	0.1526*** (0.02)	0.6452*** (0.02)	0.3675*** (0.02)
Tangible and fixed-assets spending deflated values	-0.2326 (0.15)	-0.1995 (0.14)	0.0569 (0.15)	0.2327*** (0.09)	-0.2364 (0.15)	-0.2037 (0.14)	0.0501 (0.15)	0.2334** (0.09)
_cons	-0.4156 (0.71)	-0.8280 (0.71)	0.5480 (0.73)	0.0886 (0.44)	-0.3761 (0.71)	-0.7852 (0.71)	0.5786 (0.73)	0.1099 (0.44)
N	2310	2310	2310	2310	2310	2310	2310	2310
adj. R^2	0.3488	0.6269	0.7048	0.6923	0.3329	0.5604	0.7535	0.6967

Notes:
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$
Robust standard errors are in parentheses.

increase in output could lead to further IT investments [102]. Using once-lagged values of the independent variables as an instrument, the effects of IT spending on labor productivity were estimated using two-stage least squares (2SLS) to account for any potential simultaneity bias [102]. Furthermore, a high share of qualified employees and training investments can be expected to increase the impact of IT spending [107], [108]. Thus, once-lagged values of the human capital characteristics of an industry—operationalized as the ratio between labor costs (which includes wages and training activities) and the number of employees—were considered. All the instruments passed the underidentification test and resulted to be sufficiently correlated with the endogenous variable; the Kleibergen–Papp test [109] resulted in an LM statistic of 1.274 ($p < 0.001$). Furthermore, all the instruments passed the overidentification restrictions that resulted not to be correlated with the error term [110]; a value of 0.694 resulted for the Saran/Hansen J statistic, thus indicating that the null hypothesis was not rejected [111]. Thus, all the instruments can be considered valid.

V. Findings

A. Descriptive Statistics

Table II reports the key descriptive statistics, as well as the results of the one-way analysis-of-variance models and the Bonferroni multiple-comparison test. It can be seen from the data in Table II that, with respect to its counterparts, the information goods industry shows systematic patterns of high labor productivity and higher IT spending for the considered years.

Table II also reports systematic differences in the other variables for the information goods industry. Such differences denote a different industrial structure in the information goods industry from the other industries. The information goods industry is in fact on average characterized by a smaller number of firms, lower levels of employment, a larger average firm size (in relation to the number of employees per firm and value-added), lower capital intensity (in relation to tangible fixed assets over revenues and employees), and higher personnel costs than other industries.

B. Baseline Results

Models 1_{FE}–4_{FE} in Table III report the industry-level baseline specifications used to assess the effect of IT spending on labor productivity (Model 1_{FE}), labor productivity growth (Model 2_{FE}), and its value components: output growth (Model 3_{FE}) and input reduction (Model 4_{FE}), as obtained from the industry and time fixed effects.

Models 1_{FE} and 2_{FE} show that once-lagged values of IT spending (indicated in Table III as *"L. IT spending"*) had a positive and statistically significant impact on labor productivity ($\beta_{\mathrm{IT\ spending}} = 1.56,\ p = 0.012$) and on labor productivity growth ($\beta_{\mathrm{IT\ spending}} = 1.22,\ p = 0.048$) for the years 2008–2019. Models 3_{FE} and 4_{FE} make it possible to obtain more detailed information on the determinants of the positive and significant effect of IT spending on labor productivity and its growth as they show that once-lagged values of IT spending are also associated with an employment reduction. Model 3_{FE} in particular shows that IT spending has a positive—albeit not significant—impact on value-added growth ($\beta_{\mathrm{IT\ spending}} = 0.68,\ p = 0.286$). On the other hand, Model 4_{FE} shows a negative and high statistically significant impact of IT spending on employment growth ($\beta_{\mathrm{IT\ spending}} = -1.96,\ p = 0.000$). The explained variance is 70% for Model 3_{FE} and 69% for Model 4_{FE}, respectively; F is 12.36 significant at the 0.0001 level for Model 3_{FE} and 8.30 significant at the 0.0001 level for Model 4_{FE}.

As far as the effect of the control variables included in model specification is concerned, it is worth noting that the number of firms in an industry negatively impacts labor productivity and its growth. However, at the same time, it is associated with a growth in employment. Capital intensity has a positive and significant effect on labor productivity, and this effect mainly seems to be related to the significant effect of IT spending on employment reduction. Human capital, measured through personnel costs, positively affects labor productivity. This result mainly seems to be due to its positive effect on output growth and its negative effect on employment growth. Industry-level revenues have a positive effect on all the dependent variables. Finally, tangible and fixed asset spending positively affects employment growth, thus indicating that its effect is opposite to that of IT spending. Most of these effects are plausible, considering how industrial economics depicts the effects of industry structure on performance [112].

For the sake of completeness, fixed-effects models were estimated, and the results are given in Appendix C (Models 1_{RE}–4_{RE}). The random effects model fully supports the pattern of results found for the fixed effects model, except for the negative—albeit not significant—impact of IT spending on value-added growth (Model 3_{RE}).

C. Hypotheses Validation

In Hypotheses H1, it was posited that the IT spending effects on labor productivity, due to output growth, are more visible in industries that are specialized in information goods. The results show that the positive effect of IT spending on value-added (output) growth is only visible in the information goods industry. In Model 7_{FE} in Table III, the interaction term between once-time lagged values of IT spending and the industry dummy that indicates industries that are specialized in information goods shows a positive and highly statistically significant effect on value-added growth ($\beta_{\mathrm{IT\ investments\ \times\ Information\ Goods}} = 2.85,\ p = 0.006$). Conversely, the interaction term exerts a negative and significant effect on value-added growth in industries that are not specialized in information goods ($\beta_{\mathrm{IT\ investments\ \times\ All\ other\ industries}} = -0.63,\ p = 0.07$). Taken together, these results support Hypothesis H1.

In Hypotheses H2, it was posited that the IT spending effects on labor productivity, due to input reduction, are more visible in industries that are not specialized in information goods. The results show that the negative effect of IT spending on employment (input) reduction is only visible in industries not specialized in information goods. In Model 8_{FE} in Table III, the interaction term between once-time lagged values of IT spending and the industry dummy that indicates industries that are not specialized in information goods shows a strong negative and highly significant effect on employment growth ($\beta_{\mathrm{IT\ investments\ \times\ All\ other\ industries}} = -3.33,\ p = 0.000$). Interestingly, the interaction term exerts a positive—albeit not statistically significant—effect of IT spending on employment growth in industries that are specialized in information goods ($\beta_{IT\text{ investments} \times \text{Information Goods}} = 0.32,\ \ p = 0.12$). Taken together, these results support Hypothesis H2.

For the sake of completeness, random effects models' were estimated, and the results are given in Appendix C (Models 7_{RE} and 8_{RE}). The random effects model fully supports the pattern of results found for the fixed effects model, thus giving robustness and generalizability to the hypothesis validation. Surprisingly, the interaction term between once-time lagged values of IT spending and the industry dummy that indicates industries that are specialized in information goods has a positive and statistically significant value for the random effects specification in Model 8_{RE} ($\beta_{IT\text{ investments} \times \text{Information Goods}} = 0.36,\ \ p = 0.04$), which means that—including temporal and spatial variations in the error term—employment increased in the information goods industry, which had heavily invested in IT. In order to account for any potential simultaneity bias, the 2SLS model was also estimated using once-lagged values of the independent variables [102] and once-lagged values of the human capital characteristics of the industry [107], [108] as instruments. Overall, the results of the 2SLS estimation support the pattern of sign and significance previously noted, and in some cases, the results are even stronger in magnitude. For the sake of brevity, the 2SLS models are not reported but are available from the authors upon request.

Models 5_{FE} and 6_{FE} in Table III intertwine the results highlighted above in the baseline model specifications (see Section V-B) and show that the effect of IT spending on labor productivity ($\beta_{\text{IT investments} \times \text{Information Goods}} = 0.21,\ p = 0.04$ in Model 5_{FE}) and on labor productivity growth ($\beta_{\text{IT investments} \times \text{Information Goods}} = 0.21,\ p = 0.04$ in Model 6_{FE}) is positive and significant for industries specialized in information goods. Conversely, no significant effect between IT spending and labor productivity was found for industries not specialized in information goods. As shown in Appendix C, these results were also corroborated when the model specifications were estimated considering random effects.

Taken together, the results show higher labor productivity (Model 5_{FE}) and faster labor productivity growth (Model 6_{FE}) for industries specialized in information goods than other industries. Second, and more importantly, to the extent that there is a higher and more rapid growth of labor productivity in the information goods industry, this is associated with an increasing input growth (Model 8_{FE}) and even more rapidly increasing output growth (Model 7_{FE}). To the investigation, the random effects model was also estimated, and the basic pattern of results was retained, suggesting that these results can be generalized beyond the time and sectorial variations in the error terms [106]. The validity of the assumptions on the error structure across the panels was examined, including whether the results were robust to the potential for endogeneity [102]. Finally, it is worth noting that the effects of the control variables on the dependent variables discussed in the baseline model specifications (see Section V-B) were confirmed for all the model specifications discussed above.

VI. Discussion and Conclusion

The study shows that IT expenditure is associated with labor productivity growth in the 231 triple-digit sectors representative of the Italian economy between 2008 and 2019. The study provides an industry-level view of the determinants of IT business value creation and shows the effects of output growth and employment reduction associated with IT investments. In this vein, the study provides empirical evidence that contributes to the most recent calls for studies on the IT business value aimed at disaggregating and operationalizing the multiple avenues through which IT investments can generate business value [4], [11], [16]. The study reveals that the magnitude of the output growth and employment reduction varies significantly, depending on the type of industry. It compared and contrasted the information goods industry—where, thanks to the information-based nature of the product, IT investments are more likely to play a strategic role of "transforming" the nature of the product itself—with other industries where the expected prevailing role of IT can be of "automation" or "information" [14].

Overall, the results show that IT spending has a positive effect on labor productivity and labor productivity growth in each and every industry. However, estimates show that the drivers of such growth vary across the considered industry classes. In fact, IT spending only led to output growth in the information goods industry. IT investments instead led to a reduction in the value-added of the outputs of the other industries, which suggests that sectors that invested more in IT experienced a loss in their ability to capture economic value. On the other hand, as far as the effect of IT spending on employment is concerned, the results indicate that industries that are not specialized in information goods benefited from a reduction in employment as a result of IT investments. However, econometric estimates indicate that the information goods industry did not witness any visible effect due to IT investments on employment reduction; in fact, quite the contrary. The models show a positive effect on employment growth in the information goods industry, which only became significant in a model specification run with random effects. Table IV provides a comprehensive synthesis of these results.

A. Theoretical Implications

Past research pointed out differences in IT business value across firms and industries, but the source of these differences is still partially unclear [4], [11], [16]. Specifically, the gray area pertains to the understanding of whether the IT business value consists in favoring output growth or input reduction. We have here contributed to bridging this gap in the IT business value literature by isolating the determinants through which labor productivity growth due to IT investments follows different trajectories, which depend on industry-related technological, economic, and managerial factors. In particular, the study demonstrates how labor productivity growth due to IT spending depends to a different extent on output growth or input reduction effects that are contingent on the type of industry, and, more precisely, on whether the nature of products and services

TABLE IV
SYNTHESIS OF THE RESULTS

	Value-added labor productivity		Output growth	Input Reduction
	Value added per employee [log deflated values]	**Value added per employee** annual growth rate [log deflated values]	**Value Added** annual growth rate [log deflated values]	**Employment** annual growth rate [log deflated values]
Information Goods sector	(+)***	(+)***	(+)***	(+)†
All the other sectors	(+)†		(-)*	(-)***

Notes:
(+): positive effect of IS spending over the dependent variable
(-): negative effect of IS spending over the dependent variable
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$
† statistically significant in the random effects model specification reported in Appendix C
blank cells imply a lack of any significant effect

consists of information or "atoms." The study demonstrates that the transformational role attributed to IT depends not only on idiosyncratic resources and capabilities at the firm level that act as prerequisites but also on attributes at the industry level, shedding new light on how the IT transforming role is more likely in sectors producing information goods, given their effect on output growth.

In this vein, industries specialized in information goods naturally experience more opportunities to capitalize on IT investments for the growth of the economic value, as the information-based structure of products and services leads to the use of IT resources that reinforce a firm's strategic flexibility (what Sambamurthy et al. [33] referred to as digital options) and scalability (what Brynjolfsson et al. [53] referred to as "scale without mass"). This tends to make the capabilities of operations, strategy-making, and entrepreneurial orientations more deeply cospecialized with IT investments [36], [65], [66], [113], which, in turn, leads to a more effective and faster innovation of the products, services, and business models [51]. On the other hand, technology developments in the Internet and IT (e.g., platform-based business models and sharing economy schemes) in industries that are not specialized in information goods create problems of reintermediation and decreasing value capture when such industries accelerate their rate of investments in IT resources. Today, this phenomenon is prominent in such industries as transportation, logistics, hospitality, restaurants, and retail [71], [114]. Some recent studies (e.g., [48]) have illustrated how centralized approaches to data management enabled by IoT, cloud computing, and AI will, in the future, be able to allow industries and firms that handle "bits" and data rather than "atoms" [20] to extract value from a wider tier of manufacturing and material-based industries. Under these circumstances, the shortage of IT capabilities (which are expected to be inherently less cospecialized in IT, due to the noninformation-based nature of the industry's core product) may lead such sectors to a strategic response consisting of IT investment initiatives oriented toward improving efficiency and labor use rather than toward transformative initiatives on products or services that can generate new value drivers for their customers [11], [35].

Taken together, the results provide robust empirical evidence that highlights how structural differences in the strategic role of IT and in the availability of "transformative" IT capabilities in those industries where the nature of the products and services essentially consists of information can be expected to be time-invariant. This may lead to a structural divergence in the way the IT business value is manifested on output growth or input reduction between sectors.

B. Policy and Managerial Implications

The implications of the study for policymakers are far-reaching. First, although industries continue to expand their investments in IT, the results highlight that not all industries are capable of converting IT spending into economic and employment growth. The results and theoretical arguments of this study suggest that policies addressed to fostering the digitalization of business processes and IT investments should stimulate the creation of IT capabilities and the spread of a strategic vision of IT. In other words, encouraging firms to only invest in IT could result in accelerating the competitive divergence process between the industries dealt with in this study. This issue is of utmost importance for such European countries as Italy, Germany, and France, whose economic structures are prevalently based on the manufacturing sector, and where the information goods industry still accounts for a relatively small share of the OECD business sector GDP [54].

Second, the results remind managers of the importance of developing ways to use IT to achieve economic growth and to help avoid reintermediation or loss of specific knowledge when IT pervades their operations and business models. To reap the full benefits of IT, managers should develop capabilities more deeply cospecialized with IT investments to counteract the negative inertial forces that IT and the Internet produce in some sectors.

Finally, as a result of the way the Covid-19 outbreak and the consequent lockdown restrictions have disrupted work operations at the global level, the theoretical arguments advanced in this study indicate that the technological and the economic factors at play in the information goods industry can make this industry less vulnerable to such restrictions since the virtualization of the product and its supply chain operations offer a broader repertoire of competitive actions and a superior level of capabilities that are cospecialized with IT investments. Furthermore, econometric estimates indicate that these industries can count on a superior endowment of financial resources due to the prevalent effect of output growth generated by IT spending in the previous years.

C. Limitations and Avenues for Future Research

As in any econometric study, the research design is not without limitations, especially as a result of the shortcomings concerning the data and sample. The main limitation of this study lies in the inability to disentangle the several mechanisms that generate the IT business values that were discussed in the article, including the heterogeneity in the behavior of firms related to IT use that can occur within an industry. Furthermore, the results pertaining to a diffused input reduction could be contingent on the fact that most of the years considered in the analysis were years in which the economic cycle underwent a recession. This may have made firms and managers use IT to reduce their input.

The limitations of this study offer an opportunity to work on other moderating factors in the future. Although the econometric results are robust to different estimation methods and specifications, and the theoretical arguments lead us to expect that these effects might also hold in other countries and over the next few years, further investigations are needed to generalize them across contexts and countries. Such benchmarks and other potential moderators may shift our thinking toward a more creative and efficient use of the existing IT and the adoption of new digital technologies in up-to-date ways to enhance value creation. In this regard, it is reasonable to assume that the production growth or input reduction effects isolated in this study can also be observed in the next few years when the new bundle of digital technologies related to IoT, AI, cloud computing, big data management, and analytics will become increasingly more accessible to firms, irrespective of their size [115]. A natural progression of this work would, thus, be to analyze whether the "promise" of a "digital transformation"—in particular that related to new developments in AI and IoT—will appear and lead to output growth, albeit only in industries specialized in information goods or also in the rest of the economy. The results of this study and the theoretical arguments derived from it would lead one to think that the former scenario is more likely than the latter because IT capabilities are rare, costly to be imitated, and not substitutable. This being the case, the structural divergence over the last ten years, as documented in this study, might well become worse in the future and have important social implications, given the fact that higher IT investments outside the information goods industry have been shown to lead to reductions in both employment and, unexpectedly, value-added. In this vein, the study corroborates and extends the view on the economic divides ignited by digital technologies and shows that such divides appear not only within industries (as reported by Brynjolfsson et al. [53] and McAfee and Brynjolfsson [116]) but also between industries.

REFERENCES

[1] N. Melville, V. Gurbaxani, and K. Kraemer, "The productivity impact of information technology across competitive regimes: The role of industry concentration and dynamism," *Decis. Support Syst.*, vol. 43, pp. 229–242, 2007.

[2] M. W. Chiasson and E. Davidson, "Taking industry seriously in information systems research," *MIS Quart.*, vol. 29, pp. 591–605, 2005.

[3] T. W. Malone et al., "Tools for inventing organizations: Toward a handbook of organizational processes," *Manage. Sci.*, vol. 45, pp. 425–443, 1999.

[4] G. Schryen, "Revisiting IS business value research: What we already know, what we still need to know, and how we can get there," *Eur. J. Inf. Syst.*, vol. 22, pp. 139–169, 2013.

[5] N. Mittal and B. R. Nault, "Investments in information technology: Indirect effects and information technology intensity," *Inf. Syst. Res.*, vol. 20, pp. 140–154, 2009.

[6] Z. Cheng and B. R. Nault, "Relative industry concentration and customer-driven IT spillovers," *Inf. Syst. Res.*, vol. 23, pp. 340–355, 2012.

[7] K. Han, Y. B. Chang, and J. Hahn, "Information technology spillover and productivity: The role of information technology intensity and competition," *J. Manage. Inf. Syst.*, vol. 28, pp. 115–146, 2011.

[8] W. G. Qu, A. Pinsoneault, and W. Oh, "Influence of industry characteristics on information technology outsourcing," *J. Manage. Inf. Syst.*, vol. 27, pp. 99–128, 2011.

[9] F. Ren and S. Dewan, "Industry-level analysis of information technology return and risk: What explains the variation?," *J. Manage. Inf. Syst.*, vol. 32, pp. 71–103, 2015.

[10] D. Acemoglu, D. Autor, D. Dorn, G. H. Hanson, and B. Price, "Return of the Solow paradox? IT, productivity, and employment in US manufacturing," *Amer. Econ. Rev.*, vol. 104, pp. 394–399, 2014.

[11] H. C. Chae, C. E. Koh, and K. O. Park, "Information technology capability and firm performance: Role of industry," *Inf. Manage.*, vol. 55, pp. 525–546, 2018.

[12] R. J. Kauffman, "Looking ahead: A contributor's perspective on the next-stage advances in competitive strategy, economics and information systems research," in *Proc. 40th Hawaii Int. Conf. Syst. Sci.*, 2007, pp. 213–222.

[13] E. Brynjolfsson and S. Yang, "Information technology and productivity: A review," *Adv. Comput.*, vol. 43, pp. 179–214, 1996.

[14] D. Chatterjee, V. J. Richardson, and R. W. Zmud, "Examining the shareholder wealth effects of announcements of newly created CIO positions," *MIS Quart.*, vol. 25, pp. 43–70, 2001.

[15] S. Zuboff, *In the Age of the Smart Machine: The Future of Work and Power*. New York, NY, USA: Basic Books, 1988.

[16] S. Schweikl and R. Obermaier, "Lessons from three decades of IT productivity research: Towards a better understanding of IT-induced productivity effects," *Manage. Rev. Quart.*, vol. 70, pp. 1–47, 2019.

[17] J. Fernald, "Productivity and potential output before, during, and after the great recession," in *NBER Macroeconomics Annual*, vol. 29. Chicago, IL, USA: Univ. Chicago Press, 2014.

[18] F. Schivardi and T. Schmitz, "The IT revolution and Southern Europe's two lost decades," *J. Eur. Econ. Assoc.*, vol. 18, pp. 2441–2486, 2020.

[19] J. Dedrick, V. Gurbaxani, and K. L. Kraemer, "Information technology and economic performance: A critical review of the empirical evidence," *ACM Comput. Surv.*, vol. 35, pp. 1–28, 2003.

[20] U. S. Karmarkar and U. M. Apte, "Operations management in the information economy: Information products, processes, and chains," *J. Oper. Manage.*, vol. 25, pp. 438–453, 2007.

[21] T. F. Bresnahan and M. Trajtenberg, "General purpose technologies 'Engines of growth?," *J. Econ.*, vol. 65, pp. 83–108, 1995.

[22] P. B. Evans and T. S. Wurster, "Strategy and the new economics of information," *Harvard Bus. Rev.*, vol. 75, pp. 70–82, 1997.

[23] K. J. Stiroh, "Information technology and the US productivity revival: What do the industry data say?," *Amer. Econ. Rev.*, vol. 92, pp. 1559–1576, 2002.

[24] M. U. Porat and M. R. Rubin, *The Information Economy: Definition and Measurement*. Washington, DC, USA: Government Printing Office, 1977.

[25] G. G. Dess and D. W. Beard, "Dimensions of organizational task environments," *Administ. Sci. Quart.*, vol. 29, pp. 52–73, 1984.

[26] L. Xue, G. Ray, and V. Sambamurthy, "Efficiency or innovation: How do industry environments moderate the effects of firms' IT asset portfolios?," *MIS Quart.*, vol. 36, pp. 509–528, 2012.

[27] M. E. Porter and V. E. Millar, "How information gives you competitive advantage," *Harvard Bus. Rev.*, vol. 63, pp. 149–160, 1985.

[28] O. Müller, M. Fay, and J. vom Brocke, "The effect of big data and analytics on firm performance: An econometric analysis considering industry characteristics," *J. Manage. Inf. Syst.*, vol. 35, pp. 488–509, 2018.

[29] P. Neirotti and D. Pesce, "ICT-based innovation and its competitive outcome: The role of information intensity," *Eur. J. Innov. Manage.*, vol. 22, pp. 383–404, 2019.

[30] B. Dehning, V. J. Richardson, and R. W. Zmud, "The financial performance effects of IT-based supply chain management systems in manufacturing firms," *J. Oper. Manage.*, vol. 25, pp. 806–824, 2007.

[31] L. Tornatzky and M. Fleischer, *The Process of Technological Innovation*. Lexington, MA, USA: Lexington Books, 1990.

[32] B. Dehning, V. J. Richardson, and R. W. Zmud, "The value relevance of announcements of transformational information technology investments," *MIS Quart.*, vol. 27, pp. 637–656, 2003.

[33] V. Sambamurthy, A. Bharadwaj, and V. Grover, "Shaping agility through digital options: Reconceptualizing the role of information technology in contemporary firms," *MIS Quart.*, vol. 27, pp. 237–263, 2003.

[34] A. Bharadwaj, "A resource-based perspective on information technology capability and firm performance: An empirical investigation," *MIS Quart.*, vol. 24, pp. 169–196, 2000.

[35] F. Wiesböck, T. Hess, and J. Spanjol, "The dual role of IT capabilities in the development of digital products and services," *Inf. Manage.*, vol. 57, 2020, Art. no. 103389.

[36] Y. Lu and K. R. Ramamurthy, "Understanding the link between information technology capability and organizational agility: An empirical examination," *MIS Quart.*, vol. 35, pp. 931–954, 2011.

[37] A. Barua and T. Mukhopadhyay, "Information technology and business performance: Past, present, and future," in *Framing the Domains of IT Management: Projecting the Future Through the Past*, R.W. Zmud and M.F. Price, Eds. Cincinnati, OH, USA, Pinnaflex Edu. Resources, 2000, pp. 65–84.

[38] E. Christiaanse and N. Venkatraman, "Beyond sabre: An empirical test of expertise exploitation in electronic channels," *MIS Quart.*, vol. 26, pp. 15–38, 2002.

[39] I. Benbasat and R. W. Zmud, "The identity crisis within the IS discipline: Defining and communicating the discipline's core properties," *MIS Quart.*, vol. 27, pp. 183–194, 2003.

[40] P. Weill and J. Ross, "A matrixed approach to designing IT governance," *MIT Sloan Manage. Rev.*, vol. 46, 2005, Art. no. 26.

[41] T. Mauerhoefer, S. Strese, and M. Brettel, "The impact of information technology on new product development performance," *J. Product Innov. Manage.*, vol. 34, pp. 719–738, 2017.

[42] J. R. Galbraith, *Designing Complex Organizations*. Reading, MA, USA: Addison-Wesley, 1973.

[43] I. Dierickx and K. Cool, "Asset stock accumulation and sustainability of competitive advantage," *Manage. Sci.*, vol. 35, pp. 1504–1511, 1989.

[44] N. Melville, K. Kraemer, and V. Gurbaxani, "Review: Information technology and organizational performance: An integrative model of IT business value," *MIS Quart.*, vol. 28, pp. 283–322, 2004.

[45] Y. B. Chang and V. Gurbaxani, "An empirical analysis of technical efficiency: The role of IT intensity and competition," *Inf. Syst. Res.*, vol. 24, pp. 561–578, 2013.

[46] J. I. Hagel and M. Singer, "Unbundling the corporation," *Harvard Bus. Rev.*, vol. 77, pp. 133–142, 1999.

[47] W. A. Günther, M. H. R. Mehrizi, M. Huysman, and F. Feldberg, "Debating big data: A literature review on realizing value from big data," *J. Strategic Inf. Syst.*, vol. 26, pp. 191–209, 2017.

[48] S. Helper, R. Martins, and R. Seamans, "Who profits from industry 4.0? Theory and evidence from the automotive industry," NYU Stern School of Business, Jan. 2019. Available at SSRN: [Online]. Available: https://ssrn.com/abstract=3377771

[49] C. Shapiro and H. R. Varian, *Information Rules: A Strategic Guide to the Network Economy*. Boston, MA, USA: Harvard Bus. School Press, 1999.

[50] F. Calvino, C. Criscuolo, L. Marcolin, and M. Squicciarini, "A taxonomy of digital intensive sectors," OECD Sci., Technol. Ind. Working Paper No. 2018/14, OECD, Paris, France, 2018.

[51] G. Lanzolla, D. Pesce, and C. L. Tucci, "The digital transformation of search and recombination in the innovation function: Tensions and an integrative framework," *J. Product Innov. Manage.*, vol. 38, pp. 90–113, 2021.

[52] OECD, *Measuring the Information Economy*. Paris, France: OECD, 2002.

[53] E. Brynjolfsson, A. McAfee, M. Sorell, and F. Zhu, "Scale without mass: Business process replication and industry dynamics," Harvard Business School, Boston, MA, USA, Working Paper No. 07-016, 2006.

[54] OECD, *OECD Digital Economy Outlook 2020*. Paris, France: OECD, 2020.

[55] M. D. Stoel and W. A. Muhanna, "IT capabilities and firm performance: A contingency analysis of the role of industry and IT capability type," *Inf. Manage.*, vol. 46, pp. 181–189, 2009.

[56] R. Nolan and F. W. McFarlan, "Information technology and the board of directors," *Harvard Bus. Rev.*, vol. 83, pp. 96–106, 2005.

[57] M. Broadbent, P. Weill, and B. S. Neo, "Strategic context and patterns of IT infrastructure capability," *J. Strategic Inf. Syst.*, vol. 8, pp. 157–187, 1999.

[58] J. W. Ross, C. M. Beath, and D. L. Goodhue, "Develop long-term competitiveness through IT resources," *Sloan Manage. Rev.*, vol. 38, pp. 31–42, 1996.

[59] P. Weill, M. Subramani, and M. Broadbent, "IT infrastructure for strategic agility," *Sloan Manage. Rev.*, vol. 44, pp. 57–65, 2002.

[60] F. J. Mata, W. L. Fuerst, and J. B. Barney, "Information technology and sustained competitive advantage: A resource-based analysis," *MIS Quart.*, vol. 19, pp. 487–505, 1995.

[61] M. Wade and J. Hulland, "Review: The resource-based view and information systems research: Review, extension, and suggestions for future research," *MIS Quart.*, vol. 28, pp. 107–142, 2004.

[62] P. Neirotti and E. Paolucci, "Industry and firm effects on IT diffusion processes: Firm-level evidence in Italian enterprises," *Ind. Corporate Change*, vol. 23, pp. 717–757, 2014.

[63] Y. Xue, H. Liang, and W. R. Boulton, "Information technology governance in information technology investment decision processes: The impact of investment characteristics, external environment, and internal context," *MIS Quart.*, vol. 32, pp. 67–96, 2008.

[64] C. Soh and M. L. Markus, "How IT creates business value: A process theory synthesis," in *Proceedings of the Sixteenth International Conference on Information Systems*, G. Ariav, C. Beath, J. Degross, R. Hoyer, and C. Kemerer, Eds. Amsterdam, The Netherlands: Association for Information Systems, 1995, pp. 29–41.

[65] G. Piccoli, *Information Systems for Managers: Texts and Cases*. Hoboken, NJ, USA: Wiley, 2012.

[66] G. Piccoli and B. Ives, "It-dependent strategic initiatives and sustained competitive advantage: A review and synthesis of the literature," *MIS Quart.*, vol. 29, pp. 747–776, 2005.

[67] OECD, *Measuring the Digital Transformation: A Roadmap for the Future*. Paris, France: OECD, 2019.

[68] M. H. R. Mehrizi and M. Lashkarbolouki, "Unlearning troubled business models: From realization to marginalization," *Long Range Plan.*, vol. 49, pp. 298–323, 2016.

[69] M. G. Jacobides, C. Cennamo, and A. Gawer, "Towards a theory of ecosystems," *Strategic Manage. J.*, vol. 39, pp. 2255–2276, 2018.

[70] S. Mithas, A. Tafti, I. Bardhan, and J. M. Goh, "Information technology and firm profitability: Mechanisms and empirical evidence," *MIS Quart.*, vol. 36, pp. 205–224, 2012.

[71] G. G. Parker, M. W. van Alstyne, and S. P. Choudary, *Platform Revolution: How Networked Markets are Transforming the Economy and How to Make Them Work for You*. New York, NY, USA: Norton, 2016.

[72] S. Mithas and J. Whitaker, "Is the world flat or spiky? Information intensity, skills, and global service disaggregation," *Inf. Syst. Res.*, vol. 18, pp. 237–259, 2007.

[73] S. Hendler and H. Boer, "Digital-physical product development: A review and research agenda," *Int. J. Technol. Manage.*, vol. 80, pp. 12–35, 2019.

[74] A. Bharadwaj, O. A. el Sawy, P. A. Pavlou, and N. Venkatraman, "Digital business strategy: Toward a next generation of insights," *MIS Quart.*, vol. 37, pp. 471–482, 2013.

[75] A. Badewi, E. Shehab, J. Zeng, and M. Mohamad, "ERP benefits capability framework: Orchestration theory perspective," *Bus. Process Manage. J.*, vol. 24, pp. 266–294, 2018.

[76] E. Brynjolfsson, L. M. Hitt, and H. H. Kim, "Strength in numbers: How does data-driven decisionmaking affect firm performance?" Apr. 2011. Available at SSRN: [Online]. Available: https://ssrn.com/abstract=1819486

[77] E. K. Clemons and K. R. Lang, "The decoupling of value creation from revenue: A strategic analysis of the markets for pure information goods," *Inf. Technol. Manage.*, vol. 4, pp. 259–287, 2003.

[78] T. Kumar and L. K. Jena, "Capital vs. digital labor in the post-industrial information age: A Marxist analysis," *Emerg. Econ. Stud.*, vol. 6, pp. 50–60, 2020.

[79] E. Brynjolfsson and A. McAfee, *Race Against the Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*. Lexington, MA, USA: Digital Frontier Press, 2012.

[80] C. B. Frey and M. A. Osborne, "The future of employment: How susceptible are jobs to computerisation?," *Technol. Forecasting Social Change*, vol. 114, pp. 254–280, 2017.

[81] D. Acemoglu and P. Restrepo, "Robots and jobs: Evidence from US labor markets," Nat. Bureau Econ. Res., Cambridge, MA, USA, Working Paper No. 23285, 2017.

[82] D. Autor, "Why are there still so many jobs? The history and future of workplace automation," *J. Econ. Perspectives*, vol. 29, pp. 3–30, 2015.

[83] M. Ford, *The Rise of the Robots*. New York, NY, USA: Basic Books, 2015.

[84] OECD, *OECD Digital Economy Outlook 2017*. Paris, France: OECD, 2017.

[85] Eurostat, "ICT usage in enterprises," 2019. [Online]. Available: https://Data.Europa.Eu/Euodp

[86] OECD, "Average labour productivity: Value added per employee," in *Measuring Globalisation: OECD Economic Globalisation Indicators*. Paris, France: OECD, 2010.

[87] OECD, "Measurement of aggregate and industry-level productivity growth," in *Measuring Productivity OECD Manual*. Paris, France: OECD, 2001.

[88] M. A. Mahmood and G. J. Mann, "Information technology investments and organizational productivity and performance: An empirical investigation," *J. Org. Comput. Electron. Commerce*, vol. 15, pp. 185–202, 2005.

[89] A. Rai, R. Patnayakuni, and N. Patnayakuni, "Technology investment and business performance," *Commun. ACM*, vol. 40, pp. 89–97, 1997.

[90] S. Sircar, J. L. Turnbow, and B. Bordoloi, "A framework for assessing the relationship between information technology investments and firm performance," *J. Manage. Inf. Syst.*, vol. 16, pp. 69–97, 2000.

[91] W. J. Orlikowski and C. S. Iacono, "Research commentary: Desperately seeking the ' IT ' in IT research–A call to theorizing the IT artifact," *Inf. Syst. Res.*, vol. 12, pp. 121–134, 2001.

[92] E. Brynjolfsson, D. Rock, and C. Syverson, "The productivity J-curve: How intangibles complement general purpose technologies," *Amer. Econ. J., Macroecon.*, vol. 13, pp. 333–372, 2021.

[93] L. Becchetti, D. A. I. Bedoya, and L. Paganetto, "ICT investment, productivity and efficiency: Evidence at firm level using a stochastic frontier approach," *J. Productiv. Anal.*, vol. 20, pp. 143–167, 2003.

[94] P. Mangin, V. Hovelaque, and L. Bironneau, "Enterprise resource planning contribution to firm performance: A literature review over the last 15 years," in *Proc. Congr. Int. De Genie Ind.*, 2015, pp. 1–10.

[95] S. Aral, E. Brynjolfsson, and D. J. Wu, "Which came first, IT or productivity? The virtuous cycle of investment and use in enterprise systems," in *Proc. Int. Conf. Inf. Syst.*, 2006, pp. 1–22.

[96] G. A. Gorry and M. S. Scott Morton, *A Framework for Management Information Systems*. Cambridge, MA, USA: Massachusetts Inst. Technol., 1971.

[97] K. Feng, E. T. Chen, and W. Liou, "Implementation of knowledge management systems and firm performance: An empirical investigation," *J. Comput. Inf. Syst.*, vol. 45, pp. 92–104, 2005.

[98] G. A. Moore, *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Consumers*. Boston, MA, USA, Harvard Business School Press, 1991.

[99] E. Brynjolfsson and L. M. Hitt, "Beyond computation: Information technology, organizational transformation and business performance," *J. Econ. Perspectives*, vol. 14, pp. 23–48, 2000.

[100] A. Mehra, N. Langer, R. Bapna, and R. D. Gopal, "Estimating returns to training in the knowledge economy: A firm level analysis of small and medium enterprises," *MIS Quart.*, vol. 38, pp. 757–772, 2014.

[101] D. K. Datta, J. P. Guthrie, and P. M. Wright, "Human resource management and labor productivity: Does industry matter?," *Acad. Manage. J.*, vol. 48, pp. 135–145, 2005.

[102] E. Brynjolfsson and L. Hitt, "Paradox lost? Firm-level evidence on the returns to information systems spending," *Manage. Sci.*, vol. 42, pp. 541–558, 1996.

[103] L. M. Hitt and E. Brynjolfsson, "Productivity, business profitability, and consumer surplus: Three different measures of information technology value," *MIS Quart.*, vol. 20, pp. 121–142, 1996.

[104] E. Caroli and J. van Reenen, "Skill-biased organizational change? Evidence from a panel of British and French establishments," *Quart. J. Econ.*, vol. 116, pp. 1449–1492, 2001.

[105] W. H. Greene, *Econometric Analysis*, 6th ed. Englewood Cliffs, NJ, USA: Prentice-Hall, 2008.

[106] M. Intriligator, R. Bodkin, and C. Hsiao, *Econometric Models, Techniques, and Applications*, 2nd ed. Englewood Cliffs, NJ, USA: Prentice-Hall, 1996.

[107] T. F. Bresnahan, E. Brynjolfsson, and L. M. Hitt, "Information technology, workplace organization, and the demand for skilled labor: Firm-level evidence," *Quart. J. Econ.*, vol. 117, pp. 339–376, 2002.

[108] T. Zwick, "Works councils and the productivity impact of direct employee participation," Zentrum fu¨r Europa¨ische Wirtschaftsforschung, ZEW Discussion Papers No. 03-47, Mannheim, Germany, 2003.

[109] F. Kleibergen and R. Paap, "Generalized reduced rank tests using the singular value decomposition," *J. Econ.*, vol. 133, pp. 97–126, 2006.

[110] C. F. Baum, *An Introduction to Modern Econometrics Using Stata*. College Station, TX, USA: Stata Press, 2006.

[111] M. Arellano, L. P. Hansen, and E. Sentana, "Underidentification?," *J. Econ.*, vol. 170, pp. 256–280, 2012.

[112] J. S. Bain, *Industrial Organization*. Hoboken, NJ, USA: Wiley, 1959.

[113] S. Mithas, N. Ramasubbu, and V. Sambamurthy, "How information management capability influences firm performance," *MIS Quart.*, vol. 35, pp. 237–256, 2011.

[114] A. Gawer and M. A. Cusumano, "Industry platforms and ecosystem innovation," *J. Product Innov. Manage.*, vol. 31, pp. 417–433, 2014.

[115] E. Brynjolfsson, D. Rock, and C. Syverson, "Artificial intelligence and the modern productivity paradox: A clash of expectations and statistics," in *The Economics of Artificial Intelligence: An Agenda*, A. Agrawal, J. Gans, and A. Goldfarb, Eds. Chicago, IL, USA: Univ. Chicago Press, 2019.

[116] A. McAfee and E. Brynjolfsson, "Investing in the IT that makes a competititve difference," *Harvard Bus. Rev.*, vol. 86, pp. 98–107, 2008.

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