A tough pill to swallow? The lessons learned from mandatory RFID adoption

Abstract

On some occasions, information technology (IT) is mandated rather than voluntary. However, the impact of mandatory IT adoption receives little attention in the operations management literature, and the literature shows divergent predictions about how mandatory IT affects financial performance. Using the case of mandatory radio-frequency identification (RFID) adoption in manufacturing industries, this study applies long-horizon event study to examine 95 U.S. listed firms that have adopted mandatory RFID. The results show that firms achieve significantly strong financial performance from mandatory adoption. Mandatory RFID is particularly beneficial for firms with good financial health, late adopters and high-clockspeed firms. The current study provides a deeper understanding of supplier benefits from mandatory systems supported by dominant customers. Based on the lessons learned from past mandatory RFID adoption, the present study can serve as guidance for future projects and contribute to the literature on operations management and information systems.

Keywords**:** RFID; mandate; firm performance; contextual factors

1. Introduction

Information technology (IT) investments, such as radio frequency identification (RFID) and IT-based supply chain management systems (SCMS), are considered important tools in producing business value through their ability to reduce costs and establish closer relationships between buyer and supplier via information exchange (Ha et al., 2017; Alqahtani et al., 2019; Chen et al., 2021). Large companies, such as Walmart and Ford, have exerted considerable efforts to obtain collaboration and coordination benefits with their suppliers using IT-based SCMS (Brinkhoff et al., 2015). While large companies may be willing to cede some of their profits to reward their supply chain partners' cooperation (Zheng et al., 2021), often, firms are mandated or forced to use IT by their retailers or by government entities (Venkatesh et al., 2003; Carugati et al., 2016). For example, in January 2022, Walmart mandated that its suppliers use RFID with sporting goods, home goods, toys, and electronics by September 2022, with plans to extend the mandate to more categories (Swedberg, 2022). While a mandatory-use environment is where users observe use to be organizationally compulsory, a voluntary-use environment refers to one in which users observe the technology adoption or use to be a willful choice (Hartwick and Barki, 1994; Venkatesh and Davis, 2000). Technology acceptance behavior in a mandatory environment differs from that in a voluntary environment (Hartwick and Barki, 1994; Venkatesh et al., 2003). For example, subjective norms (e.g., a person believes that other individuals want him or her to perform the behavior) have a significant impact on intention to use in a mandatory environment but not in a voluntary context (Hartwick and Barki, 1994). Moreover, the nature of the implementation and resource bases are different between mandatory and voluntary adoption (Hossain and Quaddus, 2015).

According to the institutional perspective, firms with mandatory IT focus on legitimacy over economic efficiency, while firms with voluntary IT emphasize economic efficiency. When firms comply with mandatory IT, such conformity frequently decreases organizational flexibility while diverting resources from other productive uses (Brown et al., 2002). As a result, mandatory IT can lead to more operational interruptions (e.g., employee resistance) (Hsieh et al., 2012) and less lasting change in operations (Brown

et al., 2002). Firms with mandatory adoption also may experience fewer financial benefits since the adoption tends to be standardized and can be less suitable for an organization's particular context (Westphal et al., 1997). Furthermore, mandatory adoption may offer lower financial returns than voluntary adoption because organizations with voluntary adoption tend to extend beyond compliance, while organizations with mandatory adoption are likely to limit their investment to bare-minimum compliance to reduce the costs (Sharma and Vredenburg, 1998; Klassen and Whybark, 1999; Albertini, 2014). On the other hand, complying with customer mandates can help businesses gain legitimacy and resources from customers (Meyer and Rowan, 1977; Scott, 1995; Colwell and Joshi, 2013). Some recent studies (e.g., Huo et al., 2013; Lui et al., 2021) also indicate that mandatory adoption can generate financial benefits when it aligns with a firm's business plan.

Hence, we should not expect that the performance impacts of mandatory adoption would be similar to those of voluntary adoption. While researchers have examined the impacts of IT adoption on firm performance primarily in a voluntary context, it is unclear whether previous results can apply to the mandatory context (Chan et al., 2010). In fact, previous studies suggest that treating mandatory and voluntary IT indifferently is a possible cause for mixed findings in many organizational technology acceptance model studies (Hartwick and Barki, 1994; Venkatesh and Davis, 2000). Devaraj and Kohli (Devaraj and Kohli, 2003) also suggested that the performance effects of IT might be influenced by whether the use was mandatory or voluntary.

Extensive studies have investigated the effects of mandatory IT usage on individual outcomes such as user satisfaction and user behaviors (Venkatesh et al., 2003; Chae and Poole, 2005; Carugati et al., 2016). For example, Liang et al. (2013) investigated how rewards and punishment used to regulate mandatory IT usage influenced employee compliance behavior. However, understanding of the actual effect of mandatory IT on firm returns remains relatively limited and inconclusive. In a mandatory context, users have no choice but to use a given IT, even if they hold negative perceptions of the IT (Bhattacherjee et al., 2018). The implementation of mandatory IT often results in radical changes to work procedures, business processes,

and organizational structure (Turedi and Ekebas-Turedi, 2019). Consequently, such a context often leads to negative outcomes such as user resistance (Hsieh et al., 2012), lower user satisfaction (Lee and Park, 2008), limited choices in implementation (Brown et al., 2002), and failure of IT projects (Hirschheim and Newman, 1988), which may have a negative impact on firm performance such as productivity and work quality (Hirschheim and Newman, 1988). In contrast, other studies have shown that customer firms reward higher sales volumes with suppliers if they comply with mandatory IT adoption, such as electronic data interchange (EDI) technology (Mukhopadhyay and Kekre, 2002). Furthermore, some recent studies (e.g., Rogers et al., 2007; Huo et al., 2013; Lui et al., 2021) have suggested that the adoption of technologies that conform to institutional pressures may still generate financial returns to a certain degree. For instance, Lui et al. (2021) showed that energy efficiency technologies motivated by institutional pressures such as government policies could produce positive financial outcomes. Table A1 summarizes recent literature review studies related to mandatory IT.

Therefore, our research studies the impact of mandatory RFID adoption on financial outcomes using the case of Walmart's first RFID mandate in 2003. Additionally, scholars have urged the development of research on the effect of contextual factors that may have dynamic influences on the depth and quality of mandatory IT use (Fadel, 2012; Hossain and Quaddus, 2015). Therefore, this study also examines the role of contextual factors in the mandatory RFID adoption financial performance relationship. Specifically, based on contingency theory (Reinking, 2012), we hypothesize how contingent factors influence the benefits firms to obtain from mandatory RFID adoption. Contingency theory suggests that environmental and firm-specific factors shape firms' structure ad systems (Cadez and Guilding, 2008). Therefore, firms need to match their structures and processes to the environment to optimize performance (Flynn et al., 2010). Based on the relevant literature (e.g., Bose et al., 2011; Lui et al., 2016) and given the nature of RFID adoption on firms' financial burden (in product tagging, information systems, and hardware infrastructure), maturity of the technology and RFID standards, and the characteristics of the industry sector, we identified three specific contingency factors that can have a significant impact on the link between mandatory RFID adoption and firm outcomes: (1) financial distress, (2) adoption timing, and (3) industry

clockspeed.

After many years of industry adoption, RFID implementation is still a risky and costly investment that requires large resources for successful implementation. We expected that financially healthy firms have the ability to leverage the benefits of mandatory RFID. For instance, to ensure that a mandatory RFID project can progress continuously during the implementation phase, a firm needs to have good financial status to start. We posit that late adopters will receive more financial returns from mandatory RFID adoption than early adopters. In 2003, Walmart launched the RFID mandate initiative, which was executed in three phases among its suppliers. While Walmart's top 100 suppliers need to meet the RFID mandate by January 1, 2005 (phase 1), its top 200 and top 300 suppliers need to reach the RFID mandate by January 1, 2006 (phase 2) and January 1, 2007 (phase 3), respectively. Early adopters need to overcome several problems, such as immaturity of the technology, high cost, and lack of standards (Vijayaraman and Osyk 2006), while late adopters are less impacted by these problems, which tend to resolve over time (Feng et al., 2014). We expect that firms in high-clockspeed industries obtain more financial returns from mandatory RFID adoption than firms in low-clockspeed industries. High-clockspeed industries have a high rate of change of products (e.g., new product introduction and product obsolescence rates), processes (the rates at which process technologies are replaced), and organizational structure (e.g., CEO transitions). Walmart's RFID mandate covers its suppliers from different industries (i.e., high-, medium-, and low-clockspeed industries). The visibility of material flow provided by RFID is particularly important to high-clockspeed firms, which require a more visible and responsive supply chain. Aligned with contingency theory, our findings indicate that the financial returns due to mandatory RFID adoption are more significant for firms with good financial health, late adopters and high clockspeed.

The contribution of the current research is twofold. First, this research extends previous studies on RFID by demonstrating evidence that mandatory RFID can produce financial performance, and the performance is stronger for financial healthy firms, late adopters and high-clockspeed firms. The results provide insights into the debate on whether conforming to customer mandates produces sustainable economic value in the long term. From a broader view, this study extends IT research into a mandatory

setting. Previous studies have focused on investigating the effects of IT in a voluntary context. Even though some studies have examined the impacts of mandatory IT usage on individual outcomes such as user behaviors (Carugati et al., 2016; Bhattacherjee et al., 2018), the actual impact and contingencies of mandatory IT adoption on firm performance are yet to be fully understood. Our empirical evidence of the influence of contextual factors also contributes to the literature of contingency theory in mandatory IT settings. The findings imply that a one-size-fits-all approach to RFID adoption may not be able to produce the greatest returns. The lesson learned from this study also contributes to the literature on OM and information systems (IS).

2. Theoretical development and hypotheses

2.1. RFID technology

RFID is an Internet of Things technology (Chong et al., 2015) that is based on radio waves to enable communication and data transmission between the RFID tag and an RFID reader (Bose et al., 2011). RFID can automate supply chain operations and provide information visibility, which thus has the potential to significantly improve supply chain performance. In 2003, Walmart forced its top suppliers (or manufacturers, these two terms are used interchangeably in this study) to adopt RFID tagging at the case or pallet level by January 2005 (Feng et al., 2014). Since then, RFID has gained significant attention in manufacturing industries as a promising technology to transform supply chain management.

For decades now, RFID has been considered more mature and cost-effective for firms to leverage their full potential across a supply chain. RFID is playing an increasing role in different industries and is commonly applied in many areas, from counting items in warehouse inventory to tracking cattle in smart farms. For example, in January 2022, Walmart released a new RFID mandate to its suppliers to use RFID with sporting goods, home products, entertainment and toys, and electronics by September 2022 (Swedberg, 2022). The International Air Transport Association (IATA) announced an RFID mandate in June 2018 requiring member airlines to integrate RFID into all baggage tags from 2020. The Chinese government also launched mandatory RFID to complete rail car management systems. A 2021 report by Research and

Markets predicted that the RFID market size would reach USD 17.4 billion by 2026, with a growth rate of 10.2%. Moreover, the report pointed out that COVID-19 could act as a key accelerator driving the growth of RFID adoption.

2.2. The impact of mandatory RFID

Consistent with previous RFID studies (Barratt and Choi, 2007; Deitz et al., 2009), in our research, mandatory adopters are those who apply RFID technology because of mandates from customers, without which they would not have employed RFID. Many firms have complained that mandatory RFID has issues such as high cost, integration complexity, and unstable performance (Feng et al., 2014; Reyes et al., 2016). Some firms reported failure or problems when they were adopting RFID (Schuman, 2005). Adopters occasionally show resistance because the adopting firms lack the knowledge, financial, and human resources for implementing RFID adoption successfully (NetworkWorld.com, 2004). In fact, Walmart reduced its mandate size, such as a lower level of penalties to firms that failed to tag pallets in 2006 and then abandoned its RFID mandate to suppliers in 2009.

A few researchers found that RFID mandates produced positive returns. For example, Deitz et al. (2009) found that the impacts of retailers' RFID mandates on supplier stock returns were positive in the short term, and the abnormal returns were stronger for more dependent suppliers and suppliers with greater cash flow. Whitaker et al. (2007) conducted a field study of RFID adoption and return expectations. They found that partner mandates play a positive moderating role in the link between an expectation of an earlier return and RFID investment. Lui et al. (2019) studied the moderating effect of RFID mandates on adopting firms' firm risk (i.e., cost of capital). Their results show that mandated RFID decreased firm risk, and manufacturers with higher levels of top management team (TMT) demographic heterogeneity and higher levels of pay dispersion from incentive compensation received lower firm risk following mandated RFID. Overall, the understanding of the actual effect of mandatory RFID on operating performance remains limited and inconclusive. Previous studies also indicate that contextual factors such as firm cash flow (Deitz et al., 2009) and TMT characteristics (Lui et al., 2019) affect the impact

of mandatory RFID. Therefore, this study aims to provide a deep understanding of the impacts of mandatory RFID by jointly investigating the actual impacts of mandatory RFID on operating performance (e.g., return on assets) and the factors that affect such impacts.

2.3. The financial performance effects of mandatory RFID

The OM perspective suggests that mandatory adoption often reduces a company's organizational flexibility while requiring significant capital investments (Darnall, 2009). Based on this logic, mandatory RFID can lead to more disruptions (e.g., employee resistance) in operations (Deitz et al., 2009) and less permanent change in practices and routines (Brown et al., 2002). Based on an institutional perspective, firms deploying RFID may disregard its financial benefits while focusing on social factors. However, some recent studies (e.g., Rogers et al., 2007; Huo et al., 2013; Lui et al., 2021) suggest that when innovation adoption is consistent with the business strategies of firms, mandated adoption can still potentially create financial benefits. For instance, Lui et al. (2021) found that energy-efficient systems adoption under institutional pressures could produce positive financial returns. Based on this perspective, RFID should provide firms with direct benefits when it aligns with the firms' goals. In such a context, firms will not only apply RFID loosely or symbolically but also make attempts to improve their RFID (Huo et al., 2013). Therefore, although RFID adoption is implemented due to customer mandates, substantive RFID adoption can still provide potential rewards (Walker and Wan, 2012). Furthermore, complying with customer mandates can assist firms in securing resources and legitimacy from customers for organizational survival, financial benefits, and strategic benefits (Meyer and Rowan, 1977; Scott, 1995; Colwell and Joshi, 2013). For example, suppliers can obtain business commitments from their customers when they comply with RFID mandates (Lai et al., 2006; Whitaker et al., 2007; Deitz et al., 2009). Previous studies have shown that customer firms reward higher sales volumes with suppliers if they comply with mandatory systems (Mukhopadhyay and Kekre, 2002). Moreover, firms that conform to customer mandates will receive technical support and experience sharing from their mandators (Lai et al., 2006; Whitaker et al., 2007; Deitz et al., 2009). Requesting upstream suppliers to adopt RFID is often treated as a supplier development

initiative. Mandate initiators, such as large-scale retailers, normally have an RFID team to assist their suppliers in adopting the new technology and provide support throughout the transition from the old to the new system (Roberti, 2007). For example, when Walmart asked its top suppliers to apply RFID tags to every box and pallet supplied, it ensured that the commitment and implementation plans were well communicated throughout its supply chain.

From a supply chain perspective, each mandatory RFID-adopting firm has a dedicated supply chain collaborator (the RFID mandator). Powerful RFID mandators, such as Target and Walmart, share electronic product code (EPC) data with RFID-enabled suppliers (Roberti, 2005; Shin and Eksioglu, 2015), providing manufacturers with the means to integrate their supply chain. Such integration not only maintains closer relationships with retailers but can also increase entry barriers for competitors and create switching costs for retailers (Deitz et al., 2009; Uotila et al., 2017). Both the RFID mandator and the adopter can improve profitability through more accurate sales forecasts, improved visibility of material flow, and more effective resource planning (Melville et al., 2004; Flynn et al., 2010). More specifically, the transmission of real-time information to and from downstream and upstream partners can facilitate better coordination among partners (Mishra et al., 2013). The joined efforts also allow suppliers to enhance inventory performance by reducing the replenishment lead time and lowering inventory "buffers" (Lee and Özer, 2007; Mishra et al., 2013). In addition, RFID provides higher supply chain visibility between suppliers and retailers, which enables suppliers to increase sales by providing more responsive and flexible services to customers (Nazir and Pinsonneault, 2012) as well as increasing repurchase rates due to greater customer satisfaction (Kim and Sohn, 2009; Reyes et al., 2016). Based on the above arguments, we make the prediction below. To estimate the financial performance of a firm, we used return on firm assets (ROA), which is a common measure of accessing a firm's overall operational effectiveness (Lo et al., 2012; Lo et al., 2014).

H1. The effect of mandatory RFID adoption on financial performance is positive.

2.4. Contextual factors and the performance of mandatory RFID

Although we anticipate that mandatory RFID adoption is positively associated with financial performance, there are contextual factors that may be contingent on the relationship between mandatory RFID and financial performance. The contingency theory suggests that there is no one-size-fits-all approach (Reinking, 2012). There is an agreement in the contingency literature that the environment shapes a firm's structure, and therefore, to optimize performance, firms should take into account the environment and organizational attributes (Gordon and Miller, 1976; Flynn et al., 2010). Wamba and Chatfield (2009) suggested a contingency perspective toward the appropriate RFID supply chain network project, indicating that it is likely that the financial benefits due to mandatory RFID adoption rely on the alignment of a firm's attributes and environment. Therefore, we use contingency theory to investigate the match between mandatory RFID adoption and the environment in terms of financial distress, adoption timing, and industry clockspeed, as presented below.

2.4.1. Financial distress

Financial distress refers to a low cash flow state of the firm while it incurs losses without being insolvent (Purnanandam, 2008). Firms under financial distress often have difficulty paying off their financial obligations (Purnanandam, 2008). Successful technology adoption requires sufficient management commitment and resources (Christensen and Raynor, 2003). Therefore, financially healthy firms are more likely to move from the adoption-intent phase to the actual adoption of technology (Farnoush et al., 2021). For instance, Bose et al. (2011) suggested that firms with poor financial health suffered negative stock returns from RFID investment announcements. Hayes et al. (2001) found that financially healthy firms obtained more market value from the announcement of enterprise resource planning (ERP) systems investments.

RFID adoption often requires a significant time commitment and investment, while it promises no immediate return. Firms may need to conduct several tests to integrate their RFID system into the network of their customers. These tests will raise investment costs and implementation time, as well as reduce the

overall return on investment (Bose et al., 2011; Jacobs et al., 2015). Since a financially distressed firm requires management effort to use limited resources to improve business operations, distressed firms may have limited slack to implement mandatory RFID. As a result, the adoption would produce limited benefits. On the other hand, financially healthy firms provide top managers with a more stable environment and sufficient financial resources to devote to the continuing implementation of RFID adoption, which can take over a year. Hence, we make the following prediction.

H2. Healthy financial firms obtain more financial returns from mandatory RFID adoption than unhealthy financial firms.

2.4.2. Adoption timing

Walmart launched the RFID mandate initiative among its suppliers in 2003 (e.g., Phase 1: January 1, 2005, Phase 2: January 1, 2006, and Phase 3: January 1, 2007—all products going to Walmart locations). Figure 1 illustrates the Walmart RFID timeline.

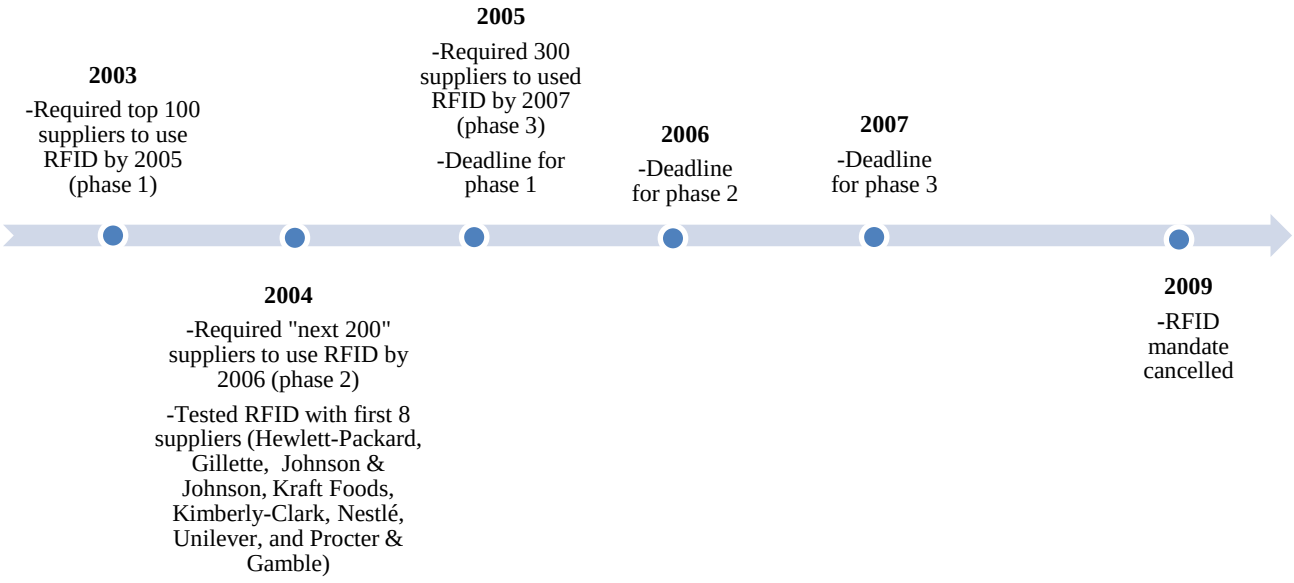

Figure 1. Mandate timeline.

Adoption timing can affect the resources and capabilities for superior performance (Feng et al., 2014; Jacobs et al., 2015; Yang et al., 2021) and is a key reason behind the success or failure of innovative investment. Scholars and practitioners have commonly agreed that the right launch timing for innovative

investments can determine the value of the investments (Huisman and Kort, 2015). First movers can obtain secure scarce resources and superior performance and take advantage of learning how to modify their operations before their competitors try to copy them. Some studies find that early IT adoption in a voluntary context provides greater returns. For example, a typical study conducted by Dos Santos and Peffers (1995) found that late adopters failed to obtain greater returns, while first movers could. Yang et al. (2021) found that early adopters of OHSAS 180001 received more performance returns than late adopters. On the other hand, followers can copy the first movers to reduce costs and risks (Porter and Millar, 1985). Some research indicates that early IT adopters face more uncertainties regarding the applicability of an IT innovation and have less knowledge of how to implement IT innovation effectively (Keng, 2003; Dewan and Ren, 2011). As knowledge and information are accumulated from the experiences of early adopters, late adopters take the opportunity to be free riders in the early learning curve of the technological innovation of a first mover (Teo et al., 2003).

Extending these notions to our research context, we argue that late adopters of mandatory RFID are more likely to gain more financial benefits. RFID adoption often involves significant uncertainties and risks (Cannon et al., 2008). Firms have to deal with several challenges, including technical issues (e.g., lack of standards and complexity of system integration) and high costs (Bottani and Rizzi, 2008). Early adopters of mandatory RFID are frequently frustrated with the high cost and immaturity of the technology (Feng et al., 2014; Reyes et al., 2016). For example, the costs per RFID tag were dollars in the early days, yet dropped to cents per tag in recent years (Feng et al., 2014). In contrast, late adopters may gain stronger performance when RFID becomes increasingly standardized, cost-effective, and mature, and the firms are more knowledgeable about RFID's applications over time. For instance, late adopters can hire employees from early adopters to shorten the learning curve (Salomon and Martin, 2008). Late adopters can also obtain additional information about RFID applications from other adopters who have served the same customers (Hoppe, 2002; Reyes et al., 2016). That is, late adopters can simply copy early adopters who have already gone through most of the glitches on RFID adoption with Walmart. Therefore, the present study makes the following hypothesis:

H3. Late adopters obtain greater financial returns from mandatory RFID adoption than early adopters.

2.4.3. Industry clockspeed

Industry clockspeed is a critical source of the environmental uncertainty faced by firms (Wang et al., 2006; Souza-Luz and Gavronski, 2020). Industry clockspeed measures the rate of industry change driven by endogenous factors (technological and competitive) (Fine, 1998) and plays a contingency role in supply chain coordination between suppliers and customers (Chavez et al., 2012). Thus, industry clockspeed has the potential to influence the way mandatory RFID impacts the financial performance of adopting firms. However, limited studies have considered the contingency perspective of industry clockspeed in IT areas (Chavez et al., 2012). Fine (1998) is the first to conceptualize industry clockspeed according to the rate of the change of products, processes, and organizational structure. Product change refers to new product introduction and product obsolescence rates. Change in process represents the rates at which process technologies are substituted. Finally, change in organizational structure reflects the rate of change in firms' structures (e.g., CEO transitions) and strategic actions (e.g., mergers and acquisitions).

In high-clockspeed industries, such as fashion and apparel, personal computers, and cosmetics, firms implement faster product development and manufacturing (Mendelson and Pillai, 1999) and continually introduce various new products to maintain their competitive advantage (Nadkarni and Narayanan, 2007). Since firms have RFID tags to track products at the item or pallet level, RFID is more beneficial in high-clockspeed firms because a large amount of tagging at the item and pallet levels ensures higher utilization rates and practical benefits.

High-clockspeed industries are associated with more environmental uncertainties and risks because of the high rate of change in these industries. High-clockspeed firms typically have to depend on speedy and precise information from customers to identify and act upon changes that drive value (Mendelson and Pillai, 1998). Compared with low-clockspeed firms, high-clockspeed firms demand more visible and more responsive supply chains that can provide efficient inventory tracking. For instance, the fashion and apparel industry launches new products every season; thus, the supply chain visibility of material flow is especially important to manage products. Mandatory RFID provides firms the means to integrate their supply chain

with mandators and enables firms to build closer connections with their mandators (e.g., information sharing), which in turn reduces uncertainty (Wong et al., 2011) and leads to greater supply chain efficiency (Chen and Xiao, 2009) and collaborative decision-making (Wong et al., 2015). The benefits of mandatory RFID can exhibit a more positive financial performance effect on high-clockspeed firms (Vijayasarathy, 2010). For example, Guimaraes et al. (2002) reported that when IT was effectively used to enable the coordination of a supply chain, industry clockspeed would likely be positively associated with supplier network performance. Hence, we posit the following:

H4. Firms in high-clockspeed industries obtain greater financial returns from mandatory RFID adoption than firms in low-clockspeed industries.

Figure 2 presents the research model and the four hypotheses examined in this research.

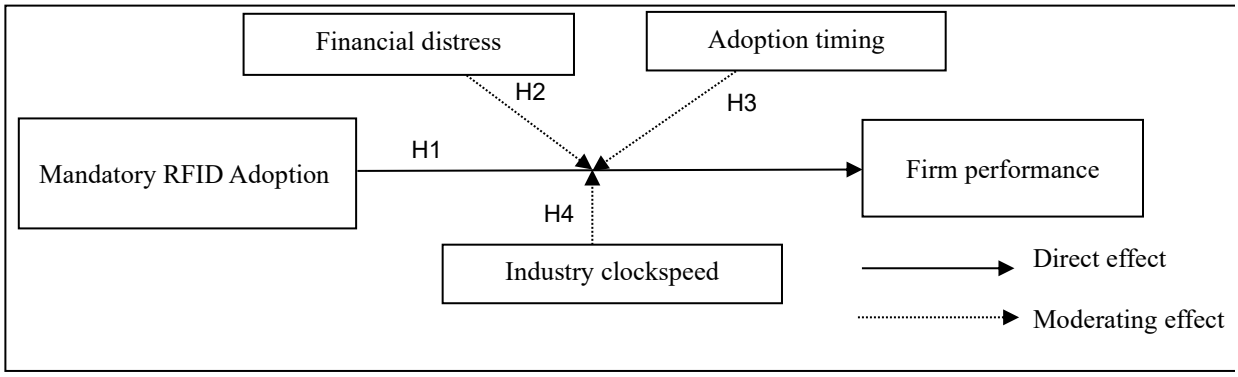

Figure 2. Research framework.

3 Methodology

3.1. Data collection

To examine the impact of mandatory RFID adoption, we gathered financial data from COMPUSTAT. We developed the sample firms based on a list of Walmart's top manufacturers who are mandated to adopt RFID by Walmart. We applied keywords, including "RFID" and "radio frequency identification" together with company name, to systematically search announcements from Factiva between 2000 and 2010. We limited our search to this period because it covers the full timeline of Walmart's first RFID mandate initiative (SupplyChainDigest, 2009). Thus, the research can provide insights into the impact of the first

RFID mandate and can be used as a reference to recent mandatory RFID by Walmart so that Walmart and its suppliers can learn from the past for better financial outcomes of mandatory adoption. Following standard practices used in previous long-horizon event studies, the research team carefully studied each announcement to determine whether it was a valid event. Announcements that were ambiguous were then discussed among the coauthors, and a consensus-based decision was employed to determine whether to include this event. We selected the first mandatory RFID initiative if we found multiple RFID initiatives. Specifically, we excluded firms if other RFID initiatives occurred in a three-year window following the announcement. We only consider firm-wide adoption and did not include firms that dropped out of RFID adoption at later phases. Firms that adopted voluntarily before the mandate were not considered in the study. We excluded a few firms that adopted mandatory RFID voluntarily. We also excluded announcements with confounding events, such as the adoption of other inventory tracking technologies (e.g., QR codes), new business development, and mergers and acquisitions during the period of RFID adoption. We collected 99 sample firms, of which 4 with missing related financial data were removed for matching purposes. Finally, 95 firms were left for further analysis.

To confirm if the firm actually had adopted RFID under the Walmart RFID mandate and the years of its adoption, the research team cross-checked announcements collected with data from other public sources. We found that among these 95 announcements, 50 had corresponding records in technology periodicals (e.g., the RFID Knowledgebase and RFID Journal), which record RFID cases, including the motivation of a firm's RFID adoption. 30 were announcements related to RFID implementation that can be verified with their RFID vendors. For example, Alien Technology Corp. (RFID solution provider) provided RFID tags and readers to jeans maker VF Corp. For the remaining 15 announcements, 9 were confirmed based on other sources such as academic journals, practitioner journals, books (e.g., Lui and Lo, 2014), and public information (e.g., SEC filings). Overall, we verified 93.7% of the announcements, showing the consistency between the announcements and firms' actual adoption of mandatory RFID.

While Table 1 shows examples of firms with the adoption year, Table 2 shows a description of the sample firms. Table 3 presents industry classifications on clockspeed based on the study by Fine (1998).

Although most of the firms belong to medium-clockspeed industries, approximately 16% and 24% belong to high- and low-clockspeed industries, respectively.

Table 1
Examples of firms with the adoption type and adoption time.

Firms	Adoption type	Adoption year*
Hewlett-Packard	Was mandated to adopt RFID by 2005	2004
Shaw Industries	Was mandated to adopt RFID by 2007	2007

* The adoption year for adopting firms may be different depending on their position in Walmart's mandate plan. Please refer to Figure 1.

Table 2
Description of the sample firms.

Variables	Mean	Median	Std. dev.	Min.	Max.
ROA	0.13	0.15	0.06	0.00	0.35
Total assets (Billion $)	7.89	4.14	6.63	0.04	45.08
R&D intensity	0.01	0.03	0.04	0.00	0.20
SGA intensity	0.17	0.20	0.14	0.01	0.68
Current assets over total assets	0.39	0.42	0.16	0.13	0.99
Sales growth	0.10	0.13	0.25	-0.51	1.49
Financial leverage	0.07	0.04	0.26	-0.57	1.28
Labor productivity (Thousand $/employee)	37.18	59.00	59.80	0.21	303.77
Inventory days	40.22	41.21	21.90	5.65	125.68

Table 3
95 sample firms across industry clockspeed.

Industry	SIC code	No. of announcements
High clockspeed		
Fashion and textiles	2200, 2300, 3100	5
Cosmetics	2840, 2844	3
Computer	3570, 3571	2
Semiconductor	3674	3
Misc. (e.g., toys)	3900	2
		15 (16%)
Medium clockspeed		
Food	2000	13
Chemical products *	2800	14
Rubber	3000	4
Industrial equipment *	3500	8
Electrical components *	3600	8
Transportation *	3700	5
Measurement tools	3800	5
		57 (60%)
Low clockspeed		
Furniture	2500	5
Paper	2600	5
Petrochemicals	2900	6
Stone products	3200	4
Primary metal	3300	3
		23 (24%)

* Exclude SIC code in high or low clockspeed industries.

3.2. Measures of Variables

3.2.1 Contextual factors

Financial distress. Altman's Z score (Altman, 1968) was applied to estimate the possibility of a firm experiencing financial distress (Miller and Shamsie, 1996). A low Z score indicates poor financial health and high financial distress.

Z score = 3.3 (EBIT/TA) + 0.999 (SALE/TA) + 1.4 (RE/TA) + 0.6 (MV/TL) + 1.2 (WCAP/TA)

where EBIT is earnings before interest and taxes, MV is the market value of equity, RE is retained earnings, TA is total assets, TL is total liabilities, and WCAP is working capital.

Adoption timing. To examine whether adoption timing is associated with the effects of mandatory RFID (H3), we measured adoption time, i.e., the year a firm successfully deploys RFID.

Industry clockspeed. To test H4, we classified the samples into high-, medium-, and low-clockspeed groups following the industry clockspeed classification of Fine (1998). Based on previous studies (e.g., Nadkarni and Narayanan, 2007; Jacobs and Singhal, 2014), we used Fines' (1998) classification because recent studies have developed the discriminant, convergent, and nomological validity of Fines' (1998) measures (Mendelson and Pillai, 1999; Nadkarni and Narayanan, 2007). A variable named *clockspeed* was established and given values of 1, 2, and 3 to indicate low-, medium-, and high-clockspeed industries, respectively. Table 3 shows details of the distribution of our sample firms across industry clockspeeds.

3.2.2 Control Variables

Several firm- and industry-level factors that might affect the abnormal performance of the sample firm were controlled. All the variables used data in year −2. For firm-level factors, a firm with high profit might be more profitable in the future. Hence, *firms' previous ROA* was controlled. *Size* (natural logarithm of total assets)*, age, capital investment* (capital expenditures over total assets), *SGA intensity*, and *R&D intensity* were also controlled because a large, old firm with high capital investment, SGA intensity, and R&D intensity might have high resource slack and the capability to deploy RFID, which could positively affect

the firm's abnormal ROA (Dehning and Richardson, 2002; Xue et al., 2012; Chen et al., 2022). Age was estimated as the difference between the year when a firm was found in our sample and the year when the firm was established. Moreover, we controlled for *inventory turnover* because low inventory levels could positively affect profitability (Chang, 2011).

Financial performance could be associated with the business environment, and thus, we controlled for *industry sales growth* (Lu and Jinghua, 2012), which was estimated as the average change in industry sales between year −2 and year +3. We also controlled for industry competitive pressures, which were measured using Boyd's (1995) Herfindahl index. A small index indicates that returns from IT investments are likely to be lost in competition (Melville et al., 2007).

4. Analysis and Results

4.1. Tests of the financial performance of mandatory RFID (H1)

A long-horizon event study approach was used to examine the causal relationship between RFID adoption and financial outcomes. We described the event study period as the period during RFID implementation, and we defined the year of RFID adoption as year 0. Previous research has reported that an SCMS requires approximately 1 to 1 and a half years to implement (Roberti, 2004; Hendricks et al., 2007). Therefore, year −2 was defined as the base year that was not affected by RFID adoption. Prior studies (e.g., Liu et al., 2014) indicate that once the adoption of an innovation begins to be carried out, it may affect firm outcomes after the base year. Hence, we studied the long-term effect of RFID adoption by investigating abnormal performance changes over a 5-year period from the beginning of implementation year −1 to post implementation year +3.

4.1.1. Matching to Control Firms

When selecting matching firms, some studies choose control firms based on specific operating performance, firm size and industry, as suggested by Barber and Lyon (1996). However, such an approach has been criticized for failing to control substantial endogeneity. Given that RFID adoption is not a random event, we used propensity score matching, which is widely applied in statistics and economics, to select

control firms (Dehejia and Wahba, 2002). This method ensures that firms are similar (a close propensity score) for direct comparisons and thus helps to avoid the issue of selection bias. We used logistic regression to obtain the propensity scores. We assigned 1 to an indicator variable if RFID was adopted by the firm and 0 if RFID was not adopted. Previous studies suggest that matching processes will be invalid if there are too many variables in a regression (Dehejia and Wahba, 2002). Therefore, we selected limited factors that affected the investment decisions according to theories and empirical evidence. We included *ROA*, *size* (natural logarithm of the total assets), *R&D intensity* (R&D expenses over sales), *SGA intensity* (sales, general & administrative expenses over sales), *current assets over total assets*, *financial leverage* (debt over total assets), *sales growth*, *labor productivity* (operating income over the number of employees), and *inventory days* (365 over inventory turnover) (Chang, 2011). All the aforementioned variables were based on year −2 data. Finally, to match the sample firms with the control firms, fixed effects for both *year* and *industry* (four-digit SIC) were applied to ensure that the industry and time of the control and sample firms were similar.

Below is the logistic model:

$$\Pr(\text{RFID}_{it}) = \alpha_0 + f_{\text{industry}} + f_{t\text{-}2} + \beta_1\text{ROA}_{it-2} + \beta_2\text{Size}_{it-2} + \beta_3\text{R\&D intensity}_{it-2} + \beta_4\text{SGA intensity}_{it-2} + \beta_5\text{Current assets over total assets}_{it-2} + \beta_6\text{Financial leverage}_{it-2} + \beta_7\text{Sales growth}_{it-2} + \beta_8\text{Labor productivity}_{it-2} + \beta_9\text{ Inventory days}_{it-2} + e_{it},$$

where t is the year of RFID adoption, α_0 is the regression intercept, and $\Pr(\text{RFID}_{it})$ is the probability of the ith firm using RFID in year t. For the 95 sample firms, we identified 2,174 potential control firms. Table 4 (prematch model) shows that large firms and firms with high current assets over total assets and high SGA intensity were more likely to deploy RFID. The performance on labor productivity and sales growth for RFID-adopting firms were lower than non-RFID-adopting firms. Moreover, the R&D intensity of RFID-adopting firms appeared to be lower than that of nonadopting firms. Thus, when firms exhibit a lower level of performance and have more resources, firms that take less risk are more likely to apply RFID to enhance their firm performance.

Table 4

Propensity score matching.

Independent Variable	Prematch	Postmatch
ROA	1.697 (1.321)	0.632 (0.421)
Size	1.915 (0.012)***	0.965 (0.624)
R&D intensity	−8.976 (0.004)***	1.518 (0.240)
SGA intensity	2.972 (0.003)***	1.205 (0.452)
Current assets over total assets	2.378 (0.029)***	1.213 (0.661)
Financial leverage	0.451 (0.310)	-0.135 (0.230)
Sales growth	−0.852 (0.021)**	-0.322 (0.490)
Labor productivity	−0.397 (0.084)*	-0.114 (0.226)
Inventory days	−0.503 (0.323)	0.429 (0.523)

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$ (two-tail).
p-values are in the brackets.

Having calculated each firm's propensity scores, we used one-to-one nearest-neighbor matching to select a control firm for each sample firm (Lui et al., 2021). Specifically, each sample firm was matched to a control firm in the same year and same industry (four-digit SIC) with the closest propensity score. Nearest neighborhood matching ensures that the control firm is most similar to its sample firm. Although some prior studies have used one-to-many matching (e.g., Lo et al., 2014), this matching approach increases the bias (Leite, 2016) because some control firms included may not be adequate (Leite, 2016). Consequently, we successfully matched 95 sample firms with control firms (we doubt-checked that the control firms are not RFID adopters). No statistically significant differences were found in the variables between the sample and control firms in the logistic model (i.e., postmatch model) in Table 4, suggesting the matching quality is satisfactory, and no selection bias was created. Furthermore, on those variables between the sample and control firms, no statistical significance was found in the t-test. Table 5 shows the firm characteristics for the sample and control firms at year −2.

Table 5
Descriptive statistics of sample and control firms (year −*2*).

Variables	Mean	Median	Std. dev.	Min.	Max.
Sample firms					
ROA	0.15	0.13	0.06	0.00	0.37
Total assets (Billion $)	6.88	3.02	8.78	0.02	35.62
R&D intensity	0.03	0.01	0.05	0.00	0.39
SGA intensity	0.25	0.23	0.15	0.01	0.68
Current assets over total assets	0.45	0.42	0.17	0.11	0.99
Financial leverage	0.04	0.05	0.33	−0.71	1.28
Sales growth	0.11	0.07	0.23	−0.51	1.49
Labor productivity (Thousand $/employee)	50.66	33.18	50.53	0.21	303.77
Inventory days	45.03	43.16	23.06	4.45	125.68

Control firms					
ROA	0.14	0.13	0.07	0.01	0.53
Total assets (Billion $)	6.36	1.75	12.76	0.22	96.41
R&D intensity	0.03	0.01	0.04	0.00	0.23
SGA intensity	0.23	0.20	0.16	0.01	0.65
Current assets over total assets	0.45	0.45	0.18	0.11	0.98
Financial leverage	0.04	0.02	0.42	−0.79	2.26
Sales growth	0.10	0.08	0.20	−0.58	0.98
Labor productivity (Thousand $/employee)	56.98	33.08	73.38	4.16	500.63
Inventory days	47.00	46.01	20.65	1.12	126.28

4.1.2. Abnormal Changes in Financial Performance

After matching each sample firm to a control firm, we used the formulas below to measure the abnormal performances of the sample firms:

$$AP_{(t+j)} = PS_{(t+j)} - EP_{(t+j)}$$

$$EP_{(t+j)} = PS_{(t+i)} + [PC_{(t+j)} - PC_{(t+i)}]$$

where AP is the abnormal performance, PS is the actual performance, PC is the performance of the control firm, t is the adoption year of RFID, EP is the expected performance of the sample firm, i (= –2) is the base year, and j (= –1, 0, 1, 2 and 3) is the end year of comparison. Financial performance was measured as ROA (ratio of operating income (before depreciation, interest, and taxes) to total assets). We conducted a t-test and a Wilcoxon signed-rank (WSR) test (Barber and Lyon, 1996). Following common practices, we discuss the findings mainly based on the WSR test because compared with a t-test, the WSR test is less affected by outliers (Barber and Lyon, 1996). To show the robustness of our results, we also conducted parametric t-tests for the means of abnormal performance.

Table 6 shows the findings of abnormal performance analyses. Similar to other event studies (e.g., Jacobs et al., 2015), due to data unavailability, the sample size, *N*, gradually decreases in the following years. The second row "−2 to −1" indicates the sample firms' abnormal changes in performance after implementing RFID. Overall, the results of the entire sample show that general RFID adoption improves ROA. More specifically, Table 6 indicates that ROA started to increase significantly in the period (−1 to 0) and continued to be significant in all other periods. Cumulative abnormal changes in ROA were also significantly ($p < 0.05$) positive in all the cumulative periods. The results support Hypothesis 1 that

mandatory adoption generates a significantly positive effect on financial performance. The findings are useful for assisting managers in determining the value of mandatory RFID at different stages and justifying their investment decisions. The findings are consistent with previous studies, such as those by Melville et al. (2004), Rai et al. (2006), Prajogo & Olhager (2012), and Wong et al. (2015), indicating that high perceived financial performance is associated with IT systems that improve coordination with customers. These findings also support recent empirical studies (Huo et al., 2013; Lui et al., 2021) and assertions (Rogers et al., 2007) that the adoption of an innovation motivated by institutional pressures can still reward potential financial benefits to some degree. However, the current results contradict those of previous empirical studies (e.g., Westphal et al., 1997; Yeung et al., 2011) that found organizational innovations associated with a high level of institutional pressure lead to deteriorating operating efficiency.

Table 6
Abnormal performance in ROA (%)

Panel A: ROA [a]

Time period	N	Median	WSR Z-statistic	Mean	t-statistic	% positive	Z-statistic
−2 to −1	95	−0.405	−1.202	−0.355	−0.916	45.86	−1.041
−1 to 0	93	0.209	1.361*	0.507	1.636*	51.30	0.242
0 to +1	92	0.467	1.681**	0.863	2.488***	51.52	0.397
+1 to +2	88	0.019	1.286*	1.033	2.309**	50.00	0.500
+2 to +3	87	0.732	1.926***	0.738	2.212***	58.16	1.515*
−2 to +0	92	0.959	2.031***	1.209	2.444***	57.58	1.654**
0 to +3	87	0.938	1.909**	1.016	1.919**	61.61	2.362***
−2 to +3	87	2.770	3.035***	2.525	2.963***	66.33	3.131***

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$ (one-tail).

4.1.3 Intermediate Organizational Outcomes

To show how mandatory RFID-adopting firms achieve improvement in ROA through cost and revenue (Hendricks and Singhal, 2008; Mithas et al., 2012), we further examined the effect of RFID on cost indicators, including labor productivity and inventory performance. While labor productivity is a good proxy for the operating effectiveness of business processes, inventory performance is a good indicator of supply chain efficiency (Mishra et al., 2013) and a primary area that can be improved by RFID. We used sales performance, a common measure of business output, to show the effect of RFID on revenue.

Panels A and B of Table 7 indicate that both the abnormal changes in labor productivity and inventory days are insignificant in the periods (−2 to −1) and (−1 to 0), whereas the results are significant ($p < 0.10$)

across all other yearly and cumulative observation periods. Panel C of Table 7 shows that sales growth has significantly ($p < 0.05$) increased in the periods (0 to +1) and (+2 to +3). The cumulative abnormal sales growth was also statistically significant ($p < 0.10$) for periods (−2 to 0) and (−2 to +3). This result is not surprising, as the major purpose of RFID is to improve labor productivity and reduce inventory.

Table 7

Abnormal performance in labor productivity, inventory days, and sales growth.

Time period	N	Median	WSR Z-statistic	Mean	t-statistic	% positive	Z-statistic
Panel A: Labor productivity							
−2 to −1	95	0.277	0.055	−1.924	−0.780	50.83	0.149
−1 to 0	93	1.190	1.644	2.163	1.236	53.90	0.886
0 to +1	92	0.696	1.510*	3.373	2.359***	55.30	0.609
+1 to +2	88	2.312	2.613***	4.128	3.145***	57.14	1.417*
+2 to +3	87	3.597	3.024***	5.229	3.494***	57.14	1.313*
−2 to +0	93	1.269	1.749**	3.829	2.050**	56.82	0.783
0 to +3	87	5.496	2.151**	4.662	2.138**	64.29	2.929***
−2 to +3	87	7.138	2.713***	7.339	2.997***	64.29	2.727***
Panel B: Inventory days							
−2 to −1	95	−0.827	−0.815	0.265	0.309	44.75	−1.196
−1 to 0	93	0.442	0.230	−0.212	−0.284	53.25	0.725
0 to +1	92	−0.973	−1.774**	−1.135	−2.180**	40.91	−2.002**
+1 to +2	88	−1.338	−1.838**	−1.483	−2.183**	41.96	−1.606*
+2 to +3	87	−1.051	−1.862**	−1.735	−2.413***	41.84	−1.515*
−2 to +0	93	−1.414	−2.137***	−2.345	−2.741***	44.70	−1.132
0 to +3	87	−0.878	−1.826**	−2.282	−2.278**	46.43	−0.661
−2 to +3	87	−1.303	−1.781**	−2.968	−2.503***	44.90	−0.909
Panel C: Sales growth							
−2 to −1	95	1.580	1.061	−0.217	−0.091	53.59	1.046
−1 to 0	93	2.575	1.101	0.533	0.287	54.81	1.209
0 to +1	92	1.885	2.320**	5.055	3.117***	53.79	0.783
+1 to +2	88	0.182	0.139	4.117	1.468*	53.75	1.228
+2 to +3	87	4.195	3.008***	5.647	3.083***	62.24	2.323***
−2 to +0	93	0.195	1.433*	6.105	2.484***	50.76	0.087
0 to +3	87	0.345	0.607	4.228	1.711**	50.00	0.000
−2 to +3	87	3.665	1.763**	4.433	1.954**	59.18	1.717**

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$ (one-tail).

4.2. Tests and results of the contextual factors (H2-H4)

To test Hypotheses 2 and 4, we followed previous long-horizon event studies to conduct a cross-sectional analysis of contextual factors (Lo et al., 2014; Lui et al., 2021). We used abnormal ROA from year −2 to year +3 as the dependent variable in the hierarchical regression analysis. We used ROA because it better represents overall economic performance (Lo et al., 2012; Lo et al., 2014). Below is the formula to examine the hypotheses:

$$\text{Abnormal ROA}_i = \alpha_0 + \beta_1\text{Firm's previous ROA}_{it-2} + \beta_2\text{Size}_{it-2} + \beta_3\text{Age}_{it-2} + \beta_4\ \text{SGA intensity}_{\ it-2} + \beta_5\text{R\&D intensity}_{\ it-2} + \beta_6\text{Capital investment}_{it-2} + \beta_7\text{Inventory turnover}_{it-2} + \beta_8\text{Industry sales growth}_{it-2} + \beta_9\text{Industry competitiveness}_{it-2} + \beta_{10}\text{Financial distress}_{it} + \beta_{11}\text{Adoption timing}_{it} + \beta_{12}\text{Clockspeed}_{it} + e_{it},$$

where abnormal ROA_i is $X_{\ it+3} - X_{\ it-2}$ of the *i*th sample firm, and *t* is the adoption year.

The correlations between various indicators are shown in Table 8, whereas the findings of the hierarchical regression analysis are shown in Table 9. The control variables that influence abnormal ROA are shown in Model 1. Models 2, 3, and 4 show the moderating effect of the firm- and industry-level factors on the link between mandatory RFID and abnormal ROA. In all models, adjusted R-squared values are between 8.5% and 27.1%, and F values are higher than 1 ($p < 0.10$), indicating that the models are well developed. Focusing on Model 2, financial distress is positively and significantly related to abnormal ROA ($p < 0.10$). This finding indicates that the benefits of mandatory RFID for financially healthy firms are greater. Therefore, H2 is supported. The result aligns with the findings presented by Hayes et al. (2001) and Bose et al. (2011).

Model 3 shows that adoption timing is positive and significantly associated with abnormal ROA ($p < 0.10$). This finding shows that the positive performance of mandatory adoption is greater for late adopters. Thus, Hypothesis 3 is supported. The result challenges some conventional wisdom and previous research that early adopters of innovations gain a unique competitive advantage (Dos Santos and Peffers, 1995; Dehning et al., 2003; Lo et al., 2013). The result suggests that in a mandatory context, RFID-adopting firms gain stronger financial performance when RFID becomes increasingly standardized, cost-effective and mature and when firms are more knowledgeable about RFID's applications over time.

As shown in Model 4, industry clockspeed is positive and significant ($p < 0.10$). This result indicates that the improvement in the performance of mandatory adopters is significantly higher for firms belonging to high-clockspeed industries. This finding supports Hypothesis 4. The result is consistent with that of Vijayasarathy (2010) and Guimaraes et al. (2002), who report that the relationship between IT investment and supply chain performance is positively associated with industry clockspeed. The result is also in line

with the evidence in OM studies, such as Peng et al. (2013), which reports that product clockspeed positively moderates the relationship between firm capabilities and customer integration

Table 8

Correlation of variables in regression analysis.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Abnormal ROA	1.00												
2 Firm's previous ROA	−0.07	1.00											
3 Size	0.18	−0.04	1.00										
4 Age	0.14	0.06	0.14	1.00									
5 SGA intensity	0.11	0.21*	−0.18	−0.07	1.00								
6 R&D intensity	0.03	0.26*	−0.20*	−0.04	−0.28**	1.00							
7 Capital investment	0.03	0.01	0.15	−0.23*	−0.04	−0.08	1.00						
8 Inventory turnover	0.24*	0.15	0.21*	0.04	0.02	0.12	−0.04	1.00					
9 Industry sales growth	0.05	−0.02	0.40**	−0.08	−0.13	0.04	0.21*	0.18	1.00				
10 Industry competitive	0.04	−0.19	−0.14	0.18	−0.15	−0.01	−0.15	−0.17	−0.28**	1.00			
11 Financial distress	0.11	0.30***	0.20***	−0.14	−0.34***	−0.39**	0.13	−0.28***	−0.10	0.03	1.00		
12 Adoption timing	0.07	−0.08	0.02	−0.30**	−0.08	−0.09	0.32**	−0.01	0.34**	−0.13	−0.24***	1.00	
13 Clockspeed	−0.10	0.11	−0.23*	−0.06	0.41**	−0.10	−0.02	−0.16	−0.26*	0.04	−0.17*	0.01	1.00

N = 95; * $p < 0.05$; ** $p < 0.01$ (two-tail).

Table 9

Hierarchical regression analysis of the abnormal ROA (year −2 to year +3).

Variable	Model 1: Controls model	Model 2: Financial distress	Model 3: Adoption timing	Model 4: Clockspeed
Intercept	−0.061 (−1.071)	−0.168 (−1.257)	−0.105 (−1.828)*	0.098 (1.333)
Firm's previous ROA	−0.236 (−1.636)	−0.178 (−0.792)	−0.234 (−1.684)*	−0.131 (−0.998)
Size	0.001 (1.874)*	0.000 (0.264)	0.001 (2.240)**	0.001 (2.985)***
Age	0.001 (1.555)	0.000 (0.350)	0.001 (1.356)	0.001 (1.329)
SGA intensity	0.217 (2.705)**	0.117 (0.906)	0.196 (2.520)**	0.180 (2.496)**
R&D intensity	0.041 (1.722)*	0.334 (1.541)	0.050 (2.168)**	0.037 (1.709)*
Capital investment	0.037 (0.420)	−0.898 (−0.830)	−0.006 (−0.066)	−0.062 (−0.735)
Inventory turnover	0.003 (1.906)*	0.005 (2.046) **	0.003 (2.179)**	0.001 (1.048)
Industry sales growth	−0.040 (−0.864)	−0.026 (−0.401)	−0.039 (−0.874)	−0.100 (−2.263)**
Industry competitive	0.042 (0.885)	−0.045 (−0.569)	0.057 (1.227)	0.039 (0.915)
Financial distress		0.058 (1.890)*	0.055 (1.821)*	0.07 (1.788)*
Adoption timing			0.080 (2.459)**	0.073 (2.290)**
Clockspeed				0.032 (1.782) *
Model F value	1.819*	2.230**	2.376**	3.580***
R square	0.189	0.238	0.251	0.376
Adjusted R square	0.085	0.131	0.145	0.271

N = 95; t-statistic in parentheses; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$ (two-tail).

4.3 Robustness tests

We perform several sensitivity analyses to check whether our findings are robust.

Endogeneity test. Ketokivi and McIntosh (2017) pointed out that endogeneity can arise due to reverse causality. To address the concern that the impact of mandatory RFID adoption was not caused by endogeneity issues, we tested abnormal performance from "t – 3 to t – 2" to examine whether abnormal performance during the event window (−2 to +3) was actually driven by earlier performance gains (Lo et al., 2014; Lui et al., 2021). As shown in Table 10, we found no significant change in ROA or other indicators in the period. The test showed that the causal relationship is not due to a systematic bias prior to mandatory RFID adoption.

Table 10

Findings of endogeneity test.

Performance	Median	WSR Z-statistic	Mean	t-statistic	% positive	Z-statistic
ROA	−0.495	−0.959	−0.796	−1.225	44.62	0.497
Labor productivity	0.420	0.569	−0.751	−0.221	51.52	0.201
Inventory days	−0.700	−0.235	0.322	0.296	47.52	−0.398
Sales growth	−0.250	−0.754	−4.503	−1.103	49.49	1.000

Applying the matching method of Barber and Lyon (1996). We tested whether the matching procedure influenced our findings by applying the matching method of Barber and Lyon (1996). This method identifies control firms based on industry, pre-event performance, and firm size (Lo et al., 2014). We matched each sample firm to approximately 5 control firms. Findings in Table A2 in the Appendix aligned with our results in Tables 6 and 7.

Conducting difference-in-difference (DID) analysis. We further conducted DID analysis (i.e., sample firms' changes minus control firms' changes) to estimate the abnormal return for comparison between the sample and control firms (Fan et al., 2021). Specifically, the estimation was:

Abnormal performance $_{(t+j)}$ = [Sample firm performance $_{(t+j)}$ – Sample firm performance $_{(t)}$] – [Control firm performance $_{(t+j)}$ – Control firm performance $_{(t)}$]

where t is the start year, and j is the end year for the comparison. The results in Table 11 are also consistent with our results in Tables 6 and 7.

Table 11

Results using DID analysis.

Panel A: ROA [a]						
Time period	Median	WSR Z-statistic	Mean	t-statistic	% positive	Z-statistic
−2 to +0	0.404	2.222**	0.258	2.103**	53.99	1.894**
0 to +3	1.053	3.376***	1.143	3.463***	63.11	2.556***
−2 to +3	0.661	2.421***	1.402	2.533***	59.22	1.717**
Panel B: Labor productivity						
−2 to +0	0.763	1.874**	1.611	1.838**	54.71	1.913**
0 to +3	5.635	4.327***	8.908	3.754***	68.09	3.440***
−2 to +3	5.499	3.717***	12.510	3.134***	61.70	2.172**
Panel C: Inventory days						
−2 to +0	−1.422	2.029**	−1.605	1.803**	46.15	2.227**
0 to +3	−1.877	4.642***	−1.272	3.725***	41.58	2.130***
−2 to +3	−2.318	5.325***	−1.912	3.623***	48.95	2.546***
Panel D: Sales growth						
−2 to +0	1.491	1.791**	2.022	1.807**	54.09	1.735**
0 to +3	2.242	2.917***	2.303	3.481***	58.70	1.688**
−2 to +3	2.534	2.526***	4.387	2.902***	60.87	2.104**

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$ (one-tail).

Test for selection bias. It is possible that the findings presented in Table 9 are affected by selection bias. For instance, before adopting mandatory RFID, financially healthy RFID adopters may have already been high performers. Therefore, we performed extra analyses that used $t - 2$ data for matching. The ROA median (mean) of the financial healthy/late/high-clockspeed firms was compared with that of financial unhealthy/late/high-clockspeed firms. We found that their ROA was insignificant ($p > 0.10$) before adoption.

Testing alternative dependent variables. We used abnormal returns with alternative event windows as the dependent variables to test whether the findings of the regression analysis were consistent. Table 12 shows the regression results with the abnormal ROA estimated over periods (−2 to +0) and (0 to +3). The three contextual factors' coefficients remain consistent and significant across different regression models, illustrating that our regression results are robust.

Table 12

Findings with alternative abnormal ROA as the dependent variable.

Models	Financial distress	Adoption timing	Industry clockspeed
−2 to +0	0.056 (1.983)*	0.071 (2.061)**	0.031 (2.289)**
0 to +3	0.075 (2.190)**	0.063 (2.112)**	0.043 (2.326)**

t-statistics are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$ (two-tail).

Additional regression analysis. The findings remain consistent when we conducted a regression analysis using ROA at year 3 from both sample and control firms (including the same control variables in Table 9) while adding the dummy variable of adoption to test the moderating effects. The dummy variable was assigned a value of 1 for firms that adopted mandatory RFID and 0 otherwise.

Table 13

Findings using dummy variable for mandatory RFID adoption.

Variable	
Mandatory adoption	0.024 (2.951) ***
Mandatory adoption x Financial distress	0.027 (2.810)***
Mandatory adoption x Adoption timing	0.071 (2.024) **
Mandatory adoption x Clockspeed	0.015 (2.3625) **

t-statistics are in parentheses. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$ (two-tail).

5. Discussion and Implications

5.1. General discussion

The findings of mandatory RFID adoption are especially relevant to the contemporary business environment, where there has been an increase in investments in mandatory systems initiated by organizations such as dominant retailers or government entities (Venkatesh et al., 2003; Carugati et al., 2016). By showing the positive impact of mandatory RFID on financial performance, this study extends the stream of research on RFID effectiveness. The study also provides a deep understanding of supplier benefits from mandatory systems supported by dominant retailers or customers. The findings are consistent with those of Mukhopadhyay and Kekre (2002), which show that the benefits of mandatory IT adoption are greater than the associated costs. The findings also align with recent studies (e.g., Rogers et al., 2007; Huo

et al., 2013; Lui et al., 2021) that show innovation adoption in response to institutional pressures can still generate financial returns. On the other hand, our results contradict those of previous studies that suggest that mandatory IT may have negative impacts on firm performance (Hirschheim and Newman, 1988) due to negative individual outcomes such as user resistance (Hsieh et al., 2012). One possible explanation for the different findings is that the RFID mandate is a supply chain initiative. Firms that adopt mandatory RFID obtain increasing operational benefits over time by coordinating with their supply chain partners.

The present study also looked beyond the effect of mandatory RFID by providing empirical evidence of how three critical factors, namely, financial distress, adoption timing, and industry clockspeed, amplify the potential advantages of mandatory RFID. Consistent with the findings of previous studies (Hayes et al., 2001; Bose et al., 2011), we found that financially healthy firms obtained more financial benefits from mandatory RFID adoption. As predicted, we found that late adopters benefit more from mandatory RFID than their early counterparts. The result challenges some conventional wisdom that the performance of early adopters of voluntary IT always improves (Dos Santos and Peffers, 1995; Chatterjee et al., 2002; Dehning et al., 2003). Our result indicates that when RFID technology is used in a mandatory context, later adopters achieve better performance when RFID becomes increasingly cost-effective, standardized, and mature and when there are more experience and knowledge about mandatory RFID applications over time.

The moderating effect of industry clockspeed has been investigated in a number of research domains, such as strategic management (e.g., Nadkarni and Narayanan, 2007) and reverse logistics (e.g., Fernández and Kekäle, 2005). However, discussion on the moderating effect of industry clockspeed on the value of mandatory IT innovation adoption is rare. We found that high-clockspeed firms benefit more from mandatory RFID than low-clockspeed firms. While the result contradicts the results by Peng et al. (2013), who report that product clockspeed has no significant moderating effect on the relationship between customer integration and firm capabilities, the result is consistent with that of Guimaraes et al. (2002), who report that the economic value of IT investment, which enhances supply chain coordination, is positively associated with industry clockspeed. We believe our results are more aligned with Guimaraes et al. (2002) because mandatory RFID adoption is more than just customer integration, as it carries both supply chain

coordination and significant new IT infrastructure implementation.

5.2 Theoretical implications

The theoretical contribution of this study is twofold. First, this study enriches RFID literature by showing empirical proof that mandatory RFID produces financial performance and the performance is stronger for firms with good financial health, late adopters, and high-clockspeed firms. The results provide insights into the controversy of whether conforming to customer mandates creates sustainable financial returns. From a broader perspective, this study extends IT research into a mandatory setting. Extensive studies have investigated the effects of IT in a voluntary context, and some studies have examined the effects of mandatory IT usage on individual outcomes such as user satisfaction and user behaviors (Carugati et al., 2016; Bhattacherjee et al., 2018). However, understanding of the actual effect of mandatory IT adoption on firm performance remains relatively limited and inconclusive. Second, our empirical evidence of the moderating effects of contextual factors contributes to the literature of contingency theory in a mandatory context. Researchers should be aware of any mandatory pressure that could have distorted the impact of IT adoption, and thus, the mandatory pressure should be either controlled or the focus of the study in the research design. Researchers on mandatory IT adoption should also consider the influence of contextual factors in future studies, for instance, examining the impacts of various types of contextual factors (e.g., top management support and user behavior) on the link between mandatory IT and financial returns. Although similar contextual factors have been examined in a voluntary context, prior literature has rarely considered the influence of contingencies in a mandatory context. Our results suggest that prior results in a voluntary context may not apply to a mandatory context. Therefore, further studies are needed to explore such possibilities.

5.3. Practical implications

In terms of practical implications, our findings indicate that mandatory RFID can result in positive effects. The result helps resolve the controversy over the impact of mandatory RFID and encourages firms to adopt mandatory RFID to obtain financial benefits. The positive returns of mandatory RFID found in

this research also enable mandators to convince their suppliers to support their mandatory RFID. By showing the moderating effect of contextual factors on financial performance, the study provides insights into why some firms fail to deliver the expected benefits of mandatory RFID and why Walmart's one-size-fits-all mandate was not successful. Mandatory RFID in a specific setting, such as late adoption and high-clockspeed industries, can help gauge the effect of RFID on operational performance. Should mandators require their suppliers to implement such adoption when their suppliers are, e.g., financially unhealthy, in low-clockspeed industries, and the technology is immature? Our results indicate that this may not be a feasible approach. We are concerned that some adopting firms may compromise their long-term performance on such a mandatory approach. The findings indicate that a one-size-fits-all approach to RFID adoption may not be able to generate optimal returns. Our findings indicate that the success and performance benefits of mandatory RFID adoption rely partly on the contextual factors studied in the study. Therefore, managers of mandators should not simply follow other firms by launching a mandatory IT initiative. They should estimate the effect of the new technologies on their operations and that of their suppliers, analyze the contextual factors and apply appropriate IT practices to maximize financial performance. The lessons learned from the present study can serve as references for future projects. For example, managers of Walmart can use this research as a reference and learn from the past for better outcomes of the new RFID mandate in 2022. The insights from this study also enrich the literature on OM and IS.

5.4. Limitations and further research

This research has some limitations. First, our scope limited our sample to only U.S. manufacturers. Manufacturers in other countries, such as European countries, may have experienced different results. Second, mainly large companies (listed firms) have adopted RFID; hence, the results might not apply to small and medium-sized enterprises. Future studies can further examine the impact of mandatory RFID in other countries and small and medium-sized enterprises. Third, similar to any research using event study methodology, announcements are included in the sample because firms publish press releases. Some

matched firms might have adopted RFID, but they did not publish information about their events; thus, their firm was not included in the sample of the study. However, if such a problem occurs, it would imply that our findings are more conservative (i.e., more difficult to detect the difference between adopters and nonadopters), rather than amplifying the magnitude of the abnormal performance. Fourth, financial data from listed firms were used to investigate the financial performance effect of RFID adoption. Reporting investment values in a public announcement or financial report is not a common practice. Because of the limited information, we were not able to examine the return on investment of the technology in this study.

Fifth, this study focuses on examining the impacts of mandatory RFID adoption on firm performance. Because we could only identify a few firms that adopted Walmart's RFID mandate voluntarily, we were not able to make a comparison between mandated firms and control firms that voluntarily adopted Walmart's mandatory RFID system, even if they were not requested by Walmart. We also did not compare mandated firms with other types of control firms that voluntarily adopted RFID systems that were not based on Walmart's mandatory RFID system. Because these RFID systems were not for the same purpose (i.e., integration with Walmart), the comparison could not correctly reflect the impact of Walmart's mandatory RFID. It is worthwhile for future studies to directly examine the different operational performance effects of mandatory versus voluntary adoption. Seventh, the current study focused on the RFID context, and the findings may not be generalizable to other types of mandatory IT. Future research can more deeply investigate the effect of other contextual factors and investigate the generalizability of our findings to other types of mandatory IT investment. In addition, using other methodologies, such as surveys and case studies, to explore the impacts of mandatory IT investment and the role of contextual factors in it is critical.

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Appendix

Table A1
Summary of some recent key studies related to mandatory IT.

Articles	Topic
Bhattacherjee et al. (2018)	Discussed seven propositions to present the causal factors and processes that motivate IT user responses and how such responses might change over time.
Carugati et al. (2016)	Discussed how key stakeholders involved in mandatory IS context shaped the firm, the users' practices, and the technology.
Chan et al. (2010)	Built and tested a model of mandatory e-government technology adoption, and found different factors linked to the different stages in launching the technology which in turn predicted citizen satisfaction.
Hsieh et al. (2012)	Conducted a field study to investigate users' satisfaction with their mandatory use of customer relationship management systems in determining their service quality.
Lee and Park (2008)	Investigated the link between mandatory adoption of mobile IT and market performance in the business-to-business context. Their results indicated that perceived loss of control impacted user satisfaction negatively and perceived market performance is affected by perceived usefulness and user satisfaction.
Liang et al. (2013)	Investigated how rewards and punishment used to regulate mandatory IT usage influenced employee compliance behavior, and found that punishment expectancy determined compliance behavior while reward expectancy did not.
Mukhopadhyay and Kekre (2002)	Performed a field study with an industrial supplier that was requested by customers to investment in EDI, and found that both supplier and customer received benefits from the system.
Ojiako et al.	Investigated the impact of mandatory enterprise technology adoption in Nigeria based on a survey. They found that users developed a negative perception of the technology.

Table A2
Abnormal changes using the matching approach of Barber and Lyon (1996).

Time period	N	Median	WSR Z-statistic	Mean	t-statistic	% positive	Z-statistic
Panel A: ROA [a]							
−2 to −1	95	−0.495	−0.959	−0.796	−1.475	54.62	0.497
−1 to 0	93	1.158	2.590***	1.513	2.791***	50.85	0.262
0 to +1	92	0.037	0.620	0.595	1.262	57.41	2.182**
+1 to +2	88	1.196	2.240**	1.862	2.526***	56.54	1.891**
+2 to +3	87	1.130	2.421***	1.128	2.536***	57.11	2.532**
−2 to +0	93	1.105	2.017**	1.512	2.202**	52.31	0.612
0 to +3	87	1.127	1.924**	1.493	1.847**	55.50	1.600*
−2 to +3	87	3.816	3.403***	4.379	4.070***	52.31	0.540
Panel B: Labor productivity							
−2 to −1	95	−0.030	−0.645	−3.340	−0.932	50.00	1.000
−1 to 0	93	4.070	2.805***	6.261	2.085**	62.69	1.955**
0 to +1	92	0.200	0.170	3.020	1.390*	50.39	1.000
+1 to +2	88	4.620	1.976**	4.567	2.199**	59.62	1.248
+2 to +3	87	6.010	2.606***	6.215	2.868***	63.04	1.622
−2 to +0	93	5.560	1.715**	5.471	1.892**	56.67	0.904
0 to +3	87	5.750	1.211	3.941	1.189	64.00	1.838**
−2 to +3	87	12.67	2.416**	9.676	2.652**	68.18	2.261**
Panel C: Inventory days							
−2 to −1	95	−1.210	−0.854	0.193	0.140	41.25	−1.246
−1 to 0	93	−1.970	−1.418*	−2.472	−1.894**	44.78	−0.733
0 to +1	92	−1.770	−1.583*	−1.357	−1.765**	38.33	−1.678**
+1 to +2	88	−2.150	−2.721***	−2.950	−2.795***	32.65	−2.286**
+2 to +3	87	−0.680	−1.276	−2.165	−1.844**	43.90	−0.625
−2 to +0	93	−2.020	−2.503***	−4.161	−2.993***	38.33	−1.678**
0 to +3	87	−1.340	−2.119**	−4.085	−2.421***	40.00	−1.273
−2 to +3	87	−3.100	−2.274**	−6.585	−3.007***	44.44	−0.596
Panel D: Sales growth							
−2 to −1	95	1.220	0.317	1.956	1.248	58.54	1.677**
−1 to 0	93	2.060	0.825	0.444	0.169	54.78	0.733
0 to +1	92	0.010	0.842	4.589	1.778**	50.12	1.000
+1 to +2	88	0.300	0.347	8.145	1.524*	57.06	0.280
+2 to +3	87	9.310	2.651***	8.001	2.753***	66.67	2.165**
−2 to +0	93	2.115	1.583*	10.180	2.404***	55.00	0.645
0 to +3	87	1.560	1.444*	9.637	2.243**	52.83	0.275
−2 to +3	87	5.200	2.497***	7.158	2.682***	70.21	2.626***

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$(one-tail).

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