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Real-Time Economy: A New Frontier in Business and Economic Growth

ART ALISHANI, CITIS CENTER FOR IT IMPACT STUDIES, JOHAN SKYTTE INSTITUTE FOR POLITICAL STUDIES, UNIVERSITY OF TARTU, ESTONIA

MAARJA OLESK, INSTITUTE OF BALTIC STUDIES, TARTU, ESTONIA

RALF-MARTIN SOE, FINEST CENTRE FOR SMART CITIES, TALLINN UNIVERSITY OF TECHNOLOGY (TALTECH), ESTONIA

TARMO KADAK, SCHOOL OF BUSINESS AND GOVERNANCE, TALLINN UNIVERSITY OF TECHNOLOGY (TALTECH), ESTONIA

ROBERT KRIMMER, DR. KRIMMER CONSULTING OÜ, TALLINN, ESTONIA

ABSTRACT

This article delves into the concept of the Real-Time Economy (RTE), defined as a joint digital ecosystem where economic and administrative transactions between private and public actors take place as close to real-time as possible. It is an emerging economic paradigm characterized by instantaneous (or near-instantaneous) data exchange, real-time decision-making, and automated business processes. We conducted a systematic literature review across research domains such as information systems, business management, accountancy, and economics to capture and understand this continual transition toward digital business and economy. Our findings suggest that RTE has the potential to become an important topic in digital transformation, enabling the economy to function independently of the physical location and human intervention. We identified the factors that have contributed to the rise of RTE, such as rapid advancements in digital technology, big data, and artificial intelligence. Further, we explore the potential benefits and challenges of embracing RTE, including increased efficiency, reduced transaction costs, and enhanced competitiveness. Our article also highlights the role of governments in promoting the adoption of RTE through policy interventions, infrastructure investments, and public–private partnerships. Lastly, we conclude by discussing the transformative potential of RTE and the challenges to ensure a sustainable and secure economic future.

Keywords: Real-Time Economy; Digitalization; Decision-making; Economic efficiency; Policy implications; Infrastructure development.

1. Introduction and background

What makes a vision of a digital, real-time and contactless economy both tempting and challenging is the stark contrast it poses to the logic of everyday business rooted in human-to-human interactions. For millennia, goods and services have been exchanged or intermediated using gold, bank notes, and coins via physical person-to-person communication. Only recently has this standard begun to be challenged by the adoption of Information and Communication Technologies (ICTs), which have introduced machine-to-machine (M2M) transactions and possibilities to replace age-old concepts (bank notes, invoices, business agreements, logistics-related documents, documents supporting services, and products) with digital alternatives (Perez 2009). In some fields, the change has already been transformative (major financial transactions are based on electronic cash instead of moving banknotes from one human being to another), whereas other sectors of business have been resistant to digitalization. For example, important business agreements still tend to be signed on paper and exchanged from person to person due to a lack of international standards (Ferencz and Gonzales 2019).

In order to understand how a large-scale transformation from an analog to a digital economy could take place, this paper provides an analytical overview of existing research related to the digitalization and automation of business management, captured in the concept of Real-Time Economy (RTE). In the context of the economy, the term "real-time" was first used in 2002 by Ludwig Siegele in his article "How about now?" in The Economist (Siegele 2002). Siegele used the concept of RTE to refer to a new type of economy where physical location and contact are becoming increasingly irrelevant, and emerging ICTs are able to reduce process latencies to the minimum. The concept was later taken up by researchers, most notably by the group of researchers and business partners in the Real-Time Economy Competence Center affiliated with the Aalto University in Finland. The Real-Time Economy Competence Center depicts RTE as a joint digital environment where financial and administrative transactions take place as close to real-time as possible (Harald 2018). Some of the key technologies for enabling real-time transactions include e-invoices, e-receipts, and e-payments, which are seen as paving the way for more complex automated accounting processes, business reporting, auditing, monitoring, and forecasting.

To date, efforts to develop RTE ecosystems have often been isolated to specific projects and applications, with national and regional blueprints still in the early stages. Finland stands out as one of the few countries that have advanced a more strategic and comprehensive approach to RTE development. Early initiatives, like the Fully Integrated Accounting projects, focused on automating business accounting and streamlining the value chain from ordering to reporting. Another initiative, the TALTIO project, developed a standardized model for entering invoice, receipt, and accounting statement data into financial management systems without manual work. The ongoing "Real-Time Economy" project focuses on establishing the foundation for an interoperable economy and setting up a management strategy and model to support its development (Finnish Patent and Registration Office 2023).

Inspired by Finland's progress, Estonia started more systematic work on RTE between 2018 and 2019 and adopted its first strategic vision of RTE at the national level in 2020 (Ministry of Economic Affairs and Communication 2020). Since then, several initiatives have been

launched, including projects focused on e-invoices, e-receipts, automating reporting using eXtensible Business Reporting Language Global Ledger (XBRL GL), e-logistics, and real-time economic forecasting, with pilot projects either in the planning stages or currently being tested (Tietoevr 2020). To strengthen regional economic collaboration, national initiatives in digital public services are being expanded to support regional RTE efforts in the Nordic and Baltic regions. For example, Finland's TALTIO project was further developed through the Nordic Smart Government initiative, a joint effort by Finland, Denmark, Iceland, Norway, and Sweden to create an interoperable cross-border ecosystem for business data exchange. In 2023, a vision and roadmap for RTE was proposed for the Nordic and Baltic countries, focusing on seamless data interoperability and governance to enhance the business environment (PwC 2023). While policy initiatives have begun addressing RTE in key areas, the primary focus has been on standardizing data and business practices. The aspect of immediacy and real-time operations has been less central to these efforts.

Furthermore, the strict measures during the COVID-19 pandemic, along with ongoing geopolitical tensions disrupting global supply chains, have prompted businesses and governments to speed up digitalization, reduce physical interactions, and reduce reliance on manual labor. As these disruptions' long-term effects become more apparent, there is a growing preference for digital interactions, real-time M2M communication, and automation of business processes. This is further fueling the transition from an analog to a fully digital economy, as organizations seek resilience in an increasingly uncertain global landscape. In this context, RTE is broadly understood as an emerging concept that refers to transferring standard business transactions (e.g., ordering and invoicing) and administrative procedures (e.g., business reporting) from paper-based and human-to-human communication to digital contactless and automated M2M data exchanges. RTE solutions promise various opportunities to save time, money, and human resources and add value to the economy (Harald 2018). The benefits mainly occur due to digital and structured transaction data. If recorded and exchanged in standardized ways, such data can be reused for various purposes, from continuous data-driven auditing and monitoring of business performance in a company to the automated submission of tax reports to government agencies.

Despite the increasing number of policy initiatives, the concept of RTE has not garnered significant attention in academic literature and remains poorly defined in both policy and research. To address this gap, we conducted a systematic review of the RTE literature using a meta-synthesis method for qualitative research (Walsh and Downe 2005). This approach involves extracting, aggregating and interpreting findings from qualitative studies related to a particular topic (Finfgeld-Connett 2010). For this study, meta-synthesis method allowed us to investigate the key trends in RTE research (Moro et al. 2015), establish a foundation to build a theoretical understanding of the topic, identify research topics that have been investigated, and discover domains where further research is required. The methodology of the literature review is described in Section 2, while Section 3 presents the results of the literature review and develops an integrated conceptual model for RTE. Lastly, Section 4 discusses its implications in the context of digital transformation in both business and government and provides an outlook toward future developments.

2. Methodology

Given our focus on building a better understanding of the concept of RTE, this study employed a meta-synthesis method for qualitative research. The method provides a standardized procedure to direct text-synthesizing practices to facilitate the discovery of new themes and metaphors to create a deeper understanding of the research subject (Siau and Long 2005). This study integrates findings from qualitative studies on RTE across several research domains and provides a comprehensive synthesis of the literature, consolidating different fragments of RTE-related knowledge from different research fields. An initial round of review was conducted in spring 2019, and an update was conducted in spring 2020 following Walsh and Downe's (2005) six-step approach for conducting a meta-synthesis of qualitative research. The steps include (1) framing the purpose and research questions of the study, (2) locating relevant literature, (3) selecting research to be included in the study, (4) evaluation of studies, (5) synthesis of studies, and (6) elucidation of more refined meanings and new concepts based on the synthesis.

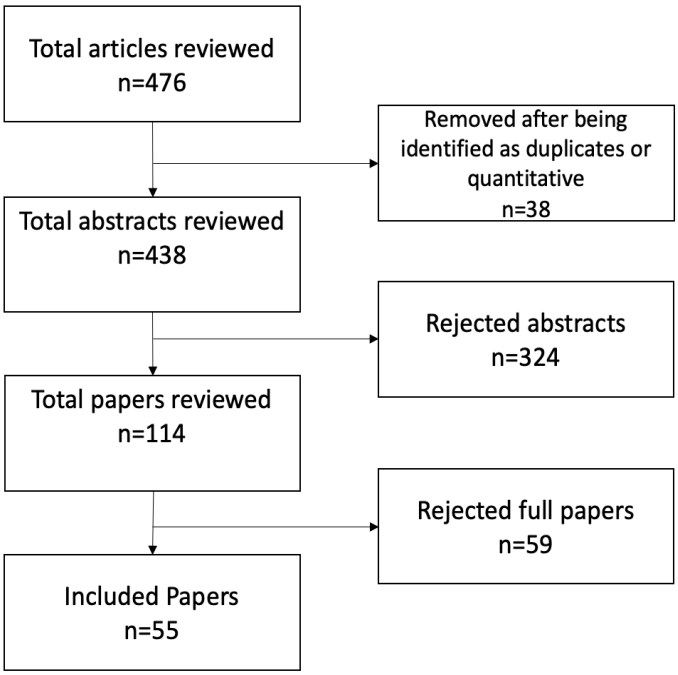
As part of the first step, three research questions were formulated:

1. What is understood by RTE in literature? How can RTE be defined?
2. What building blocks are needed to develop RTE?
3. What barriers hinder the development of RTE?

After formulating the research questions, a keyword search was conducted in the leading academic knowledge databases of Web of Science and SCOPUS. Queries were executed to find RTE-related research from the years 1990-2020. As academic research on RTE is still scarce, the same queries were repeated in Google Scholar to make sure to include all potentially important contributions beyond the two key databases. The following search terms were used: "real-time economy," "just-in-time economy," "now economy," "real-time" + "extended enterprise," "real-time platform," "real-time" + "public service," "real-time" + "supply chain," "real-time enterprise" + "interoperability," "real-time" + "XBRL."

The initial query retrieved 476 articles. Since Walsh and Downe (2005) suggest that the meta-synthesis method should be limited to qualitative studies, several review sessions took place to check the relevance of the articles for this study. First, 38 articles were ruled out because they were either identified as duplicates or quantitative research. A detailed abstract and keyword scan of the 438 remaining articles was conducted to identify the most relevant articles for the study. As a result, 324 articles were excluded due to their limited relevance. With 114 articles left, the last stage of filtering included full-text scanning. As a result, 55 articles were identified as relevant to this research topic and qualified for a detailed review. The literature selection process is summarized in Figure 1.

Figure 1: The selection process for the review of literature.



The authors conducted a thorough examination of 55 articles, focusing on their content to uncover meanings, key metaphors, and concepts that are discussed and are relevant to the purpose of this study (Walsh and Downe 2005). Findings from this step were then synthesized into broader, more abstract categories (Ang et al. 2019; Finfgeld-Connett 2010). The objective was to understand existing definitions of RTE, enablers, barriers, and key building blocks prescribed in the literature. From this exploration, three distinct yet complementary RTE perspectives emerged. Leveraging these perspectives, the authors develop an overarching RTE definition and model that are intended to serve as a guiding framework for future research and practical endeavors in the field.

The initial findings of the study were presented in the 2019 project report titled "Real-Time Economy: Definitions and Implementation Opportunities," co-authored by researchers conducting this study (Krimmer et al. 2019). The report offers a preliminary overview of RTE research based on a literature search executed in 2019, aiming to leverage RTE studies and empirical data for the development of policy recommendations and a roadmap for RTE implementation in Estonia. Since then, more studies on RTE emerged (Akagi 2023; Güldenkoh and Silberg 2022; Kästik 2019; Milisavljevic-Syed et al. 2020), whereas the gap for definitions and academic synthesis of RTE research has persisted. In response, the authors re-executed the literature search in spring 2020 based on the keywords used in 2019. The literature review served two goals: first, to systematically synthesize research findings within the RTE field and secondly, to lay the groundwork for future research by providing a cohesive and comprehensive overview of the RTE notion. The findings of the literature review have been summarized in Section 3.

The chosen method provides a systematic approach to synthesize studies across a research field (Walsh and Downe 2005). However, it is important to recognize its limitations. First, meta-

synthesis reviews are confined to qualitative research, excluding quantitative research from consideration (Walsh and Downe 2005). This is relevant as quantitative studies may provide valuable insights into RTE building blocks or barriers. Therefore, it is recommended that future research inquiries explore these avenues. A second limitation is related to the literature search terms. This study focuses on the "real-time" dimension of RTE, including synonymous terms such as "now-economy" and "just-in-time economy." This focus may have missed studies dedicated to specific RTE applications or aspects, as well as contributions related to "e-invoicing," "automated accounting," or "timeliness of information." As research in this area is evolving, extending the search terms in future studies can add valuable insights to the ongoing discussions.

3.Findings: What is an RTE?

3.1 Key perspectives

The literature review finds that the concept of the "RTE" has been present for over two decades. However, it remains a developing notion without a clear definition, and we identified three main streams of RTE research. While discussions on related topics are growing (e.g., automated reporting, automated taxation, or e-invoicing), they only offer partial insights into what a fully developed RTE ecosystem would look like in practice. To address this gap, our inquiry begins by examining diverse RTE perspectives from previous studies. Through a literature-based approach, we articulate how these various perspectives come together and make the RTE notion different from other digitalization initiatives.

For the first time, the RTE notion appears in The Economist article "How about now?" by Ludwig Siegele (2002). The author makes a critical distinction between the traditional economy and the "new" type of economy where distance and physical location are no longer relevant (Siegele 2002). Since 2002, the understanding and applications of RTE have evolved, and a broad range of concepts are now presented under this notion. A careful examination of existing RTE definitions in literature reveals the evolution of this concept through three perspectives inherent in the definitions: the financial perspective, the business network perspective, and an extended perspective that goes beyond the scope of the first two (Krimmer et al. 2019).

3.1.1 Financial perspective

The financial perspective is evident in research that focuses on applications and services tied to financial transactions, especially studies that focus on the automation of auditing, accounting, or quality control. The goal of this cluster of research is to contribute to increasing financial control for business owners, increasing process efficiency, and reducing (human) mistakes in financial services. Therefore, the RTE notion is often seen as a vision to digitally transform analog processes and improve operational efficiency, i.e., redesign business reporting processes that still rely on human interventions.

In contrast to Siegele's (2002) interpretation of RTE, this cluster of studies focuses on financial solutions implemented by individual enterprises. In this way, the financial perspective

provides a limited ecosystem perspective that emerges in later RTE research. Hence, it also does not address the implications of automated financial applications for business networks, government agencies, or end-users. Nonetheless, this cluster of studies links RTE solutions to various benefits, such as those related to automation and integration of financial management processes (Castka et al. 2020; Chan and Vasarhelyi 2011; Trigo et al. 2014; Vasarhelyi et al. 2005; Vasarhelyi, Teeter, et al. 2010; Vasarhelyi and Alles 2008), improvements in organizational efficiency (Castka et al. 2020; Eulerich and Kalinichenko 2018; Rydén and El Sawy 2019; Trigo et al. 2014; Vasarhelyi, Teeter, et al. 2010), improvements in the quality of decision-making (Castka et al. 2020; Eulerich and Kalinichenko 2018; Oliveira and Handfield 2019; Rydén and El Sawy 2019; Trigo et al. 2014; Vasarhelyi, Teeter, et al. 2010; Vasarhelyi and Alles 2008), improvements in the quality of information (Appelbaum et al. 2016; Eulerich and Kalinichenko 2018; Oliveira and Handfield 2019), and improvements in the forecasting capabilities and time responding to market changes (Appelbaum et al. 2016; Oliveira and Handfield 2019; Rydén and El Sawy 2019; Trigo et al. 2014; Vasarhelyi and Alles 2008). The key benefits of RTE from the business perspective are summarized in Table 1.

Table 1. Financial perspective on RTE

Financial perspective
RTE supports automation and integration of financial management processes.
RTE solutions improve organizational efficiency.
RTE solutions improve the quality of information.
RTE solutions improve the quality of decision-making.
RTE solutions improve forecasting capabilities.
RTE solutions reduce response times to market changes.

3.1.2 Business network perspective

Research on the business network perspective focuses on new (inter) organizational collaborations and sets digital ecosystems as a central variable for RTE. On the one hand, RTE is seen as a response to recent market changes, and on the other hand, as a way to improve business capabilities by tapping into the opportunities that ICTs create. The purpose of these studies is to highlight the value businesses capture in digital ecosystems that foster partnerships, facilitate the exchange of digital resources, support the free movement of data, and facilitate knowledge creation and exchange. In this context, "real-time enterprises" emerge as a novel business model compatible with the RTE vision. This business model enables organizations to create value based on business information and reduce delays by optimizing processes (Polites 2006).

Articles in the business network perspective also associate RTE ecosystems and applications with many benefits. These benefits include improving use of existing ICT infrastructures (Davenport et al. 2004; Kuhlin and Thielmann 2005), increasing the number of tools available to collect and process data on customer behavior (Oliveira and Handfield 2019; Rydén and El Sawy 2019), create new business opportunities and competitive advantages for RTE participants (Kuhlin and Thielmann 2005; Reichwald et al. 2005; Rydén and El Sawy 2019; Siegele 2002), provide real-time services and products, including real-time monitoring of

delivery (Chan and Chan 2006; Oliveira and Handfield 2019; Rydén and El Sawy 2019; Siegele 2002), enable real-time and local manufacturing (Kästik 2019; Reichwald et al. 2005; Vedeshin et al. 2020), support organizational differentiation in the market (Chan and Chan 2006; Kuhlin and Thielmann 2005; Reichwald et al. 2005; Siegele 2002), support real-time access to additional sources of information (Chan and Chan 2006; Davenport et al. 2004; Hope 2006; Kuhlin and Thielmann 2005; Oliveira and Handfield 2019; Rydén and El Sawy 2019), and reduce transaction costs (Kuhlin and Thielmann 2005; Siegele 2002). The benefits are summarized in Table 2.

Table 2. A business network perspective on RTE

Business network perspective
RTE is the network in which real-time enterprises perform their activities.
RTE solutions increase the use of existing ICT infrastructures.
RTE solutions increase the number of tools available to collect and process customer data.
RTE delivers new business opportunities and competitive advantages for RTE participants.
RTE allows firms to provide real-time services and products.
RTE supports real-time manufacturing.
RTE allows firms to differentiate themselves from the competition.
RTE provides direct access for companies to new sources of information.
RTE will reduce transaction costs for firms.

3.1.3 Extended RTE perspective

Research in the extended perspective broadens RTE interpretation and includes applications implemented by both the business sector and government agencies. While emphasizing the key role of businesses in a transition towards RTE, studies also recognize public administrations as a key force to drive the implementation of these initiatives in practice. This recognition is driven by significant cost-saving opportunities and the necessity to address broader governmental issues related to business administrative burden and organizational efficiency. Although studies on the extended perspective have recently emerged and are growing significantly, they do not yet offer a comprehensive understanding of the overall implications of RTE for the economy and society.

According to the extended view, RTE is a collaborative digital environment where financial and administrative transactions take place as close to real-time as possible and human interactions between businesses and governments are increasingly replaced by innovative forms of M2M communication (Harald 2018). In this scenario, most interactions between businesses and government, including financial reporting, would be contactless, automated, and take place as close to real-time as possible. The benefits associated with real-time M2M communication include a reduced administrative burden for organizations (Kästik 2019), improved business and operational efficiency (Kästik 2019), improved business transparency (Harald 2018), environmental benefits (Harald 2018; Penttinen 2008), stimulation of innovation and further developments in the field of artificial intelligence or AI (Harald 2018), further progress in the EU Digital Single Market Agenda and enhanced EU competitiveness on a global level (Harald 2018). The main benefits are summarized in Table 3.

Table 3. The extended perspective on RTE.

Extended perspective
RTE represents a virtual environment where transactions are performed as close as possible to real-time.
RTE environments connect citizens, businesses, and government.
RTE reduces administrative burdens.
RTE develops the context for further AI developments.
RTE supports businesses in improving operational efficiency.
RTE improves business transparency.
RTE solutions have environmental benefits.
RTE advances EU Digitalization Single Market Agenda.
RTE enhances EU competitiveness on a global level.

3.1.4 Developing an integrated understanding

Thus far, researchers have used various conceptual and operational definitions of RTE based on different perspectives discussed above. This has created ambiguity, hindering effective academic communication and impeding progress (Onyshkevych 1997). Conceptual ambiguity surrounding RTE has, therefore, challenged research progress and the development of more coherent theories, hypothesis, or research questions. To start addressing these concerns, we propose an integrated definition based on multiple attributes and features found in RTE literature. Using the "semantic decomposition" approach, as proposed by Akmaijan et al. (2017), we grouped existing RTE definitions and interpretations, extracted their core meanings, and formulated a more comprehensive definition to incorporate the key ideas circulating in the RTE literature. The draft version of the definition was initially presented in the project report by the authors of this study (Krimmer et al. 2019) and then re-evaluated further for the purpose of this article.

Constructing a definition entails a careful selection of properties associated with the concept (Onyshkevych 1997). Despite variations, the review of RTE interpretations revealed three core properties common across the definition. First, interactions in RTE take place in a M2M format. This refers to the exchange of data taking place autonomously between connected machines to reduce the need for human interventions and media breaks. Secondly, it necessitates the free flow of data across organizations, moving beyond traditional systems to encourage collaboration across ecosystems. Thirdly, RTE services are contactless and delivered close to real-time to ensure end-users experience minimal service delays (Weltevrede et al. 2014). Based on these insights, we propose to define RTE in the following way:

> *"Real-time Economy is a digital ecosystem where paperless transactions between public and private actors occur in or near real-time by way of an increasingly automated exchange of digital, structured and machine-readable data in a standardised format."*

In other terms, RTE is a broad concept that refers to the digitalization of business and administrative activities across a digital ecosystem. This includes transactions between business partners, interactions with the government, service delivery to end-users, organizational planning, and decision-making. RTE ecosystems are enabled by technologies

that support real-time collection, exchange, and use of data to perform activities in real-time or with minimal time lags to reduce the need for human interventions. The notion of RTE is particularly relevant in discussions about transactional services, such as invoices, receipts, business reporting, automated accounting, assurance, digital payments, and digital identification. Based on literature, shifting to RTE digital ecosystems based on M2M communication can lead to: (1) improved organizational efficiency, (2) increased process automation, (3) support for evidence-based governance, (4) enhanced connectivity among RTE participants, (5) greater business competitiveness, and (6) advancements in business forecasting. We argue that research and policies guided by this broad ecosystem view of RTE could be more effective in unlocking these benefits than previous fragmented efforts.

3.2 Building blocks

Due to the central role of ICTs in facilitating real-time data sharing (Davenport et al. 2004), service delivery, and consumption (Weltevrede et al. 2014), RTE literature maintains a strong technical focus. Therefore, the core building blocks of RTE are different types of ICTs, from hardware and sensors to AI solutions. However, the availability of digital technologies alone is not sufficient for a functional RTE environment. The latter also requires an e-service layer, constructed over the technologies, while reaping true benefits from RTE presumes a large-scale reorganization and rethinking of business processes at the organizational and cross-organizational levels. In other words, RTE requires the technology for production, storage, and sharing of data as well as rules and processes to govern the use of these data. Therefore, we divide the RTE building blocks into three layers: (1) core technological infrastructure, comprising the base solutions for RTE; (2) the e-service layer; and (3) the management layer, which encompasses business processes and management decisions relating to the use of data for organizational purposes. The building blocks are summarized in Table 5 and explained below.

Table 5. Building blocks and enablers of RTE

Technological layer	Common standards for M2M data exchange	Hardware and software for automatic data collection	XML languages	Digital nervous systems connecting value chains	Cross-organizational integration platforms	
E-service layer	eInvoicing, eReceipt	Continuous reporting and risk monitoring	Automated accounting, assurance, auditing	Real-time income register, taxation, asset reporting	eProcurement, ePayment, real-time forecasting	eID, eSignature, eAddress
Management layer	Measures to build trust between participants	Business process automation		Business process reengineering	Human decision-making frameworks	

Core technological infrastructure

Literature lists several technological enablers which facilitate the development of RTE. These include, foremost, different types of business software applications facilitating digital storage of business data and automated business processes, such as enterprise resource planning (ERP), customer relationship management (CRM), and electronic data interchange (EDI) systems (Appelbaum et al. 2016; Chan and Chan 2006; Vasarhelyi 2010). While ERPs serve as a key source of business data, EDIs facilitate M2M data exchange between organizations. Enterprise software systems have been used for decades but can also serve as a core enabler for real-time data exchange.

Another group of building blocks concerns standards for recording and exchanging data in machine-readable formats (Alles et al. 2002; Kuhlin and Thielmann 2005; Vasarhelyi, Alles, et al. 2010). An essential backbone for RTE is M2M communication standards and networks enabling connectivity between M2M devices, servers and users as well as M2M applications for processing and visualizing information in real-time (Nikaein and Krco 2011). The key to RTE is the harmonization and development of a common framework of standards (Al-Mashari et al. 2003; Chituc 2017; Umble et al. 2003; Molina et al. 2007; Narayanan et al. 2009; Nurmilaakso and Kotinurmi 2004; Penttinen 2008; Kirchmer 2004; Vasarhelyi 2008). Common standards are associated with improvements in the overall internal consistency of data (Topçu et al. 2014).

RTE literature regards eXtensible Markup Language (XML) based standards as central to managing real-time data (Chituc 2017; Eierle et al. 2014; Jones and Willis 2003; Gray and Miller 2009). XML involves machine and human-readable meta-languages used for e-document management, web publishing and data formats (Chituc 2017). XML provides the formal syntax for assigning codes and tags to define the meaning of the text and is used as a basis of specialized languages, such as the XBRL (Jones and Willis 2003).

XBRL is an XML-based format explicitly tailored for reporting and communicating business information (Eierle et al. 2014; Troshani et al. 2018). It provides a common language for assigning tags to information and exchanging data between diverse systems (Eierle et al. 2014). Although XBRL is still under development, it is already in use for web-based financial reporting, financial analysis, tax and regulatory filings, internal reports, and consolidations (Gray and Miller 2009). XBRL is also seen to have a high potential to support continuous computer-based auditing (Eulerich and Kalinichenko 2018). To date, XBRL has primarily been used for external reporting (Amrhein et al. 2009; Cohen 2009; Eierle et al. 2014; Gray and Miller 2009; Troshani et al. 2018). However, as not all information can be coded accurately with XBRL (Gary and Miller 2009), the XBRL GL taxonomy has been developed as an extension of XBRL. The XBRL GL taxonomy is recognized as a standard for representing financial and non-financial data with a high level of detail, which allows data exchanges between different systems and provides the means to drill down XBRL reports to a detailed level (Amrhein et al. 2009, Henderson et al. 2012).

RTE solutions are also facilitated by technologies such as hardware for automatic data collection, e.g., wireless sensors, radio-frequency identification (RFID), quick-response (QR) scanners, or global-positioning system (GPS) (Vasarhelyi 2011; Vasarhelyi et al. 2005) and emerging digital technologies such as AI and smart technologies. Emerging technologies

are estimated to create new opportunities for RTE, mostly as they support the automation of routine and non-routine tasks. However, existing literature does not give clear answers as to what business functions and processes could be automated with the help of AI and other smart technologies.

According to the literature, most RTE services are multifaceted and very complex in nature. Therefore, they can rarely be delivered merely by one independent entity. Consequently, organizational collaboration is recognized as the core principle upon which RTE institutions should be built. Such cross-organizational collaboration is enabled by digital nervous systems connecting enterprise, customers, employees, ICT, production, products and suppliers (Chan 2006; Siegele 2002) as well as platforms which enable integration of business processes on a cross-organizational level (Kuhlin and Thielman 2005).

E-service layer

The use of real-time solutions by businesses and other economic actors (customers, public organizations) is enabled by certain generic building blocks that constitute the e-service layer on top of underlying hardware and software. Applications such as e-invoices, e-receipts, and e-reports are often regarded as the core building blocks of RTE, allowing data about business transactions to be exchanged between transaction parties in real-time (Kuhlin and Thielman 2005; Harald 2018; Penttinen 2008). Real-time data exchange in several different fields is also facilitated by generic components such as eID, e-address, e-signature, e-payment, and e-procurement (Harald 2018, Penttinen 2008). Harald (2018) suggests that such generic services could also include a real-time income register, taxation, and asset reporting in the future.

Many authors focus on solutions that have become available for business managers to know and monitor the performance of their business in real-time (Harald 2018; Vasarhelyi and Alles 2008; Vasarhelyi et al. 2005; Vasarhelyi et al. 2010). This includes using different analytics and advanced dashboards to drill down, visualize and guide decision-making through real-time data. A key feature of RTE solutions is the possibility to automate monitoring and control processes (Vasarhelyi et al. 2005), including automated assurance, accounting, and auditing systems (Eulerich and Kalinichenko 2017; Harald 2018; Vasarhelyi and Alles 2008; Vasarhelyi 2011; Vasarhelyi et al. 2010). As organizations obtain access to real-time information on changes in the business environment, fundamental changes in risk monitoring and assessment are expected (Vasarhelyi et al. 2005; Vasarhelyi et al. 2010). Accounting will expand the measurement and reporting range from current business activities to underlying environmental factors, business strategy, lead actions, and consequent events (Mock et al. 2007; Vasarhelyi and Alles 2008). Reporting, risk monitoring, and assessment processes become continuous (Harald 2018; Vasarhelyi 2011; Vasarhelyi et al. 2005; Vasarhelyi et al. 2010), and monitoring data can be used for real-time forecasting (Harald 2018), e.g., with the help of applications and dashboards that visualize information (Kitchin et al. 2015). Moreover, such technological developments and the digitalization of core administrative and business functions also enable the shift from forecasting to "nowcasting" and predict the present or the very near plausible future (Amaboldi et al. 2017).

Management layer

Business process reengineering is regarded as a precondition for a functional RTE environment (Trego et al. 2014; Vasarhelyi et al. 2005; Vasarhelyi et al. 2010). In essence, public and private organizations must be able to redesign their business processes and establish organizational policies which align ICT strategies with general organizational goals. Moreover, organizations in RTE environments need to be able to aggregate data from different sources, integrate these into continuous measurement, monitoring, control and assurance processes, and enact advanced analytics systems (Vasarhelyi 2010). RTE also requires new management practices. For example, RTE accelerates business measurement, assessment, and business processes (Vasarhelyi and Alles 2008). The rise of real-time data supports innovations in KPI production, and significant progress in data visualization can improve accounting techniques (Knudsen 2020). Enterprises must also understand how to capture new business value in RTE ecosystems and support the integration of real-time solutions into their organizational context, culture, structures, and processes (Rydén and El Sawy 2019). Industries can improve customer experiences, save time and resources by establishing standard operating procedures, minimizing operational latencies and offering remote services in real-time (Rydén and El Sawy 2019).

RTE also presumes a better integration of human and automated decision-making. While recent technological advancements allow different business and administrative processes to be automated, literature on RTE still lacks sufficient reflections on the latest data-driven technologies and AI applications and their implications for RTE ecosystems. Older studies stress the need to achieve the integration of human and automatic decision-making processes (Vasarhelyi 2010) but highlight cognitive limitations, emphasizing that technologies are not fully capable of handling non-routine and complex tasks independently. Some of the limitations mentioned in this literature may soon become obsolete as rapid progress in the development of AI systems (in particular large language models) since the end of 2022 is reducing the need for human labor even for more complex tasks. it

In addition to integrating technology in decision-making, RTE also requires different inter-organizational collaborations that enable organizations to achieve common goals and deal with problems related to ecosystem development and maintenance. However, researchers suggest that maintaining inter-organizational collaborations can be challenging, especially when multiple different stakeholders are involved (Vangen and Huxham 2003). In this context, trust between actors is crucial to facilitate business interactions and nurture partnerships across the RTE ecosystems (Chen et al. 2006). Therefore, it is essential to develop (non) technological mechanisms (e.g., data governance frameworks) for increasing mutual trust between actors in the RTE ecosystem.

3.3 Barriers to RTE Adoption

The review suggests that RTE could become a driver of economy in the post-COVID-19 era by facilitating remote business interactions, enabling automated reporting, enhancing operational efficiency, and reducing administrative burdens. However, literature also associates problems with its implementation. Mapping barriers to adoption at an early stage

of development is essential to recognize the limitations of RTE and address concerns as soon as possible to facilitate later implementation stages.

By their nature, the barriers identified in this review are similar to those that digitalization initiatives face in general. The most prevalent impediments are related to the lack of resources in the right place, at the right time, or allocated to the right people. The implementation of RTE ecosystems and the shift toward M2M interactions will require the adoption of new ICT solutions and interventions in many business and administrative processes. Yet, businesses and government agencies may lack the required resources to cover upfront costs and development to instigate, operate, and maintain RTE solutions (Al-Mudimigh et al. 2004; Narayanan et al. 2009; Nurmilaakso and Kotinurmi 2004; Penttinen 2008).

Moreover, ownership of large-scale and complex RTE ecosystems is still hazy in literature. An essential question that needs an answer is who will build and own RTE ecosystems? If this is the sole responsibility of government agencies, how long will it take to develop such complex digital ecosystems? If the responsibility to set up RTE ecosystems is shared between public and private organizations, the question is how to balance power and design equitable RTE environments? This is especially important, assuming that SMEs lack the financial capital to contribute equally to such projects (Al-Mudimigh et al. 2004; Penttinen 2008). To fully harvest the benefits of RTE and participate in these digitally established ecosystems, firms also need to invest in reengineering some of their core business functions and processes. Lacking knowledge (Al-Mudimigh et al. 2004), financial resources, and time (Hope 2006) may reduce enthusiasm about the transition toward RTE.

On the other hand, despite the reduced costs of ICT, developing a sufficient portfolio of technical solutions is still presented as a critical barrier in the field. Participants need compatible ICT infrastructures and unified data standards to support the free flow of data in RTE ecosystems. That is why there are significant difficulties in creating RTE networks and connecting participants to communicate freely (Molina et al. 2007; Rabin 2003). The lack of common standards for information representation (Navarrete et al. 2010) and data exchange (Rabin 2003; Navarrete et al. 2010; Molina et al. 2007) is a major impediment cited in RTE literature. The presence of overlapping standards and semantic differences (Ducq et al. 2012) challenges the development of RTE solutions, as access may be restricted to only a narrow group.

Literature stresses that many organizations embody their IT systems in complex and widely established business practices. Offline processes, legacy systems (Belfo et al. 2015; Hope 2006), and incompatible technological applications (Ducq et al. 2012; Navarrete et al. 2010; Vera-Baquero et al. 2016) may lock organizations into their existing practices and hinder potential changes. Another technical barrier that the literature identifies is the result of the varying degrees of digitalization among RTE participants (Ducq et al. 2012). Since some businesses lack access to ICT tools and technological know-how, RTE solutions risk becoming exclusive and restricted only to specific organizations sharing established digital practices. On the other hand, a study in Estonia, Latvia, and Lithuania found that higher e-invoice penetration leads to a greater business willingness to adopt these technologies (Gunaratn 2020), creating the condition for a network effect that boosts e-invoice uptake.

Studies in this field also recognize organizational barriers as a concern to RTE implementation. Owing to its novelty, RTE implementation may require major changes in well-established business processes and administrative practices. That is why organizational and individual resistance to change is a key barrier threatening the implementation of RTE. While the goal is to reduce process latencies and improve input quality for decision-makers, many businesses risk not embracing RTE transformation, especially because of the vast changes required in management practices (Appelbaum et al. 2016; Al-Mudimigh et al. 2004).

The perceived risk that RTE relinquishes business autonomy and data ownership raises a significant barrier (Alles et al. 2002; Kästik 2019; Meijer 2015; Gray and Miller 2009). In a study measuring the attitude of Estonian enterprises toward e-services provided by the Estonian Tax and Customs Board, 63% of the respondents claimed they do not support the automatic transmission of business data to the state for reporting purposes (Kästik 2019). Kästik (2019) finds that three main perceived risks cause the resistance: (1) business owners believe they might lose control of their enterprises, (2) risk of third parties accessing their business data, and (3) the risk that the government will seek total control of the business environment.

In addition to resistance, studies in the field also highlight organizational and process incompatibilities among RTE participants as a possible barrier (Appelbaum et al. 2016; Al-Mudimigh et al. 2004; Chituc 2017; Lam 2005). RTE implementation requires a significant degree of process integration and unification among participants. However, aligning diverse organizational practices with the logic of RTE systems takes time. For example, a study of Estonian, Latvian, and Lithuanian enterprises found that most companies still rely on manual labor for e-invoicing operations even after adopting e-invoicing systems (Gunaratn 2020). If such gaps remain in place, especially within organizations and data transmissions between public and private sectors (Pang et al. 2014), establishing a joint digital ecosystem with shared access and unified e-services might be out of the horizon. A lack of consensus on issues such as division of labor, responsibilities, ownership, and authority (Chituc 2017) adds even more complexity to the large-scale transition.

Interestingly, RTE literature makes almost no mention of the effects of regulatory frameworks and legal constraints on RTE, although these are frequent barriers in digital government implementation literature. For example, research on e-invoicing shows that while there are no fundamental legal barriers that hinder the implementation of e-invoicing, the legislative requirements of different European Union Member States cause complexities when it comes to cross-border e-invoices (European Commission 2016). Even if states implement supportive legislation, variations in national rules may hinder cross-border initiatives (Karantjias et al. 2007).

The barriers mentioned in the literature mirror those associated with many other digitalization initiatives, in particular those striving for increased interoperability between systems and organizations. However, the ambition of RTE to transform business-as-usual comes with exceptionally high complexities, making the development of a common RTE ecosystem an extremely difficult task.

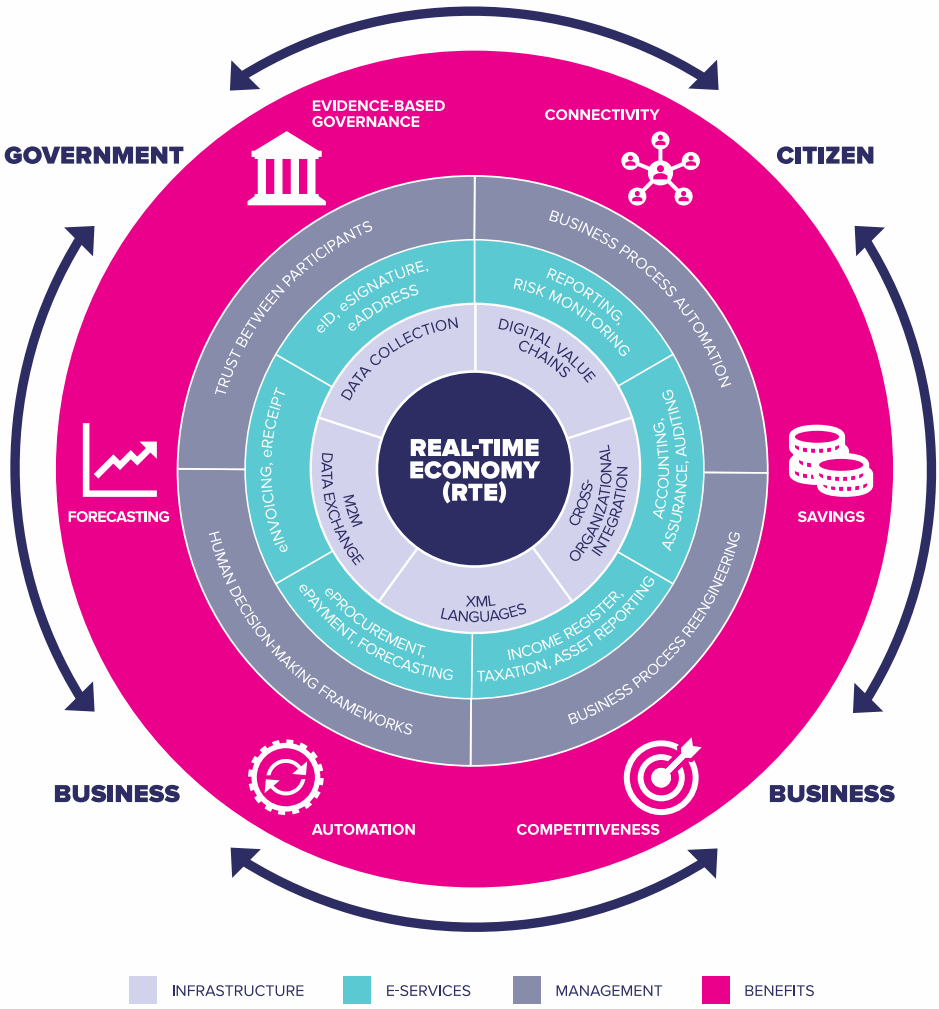
3.4 Proposal for an integrated conceptual model of RTE

Since its first appearance in 2002, the concept of RTE has undergone many changes. Today, a wide range of definitions and interpretations of RTE can be found in literature. This variety has several causes. First, literature on RTE has emerged spontaneously and in an uncoordinated manner from heterogeneous sources. Although initiatives such as e-invoices, e-receipts, or automated accounting all share RTE properties, these initiatives were developed in isolation and did not originally share a common vision. Second, the diverse nature of RTE applications and services allowed each component to become an independent field of research. For this reason, knowledge of RTE remains fragmented. There are also vast differences in what is meant by "real-time." While in some contexts, "real-time" means instant and immediate, there are cases where "real-time" may mean hours, days, and even weeks of process delays.

We argue that developing an overarching RTE definition is crucial to establish a foundation for future research and policy in the area. Moreover, the disruptive effects of the COVID-19 pandemic on the economy offered two essential lessons. In the face of a global emergency, business models and administrative processes relying on extensive use of human labor were no longer competitive. The spotlight is on developing standardized RTE solutions businesses could quickly adapt if they wish to advance their digitalization agenda and strengthen core business functions – from production to sales, service delivery, and business reporting. This helps to generate more savings and stimulate the adoption of new, digitally-driven, and competitive business models. In addition, the COVID-19 pandemic has vividly demonstrated the inefficiency of countries adopting isolated responses to global and pressing challenges. Our study argues that the concept of RTE provides a way to increase collaboration between national economies and for overcoming coordination failures to boost economic activity.

Below, we propose an integrated and refined conceptual model of RTE, based on findings from the literature review. This model primarily builds on the extended RTE perspective developed by the RTE Competence Center in Finland (Harald 2018; Penttinen 2008). According to this view, RTE could be considered as an ecosystem building on a digital infrastructure and consisting of digital applications that enable contactless real-time interactions between various stakeholders, most notably businesses and government agencies. This technology-driven ecosystem is regarded as providing fertile ground upon which innovations may emerge. Our model expands this view by including new actors (in particular citizens and consumers) and new interactions where the availability of structured business data in real-time could create or add economic value.

Figure 2. Integrated RTE ecosystem model (Source: authors).



This model presents RTE as a digital ecosystem encompassing the following elements: (1) RTE building blocks (the three internal layers), (2) the benefits that RTE applications create (outer layer), and (3) stakeholders and interactions in the RTE ecosystem (the outer circle).

The RTE ecosystem builds on *core enablers* at three levels: basic technological infrastructure, e-service layer, and management layer. The core technological enabler for RTE is the collection and availability of digital structured data, which could be exchanged through M2M communication and without human intervention. M2M communication is facilitated by uniform and widely used data standards, which so far have been mainly based on XML languages. Digitalized value chains and cross-organizational integration constitute additional preconditions for RTE-based services, whereas generic digital infrastructure components such as eID, eSignature, and eAddress enable conducting transactions fully digitally.

These core and generic components are used by *e-services*, which make up the second layer of the RTE model. These include both services consumed internally by a company (i.e., reporting and automated risk monitoring) and services that facilitate transactions and information exchange between businesses (i.e., e-procurement, e-invoicing), or between businesses and government bodies (i.e., automated business reporting, automated taxation, etc.).

The *management layer* refers to the changes needed at the level of business processes for RTE stakeholders to facilitate the adoption of this concept and reap the benefits of real-time data exchange. The availability of technological and service infrastructures enables the reengineering and automation of a number of standard business processes, including electronic invoices, executing payments, accounting, etc., to increase business efficiency. At the same, combining automated and human decision-making frameworks supports the execution of more complex business processes, which cannot be automated at this point in time. This layer also includes trust between public and private parties as an essential prerequisite of RTE (Kattel and Mergel 2019), requiring action and the formation of trusted relationships at the level of business management.

The RTE ecosystem connects three main *actors*: businesses, public sector organizations, and citizens. Whereas existing approaches to RTE primarily emphasize business-to-business (B2B) and business-to-government (B2G) interactions, our model expands these approaches by explicitly including citizens as stakeholders in the ecosystem. This aims to highlight the opportunity to create new value emerging from real-time digital communication between businesses and customers, but also between government agencies and citizens.

The backbone of the RTE ecosystems is the opportunity for contactless and real-time B2B communication in the form of instant, automated transactions between different partners (the main focus of the business network perspective), which holds the key to increasing business competitiveness on a national level. Real-time B2G interactions in automated reporting (emphasized in the extended perspective) also generate economic *benefits* through reduced administrative burdens, allowing companies to save time and resources and focus on their core business functions. For public bodies, real-time data from businesses is an important source of intelligent decision-making, evidence-based policies, and enables government bodies to forecast economic developments, risks, take predictive measures and boost the economy as needed.

In addition to B2B and B2G interactions, we argue that real-time business-to-customer (B2C) interactions are becoming increasingly important as a source of added value for businesses and customers, as well as a driver of new business models and innovation in commercial products and services. There are RTE solutions in use applying blockchain and the Internet of Things (IoT) in trade and logistics, which allows key stakeholders to exchange information in real-time, stay abreast of the state of goods and the status of shipments, and replace paper-based processes with smart contracts (Engin and Treleaven 2019). The advantages of digital real-time B2C (and C2B) interactions also became evident during the COVID-19 pandemic. The RTE logic, which is based on digital, fully automated, real-time, and contactless communication, perfectly aligns with the growing interest in online orders, contactless home delivery, instant e-payments, and real-time tracking of deliveries. Therefore, RTE solutions deliver numerous innovative opportunities to improve customer relationship management, accelerate service delivery, increase product/service personalization, and track goods along the value chain. In a full-fledged RTE ecosystem, citizens/customers act as key players, alongside businesses and public bodies.

Due to the origin of the RTE notion in business management literature, G2C relationships have been almost entirely disregarded in current RTE studies. However, instant data exchange

can play a crucial role in strengthening public efficiency and offering new mechanisms to create public value. This enables governments to save taxpayers money by optimizing the management of public resources, providing new automated and online services to citizens, and reducing administrative burdens by enabling citizens to share certain data with public bodies in real-time.

This brings us to the role of government bodies in the RTE ecosystem. In addition to public service provision to companies and individuals, the government acts as a platform and an enabler for various interactions between other ecosystem stakeholders (Linders 2012). Government bodies have the power to create favorable regulations supporting real-time data exchange and strengthening international standardization efforts to prevent the creation of isolated "digital RTE islands." Governments can also provide incentives and support for business digitalization as well as the basic technical infrastructure for companies to lower barriers to the large-scale adoption of RTE solutions. This can be done, for example, by providing simple free or low-cost software with functionalities to store accounting data as machine-readable data, send and receive e-invoices and e-receipts, submit reports to the government, etc. Our model, therefore, also suggests a policy agenda for governments interested in stimulating the economy through adopting RTE solutions.

When comparing our proposed model with existing literature on RTE, some differences become apparent. For example, e-invoicing, automated accounting, and forecasting have a relatively prominent place both in the literature and in our model. Other elements, such as electronic identity and human decision-making frameworks, are less-well represented in previous works on RTE. This model also stresses the benefits businesses can gain by becoming part of the RTE ecosystems. In particular, the idea to create new business value and develop new digital capabilities for enterprises is the fuel driving RTE implementation. At the core, RTE is an indirect digital mechanism helping firms enhance their operational practices by increasing organizational efficiency, creating new partnerships, and improving business profitability. Unlike most literature, our model places more attention on the role of government as an actor in the RTE ecosystem. We argue that in order for harmonized RTE solutions to emerge, governments need to steer and coordinate the development of the RTE system. Governments also have the potential to gain from investments in RTE – access to business information in real-time would enable governments to forecast economic trends in real-time and use real-time evidence in decision-making for economic policy to anticipate changes in the economic environment. In addition, this model highlights the role of citizens/customers as an important actor in RTE environments, which has received minimal attention in the RTE literature so far. Hence, we propose to focus more on the value that RTE solutions generate for this group and explore citizens' roles and responsibilities in RTE ecosystems.

4. Implications and future prospects: Is RTE the next stage of digital transformation?

Current discussions on RTE in both academic and policy circles have highlighted opportunities for creating and monitoring a contactless economy in real-time. This study contributes by synthesizing these discussions into a comprehensive model. Our model aims to help researchers identify new questions and assist practitioners in implementing RTE visions

effectively. However, this will not come easy. The implementation of RTE solutions faces a number of barriers which prevent these systems from quickly taking root in the economy. Some of these barriers deserve particular attention.

One of the first barriers concerns legacy systems and institutional path dependencies. Authors (e.g., Harald et al. 2018) have focused on analyzing and modeling RTE's societal and economic benefits in comparison with analogue (pre-RTE) options, i.e., on the effects of shifting from paper-based towards an automated digital economy. Such works mainly indicate that RTE can boost the effectiveness of the economy by automating several manual processes. While this seems like a valid argument, it ignores the legacy of the locked-in analogue systems due to path dependency. This, in turn, relates to a number of barriers (technical, organizational, legal) as discussed above. History can relate several examples of innovations that were technologically advanced but failed to challenge inferior technologies. According to the classical case introduced by W. Brian Arthur, Sony's Beta was superior to the VHS technology of JVC (Arthur 1990). However, the market's choice did not represent the optimal economic outcome. This can be explained by path dependency: decisions by earlier adopters are expected to have an effect on the decisions of later adopters. According to Barnes, Gartland, and Stack (2004), path dependency can be triggered both by technological lock-in (e.g., technology standards and legacy technologies) and behavioural lock-in (human habits). Similarly, David (1985) argued that the widespread QWERTY keyboard arrangement is inferior to the DHIATENSOR arrangement provided by August Dvorak – the latter would allow for faster typing as the letters are more systematically placed. However, due to technological and behavioral lock-in, society has decided to stay with the QWERTY keyboard as the standard.

In other words, if we were to introduce solutions for business transactions in 2023, we would not come up with analog and paper-based solutions such as invoices, receipts, banknotes, or checks since more effective technological solutions are already available. However, since business information systems and human practices cannot be restarted from scratch, we need to take into account path dependencies and lock-ins that hinder breakthroughs of radical innovations. Below, we list some examples of complex RTE services that follow the path dependency of pre-digital solutions but would likely follow different designs in RTE ecosystems:

- Real-time taxes. There is significant latency in how taxes are collected, going back to medieval times. In the era of ICT, there is no need for citizens to receive overpaid labor taxes, returned with delays of up to tens of months. There is also no objective need today to distinguish between payment of wages and taxes to justify several months' delay in paying labor taxes. Similarly, in RTE, Value-Added Tax (VAT) could be collected automatically. If company A transacts business with company B, VAT could be deducted automatically and collected by the Tax Authority instead of claiming back overpaid or underpaid VAT with all the related reporting and accounting involved.
- Real-time accounting, data-based reporting, analysis, and audit. A legal entity's annual report is another example of practice from the pre-digital era. In the digital economy, it makes little sense to create tens of months of delays in presenting reliable financial data to external parties. Currently, financial information of transactions will often only become available with approximately 18 months' delay for most SMEs. The actual value of such reports for business partners and economic policy-makers can

be limited, especially in dynamic economies. In a real-time environment, there could be automatic daily, weekly, or monthly reports in order to build trust. At the same time, company management could enjoy a real-time view of their current accounts, cash flow, and sales. In turn, outcomes of analysis and auditing benefit companies due to earlier reports.

Is it possible to radically switch from an analog to a digital economy? Under normal circumstances, this is very complicated due to path dependencies, lock-ins, and other barriers. Rebuilding an old farmhouse into a new smart zero-energy house is difficult unless radical changes are implemented (e.g., deconstruction on purpose) or unless extreme situations occur, such as a fire burning the old building down. During stable periods, radical innovations are complex, painful, and expensive. However, during extreme (and mostly unwanted) crises, the leap-frogging effect may effectively enable bypassing intermediate stages of technology development and stimulate the adoption of radically new practices.

Therefore, it is interesting to understand the impact of the COVID-19 pandemic in automating the economy and what kinds of leap-frogging effects it has created to overcome the existing barriers to RTE. When it started, the COVID-19 pandemic socially isolated approximately one third to a half of the global population for months, with severe effects on the economy. At the same time, while face-to-face communication and traveling were on pause, the lockdowns increased the adoption of different digital solutions and boosted M2M interactions. Although more research is needed on the impacts of the pandemic, it has likely accelerated the global shift towards digital, contactless, and real-time applications:

- Cash-based transactions have decreased significantly.
- There has been a significant shift toward e-invoicing. For late-adopters who preferred paper-based solutions, COVID-19 provided an impetus to switch to digital ones.
- On many levels, paper receipts were replaced by digital ones.
- Key service providers were required to offer more digital, contactless, and automated services (e.g., open bank accounts or negotiate loan agreements when socially distanced via video link-up).
- The crisis boosted the adoption and development of digital validation tools, including authentication and certified digital signatures.
- Private and public sectors increased the number of digital and automated services. This creates an opportunity to integrate these services effectively with financial services providers such as banks, leading to automated salary payments, and VAT declarations.

In addition to numerous developments and opportunities, implementation of RTE may also pose risks, which – much to our surprise – are infrequently discussed in the existing literature. Based on the few existing studies, one of the key risks concerns maintaining the confidentiality of company business secrets. Exchanging real-time data and offering real-time services exposes data to the risk of leaks to unauthorized parties and increases demand for transparent cryptography services. Loss of control over data is perceived as a real risk that business owners associate with sharing real-time data; furthermore, entrepreneurs fear

that real-time data provision to government agencies may yield excessive control over the business environment to the state (Kästik 2019). These are valid concerns meriting more attention in future research on RTE and careful consideration in emerging RTE policy initiatives.

Moving forward, the COVID-19 pandemic established a potential turning point for the digital economy, as it has created a clear division between the pre-pandemic and post-pandemic worlds. While the former prefers human contact and analog interventions, the latter is much more about automation, as well as integrated data opportunities at the expense of privacy and confidentiality. Despite technological advancements and two decades of thinking, the development of RTE ecosystems has been slow in practice and rife with barriers. Although consistent efforts to develop RTE in stable times help build the foundation for change. pandemics or other unexpected sources of pressure may stimulate a more radical switch than has been possible previously.

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Art Alishani is a Junior Research Fellow at the Johan Skytte Institute of Political Science at the University of Tartu. He holds an MSc in Public Sector Innovation and e-Governance (KU Leuven, University of Münster, and TalTech). Art's PhD research focuses on the uses of artificial intelligence applications in encounters between citizens and government, and what this means for their relationship. Email: art.alishani@ut.ee

Ralf-Martin Soe is an Assistant Professor of Smart City Studies and a Founding Director of the FinEst Centre for Smart Cities (www.finestcentre.eu) at Tallinn University of Technology (Estonia). In 2024, he was also an Academic Visitor at the Computer Science Department of Aalto University (Finland) and in 2023, he was a Global Digital Governance Fellow at Stanford University (USA). His previous positions include being an ICT Counsellor to the Minister of Entrepreneurship and Information Technology in Estonia, a Supervisory Board Member at the Estonian Internet Foundation and a Government Fellow at the United Nations University's e-Government Unit (Portugal). During 2009-2013, he was a Financial and Digitalization Consultant working with the UK Government, PwC, Praxis and United Nations University. From 2006-2009, he was an Investigative Journalist at the Business Daily Äripäev and was selected as the Best Young Journalist in Estonia by the Estonian Newspaper Association in 2008, after several nominations. Ralf has two master's degrees in financial management (MSc, Maastricht University/ United Nations University and MBA, University of Tartu) and has a PhD degree in Technology Governance from TalTech. He was selected as the TalTech Junior Researcher of the Year 2019 and most influential person of the year 2019 in Estonia by the Estonian Association of Information Technology and Telecommunications.

Tarmo Kadak is Associate Professor of Accounting at Tallinn University of Technology. He received his PhD from the same University in 2011. His research interests include best practice and benefits from Costing, Management Accounting, Performance Measurement and Management, Real-Time Economy, Accounting Information Systems. He has researched these topics in business and as well in public sector organizations. He has published a number of papers in leading journals such as Measuring Business Excellence, International Journal of Productivity and Performance Management, International Journal of Management and Enterprise Development and Journal of Business Economics and Management.

Robert Krimmer is a digital transformation expert and entrepreneur. Between 2014 and 2022 he was a professor for e-governance in Estonia. Since 2022, he has been focusing on digital transformation in the private sector.