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The Quest for National Digital Agility: Digital Responses to Covid-19 in Five Countries

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Abstract:

Countries worldwide have employed different digital solutions to contain and cope with the Covid-19 pandemic. In this explorative case research, we examine national-level digital responses to the pandemic in four specific areas—tracking and tracing, health data reporting, teleconsultation, and vaccination mobilization—across five countries: China, Denmark, Germany, South Korea, and the U.S. Drawing on the notion of agility and digital infrastructures, our cross-case analysis unveils how the countries' digital responses to the pandemic have been shaped by their national health system characteristics. In addition, we highlight how existing digital health infrastructures, regulatory adaptations, and industry collaborations fostered the alacrity with which nations responded to the pandemic. We define national-level digital agility as the ability of a nation to leverage digital infrastructure capabilities to address urgent societal challenges in a contextually appropriate way. Our key contribution is a model of this complex, but urgently needed concept containing five building blocks, each of which is a critical prerequisite to building such agility. Despite focusing on addressing the existing challenges of the ongoing Covid-19 pandemic, we believe that researchers and policymakers can also take pointers away from our framework to tackle other socio-environmental challenges.

Keywords: COVID-19, Organizational Agility, Digital Infrastructures, Cross-country Research, Policy Implications.

[Department statements, if appropriate, will be added by the editors. Teaching cases and panel reports will have a statement, which is also added by the editors.]

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1 Introduction

The Covid-19 pandemic, despite being a humanitarian crisis with yet inestimable impacts for global health and economics (Cash & Patel, 2020), has been viewed by many as an unprecedented accelerator for digital transformation initiatives in healthcare and other sectors (Marr, 2020; Mumm et al., 2021; Stern et al., 2020). At the same time, the pandemic exposed existing structural weaknesses within many countries' health systems and their underlying technology infrastructures (Faraj et al., 2021). In many countries, established processes and legislation had to be changed swiftly to adapt to the pandemic (Harris et al., 2020). Both, existing digital infrastructures and rapidly developed new digital platforms played a major role in responding to the crisis, by tracking and tracing the virus spread (Quer et al., 2021; Riemer et al., 2020; Rowe et al., 2020; Urbaczewski & Lee, 2020), allowing in-time public health reporting and analytics (Pietz et al., 2020; Recker, 2021), enabling physicians and patients to engage in remote consultations (Anthony Jnr., 2020; Wherton et al., 2020), and mobilizing the population for the vaccination campaigns and issuing digital vaccination passports (Dasgupta et al., 2021; Marhold & Fell, 2021; The Lancet Digital Health, 2021). While the pandemic represented a shock of global scale, countries worldwide had different starting positions in digital health. Their initiatives to address the specific challenges of the pandemic differed widely in terms of the speed and the design choices made, depending significantly on their national healthcare system characteristics.

Following calls from IS researchers to consider how the IS discipline can help address the world's grand challenges (Davidson et al., 2023; Faik et al., 2020; Majchrzak et al., 2016), this inductive exploratory case study is conducted in a cross-national context. We build on the premise that the Covid-19 crisis presents a unique opportunity for research in information systems that can provide helpful knowledge and insights (Ågerfalk et al., 2020; Sein, 2020a), specifically for exploring digital agility on a national level. Although national digital agility, understood here as the ability to address urgent societal challenges through technological capabilities, is key in a situation of an exponential virus spread, there is limited insight into how governments can actually facilitate this type of agility. In fact, many governments have been criticized for not having been agile enough (e.g., Janssen & van der Voort, 2020) and countries have had varying degrees of success in fighting the pandemic through digital means (Haug et al., 2020). In order to learn from the past and to prepare for the future, researchers and policy makers have a legitimate interest in knowing how a country can become more digitally agile. This is especially important given that Covid-19 is seen by many as part of a pattern of increasingly frequent epidemics that are interwoven with climate change and other environmental problems (Lancet, 2021). Therefore, a country's ability to marshal its digital capabilities to respond in a timely manner will be an essential element to combat such issues and to contain their adverse effects (Sakurai & Chughtai, 2020). Accordingly, the key question we examine in this research is: how can one conceptualize, describe, and foster digital agility at the country level?

In an attempt to address this question, we first review prior literature on agility (e.g., Park, El Sawy, & Fiss, 2017; Tallon, Queiroz, Coltman, & Sharma, 2019) and digital infrastructures (e.g., Hanseth & Lyytinen, 2010; Henfridsson & Bygstad, 2013; Tilson, Lyytinen, & Sørensen, 2010), as the realities of the digital era need to be considered to conceptualize digital agility (Salmela et al., 2022). We do so under the premise that there is a need for understanding concepts such as agility and digital infrastructures at the macro level of an entire country to study digital responses to Covid-19 (Riemer et al., 2020). We then examine digital responses to the pandemic in the areas of tracking and tracing, health data reporting, teleconsultation, and vaccination mobilization across five countries that have taken different trajectories in their fight against the pandemic: China, Denmark, Germany, South Korea, and the U.S. We iterated our comparative research continuously as the pandemic progressed, with a focus on how the countries' health system characteristics influenced the speed and nature of their digital responses to Covid-19.

Our cross-country comparison yields a model of five building blocks that jointly explain and contribute to national digital agility in the context of a global health crisis. We argue that national digital agility is about policy makers (1) weighing design options for digital responses and (2) selecting and implementing them to (3) fit the sectoral system with its actors. In this process, decision makers could and should (4) harness digital infrastructures and (5) leverage potential facilitators to build these solutions. We also discuss how our conceptualization of national digital agility differs from established notions of (organizational) agility predominant in the literature and how it provides an impetus for further comparative cross-country research in digital health and other societally relevant information systems phenomena. Our research contributes to the literature by proposing a first definition of national digital agility and a conceptual model

that fuses agility with infrastructure thinking at the national level. As such, it has the potential to inform research and practice on how to build, foster, and enhance national digital agility, and serve as a foundation for further research.

2 Theoretical Framework: Towards National-level Digital Agility

2.1 The Concept of Agility

In today's globalized and dynamically changing environment, business research and practice have taken great interest in studying agility (Tallon et al., 2019). In general, "being agile means being proficient at change" (Dove, 2001, p. 5). The concept originated in fields in which organizations were exposed to a high level of uncertainty (e.g., software development or manufacturing) and needed to react in an adequate way. Although existing studies have considered the agility construct on various levels, including team and process levels (Sambamurthy et al., 2003), the majority of the literature has focused on agility as an organization-level construct (Park et al., 2017; Tallon et al., 2019), which is often described as "the ability of an organization to sense and respond with a relative degree of speed to environmental changes and to take advantage of new opportunities" (Chan et al., 2019, p. 438).

Recent events with global impact, such as the Covid-19 pandemic, have distinctly highlighted that entire nations must react to environmental changes. What we lack in this context, however, is an understanding of agility at the national level. In a globalized world, a country can be seen as part of a rapidly changing global ecosystem, where events outside as well as within its own borders require adequate reactions with an appropriate degree of speed. In other words, it requires agility. However, orchestrating the response of a nation is remarkably different from that of an organization due to the involvement of a variety of actors and applicable regulations. Because we cannot simply adopt the existing notion of agility on a higher level, we argue that it is necessary to inductively explore agility as a new concept at the macro level. More specifically, because Covid-19 has shown how information technology and digital infrastructures have become indispensable for responding to a global crisis of this kind, there is a need to take a closer look at national digital agility from a research perspective and attempt a first exploration and conceptualization of this notion.

2.2 The Role of Digital Infrastructures

Information technologies and systems play a pivotal role in the emergence of agility and have been studied at different levels—from the individual to the global level. In order to better understand the challenges related to managing a set of highly interconnected systems, the literature has adopted the notion of digital infrastructure (Henfridsson & Bygstad, 2013).[1] Digital infrastructures can be defined as the "basic information technologies and organizational structures, along with the related services and facilities necessary for an enterprise or industry to function" (Tilson et al., 2010, p. 1). Structurally, they are recursively composed of other infrastructures, platforms or apps[2] and often governed by emergent and distributed forms of control (Hanseth & Lyytinen, 2010). Digital infrastructures represent a new stage in the evolution of information technology inasmuch as they are deeply embedded in our everyday lives and connect diverse sociotechnical worlds (Star & Ruhleder, 1996; Tilson et al., 2010). They are coordinated through numerous technological standards by taking on "transparency by plugging into other infrastructures and tools in a standardized fashion" (Star & Ruhleder, 1996, p. 113). This embeddedness is illustrated by the fact that the impact of digital infrastructures usually becomes most visible when they break down (Star & Ruhleder, 1996; Tilson et al., 2010).

Digital infrastructures exist and can be analyzed at various levels (Tilson et al., 2010), ranging from organizational levels (e.g., the evolving system landscape of an airline company, Henfridsson & Bygstad, 2013), to regional (e.g., a standardized patient data exchange, Aanestad & Jensen, 2011), national and global levels (e.g., the emergence of the Internet, Hanseth & Lyytinen, 2010). Studies taking a digital infrastructure perspective share the notion that digital infrastructures are heterogeneous, open, unbounded and shared socio-technical systems that evolve over time (Hanseth & Lyytinen, 2010). Their

[1] While different terms (e.g., information infrastructure, information technology infrastructure, digital infrastructure) have emerged to capture the phenomenon of interconnected sociotechnical systems, we follow the commentary of Tilson et al. (2010) and use the term digital infrastructure throughout this paper to refer to this key concept.
[2] We use the term apps to refer to software applications (regardless of whether they are stationary, mobile, web-based, etc.).

overall evolution results from the evolution of their individual, but interdependent systems in relation to each other (Fürstenau et al., 2019).

To understand how digital infrastructures evolve over time, Henfridsson and Bygstad (2013) paid attention to three generative mechanisms of evolution, each of which is a self-reinforcing process that propels the growth of a digital infrastructure in a different dimension. Innovation is described as the creation of new products or services that is enabled by malleable infrastructures which allow a recombination of resources. Adoption illustrates the increasing usefulness of the infrastructure as more resources are invested because more users adopt the infrastructure. Scaling describes the expansion of the infrastructure's reach through the creation of collaboration incentives that attracts new partners and user groups (Henfridsson & Bygstad, 2013).—Our research uses these mechanisms to describe how digital health infrastructures potentially evolved to support national digital responses to the Covid-19 pandemic.

2.3 Covid-19 as an Opportunity for Cross-Country Research on Digital Agility

While agility has been primarily studied at the organization level, both agility and digital infrastructures are concepts that lend themselves to the analysis at various levels. From the evolvable systems perspective, a "system-level approach is conceptually agnostic to the unit of analysis" (Agarwal & Tiwana, 2015, p. 476). This notion also applies to adaptive complex systems such as digital infrastructures (Hanseth & Lyytinen, 2010). In this context, one can zoom in to a micro level or zoom out to a macro level. A wide range of variations are possible in this context, from the microarchitecture of an individual app to the macro-architecture of an ecosystem or an entire country (Agarwal & Tiwana, 2015). Similarly, our understanding of agility can be extended "to obtain finer insights into what we already know by using a new level of analysis" (Tallon et al., 2019, p. 231). Some agility research has focused on the micro-level of a process or a user. The research presented here, in contrast, shifts the level of analysis to a macro-level to study the digital agility of an entire country and its health system (including its institutions, people, and policies) as the focal entity of investigation. In an attempt to develop a new concept that is conceptually clear (Suddaby, 2017), we inductively derive a definition and a framework for national digital agility.

The Covid-19 pandemic, due to its global scale and synchronicity, provides a unique opportunity to study digital agility at a national health system level (Sein, 2020b). A crisis such as Covid-19 can be seen as a system shock that shifted the mode of operation drastically from a non-volatile (e.g., with relatively stable and predictable patient intake) to a highly volatile one (e.g., exponentially increasing patient numbers and high uncertainty). Time plays a pivotal role in the situation of a pandemic (Ågerfalk et al., 2020), and so does agility. Therefore, it is worth studying how different countries reacted to this shock and how this resulted in various digital platforms designed to respond to the crisis situation.

The majority of Covid-19 studies in information systems has focused on singular areas of responses to the crisis, such as the adoption, governance and effectiveness of (voluntary or mandatory) digital contact tracing applications (Riemer et al., 2020; Rowe et al., 2020; Urbaczewski & Lee, 2020) and design principles for and communication effectiveness of reporting dashboards (Pietz et al., 2020; Recker, 2021). Other research addressed usage guidelines and implementation challenges of teleconsultation solutions (Anthony Jnr., 2020; Wherton et al., 2020), interoperability of vaccination certificates (Marhold & Fell, 2021) and functionality of vaccine apps (Dasgupta et al., 2021). This study considers multiple areas of digital responses to Covid-19, including tracking and tracing, health data reporting, teleconsultation, and vaccination mobilization, with the goal of understanding national digital agility.

While national health systems are usually not thought of as being particularly agile, a few authors have recently put forward the notion of agility in the context of Covid-19 and made different geographical references. For example, Moon (2020) describes the early agile, adaptive, and transparent actions of the government of South Korea, a country that has often been cited for its successful management of the pandemic. Janssen and van der Voort (2020) contrast the concept of agile governance with adaptive governance based on Covid-19 events in the Netherlands. In a BMJ editorial, Mak et al. (2020) even speak of a "global regulatory agility" that captured the world in the wake of this health emergency.—While these voices underline the increasing attention on agility as a macro-level concept, this discourse has not yet conceptualized national digital agility and also lacked cross-country research designed to unveil how policy-makers can foster this type of agility.

This inductive exploratory case research conceptualizes national digital agility as the ability of a nation to leverage digital infrastructure capabilities to address urgent societal challenges in a contextually appropriate way. Recognizing the equifinality in the notion of (organizational) agility, and given the crucial

role of the structural and cultural preconditions of each country (Avgerou, 2001), we expect the creation of national digital agility to be highly context dependent. Especially regarding Covid-19, "context is central to the control of any epidemic" and therefore of high importance (Cash & Patel, 2020, p. 1687). Within the existing literature, there is surprisingly little cross-country research on information system phenomena within healthcare. Exceptions focus on specific health information technologies such as electronic health records (EHR) (Jha et al., 2008) and computerized physician order entry systems (CPOE) (Aarts & Koppel, 2009). We are therefore hopeful that this cross-country study of national digital agility will also provide an impetus for researchers to incorporate the role of national context in health information systems research more broadly.

3 Methods: Four Phases of Comparative Research

The research presented in this paper encapsulates a multi-year effort by authors from five different countries.[3] We argue the set of included countries as a revelatory one to study national digital agility because it includes industrialized countries of different sizes, all of which have often been cited for their particular—successful or less successful—management of the pandemic. Our research can be described as a process constituting four major phases (see Figure 1).

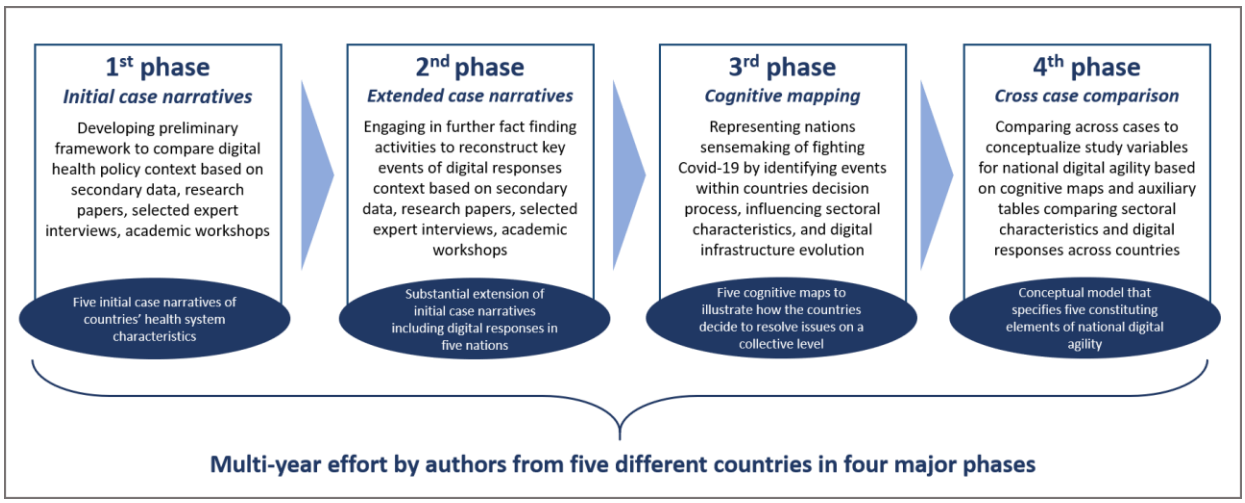

Figure 1. Methodological Approach

With the initial aim to study emerging digital health policies across nations, we designed a data aggregation process to gather information about the countries in our included set. Data on national digital health policies and their contextual characteristics was collected through the study of secondary sources (e.g., policy documents, government websites, news articles), selected expert interviews, and a series of academic workshops at four locations. The dual purpose of these workshops held in Denmark, Germany, the USA, and Hong Kong[4] was to present the preliminary results to the audiences as well as to obtain feedback from panels of invited health information systems researchers and local participants with the goal to shape this explorative research effort. These meetings were also helpful in contextualizing our research in the actual health issues facing each country. These different data collection and aggregation methods thus helped establish the facts, referring to "objective, and publicly verifiable observations and truths" (Sarker et al., 2018, p. 758; Silverman, 2001). In the course of this first phase, a preliminary comparative framework was developed (including structure, policy, socio-cultural, and technology dimensions) which allowed for the comparison of the digital health policy context in each country. The findings were captured in five initial case narratives[5], that employed this framework as a common structure.

The research focuses on national digital agility as a core phenomenon emerged in early 2020 when the Covid-19 pandemic hit the world. Our preliminary framework from phase one provided a robust foundation to study the responses of various nations to the Covid-19 pandemic in their respective contexts. We

[3] We refer to the location of academic affiliation, rather than the nationality, when describing the author team of this paper.
[4] The Hong Kong workshop invited academics from China and South Korea, amongst other researchers.
[5] The supplementary case narratives are provided in Kendziorra et al. (2023)

considered the digital responses of different countries to this global shock as an opportunity to study national digital agility in a quasi-natural experiment setting (DiNardo, 2008). In this second phase, we engaged in further fact-finding activities to reconstruct the key events in four emerging areas of digital responses, which cover the initial approaches to tracking and tracing in early 2020 and end with the digital supports in the vaccination campaigns that mobilized people in the first half of 2021. In the course of this second data aggregation phase, the role of digital infrastructures for national digital agility became more evident as an auxiliary concept to draw on in our analysis. The facts and findings regarding digital responses for each country were captured in substantial extensions of the initial case narratives. These narratives underwent multiple iterations (see Kendziorra et al., 2023). Table 1 provides an overview and examples of the data sources used in phases one and two of this research.

Table 1. Used Data Sources

Data sources	Description	Exemplary references
Centers for disease control	Reports and updates from government agencies and public entities in charge of public health reporting, controlling diseases and managing prevention.	(CDC, 2021a; China CDC, 2021; KDCA, 2021; Robert Koch-Institut, 2021; Statens Serum Institut, 2021)
Other government bodies	Other national and (federal)[6] state authorities such as ministries, informing about governmental decisions, recent developments, and ongoing initiatives.	(Bundesministerium für Gesundheit, 2021; HHS, 2021b; MOHW, 2021; National Health Commission PRC, 2020; Sundhedsstyrelsen, 2021)
News articles	Articles from independent newspapers, magazines, and press agencies discussing recent news of general or specific interest.	(Brause, 2020; China Daily, 2020; Steinhauer & Goodnough, 2020; The Local, 2021; Yonhap, 2020)
Research papers	Peer-reviewed research published in books, journals, and conference proceedings providing scientific knowledge with relevance for the study.	(Hollander & Carr, 2020; Kierkegaard, 2015; Kim et al., 2017; Lutz et al., 2020; Yang et al., 2021)
Expert interviews	Five explorative interviews with external experts in various areas of the national health systems to gain additional insights or verify desk research findings.	
Academic workshops	Four research workshops (in Denmark, Germany, USA, Hong Kong) and one conference workshop for presenting work-in-progress results of the digital health policy comparison and collecting feedback (phase 1)	
Others	Information retrieved from company websites (Deloitte, 2021; Trifork, 2020a) and published expert interviews (Müller & Schmergal, 2021).	

In order to structure and analyze the sectoral characteristics and digital responses of each country—and thus represent a nation's sensemaking of fighting Covid-19—we applied the qualitative research approach of cognitive mapping in a third phase (see, e.g., Leonhardt Kjaergaard et al., 2014 who used the cognitive mapping method with a case example of the electronic patient record system in a hospital). Each cognitive map represents a country's digital responses to the pandemic and therefore illustrates how a nation decides to resolve issues on a collective level (Eden, 2004). In this regard, we proceeded as follows: (1) within each country's decision process for each of the digital responses, we identified the individual events and their sequence, e.g., event A followed event B (Swan, 1997), (2) connected the sectoral characteristics that have influence on the design of a country's digital response to each of the respective digital responses, and (3) identified the predominant digital infrastructure evolution mechanisms within each cognitive map (see Kendziorra et al., 2023).

In a fourth phase we engaged in an inductive process in which we compared each of the sectoral characteristics and digital responses within and across the five country cases—supported by our cognitive maps and auxiliary tables (see Kendziorra et al., 2023 as well as Tables 2 and 3). As a result, the characteristics of the national digital health systems and the digital responses were conceptualized as variables with certain levels (e.g., healthcare system structure can be centralized or fragmented; tracking and tracing approaches can be data-intensive or privacy-preserving). While the conceptualization as study variables stripped off many nuances from the complex national-level cases, it also allowed for the reduction and abstraction that is necessary to identify potential relationships between the concepts

[6] We refer to federal states in the case of Germany and states in the case of the U.S.

(Eisenhardt, 1989). A result of this process is the conceptual model presented in Figure 2, which describes and guides our arguments presented in the subsequent section.

In summary, our multi-phased research process can best be classified as a multiple case study (Yin, 1994), on the country-level with some longitudinal elements. We generally treated our data as representative facts, compiled case narratives as an intermediary step for a reconstruction of the major events per case, and primarily relied on inductive reasoning for our analysis—all of which are common characteristics of the exploratory case study genre (Sarker et al., 2018). We argue this approach is appropriate given (a) the poor prior understanding of the digital agility phenomenon at the national level, (b) the need for complexity reduction in any macro-level analysis, and (c) the dynamism of events in the special Covid-19 context. In addition, we used theory as a "conception or mental scheme" (Gregor, 2006, p. 614), which served as a guide for our case study reasoning and supported the iterative process between data collection, case analysis, and conceptual development (Eisenhardt, 1989).

4 Findings: Digital Responses in Five Nations

We next discuss the results of our cross-national case study, beginning with the digital solutions that the five different nations employed to respond to the pandemic crisis. These digital responses supported or enabled (1) the tracking and tracing of Covid-19 cases and symptoms, (2) the public reporting of health data such as aggregate infection and vaccination numbers, (3) the application of teleconsultation solutions allowing for contactless patient treatment, and (4) the mobilization for the vaccination campaign, which encompasses appointment bookings and vaccination certificate provision. Table 2 provides an overview of these digital responses and their underlying design options.

Table 2. Digital Responses in Five Nations

	China	**Denmark**	**Germany**	**South Korea**	**United States**
Tracking and tracing	QR code and other data-intensive tracking apps	Contact tracing app and data donation app	Privacy-preserving tracing app and data donation app	Mobile location and credit card data for confirmed people	Varying state-level efforts for contact tracing apps
Design option	**Privacy**: Data-intensive vs. Privacy-preserving				
Health data reporting	Real-time information infrastructures in place since 2004 SARS pandemic	Data sharing through existing infrastructure and integration of new functionality	Low data interoperability and partly fax-based reporting causing delays	Integrated disease and health management system	Multiple systems for reporting to state agencies and the national CDC
Design option	**Accuracy**: Real-time vs. Batch-based				
Tele-consultation	Steep increase in teleconsultation via existing third-party and newly built platforms	Fast new developments and uptake especially in the first few months	Unprecedented push for teleconsultation with regulatory adaptations	Temporary permission of teleconsultation, emergence of new solutions	Increased use of teleconsultation with temporary regulatory HIPAA flexibility
Design option	**Coordination**: Endorsed platforms vs. Market of choices				
Vaccination mobilization	Electronic systems for vaccination planning, decentralized administration information integration into health QR code	Coordinated process supported by IT infrastructures, vaccination certificate accompanying the reopening strategy	Different federal vaccination strategies and digital support tools, digital and paper-based vaccination certificates	Coordinated vaccination process, centralized administration through KDCA platform, vaccination certificate planned	Decentralized administration with different appointment booking solutions, no mandatory vaccination certificate
Design option	**Governance**: Centralized vs. Decentralized				

Abbreviations: CDC: Centers for Disease Control and Prevention, HIPAA: Health Insurance Portability and Accountability Act, KDCA: Korea Disease Control and Prevention Agency, QR: Quick response, SARS: Severe Acute Respiratory Syndrome

4.1 Tracking and Tracing – Data-intensive versus Privacy-Preserving Design Options

Tracking and tracing refers to digital solutions that help to monitor the virus spread and Covid-19 symptoms, such as apps for tracking Covid-19 infection chains (Quer et al., 2021; Riemer et al., 2020; Rowe et al., 2020; Urbaczewski & Lee, 2020).

Public authorities in China quickly employed the health QR code and the Close Contact Detector apps. Residents of certain cities were required to download the health QR app to their mobile phones and submit certain personal data, leading to a color that decided whether a person was allowed to enter public spaces or had to stay home (China Daily, 2020). Chinese authorities collaborated closely with the big tech companies (e.g., Baidu, Alibaba, Tencent, Telecom companies) to provide these platforms and used the data collected by the companies for tracking purposes. The contact-tracing app ‚Close Contact Detector', which was launched by official authorities, integrates big data from various official sources and tells the users if they had close contact with an infected person (BBC, 2020). Covid-related services (e.g., health QR code and pandemic situation query) have also been integrated into existing and widely adopted platforms such as Alipay and WeChat (L. Zhang, 2020).

Denmark was able to react relatively fast and effectively to the pandemic by building and integrating their digital responses with existing digital infrastructures. To track the spread of the virus, the Danish government contracted with local companies that developed the contact tracing app Smittestop. In addition, the data donation website Covidmeter allowed users to voluntarily report their health status on a weekly basis to the Danish CDC (the Statens Serum Institute).

To support tracking and tracing in Germany, a privacy-preserving contact tracing app (Corona Warn App) has been developed by an industry consortium (SAP SE and Deutsche Telekom) after considerable controversy regarding its technical architecture and privacy. Based on the collected proximity data the contact tracing app calculates an individual risk on the smartphone of the user. Besides that, collaborations between the government, research institutes and ehealth companies also spawned a voluntary data donation app (Corona-Datenspende-App) and a voluntary symptom tracking app (CovApp), both of which however received relatively little public attention, as well as several different group infection chain tracing apps (e.g. Luca).

To track the virus, the Korean government rapidly ramped up a new platform (the Epidemiological Investigation Rapid Support System) that gathers and analyzes movement data of confirmed Covid-19 patients almost in real time and thus "speeds up the release of transparent and accurate information about the virus" (WeGO, 2021). Various public and private companies, including 22 credit card companies, joined forces to realize this big data analytic system based on an existing Smart City Data Hub infrastructure developed by multiple research institutions. The Global Positioning System (GPS) locations of people confirmed to have Covid-19 were made available as a service via open APIs. App developers provided numerous mobile apps that citizens used to avoid areas with confirmed cases (Ladner, 2020; Nature, 2020).

The United States did not launch a national-level tracking and tracing mobile app. However, several US states made plans to build apps on the contract tracing APIs (application programming interfaces) provided by Apple and Google in early 2020. By the end of 2020, less than half of the states had developed a tracking app and user adoption was rather low (Anderson & O'Brien, 2021; NBC, 2020).

Comparing the tracking and tracing responses of five nations, it was found that the solutions differed between data-intensive and privacy-preserving designs.

4.2 Health Data Reporting – Real-time vs. Batch-Based Design Options

Health data reporting refers to reporting and analyzing up-to-date public health data, such as data analytics dashboards to visualize the disease spread (Pietz et al., 2020; Recker, 2021).

National-level health reporting is supported by China's National Infectious Disease Information System (IDIS), an infrastructure that has been developed after the SARS outbreak in 2004.[7] Most of the larger medical institutions can report confirmed cases via IDIS immediately. Others send the infectious disease report card to the county level Chinese Center for Disease Control (CCDC), which then reports these cases via IDIS on a daily basis (China CDC, 2020). The National Health Commission (NHC) uses this data to publish a Daily Briefing on their website, which is a central source of information for the public (National Health Commission PRC, 2021).

The Danish Health Data Network enables data sharing across most stakeholders in the Danish health system, including hospitals, general physicians, pharmacies, governmental institutions, and citizens. Covid data such as confirmed cases, deaths, and test rates are reported—like any other health data—via this digital infrastructure to a government agency, which informs the public via interactive dashboards.

In the German health system, data sharing and systems interoperability are well-known issues. Especially at the beginning of the pandemic, fax-based reporting and analog communication hindered and delayed the reporting of Covid-19 related numbers. For example, the director of one of the largest research hospitals noted in an interview that there was "a blatant maladministration without public outcry as we all saw for 15 months on the 'Tagesschau' [German evening news] that the latest infection figures were always wrong because the authorities didn't fax on weekends" (quote translated, Müller & Schmergal, 2021). An ongoing infrastructure project (DEMIS) has been sped up to enable laboratories to electronically report to the health authorities (gematik, 2020). The numbers presented in an interactive dashboard by the German Center for Disease Control (Robert Koch-Institut) were subject to fluctuations due to the reporting delays.

The Korea Disease Control and Prevention Agency (KDCA) requires medical doctors and medical institutions to report to the Integrated Disease and Health Management System as soon as infectious diseases are confirmed. The collected data is then shared with the public by local authorities.

In the US, the reporting of Covid-19 data collected in hospitals, laboratories and other health institutions can be mandated by the health departments at different levels. These jurisdictions can then voluntarily report their data (largely electronically) to the CDC, which consolidates and reports the data at a national level. Most of these data can be drilled down to the city and county levels. The Department of Health and Human Services (HHS) has defined certain reporting standards for laboratories to ensure a high data quality (HHS, 2021c). These standards stipulate amongst others that "entities must report (1) information for each individual test, (2) within 24 hours of results being known or determined, (3) at least on a daily basis, and (4) to the appropriate STLT health department based on the individual's residence […] using one of the existing reporting channels" (HHS, 2021c). However, there were still inadequacies in data reporting due to partly fragmented information systems and interoperability problems that hinder an easy data sharing between the various data providers (e.g., hospitals, pharmacies, laboratories, governmental institutions) (Banco, 2021). To bring together different data sources and share data faster with first responders at national, state, and local levels, the HHS built a secure data ecosystem (HHS Protect), which integrates more than 200 datasets into one system (CDC, 2022).

Comparing the health data reporting solutions implemented in five nations, it was found that the digital responses differ between real-time vs. batch-based designs.

4.3 Teleconsultation – Endorsed Platforms vs. Market of Choices Design Options

Teleconsultation refers to engaging physicians and patients in remote consultations to limit the impact of contact restrictions on patient treatment, such as via video consultation solutions (Anthony Jnr., 2020; Wherton et al., 2020).

In China, the NHC made several efforts to take advantage of internet-based medical care and teleconsultation during the Covid-19 pandemic. This has led to the emergence of new platforms in certain provinces and an increased usage of existing telemedicine platforms, such as "Ping An Good Doctor" or "Good Doctor Online" (X. Zhang, 2020). In addition, local governments organized telemedicine, free online consultations and drug delivery services.

[7] The severe acute respiratory syndrome (SARS) coronavirus 1, which was first identified in Foshan, Guangdong, China in 2002, is related to the SARS coronavirus 2 virus that has caused the coronavirus disease 2019 (Covid-19).

The Danish government actively encouraged citizens to make use of existing teleconsultation solutions whenever possible to avoid physical interactions (Sundhedsstyrelsen, 2021). For example, the chairman of the Danish Organization of General Practitioners (PLO) turned to the public at a press conference and pointed out that "video consultations with your GP is now a possibility through the MyDoctor App (MinLæge App)" (Trifork, 2020a) to increase awareness and use among the Danish population. Within a short time, the company behind MyDoctor (Min Læge), an official app that connects patients and general practitioners, had integrated video consultation as an additional feature (Trifork, 2020b). Many citizens downloaded the app at the beginning of the pandemic and the numbers of teleconsultations increased from 4,000 to more than 30,000 per month (Health Europa, 2021).

While the regulatory prerequisites for teleconsultation in Germany had been established in 2018, the actual use in practice (including phone and video consultations) increased only after the Covid-19 outbreak (aerzteblatt, 2021). A number of platform providers entered this market (e.g., Samedi, Noventi, Jameda). Pragmatic decisions by the national and state governments further aimed to push teleconsultation during the crisis (Schmidt, 2020).

Although physicians in Korea were previously not allowed to perform teleconsultation, the government temporarily permitted them to perform teleconsultation and telemedicine starting February 2020 to prevent group contagion in vulnerable healthcare facilities (Yonhap, 2020). One outcome was the app Medihere, which enables remote medical advice with experienced physicians (Public Health Update, 2020).

As another response to the crisis, the US government made several temporary changes to the law to facilitate health care and especially telehealth. Major changes include those to allow teleconsultation on systems that may not be fully HIPAA compliant, health care across state-lines and the prescription of controlled substances via telehealth (HHS, 2021a). The government clearly stated that the "Office for Civil Rights will not impose penalties against covered health care providers for the lack of a business associate agreement with video communication vendors or any other noncompliance with the HIPAA Rules that relates to the good faith provision of telehealth services during the COVID-19 nationwide public health emergency" (HHS, 2021d).

Comparing the design of teleconsultations in five nations, it was found that the difference lies in whether the solutions are offered via endorsed platforms or whether there is a market of choices.

4.4 Vaccination mobilization – Centralized vs. Decentralized Design Options

Vaccination mobilization refers to issuing digital vaccination passports and mobilizing the population for the vaccination campaigns, such as via electronic vaccination certificates (Dasgupta et al., 2021; Marhold & Fell, 2021; The Lancet Digital Health, 2021).

Various information systems are available in China to support the information flow for vaccination throughout the country, such as an electronic vaccine tracing platform, immunization planning systems and related systems in each province (China CDC, 2021). In terms of vaccination mobilization, local governments developed own plans and strategies using existing apps such as Alipay and WeChat to schedule appointments and let citizens check their results. The vaccination status is integrated into the existing Health QR Code in some areas. In July 2021, the CCDC planned to enable the vaccination information exchange across cities and across provinces (China CDC, 2021).

The vaccination process in Demark was managed centrally by the government in a 'push' approach. Based on defined priority groups, citizens received a notification when it was their turn to be vaccinated. Only then they were able to log into a new nationwide platform (vacciner.dk) and book an appointment (SynLab, 2021). Another new solution for a digital vaccination certificate (Coronapas app) has accompanied the reopening strategy of the country.

Vaccination strategies and management differed within federal states in Germany. The digital support of the vaccination campaign was mainly facilitated by appointment booking platforms. Even though there are various offers of platforms and apps on the market (bitkom, 2021) none of them was used nationwide, for example, Berlin chose to use Doctolib. The vaccination certificate is still paper-based and susceptible to forgery (Brause, 2020). Since June 2021, citizens can use a digital alternative which can be integrated, amongst others, into the existing Corona Warn App (Bundesministerium für Gesundheit, 2021).

The vaccination administration in Korea is centrally coordinated by the government. Citizens receive a push notification if they belong to the current priority group and can book an appointment through the KDCA website or by phone. In June 2021, South Korea launched the officially approved "COOV (Covid

Overcome)" vaccine passport (Korean Consulate, 2021), which allowed fully vaccinated travellers to be exempt from the two-week quarantine. The app uses blockchain technology to prevent forgeries and to protect personal information (J. Lee & Smith, 2021). Individuals leave no trace of where they have travelled and the passport holders have full control over their data (Ledger Insights, 2021).

Vaccination administration was highly decentralized in the US where the different types of vaccine providers (e.g., pharmacies, physicians, schools, employers, counties, hospitals) had to enroll in the official CDC Covid-19 vaccination program to be authorized to "legally store, handle, and administer COVID-19 vaccine in the United States" (CDC, 2021b). A developed national appointment scheduling system had been widely rejected by many of the states and counties. Instead, a plethora of third-party ad-hoc solutions were quickly put together for appointment scheduling, which resulted in difficulties for both, citizens and vaccine providers (Ferguson, 2021), but also accelerated the speed with which eligible citizens could be contacted.

Comparing the vaccination mobilization in five nations, it was found that the solutions differ between centralized and decentralized designs of vaccination administration and management.

5 Analysis: A Conceptual Model of National Digital Agility

Figure 2 provides a conceptual model that illustrates the five constituting building blocks of national digital agility (in boxes) and summarizes in its center the four design options employed by employed by nations.

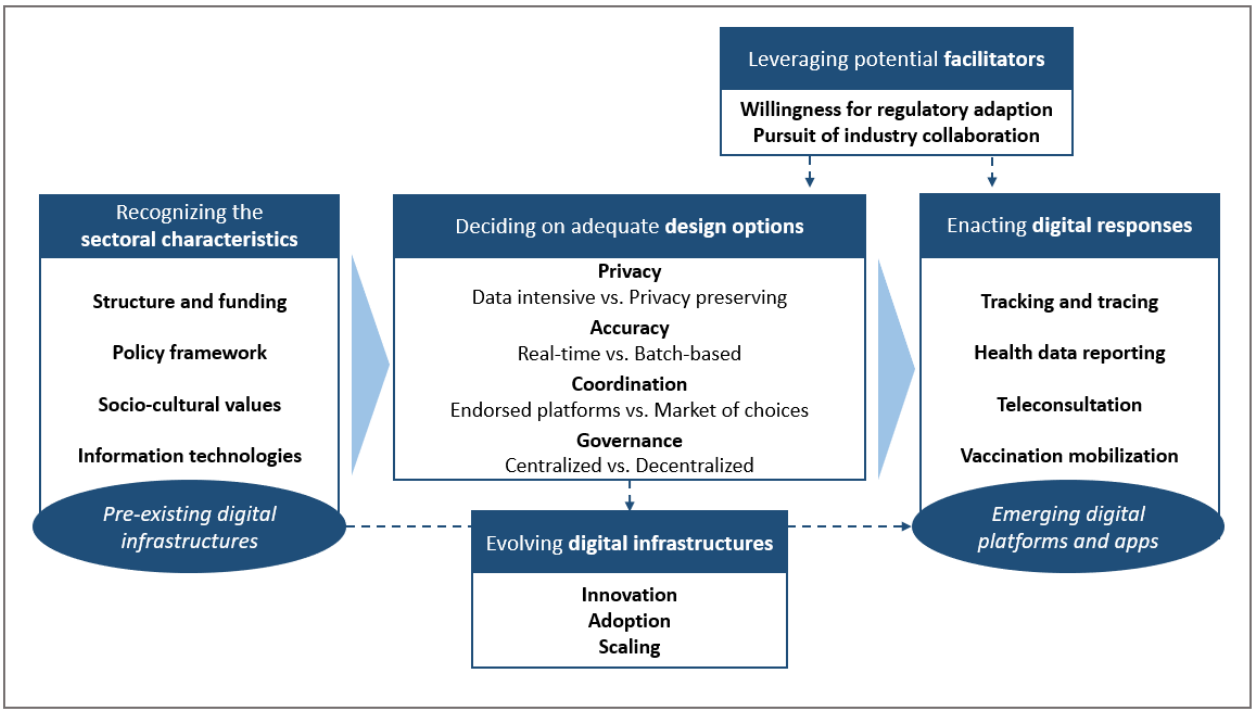

Figure 2. A Conceptual Model of National Digital Agility

The relationships between the blocks can be interpreted as follows: In a crisis situation of national scope, one way to respond is to draw on the potential of digital technologies. Here, each country has a certain starting position with regard to different areas—the sectoral characteristics—which have an influence on the design and implementation of digital solutions. It is, therefore, crucial that a country recognizes its unique sectoral characteristics before making decisions. Solutions should be designed, and enacted under consideration of the sectoral characteristics. Specific facilitators can influence both steps, the design and enactment, by accelerating or enabling certain design options and its enactment.

Since the focus of this study is on national digital agility, the role of digital infrastructures becomes particularly important. Instead of developing new and independent digital solutions, the focus should be turned towards the evolution of and the integration with existing digital infrastructures. As part of the sectoral characteristics to be understood, certain pre-existing digital infrastructures exist in a country that

can evolve through different generative mechanisms. While these mechanisms are indeed reinforcing, they can also be triggered by conscious decisions of decision makers.

In sum, we argue that a country's national digital agility is determined by how well the five building blocks in our conceptual model interact. Having summarized the digital responses in five countries and their underlying design options in the previous section, this section continues by explaining—based our cognitive mapping approach—how the sectoral characteristics of the countries' health system shaped the design of these responses. We then proceed with analyzing the mechanisms of digital infrastructure evolution in the crisis response process before we explain two key facilitators.

5.1 How Sectoral Characteristics Shape Digital Responses

The capability to deeply understand the sectoral characteristics of the public system is crucial for marshalling digital responses. In the case of a pandemic such as Covid-19, we found that these characteristics include the health system's overall structure and funding, prevailing policy frameworks, socio-cultural values, and information technologies. The overall structure of a country's health system and how it is funded determines whether and how its citizens access care. The prevailing policy frameworks help protect the rights and welfare of patients and provide direction for possible actions. The socio-cultural values prevalent in a country provide a strong indication regarding how its citizens may react to various policy and health initiatives. Finally, the stock of IT available in a country determines whether it can digitally respond to crises with alacrity.

Based on these sectoral characteristics as 'starting positions' (i.e., prior to the Covid-19 pandemic), governments and policy makers decided on adequate design options for digital responses (i.e., the privacy of tracking and tracing applications, the accuracy of health data reporting, the coordination of teleconsultation, and the governance of vaccination mobilization (see Table 2). Table 3 provides a descriptive overview of the four sectoral characteristics across the countries under investigation.

Table 3. Starting Positions: Health System Characteristics prior to Covid-19 in Five Countries

	China	Denmark	Germany	South Korea	United States
Structure and funding	Single-payer, public health insurance and three-tier hospital system with national, regional, and local responsibilities	Single-payer health system, national health strategy with regional responsibilities	Multi-payer health system based on shared decision making in a federal context	State-monopolized single-payer system providing universal health insurance	Pluralist, fragmented health system funded through public allocations and private insurance
Key characteristics	Federalism, Distribution of decision rights				
Policy framework	National ehealth strategies and deregulation to disburden hospitals, boom of Internet hospitals	National and European regulations for privacy and national ehealth standards	Late mover, but recent advances in digital health policy through a set of modernization acts	Flexible privacy laws since the 2015 MERS crisis, prohibition of any form of teleconsultation	Heavily regulated for patient safety through HIPAA, HITECH Act fostered EHR adoption
Key characteristics	Implementation of a national (digital) healthcare strategy, Level of regulation				
Socio-cultural values	General trust in government, collectivist values, privacy concerns trending lately	Comparably high trust in the government, mobile literacy and social cohesion	High attention regarding data privacy, individualism and uncertainty avoidance	Collectivist values putting collective over individual rights, high mobile literacy	Individual freedom and liberty in high regard, privacy traded for benefits
Key characteristics	Trust in government, Collectivism, Mobile literacy, Privacy sensitivity				

Information technologies	Fragmented EHR markets, but >90% adoption, public health reporting infrastructure in place since SARS	100% EHR adoption, nationwide digital health network and patient portal, high level of data sharing	Wide EHR use, low interoperability, fragmented digital health infrastructures, standardization attempts starting	>90% EHR/EMR adoption, national standardization efforts, for example for extending the Smart City Data Hub	Wide EHR use (96% hospitals, 80% physicians), increased HIE use, still plagued by interoperability challenges
Key characteristics	Use of EHRs, Implementation of interoperable technological infrastructures, Effort for national health information exchange and data sharing				

Abbreviations: EHR: Electronic Health Records; HIE: Health Information Exchange; HIPAA: Health Insurance Portability and Accountability Act; HITECH Act: Health Information Technology for Economic and Clinical Health Act; MERS: Middle East Respiratory Syndrome; SARS: Severe Acute Respiratory Syndrome

5.1.1 Structure and Funding Shaping Digital Responses

Health system structure and funding describe the way in which the provision of medical services is realized. This characteristic, in broad terms, differentiates centralized single-payer versus decentralized, federally structured multi-payer systems. The health system structure was a major influence for the decision on adequate design options for digital responses because the distribution of decision rights (centralized versus decentralized) and the level of regional autonomy also shape how and how fast digital responses can be planned and implemented.

For example, in health systems such as the US and Germany, each (federal) state could—or had to—decide which concrete measures it planned to implement. In the US, some states developed and adopted tracing apps while others did not (NBC, 2020). Germany managed to provide a national app for individual tracing, but the group infection chain tracing apps (e.g., Luca) were declared a matter of choice for the federal states (dpa, 2021). When it came to vaccination mobilization, US government made suggestions, for example, about the implementation of the Vaccine Administration Management System (VAMS). However, the actually employed responses differed widely even between counties within the same state (Ferguson, 2021). Similar arguments can be made for vaccination mobilization in Germany (Bebermeier & Kummert, 2021).

Centralized single-payer systems such as South Korea and Denmark, in contrast, were able to employ national tracking and tracing apps relatively quickly. They also provided central platforms for vaccine appointment scheduling instead of having various individual local solutions. This, in turn, allowed them to invite citizens for vaccination in a prioritized push approach and ensured a quick vaccination uptake, as the Danish case shows (O'Leary, 2021). The different structures also had an impact on health data reporting, because while this was quite aligned in Denmark, the reporting differed between the US states and thus led to inconsistencies and difficulties (Makulec, 2020).

In sum, it appeared to be much harder, if not infeasible, to provide nationally coordinated digital responses for countries with federal structures than for those with more centralized structures. Decision makers needed to recognize, and make sense of, their countries' health system structures before designing digital responses to the pandemic.

5.1.2 Policy Framework Shaping Digital Responses

Policy frameworks refer to national healthcare strategies and regulations that define the potential and legal scope of action of all involved factors (e.g., regarding rights and responsibilities, data sharing, and privacy). Strategies and regulations play a major role in the design of digital responses, because they set the goals of what is desired and the boundaries of what is legally possible. As such, the national policy framework can be an enabler for the preparedness and readiness of the authorities but also for the availability and distribution of digital infrastructures.

For example, in Denmark and China the policy frameworks have been strong enablers of progress in the digitalization of the health sector over the past decades. Danish health authorities have enacted strategies since the mid-1990s to push nationwide digital health progress (Bruun-Rasmussen et al., 2008). During the past decades, efforts have been ongoing to consolidate infrastructures and extend the scope of health data, resulting in the creation of certain standards that ensure interoperability between all stakeholders in the national health data network (Healthcare Denmark, 2021). In addition, there is a common authentication infrastructure for egovernment and ehealth services, including a digital inbox. These

nationwide infrastructures enabled not only timely and reliable health data reporting in the pandemic, but also facilitated the centrally coordinated 'push' invitation approach for the vaccination campaign (Danish Health Authority, 2021). In China, the 13th Five-Year Plan and the Healthy China 2030 strategies included telehealth as one important building block in the medical and healthcare system reforms (Xinhua, 2016). Amongst others, this has laid the policy groundwork for the development of ehealth and the proliferation of Internet hospitals offering teleconsultation which, of course, helped to keep up health services during the pandemic (Yang et al., 2021).—In South Korea, in contrast, laws prohibited doctors to perform teleconsultation prior to Covid-19 (Sup, 2020).

Specific privacy regulations in South Korea apply for pandemic outbreaks. The authorities are allowed to access personal data of the citizens, including data from cell phones, GPS, or bank records, in order to track the virus spread (S. Lee et al., 2020). However, in South Korea as well as in Germany, national long-term strategies for digital health system are in earlier implementation stages compared to countries such as Denmark or China, which influenced how their different responses were designed.

In sum, the policy frameworks and regulations implemented in a country prepare it differentially to effectively address the challenges posed by a pandemic such as Covid-19. This is why one needs to be sensitive to the policy framework as a boundary condition for designing digital responses.

5.1.3 Socio-Cultural Values Shaping Digital Responses

Socio-cultural values represent the shared attitudes and norms of a country's population. These values shape the digital responses to a crisis. While there are many ways to characterize national culture (Leidner & Kayworth, 2006), our cases suggest that the following key characteristics influenced the design of digital responses to the pandemic: whether culture is individualistic or collectivist, the citizens' privacy concerns and trust in the government, and the general computer and mobile literacy of the population.

For example, China and South Korea's collectivist cultures have a greater tendency to accept self-sacrifice and surrender personal freedom to ensure the welfare of the group (Sonn, 2020). In combination with overall trust in the government (Edelman, 2021; Shangaiist.com, 2018) and comparably low privacy concerns, this laid the ground so that even data-intensive tracking and tracing solutions and vaccination records could be implemented and were widely adopted. For instance, the use of QR code in China was necessary to enter public transport, supermarkets and other public spaces, yet it was readily accepted. (Kostka & Habich-Sobiegalla, 2021; Mozur et al., 2021).

Political decision makers in countries such as Germany and the US, where there is a much greater attention to privacy and the use of tracing apps had been controversial, were unanimous that the use of digital tracing must be voluntary. Many US states deliberately decided not to engage in developing and providing tracking and tracing apps or to implement a mandatory nationwide Covid-19 passport. Although Germany ultimately developed a national contact tracing app, decision makers converged to the most privacy-preserving design of this app, which resulted in users remaining anonymous and therefore health authorities not being able to contact them through the app (Lokalkompass Gelsenkirchen, 2021). Moreover, only few users actually used the national contact tracing app to share a positive Covid-19 test result (on a voluntary basis) which is necessary to generate a warning for other users who were in proximity (Urbanek, 2021).

Denmark, as one of the pioneers in digitization in Europe, was also among the first countries to introduce a Covid passport (Euronews, 2021). The fact that this solution was discussed early on in the country as a promising solution can be attributed not only to the higher mobile literacy of individual citizens, but also to social cohesion and trust in the government (Digital Denmark, 2021; Larsen, 2013).

In sum, a nation's socio-cultural values not only influence the design of the digital responses, but also determine the general adoption of those responses. For this reason, it is of primordial importance that decision makers are aware of the idiosyncrasies of their national cultural context before engaging in a discussion of design alternatives for digital responses.

5.1.4 Information Technologies Shaping Digital Responses

Information technologies describe the existing information systems (e.g., EHRs) and underlying interoperable technological infrastructures within the health system including health information exchanges. Existing information technologies evidently shaped digital responses because, depending on

the existing digital infrastructures and their interoperability levels, countries had more or fewer options for responding to challenges by integrating new digital solutions with these existing infrastructures.

For example, Denmark's digital health data network enabled nationwide data reporting close to real-time. Nationally endorsed solutions for teleconsultation, tracking and vaccination have been integrated into these existing infrastructures and made accessible through the national patient portal (sundhed.dk). Digital responses in China and South Korea built on, or integrated with, digital infrastructures developed by other parties, most prominently platforms of large tech companies in China (e.g., WeChat and AliPay) and the Smart City Data Hub developed by research institutions in South Korea. Although Germany and the US have had initiatives to increase interoperability and information exchange within the health system, the status at the time of the pandemic still hindered an easy and timely flow of health information in many areas. This applies, for example, to the reporting of confirmed Covid-19 cases in Germany as "important parts of the reporting system were still analog and, in the absence of interoperable interfaces and suitable software solutions, were based on faxes" (Augurzky et al., 2020, p. 64). For months, Germans were told in the evening news that Covid numbers were subject to fluctuations since health departments did not send faxes on the weekends (Müller & Schmergal, 2021). In the US, while most—but by no means all—data is transmitted electronically between jurisdictions, different systems are in use by different parties in the healthcare system. Therefore, reporting is still plagued by interoperability issues and other (technological) hurdles (Banco, 2021) that cause variations in health data. Healthcare providers' choice of specific teleconsultation solutions in the crisis was left to the market in these countries, which spawned a plethora of different third-party platforms for doctors and patients to choose from, with minimal guidance by the authorities.

In sum, the presence of technological infrastructures enabled a nation to rapidly leverage and incorporate new digital responses, while the absence of such interoperable infrastructures led to more decentralized and fragmented responses. Again, decision makers who strive for agility need to recognize the specifics of their countries' sectoral information technology infrastructures as an important determinant for how to structure and design their country's digital responses.

5.2 Digital Infrastructure and Emerging Platform Evolution

Regardless of whether platforms and apps have been contracted out by governments or provided by third parties, information technology has been a crucial determining factor for the digital responses. We draw on Henfridsson and Bygstad's (2013) generative mechanisms to analyze the extent to which existing digital infrastructures and emerging digital platforms and apps were innovated, adopted, and scaled during the pandemic. Integrating these mechanisms in our framework allows us to understand the substantive role of technology for national digital agility. We next highlight selected case examples for each mechanism.

5.2.1 Innovation Mechanisms

Innovation refers to the creation of new products or services. We distinguish the provision of new services on their own (standalone innovations) vis-à-vis services that are built on top of existing digital infrastructures (integrated innovations). In terms of tracking and tracing, all countries (and certain states in the US) have shown high levels of innovation. While in China and South Korea the outcomes have been partly integrated and connected with existing services (for example credit card companies), the Western countries investigated here innovated through standalone (and more privacy-preserving) solutions.

With regards to health data reporting, all national governments quickly provided new dashboards with regular updates—of varying accuracy—for the public. While in some countries the reporting infrastructures had already been in place (e.g., China's IDIS or Denmark's Health Data Network), other countries (e.g., the US or Germany) had to collect the data from more fragmented systems in their (federal) states. At the same time, Germany and the US innovated part of their infrastructures through integrating an additional module for the reporting of Covid-19 related data into the existing National Health Safety Network (US) and by pushing an ongoing reporting infrastructure implementation (e.g., DEMIS in Germany).

The innovation level for teleconsultation services can be regarded as high across all our cases. After policy adjustments in South Korea and the US, existing and new third-party providers provided standalone platforms for teleconsultation to care providers. Although this could be observed in the other countries as well, governments in China and Denmark tried to provide more integrated solutions (such as a teleconsultation platform for Hubei province and an additional video function in the MyDoctor app).

For vaccination mobilization, strong innovation mechanisms could be observed both for providing integrated websites for appointment scheduling (South Korea and Denmark) and for monitoring vaccination progress (China and Denmark developed integrated vaccination certificates). In the United States individuals and organizations themselves developed several applications to allow people to view vaccine appointments across different providers, such as a bot on Twitter which sends notifications as soon as new appointments are available in the region (Dean, 2021). In Germany, the picture was mixed; although the government did not decide for a nationwide appointment scheduling solution (instead, different standalone platforms have been chosen locally), a vaccination certificate app has been developed. Proof of complete vaccination is imported into the app via a paper-issued QR code, which can also be imported into the national contact tracing app, among others (Bundesministerium für Gesundheit, 2021).

5.2.2 Adoption Mechanisms

The adoption of digital responses was evidenced in all of the studied countries, yet to different extents. We distinguish mandatory and voluntary adoption in this context. Especially in the case of tracking and tracing, governments underlined that the more citizens download and use the app, the better the contact tracing applications would work. Despite millions of people who downloaded the apps, the usage numbers have remained well below 50 percent of the populations in Denmark, Germany, and the US states that developed such apps (LibertiesEU, 2021; NBC, 2020). Contrasting with this, the mandatory use of the health QR code in China as well as apps using credit card and GPS data in South Korea, consequently led to high adoption rates.

For health data reporting, we consider adoption by institutions and health care providers and not ordinary citizens. In all country cases, new platforms that were useful or required for health reporting have been adopted to report Covid-19 related numbers. In the US, for example, the government requested hospitals to adopt the new HHS Protect System and report through this new platform. In Germany, health departments were linked faster than planned to the reporting infrastructure DEMIS to facilitate the sharing of Covid-19 data on a national level. China already had a high level of adoption of the health data reporting system in place (IDIS) prior to Covid-19.

Adoption of teleconsultation during Covid-19 peaked across all countries, albeit with different design options. To reduce the number of physical contacts in the health system, authorities have facilitated the use of telehealth through law changes (South Korea and US), collaborated in developing ‘governmental’ solutions (China and Denmark) and actively encouraged the people to shift to virtual consultations when possible. Adoption of teleconsultation increased, in Denmark for example through the officially endorsed MyDoctor app, from 4,000 to more than 30,000 consultations per month (Health Europa, 2021). In countries where no provider was officially endorsed (market of choice), such as USA and Germany, healthcare providers and patients used teleconsultation solutions on an unprecedented scale. For example, in 2019 there were 3,000 video consultations in total in Germany, but only in the second quarter of 2020 1.2 million patients consulted a physician or psychotherapist via video (aerzteblatt, 2021).

A similar picture could be observed for the adoption of vaccination appointment scheduling solutions. South Korea and Denmark set up web-based platforms for all citizens while other countries decentralized the responsibility to choose an adequate solution to the local level, leading to a number of different adopted solutions that citizens then used to book appointments. With the beginning of the vaccination campaigns, vaccination certificates have been one tool to accompany the reopening of the societies. In Denmark, citizens quickly adopted an official app to prove their vaccination status (with a paper-based alternative for a small part of the population). In Germany, a newly developed app has so far been a voluntary digital alternative to the dominant paper-based vaccination passport. Although the US government initially decided to not implement any mandatory certification system, an increasing number of public and private authorities and workplaces required such a proof. This has led to private companies bringing various certification apps on the market (DiValentino, 2021). US citizens can use either a digitized form of their immunization record or a physical copy.

5.2.3 Scaling Mechanisms

Scaling, the attraction of new partners or user groups, was less present in the evolution of infrastructures and platforms related to Covid-19. A reason might be that most of the considered digital responses were developed for specific user groups and still new at the time. However, a few pre-existing infrastructures

and platforms can be argued to have scaled their reach to different user groups as the pandemic progressed.

For example, in South Korea, the fact that credit companies joined forces with private and public companies to deliver data for contact tracing (WeGO, 2021) can be viewed as the scaling of a health infrastructure to a non-health collaboration partner. In the area of teleconsultation, in the US, several third-party providers of online meeting services launched fully and partially HIPAA-compliant versions of their services (e.g., Zoom, 2021) and thereby scaled their offerings to a growing customer segment in healthcare. For vaccination mobilization, in some of the German states (e.g., Berlin), a third-party platform (Doctolib) was chosen for vaccination scheduling and originally intended only for health providers and patients (bitkom, 2021), but then scaled to vaccination centers as new user groups that joined this platform.

5.3 Facilitators of National Digital Health Agility

In addition to the evolution of infrastructures and platforms, our cross-case analysis shows that certain facilitators can positively influence digital agility. In the case of Covid-19, these facilitators include the willingness of nations to adapt existing regulations and their pursuit of industry collaboration, both of which can impact options for digital responses, both in terms of their design and their implementation.

5.3.1 Regulatory Adaptation

Covid-19 demonstrated how policymakers can make regulatory adaptations in an unprecedented period to react to a crisis situation. In particular, the US temporarily relaxed some HIPAA regulations to allow non HIPAA-compliant systems for teleconsultation (e.g., Skype) to enable more teleconsultation (HHS, 2021a). South Korea suspended the previous ban for physicians and allowed the temporary use of teleconsultation (Yonhap, 2020). New platforms emerged immediately (e.g., Medihere), which enabled remote medical advice with experienced physicians. These and other examples (Mak et al., 2020) show how regulatory adaptiveness has in some countries been a crucial facilitator to enable digital agility on a national level.

5.3.2 Industry Collaboration

Across all countries included in this study, virtually all of the digital responses resulted from collaborations with industry partners, either to develop new solutions (e.g., apps and platforms) or from making use of existing partner solutions (such as for teleconsultation and vaccination scheduling). These collaborations enabled governments to use the expertise of specialized organizations (mostly software companies) and react to the different needs. Some countries partnered with smaller local partners (e.g., Denmark with Netcompany and Trifork), while others leveraged the expertise of local industry giants (e.g., China's Baidu, Alibaba, and Tencent, and Germany's SAP and Telekom). Nevertheless, the success from industry collaborations may still vary. The US government commissioned Deloitte to develop a software for vaccine roll-out and management (VAMS) which was offered free to all states. However, due to initial bugs and a lack of flexibility, many states opted for alternative solutions (Ferguson, 2021).

6 Discussion

The Covid-19 pandemic forced nations to react quickly and develop responses involving digital solutions within their scope of possibility to control and contain the spread of the virus. Because these reactions are key also in other crisis situations, we were keen to conceptualize digital agility at the national level and examine what it is that can make a nation more digitally agile. Comparing the digital responses in a set of industrialized countries from around the globe, we found there are essentially five building blocks that jointly make up national digital agility as illustrated in our conceptual model (Figure 2).

First, we propose that national digital agility is about recognizing and understanding the characteristics of the sector that is subject to the crisis in order to adequately and swiftly address a crisis. This goes beyond experts knowing about the details of this context; it requires political decision makers to recognize how this context matters and to communicate this to the public in order to rationalize their responses. While it may appear easier to accurately recognize sectoral characteristics in a decentralized system (where decision makers are 'closer' to the population), it can also lead to confusion of the general public when too many different regulations, platforms, and apps are discussed and adopted in different regions of a country. In the case of a global pandemic, it is the structural, policy, cultural, and technological

characteristics of the health system that provide an idiosyncratic context in each country. This is why a crisis response in one context cannot be simply copied to another country without careful consideration of the four characteristics mentioned above. For example, plans to copy a less privacy-preserving design for the German tracking and tracing app were discarded after the public controversy made clear that this design did not fit the cultural context. Critics commented that valuable time could have been saved, if the adequate design had been chosen from the outset (Beerheide & Krüger-Brand, 2020). In summary, we argue that recognizing and understanding the relevant sectoral characteristics is one building block that contributes to national agility.

Second, agility entails that national expert groups make adequate design choices for swift digital responses based on the recognized sectoral characteristics. Our cross-country analysis showed that nations have designed their digital responses differently on a continuum of design options in different areas and that much time and energy can be lost in this process if it is done inappropriately. More centrally governed countries had an advantage in making such decisions swiftly, while the decision-making process becomes more complex and protracted the more parties have a say. In this context, it is important to carefully evaluate design options for and modification frequencies of digital responses. This decision process may solve dilemmas such as how data-intensive versus privacy-preserving the systems should be, which mode for health data reporting (batch-based versus real-time) is acceptable, which platforms and apps (if at all) should be endorsed versus relying completely on the market forces, and whether action of citizens can be facilitated in a centralized manner versus being left to more decentralized forms of coordination. In summary, we argue that deciding on an adequate design option in a timely manner is another important building block of national digital agility.

Third, with regards to the enactment of responses, agility means that governments enact their responses effectively. In the case of Covid-19, numerous platforms and apps were implemented that supported, or enabled, tracking and tracing, health data reporting, teleconsultation, and vaccination mobilization. Many of these enacted responses were jointly developed by government bodies and private companies. Interestingly, other platforms and apps also emerged independent of governmental interventions (e.g., the Luca App in Germany which was pushed by the event industry) and some were primarily initiated by state institutions (e.g., the different contact tracing apps in the different countries). While some of the apps and platforms were designed from the outset to integrate with pre-existing digital infrastructures, many were not. Those that were not either remained as standalone solutions or became embedded at a later stage, as they built on interoperable interfaces of existing digital infrastructures. In this regard, it is crucial to ensure a stable structure by leveraging existing digital infrastructures that at the same time maintain their modularity and provide the right level of flexibility for integrating new innovations. In summary, we argue that the effective translation of the defined design options into digital responses is the third building block of national digital agility.

Fourth, existing digital infrastructures play an important role, because they are not only an important sectoral characteristic to recognize, but can also be specifically harnessed by decision-makers in the development of digital responses through innovation, adoption and scaling mechanisms (Henfridsson and Bygstad (2013). In addition to innovating new services and fostering their adoption, the providers of public digital infrastructures should also consider the scaling of existing platforms to new uses and user groups in order to avoid long-term fragmentation. While scaling it is important that the platform retains its interoperability with already embedded platforms, apps and user groups. In the longer term, this then leads to a changed—and at best improved—starting position, and thus to new sectoral characteristics, which can influence responses to subsequent situations in which digital national agility is required. In addition to the deliberate action by decision makers to build on top of existing digital infrastructures, these infrastructures also reinforce and develop themselves, e.g., as more people increase their use of existing telehealth solutions (i.e., adoption).

Fifthly and lastly, there are certain facilitators that enhance agility both in terms of decision making and responding. Specifically, we highlighted how regulatory adaptations and industry collaborations have been, and can be, leveraged in the future, as facilitators of national digital agility.

In our cross-case analysis, the primary goal was to capture the building blocks of national digital agility in the context of a global health crisis. We deliberately refrained from ranking countries or assessing which country is more or less agile and how it managed the crisis. Each country has a unique starting situation to which it responds and some starting situations or sectoral characteristics probably offer a wider range of options than others for managing a crisis. However, depending on the degree to which a nation is able

to leverage digital infrastructure capabilities in a contextually appropriate way, it can become agile, regardless of the starting situation.

Furthermore, it can be assumed that the Covid-19 pandemic will affect the digital agility of countries in the long term. The analysis showed that a country's earlier crises have an influence on how it manages a new one, as China and South Korea, for example, were able to draw on existing health data reporting systems at the start of the pandemic. As Sakurai & Chughtai (2020) note, the Covid-19 pandemic could also be seen as an opportunity to increase preparedness for the next crisis by redesigning digital processes. On the one hand, certain sectoral characteristics automatically evolve. These certainly include the digital infrastructures, but also the attitudes and values of the population regarding the design, implementation and use of technological responses. On the other hand, the sectoral characteristics as well as future courses of action can also be consciously changed or adapted by a country, as for example countries have already evaluated their Covid-19 strategies and drawn lessons from them (OECD 2022). This leads to the need to reassess the sectoral characteristics in each upcoming crisis situation. Therefore, in the long run, our conceptual model can probably be modified by adding a backward arrow from the responses to the sectoral characteristics.

To synthesize, we put forward that national digital agility is not a single trait (or potentially something that simply can be measured), but a multifaceted concept with constituting elements, each of which contributes to building such agility. Consequently, we propose that national digital agility requires recognizing the relevant system characteristics, deciding on adequate design options, enacting digital responses effectively and making use of and evolving underlying infrastructures and possible facilitators. In sum, our definition of national digital agility parallels recent arguments in the organizational agility literature that emphasize the need to conceptualize an integrated notion of digital agility that does justice to the crucial role of technology in the digital era (Salmela et al., 2022).

However, national digital agility exhibits some key differences from the prevailing notions of agility on the organizational level. First and foremost, organizational and national digital agility differ in their aims. While organizations aim to maintain their competitive advantage, nations enact digital responses to address a crisis with the overall aim to protect a public good (e.g., health). Here, agility serves the well-being of the whole population and does not have the aim—as in the case of organizations—to perform better compared to other players. Second, while companies need a sensing capability to be attentive to opportunities and threats in their industry network, nations need to be cognizant of the own sectoral and local contexts in which they can enact their digital responses. Moreover, in our cross-case analysis, we found that regulatory adaptation can be leveraged as a facilitator of national digital agility as policy adjustments for crisis management have created new opportunities to enact digital responses. In contrast to that, regulatory policy is commonly seen as a barrier of agility of firms on the organizational level (Tallon et al., 2019, p. 232).

Regarding the role of digital technology for agility, the organizational agility literature mainly considers a firm’s information systems and platforms (Ravichandran, 2018), which can play an enabling or impeding role in the context of agility (Lu & Ramamurthy, 2011). On the one hand, digital options extend real-time information aggregation that support decision making (Tallon et al., 2019). On the other hand, there is a “dark side” of information systems when it comes to achieving organizational agility (Seo & La Paz, 2008), which is caused by missing standardization of data, information overflow, inflexibility of information systems, or technology dependency.

When it comes to national agility, we have to zoom out to a macro level and consider larger digital infrastructures (Hanseth & Lyytinen, 2010). Our cross-case analysis has shown that while many individual digital solutions contribute positively to certain goals, they can also have an inhibiting role on agility. In cases where new apps and platforms to fight the Covid-19 pandemic were built on existing digital infrastructures, our analysis found technology mostly as an enabler of national agility, as long as it was—just like organizational agility—“organized in ways that are simultaneously stable and flexible as well as offering both control and autonomy.” (Tilson et al., 2010, p. 6). Standalone innovations that are not embedded in existing digital infrastructures, however, might cause a risk of incompatibility or inflexibility. For example, the decentralized vaccination campaign in the US prompted herds of third-party developers to provide solutions for online appointment booking. However, these quick ‘hacks’ likely lack the integrative capabilities for supporting potential future vaccination campaigns and thus may hinder national agility in the long run. This required balance between a stable core and flexible ‘add-ons’ in national digital infrastructures is consonant with the literature that investigated digital infrastructures at the organizational level (Fürstenau et al., 2019).

6.1 Policy Implications

Two important implications for policy emerge from our cross-country study of digital agility. First, there is no one-size-fits-all approach to national digital agility. Digital responses rather need to be designed with great sensitivity to a country's specific sectoral conditions. For these reasons, policy makers need to pay close attention to the structural, policy, cultural, and technology-related conditions of their nation. This also implies that to simply mimic the approaches taken in a country with different conditions is not likely to lead to success.

Second, many countries worldwide have been facing challenges in extending their digital infrastructures and the pandemic has laid bare the weakness within many countries' health systems and their underlying technology infrastructures. Given the enabling role of technology for digital agility witnessed in our work, policy makers need a sound understanding of how to integrate emerging solutions into these infrastructures to avoid the creation of siloed digital landscapes in order to steer the evolution of national digital infrastructures in beneficial ways.

6.2 Limitations

The following limitations merit considerations. First, our multiple case study is limited by the choice of the health system context of five nations, which we argue provides a revelatory selection of countries for studying national digital agility. Second, our case narratives are based on a number of primary and secondary sources selected by the authors (see Kendziorra et al., 2023). Information aggregation was a necessary step in our analysis due to the sheer amount of available information. This might create potential omissions, including those regarding less prominent digital responses. Based on both of the aforementioned points, it seems only reasonable that we do not claim to have created a final and universal concept of national digital agility with unalterable elements. Rather, analyzing more secondary sources or more countries might perhaps have led to additional or slightly different elements or factors in our conceptual model. Furthermore, the applicability and validity of our conceptual model to other areas and potential crises affecting an entire country needs to be tested, validated and/or adapted as necessary. There might be context-specific sectoral characteristics, design options and special facilitators that are not yet captured in our inductively derived model. Third, while it is clear that not all measures to fight the pandemic have been digital (e.g., social distancing, facemasks, curfews, etc.), we deliberately put a focus on digital agility and digital responses. It is not our intention to suggest that digital responses are the only or most effective option to fight a pandemic, but rather a way to digitally support the other pandemic measures. Digital responses could be complementary or substitutive to these other measures adopted by countries.

6.3 Future Research Opportunities

From a practical standpoint, Covid-19 has pushed national governments to recognize, reflect about, and rethink their own health systems. In this regard, existing but also new challenges have come to the surface, revealing promising opportunities that will likely influence the future of health care provision (e.g., teleconsultation). Hence, future research should investigate whether the ad-hoc and short-term solutions specifically implemented in the context of Covid-19 and described in this paper also lead to long-term changes or strategy adaptations in national health systems.

Although we assume that our preliminary model of national digital agility is applicable in diverse kinds of crises and contexts, it was developed in the context of Covid-19 and thus has an inherently intensive focus on health system characteristics and underlying health data infrastructures. Future researchers are invited to apply our model of five building blocks in other sectoral contexts such as economic or commercial crises, sudden migration flows, climate change and other environmental problems, to validate the extent to which our framework may hold for other classes of societal challenges.

As mentioned earlier, we have been trying to understand the building blocks of digital national agility on a conceptual level without measuring a level of this concept and the different starting positions of the countries or the factor 'speed'. Further research could validate our conceptualization and operationalize national digital agility. In this sense, and as previously discussed, we argue that subsequent studies should examine the linkages between digital crisis readiness and the concept of national digital agility as a whole.

7 Conclusion

National digital agility is the ability to leverage information technology capabilities to address urgent societal challenges—such as a global pandemic—in a contextually appropriate way. Our comparative research in the course of Covid-19 provides a preliminary model of this urgently needed concept containing five building blocks which we found to jointly contribute to national digital agility. Our study adds to Covid-19 research in information systems by proposing a framework that considers various digital responses—namely tracking and tracing, health data reporting, teleconsultation and vaccination mobilization—which support the detection and containment of the virus to tackle the crisis. The illustration of our model with five country cases (China, Denmark, Germany, South Korea, and the U.S.) shows how the responses deployed by different countries are determined by their national health system characteristics. Our research also highlights how existing digital infrastructures primarily evolved through innovation and adoption mechanisms either by supporting these responses as standalone solutions or by integrating standalone solutions with digital infrastructures post-hoc. Moreover, we found regulatory adaptations and industry collaborations as common facilitators of the nations' digital responses. From a theoretical perspective, we contribute a macro-level understanding of digital agility to the literature and discussed how this novel perspective contrasts with the predominant organizational-level perspective. Our research has the potential to inform policy and practice on how to leverage information technology and infrastructures to prepare countries for future societal and environmental challenges that require quick responses catered to a specific national context.

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