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RESEARCH ARTICLE

How can interoperability stimulate the use of digital public services? An analysis of national interoperability frameworks and e-Government in the European Union

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Abbreviations: EIF, European interoperability framework; EU, European Union; GDP, gross domestic product; IT, information technology; NIF, national interoperability framework; OLS, ordinary least squares; R&D, research and development

Abstract

This article explores the role of interoperability in the development of digital public services in Europe, analyzing the effects of an European Union (EU)-level initiative (the European interoperability framework, EIF) and the development of e-Government services on how citizens interact online with public administrations. The EIF is a common EU framework providing guidance on public sector interoperability. EU countries are not mandated to follow the EIF, but they are encouraged to take up its guidance in their respective national interoperability frameworks (NIFs). Against this background, this article tests two hypotheses: (a) the introduction of NIFs facilitates the online interaction between citizens and public administrations and (b) better e-Government services encourage citizens to interact online with public administrations. Both hypotheses are confirmed by a panel data analysis covering 26 European countries over the period 2012–2019. The analysis relies on a dummy variable reflecting the adoption of NIFs, built by carefully examining official documents of the countries in the scope of the analysis. Based on the empirical results, this article puts forward two main policy recommendations. First, efforts to improve e-Government services across Europe should be intensified in order to support the overarching digital agenda of the EU and increase benefits for European citizens. Second, interoperability should become a central element when designing new digital public services. Therefore, the European Commission could foster a common approach to interoperability of digital public services across the EU by strengthening the governance of interoperability initiatives and encouraging the adoption of specific interoperability requirements.

Policy Significance Statement

The 2020 Communication "Shaping Europe's digital future" of the European Commission puts forward as a key action the development of a "reinforced European Union (EU) governments interoperability strategy." This article contributes to the development of the strategy by proposing two policy recommendations. First, efforts to improve e-Government services across the EU should be intensified to support the overarching digital agenda of the EU and increase benefits for European citizens. Second, interoperability should become a central element when designing new digital public services. In shaping a new interoperability strategy for the public sector, the Commission could further enhance a common approach to interoperability across the EU's public sector by strengthening the governance of interoperability initiatives and encouraging the adoption of specific interoperability requirements.

1. Introduction

Digitalization holds great promise for improving the provision of public services in the European Union (EU). It can help increase the efficiency of public administrations, reduce red tape, and facilitate the interactions among public administrations, businesses, and citizens (Dilmegani et al., 2014). Ultimately, an effective e-Government strategy should aim to increase public value and enable "greater openness, transparency, engagement with and trust in government" (OECD, 2016, p. 10). Recent developments are encouraging: an increasing number of government services in the EU Member States are offered online and, overall, 64% of EU citizens opt for online services, a growing share in comparison to previous years according to the 2019 Digital Economy and Society Index.[1]

In the process of digitalizing the public sector, interoperability is the key enabler through which digital public services goals can become reality. Without interoperability, the digital transformation of the public sector is severely hampered. Limited data flows in the public sector can hinder the development of new technologies and increase administrative burdens. Administrative silos, inefficient use of scarce resources and lack of coordination are some of the main challenges that interoperability initiatives in the public sector are meant to address, thus further supporting the digitalization of public administrations (Misuraca et al., 2020).

In this context, the European interoperability framework (EIF) was adopted as common EU-level guidance on interoperability in the public sector. Developed by the European Commission, the EIF provides common principles and guidance to develop interoperable and integrated digital public services across the EU and beyond. It was first introduced in 2004 and revised twice, in 2010 and 2017. A key feature of the framework is its voluntary nature. EU countries are not mandated to follow the EIF, but they are encouraged to take up its guidance in their respective national interoperability frameworks (NIFs) and contextualize it as necessary. In addition, the recommendations included in the EIF can also be taken up by countries who are not members of the EU.

Against this background, for the first time in the literature, this article assesses to what extent the development of e-Government services and the adoption of NIFs aligned with the EIF generate benefits for citizens. More specifically, the article checks whether better e-Government services and NIFs that reflect the features of the EIF lead to more online interactions between citizens and public administrations. The assessment is performed via a panel data analysis with country-level fixed effects, based on observations from EU and European Free Trade Association (EFTA) countries (22 EU Member States, Iceland, Norway, and Switzerland) and the UK, over the period 2012–2019. The analysis relies, inter alia, on a dummy variable reflecting the adoption of NIFs, built by carefully examining official documents of the countries under investigation.

The remainder of this article is structured as follows. Section 2 includes a brief review of the main literature on the topic. Section 3 presents the theoretical framework on which the analysis performed in the article relies. Section 4 describes the different variables considered in the econometric model used to test the hypotheses spelt out in Section 3. Section 5 specifies the econometric model. Section 6 discusses the finding of the econometric analysis. Section 7 identifies the main limitations of the analysis presented in the article. Section 8 provides concluding remarks and policy recommendations. The analysis performed to build the NIF variable is summarized in the Annex.

2. Literature and Policy Context

2.1. The role of interoperability and e-Government

In the context of e-Government, Pardo et al. (2012) define interoperability as a "set of multidimensional, complementary, and dynamic capabilities that are specific to a defined network of organizations with

[1] For further details, please see: The Digital Economy and Society Index (DESI) (2019) Available at https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2019 (accessed 6 September 2021).

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particular goals and a common environment." Interoperability is a key enabler of digitalization in the public sector, representing the ability of public administrations to exchange information between themselves as well as with citizens and businesses while ensuring that the meaning of the information is well preserved (European Commission, 2017).

In the process of digitalizing the public sector, interoperability facilitates data flows, allows systems to communicate and streamlines processes. By contrast, the lack of interoperability has a negative impact on the development of digital public services. Limited interoperability in the public sector at the EU, national, regional and local levels impinges on the interactions of public administrations among themselves and with citizens (Simonelli et al., 2019). Limited data flows in the public sector can hinder the development of new technologies, such as Artificial Intelligence and Big Data, which require significant quantities of data (Barcevičius et al., 2019, p. 58). In addition, limited interoperability increases administrative burdens for citizens when interacting with public administrations (Gallo et al., 2014, p. 35; Cave et al., 2017).

Several factors affecting interoperability are identified in the literature. At the technical level, incompatibility of information technology (IT) infrastructures as well the use of different data models and standards limit interoperability between and within organizations (Pardo et al., 2012; Kalvet et al., 2018a,b). Beyond technical constraints, other factors impinging on interoperability include organizational and administrative fragmentation (including, for instance, administrative silos, slow pace of reform, legacy processes; Lam, 2005; Kalvet et al., 2018b; Margariti et al., 2020), legal obstacles (especially in a cross-border setting, differences in national legislation were identified as a barrier to interoperability; Kalvet et al., 2018b), and lack of cooperation on and shared governance of interoperability initiatives among public administrations (a problem particularly salient in the context of cross-border interoperability in the EU; de Abreu, 2017; Kouroubali and Katehakis, 2019). When it comes to the public sector in the EU, the different administrative levels involved (local, regional, national, and the EU level) represent an additional element of complexity in the e-Government interoperability landscape.

Various models have been proposed to assess the impacts of e-Government and interoperability, employing different conceptual approaches and levels of analysis. Pardo et al. (2012) propose a methodological framework to assess interoperability impacts that takes into account a multitude of dynamic dimensions (policy, management, technology) interacting with each other. Building on models on the stages of development of e-Government, Thomas et al. (2019) show the relevance of focusing on specific interoperability aspects, such as data management maturity, through an empirical analysis of public sector agencies. Another approach is exemplified by Margariti et al. (2020), emphasizing the need to develop models to assess organizational interoperability maturity in order to effectively support e-Government initiatives. While the existing literature proposed theoretical frameworks for assessing the role of interoperability in the development of public services, empirical results are not yet available.

2.2. The EU common framework for public sector interoperability

As mentioned in the introduction to this article, at the EU level, a common framework for public sector interoperability was developed in the form of the EIF. The first version of the EIF, adopted in 2004, was subsequently revised in 2010, through the 2010 Communication "Towards interoperability for European public services" (European Commission, 2010). To support the ambitions of the European Commission to harness the potential of the digital transformation and create a Digital Single Market,[2] a new EIF was adopted in 2017 (European Commission, 2017), expanding on the previous version and bringing more targeted recommendations. The EIF provides a consistent framework of principles and guidance for

[2] The Digital Single Market Strategy was set up through a Communication issued by the European Commission in 2015. The Communication is available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52015DC0192 (accessed 6 September 2021).

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developing interoperable and integrated digital public services in Europe. A key feature of the framework is its voluntary nature: EU countries are not mandated to follow the EIF; they are encouraged to take up its guidance in their respective NIFs and contextualize it as necessary. The framework thus can help coordinate the e-Government interoperability initiatives of EU countries. EIF guidance can be followed also by non-EU countries.

The EIF relies on a comprehensive analysis of the role of interoperability in digital public services, going well beyond purely technical factors. To this end, the EIF relies on three main components, namely interoperability principles, interoperability layers, and the conceptual model for integrated public services. The components are then accompanied by 47 recommendations that all public administrations may decide to operationalize. The interoperability principles outline key concepts for the development of interoperable digital public services in the EU. They emphasize the importance of coordinating interoperability initiatives across the EU based on the EIF (the principle of subsidiarity and proportionality), key approaches to data and services (openness, transparency, reusability, technological neutrality, and data portability), the need to account for user needs (user-centricity, inclusion and accessibility, security and privacy, and multilingualism), and the need to encourage cooperation among public administrations (administrative simplification, preservation of information, and assessment of effectiveness and efficiency). The layered interoperability model defines and focuses on four main interoperability layers and their governance, namely legal interoperability (i.e., the need for legal and regulatory frameworks that support interoperability initiatives), organizational interoperability (reflecting the procedures and policies in place in organizations that facilitate cooperation and data exchanges), semantic interoperability (capturing the ability of information exchanged between systems to be interpreted without ambiguity), and technical interoperability (the need for technical infrastructure to enable data exchanges). Finally, the EIF also defines a conceptual model for integrated public services that aims to support the interoperability-by-design of European public services. The conceptual model emphasizes the role of basic components such as open data and base registries.

2.3. The evolving EU policy context

The 2020 Communication "Shaping Europe's digital future" of the European Commission (2020) acknowledged the role of interoperability for achieving the headline ambition of making "Europe fit for the digital age." In this Communication, the Commission explicitly committed to develop "a reinforced EU governments interoperability strategy to ensure coordination and common standards for secure and borderless public sector data flows and services." This is expected to be a major EU initiative, generating significant impacts on the digital transformation of the EU public sector. This initiative may also entail a revision of the EIF.

More generally, interoperability is expected to play a key role in several connected EU initiatives such as the roll out of Common European Data Spaces in specific sectors,[3] including a data space for public administrations. Efforts in the area of e-Government will be financially supported through the Digital Europe Programme,[4] which will invest over €1 billion between 2021 and 2027 in interoperability initiatives. The next years will be crucial in defining the digital leadership of the EU. Enhanced interoperability will be necessary to unlock the potential of data use and reuse for improved European public services, to enable cross-border collaboration, and to support the sector-specific policy goals set by the Commission in the first half of 2020.

[3] The Common European Data Spaces are described in the 2020 Communication from the Commission on A European strategy for data. (COM(2020) 66 final). The Communication is available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066 (accessed 6 September 2021).

[4] The Digital European Programme was legally established through Regulation (EU) 2021/694 of the European Parliament and of the Council of 29 April 2021 establishing the Digital Europe Programme and repealing Decision (EU) 2015/2240.

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Against this background, research is necessary to understand to what extent the activities of the Commission in the area of e-Government interoperability had positive impacts on the development and uptake of digital public services so far. Drawing lessons from the EIF experience can inform the implementation of new initiatives and especially help EU policymakers prepare a "reinforced EU governments interoperability strategy."

Put into a broader context, the need for coordination on interoperability issues and for enhancing the provision of e-Government services has become ever more salient during the COVID-19 pandemic. At the EU level, several measures such as the coordination of the contact tracing apps through the EU Interoperability Gateway[5] and the development of the EU Digital COVID certificate[6] showcased the importance of interoperability in the design of public sector solutions in times of emergency. Moreover, to comply with social distancing measures, the demand and supply of e-Government services increased across the globe in a short timeframe to respond to the crisis. The pandemic has also prompted governments around the world to increase their focus on the role of digital technologies to enhance the provision of public services (UN, 2020).

3. Hypothesis Development

As discussed in Section 2, several models have been considered to assess the impacts of e-Government and interoperability. Building on previous research, this article devises a theoretical framework to assess one of the main impacts of the EIF on citizens. In a nutshell, by relying on publicly available data and information, the article analyses whether and how NIFs implementing the EIF affected the way citizens interact with the public administrations online in the country where they live. In addition, the article also assesses the role that e-Government services play in shaping the interactions between citizens and public administrations. The analysis thus tests two main hypotheses:

i) The introduction of NIFs that follow the EIF model facilitates the online interaction between citizens and public administrations;
ii) Better e-Government services encourage citizens to interact online with public administrations.

More specifically, the analysis measures the impact of the adoption of NIFs (represented by an independent, dummy variable showing whether a country has a NIF or similar documents implementing the EIF in place or not) and the development of e-Government services (represented by another independent variable capturing the quality of e-Government) on the way citizens interact with public administrations online (represented by a composite indicator).

The article contributes to the literature on interoperability and e-Government by proposing a novel theoretical framework, based on econometric methods, to test the two hypotheses. Testing hypothesis (i) is the first attempt to quantify econometrically the impacts on citizens of strategic actions coordinated across the EU to enhance the interoperability of digital public services. Testing hypothesis (ii) allows to estimate the impact on citizens of better e-Government services and to move from a descriptive analysis of the field (e.g., how many public services are available online) to an analysis of outcomes (whether such services are used), thus providing a richer perspective on the progress made in the field of e-Government. While both hypothesis (especially the second one) may be intuitive, the article provides a concrete basis for estimating the impact of existing EU and national initiatives in the

[5] The EU Interoperability Gateway is an initiative of the European Commission launched in November 2020 with the aim to coordinate the development and the compatibility of the contact tracing apps developed in the EU countries to track and manage the spread of the SARS-CoV-2 virus. See https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1904.

[6] The EU Digital COVID certificate was established through Regulation (EU) 2021/953 of the European Parliament and of the Council of 14 June 2021 on a framework for the issuance, verification, and acceptance of interoperable COVID-19 vaccination, test, and recovery certificates (EU Digital COVID Certificate) to facilitate free movement during the COVID-19 pandemic.

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Table 1. *Top 10 countries in terms of online interactions between citizens and public administrations over 2012–2019 (analysis limited to the countries analyzed in this article)*

Rank	Countries	Adoption of the NIF
1	Denmark	Since 2017
2	Norway	Since 2018
3	Iceland	No
4	Finland	No
5	Sweden	No
6	Netherlands	Since 2016
7	Switzerland	No
8	Estonia	Since 2011
9	France	Since 2016 (EIF guidance only partly taken up)
10	Luxembourg	Since 2019

Note: Countries are ranked based on the average values of the online public services use index (see Table 2) over the period 2012–2019.
Source: Authors' elaboration on Eurostat and the information presented in the Annex concerning the adoption of NIFs.

fields of interoperability and the provision of digital public services and for shaping better policies in the future.

With respect to hypothesis (i), it could be argued that countries with a higher level of use of online public services are more likely to adopt NIFs. Nonetheless, this reverse causality is not observed. For instance, among the 10 leading countries in terms of the online interaction between citizens and public administrations between 2012 and 2019, four countries did not adopt a NIF and only Estonia has fully implemented a NIF since the beginning of the period under investigation (see Table 1). Based on the sample of countries analyzed, it cannot be concluded that countries with higher levels of use of online public services adopt NIFs.

4. Data

The overall analysis is based on country-level data from 26 European countries (22 EU Member States, Iceland, Norway, Switzerland, and the UK)[7] collected over the period 2012–2019.

The dependent variable, that is *online public services use*, reflects the citizens' use of online public services by relying on four different variables measured by Eurostat. More specifically, the dependent variable is computed as the simple average of the percentages of individuals that in each country: (a) interact with public authorities via the Internet; (b) obtain information from public authorities' websites; (c) download official forms; and (d) submit completed forms to public administrations.

The first hypothesis presented in Section 3 is tested through a dummy variable, which represents one of the contributions of this work, as it was built by carefully examining official documents of the countries in the scope of the analysis, capturing strategic guidance on digitalization and interoperability in the public sector. The construction of the dummy variable is detailed in the Annex. The analysis differentiates between a complete adoption and an incomplete adoption of the EIF. In particular, two variables are considered:

[7] The 22 Member States are Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, and Sweden. While still an EU Member State during the timeframe under analysis (2012–2019), the UK is mentioned separately given its current status as a non-EU country.

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- *NIF complete*, which encompasses countries that have adopted NIFs that fully reflect the features of the EIF;
- *NIF complete and incomplete*, which encompasses both countries that have adopted NIFs fully reflecting the EIF, as well as countries that have implemented only some parts of the EIF in their NIFs (or equivalent documents).

The second hypothesis is tested through the *development of e-Government services* variable, which is computed by relying on indicators included in the so-called "e-Government benchmark."[8] This variable assesses the availability and delivery of online public services according to the exhaustiveness and relevance of the information provided online by public administrations as well as the range of services provided. This approach in line with UNDP (2014, p. 14), which emphasized the need to shift the focus from "e-Government maturity models" to the deployment of "a portfolio of e-services" when analyzing e-Government progress.

It is worth emphasizing that the analysis focuses on effects within countries, capturing the impact of NIFs and the development of e-Government services on how citizens interact with the public administrations in the countries where they live. The cross-border dimension of public services is taken, however, into account as part of *the development of e-Government services* variable, which is composed of a series of indicators including an indicator on public services provided to foreign citizens.

When exploring the nexus between e-Government development and citizens' use of digital services, the limited empirical literature identifies several factors that need to be controlled for in order to properly isolate the effects of the independent variables. Zhao et al. (2014) and Lakka et al. (2015) account for the available *communication infrastructure* to capture the extent to which citizens have access to communication lines that may allow them to interact with public administrations. Similarly, our model factors in the availability of infrastructure to access the Internet in each country. Furthermore, the model used in this article also includes *general public services expenditure*, a proxy that controls for all the effects that can arise from discrepancies between public spending in different countries for developing innovative public services. Finally, the influence of contextual factors, such as economic, cultural, political or educational ones, may also play a role in the relationship under investigation (Zhao et al., 2014). Against this background, the model also accounts for:

- Economic factors, by focusing on the *real gross domestic product (GDP)* per capita, which allows to control for any differences that may stem from the economic development of the countries under investigation (see, for instance, Taipale, 2013, who studies the role of sociodemographic, economic and geographical predictors on the e-Government use in Finland by relying on household income);
- Educational factors, by including the national level of *IT skills* (in the same vein, to control for this factor, Lakka et al., 2013 and Taipale, 2013, consider the level of education and education expenditures, respectively);
- Political factors through a *government effectiveness* variable that captures the perception of the quality of public services, the quality and independence of the civil service, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies (Lakka et al., 2013, rely on the same variable).

Table 2 summarizes the different variables included in the analysis, specifies the unit used and provides the sources. Table 3 presents descriptive statistics of the variables used in the econometric analysis. In the countries under analysis, on average, around 47% of the population aged 16–74 use the Internet to interact with public administrations. Substantial differences exist, however, among countries. For instance, Finland records the highest usage rate (80%) in 2019. In this context, Northern European countries (Sweden, Iceland, Denmark, and Finland) also record very high digital literacy scores and Internet use

[8] For further information, please see https://digital-agenda-data.eu/datasets/e-gov/indicators (accessed 6 September 2021).

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Table 2. *Description of the variables used in the econometric analysis*

Variable	Description	Unit	Source
Dependent variable			
Online public services use (*index_PA*)	Index computed as the simple average of the percentages of individuals (aged between 16 and 74): using the Internet to interact with public authorities; obtaining information from public authorities' websites; downloading official forms; and submitting completed forms (by country, over the last 12 months)	Percentage of individuals	Eurostat, https://ec.europa.eu/eurostat/databrowser/view/tin00012/default/table?lang=en
Independent variables			
e-Government indicators (*index_egov*)	Index computed as the simple average of user centricity, transparency, citizen mobility, business mobility,[a] and use of key enablers[b]	Percentage index, theoretically ranging from 0% (low e-Government development) to 100% (high e-Government development)	e-Government Benchmark https://digital-agenda-data.eu/datasets/e-gov
National interoperability framework (*NIF_comp* and *NIF_comp + incomp*)	*NIF complete* shows whether the country has fully implemented the EIF in their NIFs. NIF complete + incomplete also includes those countries that have only implemented part of the EIF in their NIFs. The value 1 is assigned from the year in which the country implemented the NIF onward; otherwise, the value 0 is assigned in years where the country does/did not have a NIF	Dummy	Authors' elaboration on the findings presented in the Annex

(Continued)

Table 2. *Continued*

Variable	Description	Unit	Source
Control variables			
General public services expenditure (*l_gen_pub*)	Government spending to support broader activities, that is: executive and legislative organs; financial and fiscal affairs; external affairs; foreign economic aid; general services; basic research; R&D related to general public services; general public services; public debt transactions; and transfers of a general character between different levels of government	Millions of EUR—transformed in logarithm	Eurostat, https://ec.europa.eu/eurostat/databrowser/view/gov_10a_exp/default/table?lang=en
Real GDP per capita (*l_GDP_cap*)	Ratio of real GDP to the average population	Thousands of EUR—transformed in logarithm	Eurostat, https://ec.europa.eu/eurostat/web/products-datasets/-/SDG_08_10
Government effectiveness (*gov_eff*)	Perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies	The index ranges from approximately −2.5 (low quality) to 2.5 (high quality)	World Bank (Kaufmann et al., 2010)
Infrastructure (*infra*)	This variable captures the level of infrastructure to access the Internet in each country. Total communication refers to the total access to telephone lines, total fixed broadband, and mobile subscribers	Total communication access paths per 100 inhabitants	OECD, https://www.oecd.org/digital/broadband/oecdkeyictindicators.htm

(Continued)

Table 2. *Continued*

Variable	Description	Unit	Source
Digital/technical skills (*IT_skills*)	Know-how necessary to discover, understand and build new technologies. Based on both hard data (i.e., statistics from international regional and national sources) and survey data (i.e., international panel of experts), this indicator captures three subfactors, that is talent, training and education, and scientific concentration	Index ranging from 0 (low skills) to 10 (high skills)	IMD, https://worldcompetitiveness.imd.org/rankings/digital

[a]Data related to business mobility are missing for 2012 and 2016.

[b]User centricity reflects the extent to which (information about) a public service is provided online, how the online journey is supported and if public websites are mobile friendly. Transparency evaluates the transparency of government authorities' operations, service delivery procedures as well as consultation of personal data by public administrations. Citizen mobility mirrors the extent to which public services that aim at foreign citizens are available online, usable, and implement electronic identification and eDocument capabilities. In the same vein, business mobility assesses the extent to which public services that aim at foreign businesses are available online, usable, and implement electronic identification and eDocument capabilities. Finally, key enablers estimate the extent to which technical pre-conditions for e-Government service provision are used. The key enablers used for measuring the quality of the services to businesses and citizens are: (a) electronic identification; (b) electronic documents (eDocuments); (c) authentic sources; (d) digital post; (e) eSafe; and (f) single sign on.

Source: Authors' elaboration.

Table 3. *Descriptive statistics of the variables*

Variables		Observations	Mean	Standard deviation	Min	Max
Online public services use (*index_PA*)		201	46.73	15.69	16.75	80
e-Government indicators (*index_egov*)		208	62.05	15.4	22.5	93.75
National Interoperability Framework (NIF)	*NIF_comp*	208	0.28	0.45	0	1
	NIF_comp+incomp	208	0.45	0.50	0	1
General public services expenditure (*l_gen_pub*)		184	9.57	1.53	6.57	12.15
Real GDP per capita (*l_GDP_cap*)		208	10.19	0.59	9.19	11.33
Government effectiveness (*gov_eff*)		208	1.29	0.49	0.22	2.22
Infrastructure (*Infra*)		182	190.23	23.39	145.53	242.85
IT skills (*IT_skills*)		207	7.58	0.92	4.67	9.30

Source: Authors' elaboration.

rates. On the other side of the spectrum, only 17% of Italians aged 16–74 used online public services in 2012, with very slight improvements over the study period, as the maximum recorded user rate in Italy reached 20% in 2019. With the highest value for the e-Government index in 2016, the Netherlands is a front-runner in the field. By contrast, Slovakia registers the lowest value for this index (22.5). When it comes to NIFs, almost half of the countries under analysis have adopted at some point in time a NIF that fully or partially reflect the features of the EIF (the full list is available in the Annex). When it comes to the control variables, the countries in the sample are quite heterogenous. While several countries (e.g., Austria, France, Latvia, and Luxembourg at the beginning of the period, and Iceland and Ireland over the entire period) invested little or nothing in research and development (R&D) related to general public services, Greece made considerable efforts over the whole period, which resulted in both a significant improvement in the quality of online public services and a greater use of these services. Overall, all the countries under investigation rank quite high in terms of government effectiveness, although Greece, Hungary, and Italy display lower scores than the other countries.

5. Statistical Analysis

To test the two hypotheses presented above, a panel data analysis covering 26 European countries over the period 2012–2019 is performed. The set of variables considered is, therefore, characterized by both the spatial and time dimensions, that is, $i = 26$ and $t = 8$, respectively. The analysis assesses the ceteris paribus effects of each of the independent variables, described in Table 2 and measured at the country level, on the online interaction between citizens and public administrations. The corresponding econometric model is described by the following equation:

$$\begin{aligned} \text{Index\_PA}_{i,t} = {} & c + \beta_1 \times \text{Index\_egov}_{i,t} + \beta_2 \times \text{NIF}_{i,t} + \beta_3 \times \text{l\_gen\_pub}_{i,t} + \beta_4 \\ & \times \text{l\_GDP\_cap}_{i,t} + \beta_5 \times \text{gov\_eff}_{i,t} + \beta_6 \times \text{infra}_{i,t} + \beta_7 \times \text{IT\_skills}_{i,t} + u_i \\ & + \varepsilon_{i,t}, \end{aligned} \tag{1}$$

where c is the intercept, $\sum_{j=1}^{7} \beta_j$ are the coefficients associated to each explanatory variable accounted for in the model, u_i defines the fixed effects per country, and $\varepsilon_{i,t}$ is the error term. $\text{Index\_PA}_{i,t}$ is the dependent variable.

Before carrying out the analysis, it is crucial to ascertain that the independent variables (i.e., the explanatory variables) are not highly correlated with each other. The simultaneous introduction of two

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Table 4. *Correlation matrix*

	index_egov	l_*gen_pub*	*IT_skill*	l_*GDP_cap*	*infra*	*gov_eff*	*NIF_comp*	*NIF_comp + incomp*
index_egov	1							
l_gen_pub	−0.119	1						
IT_skills	0.142*	0.012	1					
l_GDP_cap	0.2*	0.338*	0.306*	1				
infra	0.127	0.285*	−0.042	0.374*	1			
gov_eff	0.415*	0.184*	0.505*	0.787*	0.219*	1		
NIF_comp	0.214*	−0.034	−0.221*	−0.022	−0.062	−0.087	1	
NIF_comp + incomp	0.146*	−0.076	−0.366*	−0.192*	−0.029	−0.183*	0.693*	1

Notes: All significance levels are at the $p > .05$, except where denoted by: $*p < .05$.
Source: Authors' elaboration.

highly correlated variables in the model could lead to erratic results due to collinearity. To avoid this issue, in principle the correlations should be lower than 0.8.[9] In this context, Table 4 presents the pairwise correlations between the independent variables used in the analysis. Based on the model given by equation (1), only the positive correlations between the government effectiveness and the real GDP per capita could alter the robustness of the estimates as the correlation displays a value very close to 0.8.[10] Therefore, to ensure the robustness of the results, regressions are performed by dropping alternatively the *government effectiveness* and *real GDP* per capita (in logarithm) variables from the model.

Specification tests are then conducted in order to apply the model that best fits the data. In panel data models, the question of the treatment of the fixed effects (u_i) often arises; in fact, it is important to determine whether to treat individual effects as constant over time or as a random variable. The Hausmann specification test between random and fixed effects is run with *NIF_comp* + *incomp* ($\chi^2(7) = 14.65, p = 0.04$) and *NIF_comp* ($\chi^2(7) = 14.66, p = 0.04$) and indicates that fixed effects are the best analytical approach. The Breush and Pagan Lagrangian multiplier (LM) test for random effects supports the use of fixed effects since the variance of individual specific effects (u_i) is significantly different from 0 ($\chi^2(1) = 246.98, p = 0$ under the null hypothesis $Var(u_i) = 0$). The model, therefore, controls for country-level variables that are difficult to measure or observe and that do not vary over time (such as some types of cultural factors). Fixed effects isolate the impacts of time-invariant characteristics so that it is possible to assess the net effect of the explanatory variables on the selected dependent variable. In other words, the proposed model estimates an additional and single effect (u_i) for each country, which is assumed to be constant in the entire period of observation (2012–2019).

As panel models often violate the assumptions underlying the standard ordinary least square (OLS) regressions, two post-estimation tests for serial autocorrelation and heteroscedasticity are performed. The Wooldridge test for autocorrelation in panel data shows evidence of serial autocorrelation at the first order ($F(1,25) = 5.12, p = 0.03$). The Modified Wald test for groupwise heteroscedasticity in fixed effect regression model indicates that errors are heteroskedastic ($\chi^2(28) = 1150.44, p = 0$). Based on these results, the analysis is adjusted to correct biases that may result from serial autocorrelation and heteroscedasticity.

To increase the robustness of the results, the hypotheses are therefore tested using different model specifications:

i. First, the variable of interest, *NIF_comp* and *NIF_comp* + *incomp* are tested using a lag of 1 year. While the main model tests for a contemporaneous effect of the NIF on the online public services, the lagged model account for possible delays between the moment when the NIF is adopted and the moment when this translates in more online interaction between citizens and public administrations.
ii. Second, a model accounting for an interaction variable between the e-Government index and *NIF_comp* and *NIF_comp* + *incomp*, alternatively, is included in the analysis. This model allows us to test whether the effect of the e-Government index on the online interaction between citizens and public administrations depends on the adoption of NIFs based on the EIF and vice versa. If interaction effects can be detected, this means that the two variables combined have a greater effect than the sum of their individual effects.

6. Results and Discussion

By relying on the above-mentioned specifications, the results of the analysis support the two main hypotheses. Table 5 presents the results of the first model specifications (i.e., equation (1) which presents the main model with contemporaneous effects and the model in which *NIF_comp*

[9] This criterion is suggested in Kennedy (2003).

[10] Please note that the variables *NIF_comp* and *NIF_comp+incomp* are never used together in the model, hence their high correlation (justified by the way the two variables are built) does not create any collinearity problem.

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Table 5. *Regression results with contemporaneous and lagged effects*

Variables	index_PA							
	Contemporaneous effects				Lagged effects			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
NIF_comp	2.290	2.682*						
	(1.602)	(1.634)						
L.NIF_comp					2.526	2.018		
					(1.712)	(1.801)		
NIF_comp+incomp			5.666***	4.376***				
			(1.695)	(1.531)				
L.NIF_comp+incomp							5.488**	3.528*
							(2.350)	(1.941)
index_e-gov	0.212***	0.0932*	0.189***	0.0995**	0.213***	0.0747	0.205***	0.0877*
	(0.063)	(0.053)	(0.053)	(0.048)	(0.066)	(0.058)	(0.056)	(0.054)
l_Gen_pub	7.773	5.431	6.783	4.848	11.39	9.762	12.12	10.29
	(8.938)	(8.590)	(8.104)	(7.872)	(11.05)	(10.60)	(10.68)	(10.35)
Gov_eff	−2.961		−4.451		−2.303		−3.297	
	(5.110)		(4.421)		(4.758)		(4.118)	
l_GDP_cap		31.42**		25.51**		36.98**		32.28**
		(14.18)		(11.53)		(15.29)		(12.83)
Infra	−0.0981	−0.0583	−0.120	−0.0834	−0.108	−0.0673	−0.155	−0.102
	(0.090)	(0.080)	(0.085)	(0.080)	(0.108)	(0.090)	(0.104)	(0.0904)
IT_skill	−0.987	−0.331	0.360	0.419	−1.320	−0.639	−0.314	−0.142
	(1.507)	(1.309)	(1.467)	(1.305)	(1.451)	(1.148)	(1.474)	(1.190)
Constant	−12.22	−318.2*	−7.423	−255.1	−43.08	−410.6*	−48.46	−366.7*
	(85.68)	(176.1)	(77.33)	(151.3)	(105.7)	(201.1)	(101.9)	(179.5)
Observations	174	174	174	174	150	150	150	150
R-squared	0.176	0.274	0.261	0.318	0.168	0.290	0.228	0.312
Number of countries	26	26	26	26	26	26	26	26

Notes: Robust standard errors are in parentheses.
***$p < .01$; **$p < .05$; *$p < .1$.
Source: Authors' elaboration.

Table 6. *Regression results with interaction effects*

	index_pa			
Variables	(1)	(2)	(3)	(4)
NIF_comp	2.163	2.691		
	(2.215)	(2.155)		
NIF_comp×index_egov	−3.38E-4	−2.3E-4		
	(0.0330)	(0.0339)		
NIF_comp+incomp			4.599***	3.724**
			(1.368)	(1.373)
NIF_comp+incomp×index_egov			0.035	0.023
			(0.028)	(0.026)
index_e-gov	0.210***	0.093*	0.177***	0.095*
	(0.061)	(0.052)	(0.046)	(0.046)
l_Gen_pub	7.742	5.433	6.880	4.950
	(8.888)	(8.577)	(8.006)	(7.833)
Gov_eff	−2.934		−4.601	
	(5.165)		(4.360)	
infra	−0.0990	−0.0582	−0.140	−0.0977
	(0.093)	(0.083)	(0.092)	(0.087)
IT_skill	−0.995	−0.331	0.506	0.494
	(1.483)	(1.292)	(1.509)	(1.348)
l_GDP_cap		31.42**		24.61**
		(14.22)		(10.93)
Total effects				
NIF_comp	2.163	2.691		
NIF_comp+incomp			4.634***	3.747**
index_egov	0.210***	0.093	0.212***	0.118**
Observations	174	174	174	174
R-squared	0.176	0.274	0.271	0.322
Number of countries	26	26	26	26

Note: Robust standard errors are in parentheses.
***$p < .01$;
**$p < .05$;
*$p < .1$.
Source: Authors' elaboration.

and *NIF_comp + incomp* are lagged). Table 6 displays the results when the regression introduces interaction effects between the NIF and the e-Government index. The results associated with the *NIF_comp* variable are presented in (1) and (2) and those associated with *NIF_comp + incomp* are shown in (3) and (4). In addition, to address the problem of correlation presented in Table 4, the results when including the *government effectiveness* variable are described in (1) and (3) and those when including the *real GDP* per capita (in logarithm) variable are in (2) and (4). Several findings of the analysis are worth commenting as they can have substantial policy implications.

Focusing on the first hypothesis (the introduction of NIFs facilitates the online interaction between citizens and public administrations):

- On average and all other variables being equal, countries that have at least partially implemented the EIF (*NIF_comp + incomp*) register a higher level of citizens' use of the Internet to interact with their public administrations compared to countries that have not adopted the EIF at all. The

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associated variable (*NIF_comp* + *incomp*) is significant at the 1, 5, or 10% level across all model specifications.

- The dummy variable identifying countries that have implemented the EIF in full (*NIF_comp*), however, is significant only under one model specification at the 10% level (namely the second specification of the contemporaneous effects model). Given that only one specification led to significant results, it cannot be concluded that there is an overall effect associated with this variable. Therefore, considering the results associated with both dummy variables of interest (*NIF_comp* + *incomp* and *NIF_comp*), an effect from the partial implementation of the EIF can be confirmed through this analysis, but no effects can be confirmed in the case of the full implementation of the EIF based on the data and models available.
- The key takeaway is that the true difference is not necessarily made only by the full implementation of the EIF. The main effect seems to come from the adoption of a well-crafted set of policies to foster interoperability in the public sector, which build to different extents on the EIF, and which also account for national specificities in their aim to enhance interoperability.

Moving to the second hypothesis (better e-Government services encourage citizens to interact online with public administrations):

- All models (with the exception of one specification—namely specification (2) of the lagged-effects model) confirm that the availability and delivery of online public services (as captured by the index_egov variable) has a positive impact on citizens' use of the Internet to interact with public administrations.
- A 10% increase in the e-Government index, with all other variables being equal, leads to an increase of approximately 1–2% in citizens' use of the Internet to interact with public authorities.

When it comes to the effect of the control variables, all model specifications indicate that higher levels of *GDP* per capita have a positive impact on the online interactions between citizens and public administrations. The coefficient should be interpreted as a semi-elasticity, that is, a 1% increase in GDP per capita leads, all else being equal, to an increase of about 0.3% in online interactions between citizens and the public administration services.

Finally, the model featuring interaction effects presented in Table 6 does not display a significant interaction term. In other words, the variable capturing the adoption of NIFs based on the EIF does not seem to impact the relationship between the e-Government index variable and citizens-government online interactions. Similarly, the level of the e-Government index does not seem to have an impact on the relationship between the variable capturing the adoption of NIFs implementing the EIF and the online interaction between citizens and public administrations. As reported in the key results related to the independent variables, the only interesting results lie in the individual effects of each variable, namely *NIF_comp* + *incomp* or *NIF_comp* and *index_egov*, on the dependent variable *index_PA.*

7. Limitations

The model and the analysis presented in this article test and validate the effect of the EIF and the general development of eGovernment services on how citizens interact online with their public administrations. There are, however, some limitations to the analysis that need to be discussed.

First, the analysis captures effects stemming from actions taken at the strategic level of interoperability. The guidance provided by the EIF is valid at the governance and strategic levels, aiming to increase coordination across the EU and improve the way EU countries design interoperable public services. Therefore, the model does not capture, at least directly, the effects stemming from the practical implementation of the interoperability requirements included in the EIF. Further research could consider analyzing the implementation of specific interoperability requirements to understand which concrete measures may yield more results. Further analysis on the effects stemming from certain interoperability

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requirements can also lead to more granular policy recommendations, thus also contributing to the ongoing debate on interoperability as a tool to foster competition in digital services.

Second, cultural factors are not directly accounted for in the analysis through dedicated explanatory variables as such factors are difficult to capture and measure. Cultural factors, that are specific to individual countries, may affect the way public services are developed, the extent to which they are interoperable (for instance, cultural factors may include resistance to technological change, Navarrete et al., 2010) and the citizens' propensity to use digital public services. Nevertheless, the choice of the model mitigates this issue. The fixed effects model isolates the impact of factors that are country specific and that do not vary over time. Cultural factors are expected to be time-invariant over the limited period of analysis (2012–2019).

Finally, while time-invariant effects that are specific to individual countries are captured in the model via country fixed effects, additional time-varying effects that are not captured by the control variables are not included in the model. There are two main considerations that motivate the decision not to include time-fixed effects in the analysis. First, including additional dummy variables in the model to account for time-fixed effects could yield problems of collinearity.[11] Second, the relatively short time period considered in the analysis could also be a limitation, meaning that only a limited set of data could be integrated in the analysis based on available sources. Over time, as more data become available, further research could rely on a longer timeframe and could apply a parametric approach to approximate time-fixed effects in case time dummy variables are hardly applicable as suggested by Gösser and Moshgbar (2020).

In spite of the limitations listed in this section, this article contributes to the academic and policy debates on the role of interoperability and its impact on digital innovation. In line with Hodapp and Hanelt (2022), it provides a more comprehensive perspective on interoperability that is not restricted only to the technical aspects but acknowledges the sociotechnical nature of interoperability. In addition, it also contributes to wider debates on the adoption of open source solutions as open source software can play a significant role in the public sector and in the development of digital public services (Spagnoletti and Federici, 2011).

8. Conclusions

This article is a first empirical attempt to analyze the effect of the EIF and the adoption of NIFs on the online interaction between citizens and public administration services. Despite the need for further empirical evidence, the results presented in Section 6 allow to identify two main recommendations for EU policymakers, who are now in the process of devising a "reinforced EU governments interoperability strategy," as outlined in the 2020 Communication "Shaping Europe's digital future" of the European Commission (2020).

First, efforts to improve e-Government services across Europe should be intensified in order to support the overarching digital agenda of the EU and, especially, increase benefits for European citizens. Second, and closely related, the EU should continue to foster the development of a common EU approach to interoperability, provide updated guidance and outline key areas of strengthened cooperation for the design of new digital public services. The need for interoperability of digital public services and the crucial role played by the EU have become more prominent than ever during the COVID-19 crisis.

The analysis presented in this article shows that there is value in the existing guidance, and the uptake (at least partial) at the national level of the recommendations contained in the EIF leads to improved outcomes for citizens. In shaping a new interoperability strategy for Europe, the Commission could strengthen the governance of interoperability initiatives and introduce specific requirements for interoperability to be implemented in the EU. It should, however, leave room for a flexible approach in the

[11] The correlation matrix performed after running equation (1), including the time-fixed effects, shows that the correlation values between the time-fixed effects are between 0.8 and 0.95.

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implementation of such requirements to account for national specificities. This way, the Commission could support the adoption of well-crafted policies for interoperable digital public services in the EU without imposing measures that may be too restrictive and unfit for national specificities. Building on the benefits derived from the adoption of NIFs based on the EIF, an enhanced and more versatile piece of EU legislation could contribute to increased coherence in the development of digital and interoperable public services and would ultimately increase the benefits for citizens in their interaction with public administrations.

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A. Annex

This annex presents an overview of the countries in the scope of the analysis with respect to the adoption of NIFs. More specifically, Table A1 describes whether the countries under analysis have a NIF in place, the year in which the framework was adopted, and whether the guidance from the EIF was either fully or partially taken up in the NIF (or other similar national strategies related to interoperability). It also provides remarks on the specificities of the NIFs (or similar national strategies related to interoperability) in relation to the EIF.

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Table A1. *Overview of the adoption of national interoperability frameworks in the countries analyzed in this article*

Country	National interoperability framework	Year of adoption[a]	EIF guidance fully or partly taken up	Remarks
Austria	Austrian interoperability Framework (AIFv1.0)	2015	Fully	The *Austrian Interoperability Framework (AIFv1.0)* was found to be almost perfectly aligned with the EIF (with an alignment score of 95%)[b]
Belgium	Belgian Interoperability Framework (BelgIF)	2005	Fully	Interoperability in Belgian public services was initially addressed in 2005 when the first NIF was adopted. In 2017, BelgIF was adapted to the new EIF. The current *Belgian Interoperability Framework* relies on the 12 principles of the EIF as the basis on which the federal and regional public authorities define interoperability. The BelgIF endorses the 47 recommendations put forward in the 2017 version of the EIF
Czech Republic	Not available, but other official documents serve a similar purpose	2018	Partially	The Czech Republic does not have a dedicated NIF. It does, however, take into account principles of e-Government in the description of its "*National e-Government Architecture of Public Administration*," which was implemented based on the *Information Concept Plan* (adopted in 2018)
Denmark	The Common framework for Public Sector Digital architecture	2017	Fully	The *Common framework for Public Sector Digital architecture* (2017) takes into account interoperability layers and several interoperability principles of EIF. Also, it is built partly on the European Interoperability Reference Architecture
Estonia	Estonian Interoperability Framework (EIF)	2011	Fully	Estonia has addressed the interoperability of public services for a long time. The third version of the Estonian Interoperability Framework was published in 2011. The current version of the *Estonian Interoperability Framework* is aligned with the new EIF on the basis of terminology and general principles. It includes three layers of interoperability; technical interoperability, organizational and semantic interoperability
Finland	Not available	—	—	Finland does not have a dedicated NIF

(Continued)

Table A1. *Continued*

Country	National interoperability framework	Year of adoption[a]	EIF guidance fully or partly taken up	Remarks
France	Not available, but other official documents serve a similar purpose	2016	Partially	France does not have a strategic document dedicated to the NIF. However, France adopted the *General Interoperability Repository* (2016) that refers to technical and semantic interoperability. The repository is a set of recommendations referencing norms and standards that promote interoperability within the public administration's information systems. The referencing of norms and standards is based on criteria developed by the European Commission (the Common Assessment Method for Standards and Specifications)
Germany	Not available, but other official documents serve a similar purpose	2017	Partially	The Federal Republic of Germany does not have a dedicated NIF. However, it does take EIF into account in the *Architectural Guideline for Federal IT*, which aims to help public administrations develop new public services by providing technical and semantic guidelines. *The binding Architecture Guidelines were first adopted in 2017*
Greece	Greek e-Government Interoperability Framework (Greek eGIF)	2006	Fully	The *Greek e-Government Interoperability Framework* has been developed in 2006, providing standards and specifications for the development of web-based services and guidelines for public administrations. The framework was officially adopted through state law in 2010
Hungary	Not available, but other official documents serve a similar purpose	2014	Partially	Hungary does not have a dedicated NIF. However in the *"National Info Communication Strategy 2014–2020"* several principles of EIF are addressed such as openness, technological neutrality, and security
Iceland	Not available	—	—	Iceland does not have a dedicated NIF. However, National bodies are currently working on the development of a NIF that will include all government levels, public administrations and private entities
Ireland	Not available	—	—	Ireland does not have a dedicated NIF

(Continued)

Table A1. *Continued*

Country	National interoperability framework	Year of adoption[a]	EIF guidance fully or partly taken up	Remarks
Italy	The New Interoperability Model	2020	Fully	A *New Interoperability Model* was developed in Italy as a cornerstone for the IT plan for public administrations between 2020–2022. It provides guidelines and technological specifications and standards for Italian public administrations. The design for the new interoperability model is based on the principles of the European Interoperability Framework (the 2010 version)
Latvia	Not available, but other official documents serve a similar purpose	2015	Partially	Latvia does not a dedicated NIF. However, the *Conceptual Architecture of Public Administration Information Systems* (2015) provides an architectural reference covering all aspects of public information systems, organization, data, systems, and technology. It includes 40 recommendations on the long-term vision for development of public services. Furthermore, the Latvian Cabinet of Ministers suggested that the Conceptual Framework needs to be more aligned with the current EIF
Lithuania	Not available	—	—	The Republic of Lithuania does not have a dedicated National Interoperability Framework
Luxembourg	The Luxembourg National Interoperability Framework (NIF)	2019	Fully	The *Luxembourg National Interoperability framework* is developed on the basis of the EIF. It consists of 11 principles and 48 recommendations, providing guidelines for development of interoperable public services in Luxembourg
The Netherlands	Dutch Government Reference Architecture (NORA)	2006	Fully	The *Dutch Government Reference Architecture (NORA)*, playing the role of a NIF, was first adopted in 2006. It includes 10 basic principles and 38 derived principles for successful development of interoperable public services. In 2016 NORA was almost perfectly aligned with the previous version of the EIF[c]

(Continued)

Table A1. *Continued*

Country	National interoperability framework	Year of adoption[a]	EIF guidance fully or partly taken up	Remarks
Norway	Norwegian Interoperability Framework	2018	Fully	The *Norwegian Interoperability Framework* is considered as the national transposition of the EIF. The NIF is mandatory only for the national levels of public administrations, while for the local and regional levels it is strongly recommended. It is built on the three main elements (principles, interoperability layers, and conceptual model for public services) of the EIF. Furthermore, it provides guidelines and recommendations on how to develop interoperable public services in Norway
Poland	Not available, but other official documents serve a similar purpose	2018	Partially	Poland does not have a dedicated NIF. However, Poland set up *the State Information Architecture* (2018) which aims to ensure that IT activities and processes taking place in public administrations are consistent. The work undertaken in Poland, starting from the State Information Architecture, is carried out in accordance with the European Interoperability Reference Architecture and the EIF[d]
Portugal	Not available, but other official documents serve a similar purpose	2015	Partially	Portugal does not have a dedicated NIF. However, a *platform for the interoperability of public administrations* is available online (*created in 2015*). The platform includes several tools enabling public administrations to provide interoperable electronic services
Slovakia	Not available	—	—	Slovakia does not have a dedicated NIF
Slovenia	The Slovenian National Interoperability Framework (NIO)	2012	Fully	While a Slovenian NIF exists, this has been established as a portal for coordinated development of interoperable public services in Slovenia, rather than as a strategic document. The *NIO portal* provides guidelines, recommendations and sharing of best practices for relevant stakeholders. Interoperability is considered in strategic documents such as the "*Public Administration Development Strategy 2015–2020*"

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Table A1. *Continued*

Country	National interoperability framework	Year of adoption[a]	EIF guidance fully or partly taken up	Remarks
Spain	Spanish National Interoperability Framework (EIN)	2010	Fully	The *Spanish National Interoperability Framework* (EIN) was first published in 2010 and was aligned in 2018 with the new EIF
Sweden	Not available	—	—	Sweden does not have a dedicated NIF
Switzerland	Not available	—	—	Switzerland does not have a dedicated NIF
United Kingdom	Not available, but other official documents serve a similar purpose	—	Partially (from 2011)	The UK does not have a dedicated NIF. However, the United Kingdom has adopted the "*The Digital Service Standard*" and the "*Technology Code of Practice*." Both documents are aligned with the current EIF. The UK has had a series of ICT strategies to improve the delivery of public services, including a strategy adopted in 2011 (*Government ICT Strategy*), the 2012 *Government Digital Strategy*, and the 2017 *Government Transformation Strategy*

Note: The information presented was collected in January 2021.

[a]This column refers to the first adoption of NIFs. It should be noted that the data accuracy depends on the data availability online.

[b]Further details on the alignment score is available here: https://joinup.ec.europa.eu/collection/nifo-national-interoperability-framework-observatory/news/austrias-renewed-interoperab (accessed 6 September 2021).

[c]Further details on the alignment score are available here: https://joinup.ec.europa.eu/sites/default/files/custom-page/attachment/2017-10/NIFO_Updated_Analytical%20Model_NETHERLANDS_2016_published.pdf.

[d]See: Digital Public Administration factsheet 2020: Poland, https://joinup.ec.europa.eu/sites/default/files/inline-files/Digital_Public_Administration_Factsheets_Poland_vFINAL.pdf.

Source: Authors' elaboration based on CEPS (2021).