Is innovation linked to demographic shifts? A study on the association between the demographic decline and the digital transformation of Italian local governments

Di Loreto, Manuel

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Author: Manuel Di Loreto

Supervisor: Kohei Suzuki, Dr.

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Abstract

Several advanced countries are experiencing sub-replacement level fertility rates which, together with an increase in life expectancy, results in population decrease and ageing. Scholars have focused on studying these phenomena as potential trigger of societal and economic changes. However, the link between demographic decline and public sector innovation remains unexplored: we know little about innovation by governments when they are pressured by a population that is shrinking and ageing. This study tries to fill this gap by examining the digital transformation of Italian provincial capitals. I argue that the demographic decline can make the digitalization of local administrations less attractive, since it would shrink the pool of potential users of the innovative item. This hypothesis was tested with multiple regression analyses and the findings support the existence of a negative and statistically significant correlation between demographic decline and local government digitalization.

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1. Introduction

The global population is expected to age at an impressive rate in the next 30 years (OECD, 2011). This phenomenon is particularly severe in OECD countries, where the amount of people aged over 80 is expected to rise to 10% of the total population by 2050 (OECD, 2011). This percentage is even higher in countries like Italy, Japan, South Korea, and Germany, where it will be higher than 15% (OECD, 2011). Furthermore, these countries have already started to experience depopulation, which threatens the very existence of thousands of small towns and rural areas (UVAL: Public Investment Evaluation Unit, 2014).

Researchers have typically focused on studying the consequences of the demographic decline on the economy. This phenomenon is expected to shrink the working-age population and increase the number of pensioners. As a result, population shrinking and aging are seen as a threat to the ability to sustain the current levels of public pensions (Barr, 2020); economic growth (European Commission, 2020); and public budgets, as it will increase the cost of long-term care and healthcare (OECD, 2011). Yet, the possibility that the demographic decline might influence innovative behavior in the public sector remains widely unexplored. Some researchers studied public sector innovation in response to immigration, which can potentially change the ethnic composition of the population or the age structure of the workforce. But, to the best of my knowledge, only Suzuki, Ha, and Avellaneda (2020) investigated the demographic decline as a potential causal factor of public sector innovation in Japanese municipalities. The researchers found a non-linear relationship in which too strong or too weak expected demographic decline leads to less visible innovation.

In this thesis, I investigate the relationship between demographic decline and innovation in Italian municipalities. Italy represents an interesting context for this study since it is severely affected by depopulation and aging. In 2019, the share of elderly people as a percentage of the total population was 23.06%, second only to Japan (OECD, 2021). Furthermore, since 1992, Italy has consistently registered a negative rate of natural increase. In other words, the number of deaths exceeded the number of births. From 2014 to 2020, the country has lost more than 1 million people.

The focus lies on a specific type of innovation, known as *digitalization*, which is broadly defined as the employment of ICTs to provide services to and interact with citizens and businesses. I observe the level of digitalization achieved in 2021 by 110 Italian municipalities known as *capoluoghi di provincia* (provincial capitals). The aim of this paper is purely exploratory: I investigate whether the demographic decline and local government's digitalization are statistically correlated. However, due to data unavailability and the cross-sectional nature of the data on digitalization, this thesis does not aim to assess the causal impact of demographic decline on digitalization. Therefore, the research question is formulated as follows: *"Is the demographic decline empirically linked to the digital transformation of local governments?"*

According to Arduini et al. (2011), innovative technologies tend to be adopted where there is a higher concentration of potential users, suggesting that larger municipalities have a higher level of digitalization. However, it also implies that the demographic decline, through depopulation and aging, can shrink the pool of potential users of the innovative item. In particular, the elderly tend to use digital and new technologies much less than the younger population and do not invest as much in learning new skills. Furthermore, an older population can create an age-dependent demand structure (Suzuki et al., 2020), which pressures the public sector to focus on health care and elderly care rather than investing in the provision of other kinds of services that can be supplied digitally. It follows that the demographic decline can make the digital transformation of the administration less attractive. In light of these considerations, I hypothesize the existence of a negative correlation between the intensity of the demographic decline and the digital transformation of local governments. In other words, the administration of municipalities that were most affected by the demographic decline will be less digitalized.

To test this hypothesis, I conducted a quantitative analysis with the method of Ordinary Least Squares (OLS). The demographic decline was operationalized mainly in terms of population change and workforce aging rates. The focus, therefore, lies on how quickly the population shrunk and aged in each municipality. The data on the digitalization of Italian provincial capitals was supplied to me by DedaGroup Public Services. The findings provide support to a statistically significant correlation between demographic decline and digitalization. Partly to overcome the limitations mentioned above, and more importantly, to show the mechanisms through which the demographic decline can influence the choice of administrators regarding digitalization, I conducted an illustrative qualitative study following an inductive Most Similar System Design.

This study contributes to the literature in at least two ways. First, it contributes to the innovation literature by increasing the understanding of the link between demographic decline and public sector innovation, which is widely understudied. Second, it contributes to the literature on local government digitalization in Italy, which is underdeveloped due to data unavailability and lack of transparency. The thesis is organized as follows: the next chapter reviews the current literature on the demographic transition theory and public sector innovation. The objective is to illustrate and properly conceptualize the phenomena of demographic decline and innovation in the public sector. Chapter 3 describes the research method that has been adopted and the variable operationalization. Chapter 4 and 5 contain respectively the main regression models and the robustness check, while the results are discussed in Chapter 6. In Chapters 7 and 8, I introduce and conduct the qualitative study. Finally, in Chapter 9, I draw the conclusion, summarize the main findings, and provide some avenues for future research.

2. Theory and Literature Review

This chapter explores the literature and the main trends in both the fields of demography and public sector innovation. While the first section illustrates the theories of the first and second demographic transitions to explain decreasing fertility rates, depopulation, and aging in advanced countries, the second section reviews the literature on innovation and narrows down a definition of digitalization and digital services. Finally, in the third section, I examine existing research on the interaction between demographic shifts and innovation, from which I formulate a Hypothesis.

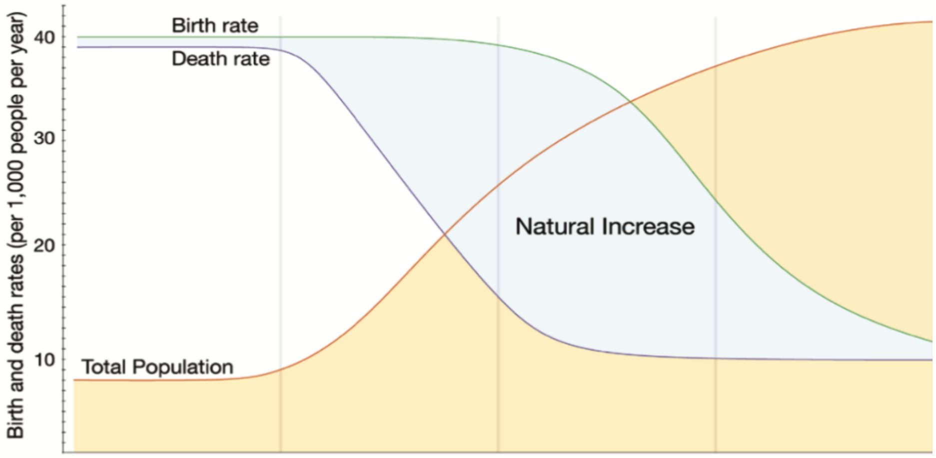
2.1. The theory of the demographic transition

Since the early 20th century, scholars have been trying to explain the phenomena of declining birth rates and mortality rates that were predominant in industrialized countries at the time (Kirk, 1996). Their observations and analyses culminated with the creation of the demographic transition theory.

The first contributions came from Warren Thompson (1929), who classified countries into three groups as regards their population growth, and from Adolphe Landry (1934), who observed the phenomenon of de-natality in Europe and hinted at a *Demographic Revolution*. According to their data and forecasts, developed countries in Western Europe and the United States would experience depopulation caused by a striking decline in birth rates below replacement level. Instead, the population of Southern and Eastern European countries, as well as of Asian countries, was expected to grow. In 1944, Frank Notestein, on behalf of the League of Nations, published his work "*The Future Population of Europe and the Soviet Union*" and reached conclusions similar to those of Thompson and Landry (Kirk, 1996). The demographic transition theory was formulated by the Office of Population Research in Princeton, based on Notestein's work (Kirk, 1996). Figure 1 illustrates the classic theory, divided into four different stages.

It was widely accepted that the decrease in mortality rates reflected the rising public order, improved hygiene, and discoveries in the medical fields (Kirk, 1996). Explaining the decline of birth rates was instead more challenging and controversial. The classic theorists, such as Coale and Hoover (1958) and Notestein (1953), considered both socio-economic and cultural factors but greatly emphasized the formers (Kirk, 1996).

Figure 1: Visualization of the Classical Demographic Transition Theory.



	Stage 1	Stage 2	Stage 3	Stage 4
Birth rate	*High*	*High*	*Falling*	*Low*
Death rate	*High*	*Falls rapidly*	*Falls more slowly*	*Low*
Natural increase	*Stable or slow increase*	*Very rapid increase*	*Increase slows down*	*Stable or slow increase*

Source: ourworldindata.org.
Notes: First stage: population is stationary; Second stage: death rate decreases; total population increases very rapidly; Third stage: birth rate starts decreasing, population grows at a progressively slower rate; Fourth stage: population growth is at replacement rate or slightly positive

Notestein, in particular, argues that the greater importance of education and individual achievement increased the cost of child-rearing. Furthermore, "*women found new independence from household obligations and new economic roles less compatible with childbearing*" (Notestein, 1953). Conversely, Caldwell (1976, p. 352) criticizes western scholars for "*omitting transmitted European cultural traditions from the study of modernization*" and makes a sharp distinction between modernization and westernization. While the former is an economic concept, the latter is a social process entailing secularization, individualism, mass education, the diffusion of the nuclear family model, and the affirmation of women's rights that results in declining fertility rates (Caldwell, 1976).

According to the classic formulation of the theory, the transition would end by reaching an equilibrium between birth rate and death rate that is equal or just slightly above replacement level (Stage 4 in Figure 1). In other words, the population would remain stable or grow slightly even without immigration. Caldwell, Lesthaeghe, and Van de Kaa criticized this assumption. Caldwell (1982) predicted that fertility rates would continue to drop past replacement level and that population would be decreasing in all advanced countries in the early 21st century. Similarly, Lesthaeghe and Van de Kaa (1986), on the basis of several societal changes observed between 1960 and 1970, formulated the *Second Demographic Transition* theory (SDT) and predicted sub-replacement fertility level. They argue that the fertility decline in the classic (or 'first') demographic transition was driven by the predominance of the nuclear family model, familistic policies, and preoccupation with basic material needs (i.e., income, work conditions, housing, health, schooling, social security). In the SDT, individuals are still worried about securing basic material needs, but the fertility rate is further reduced by the rise of higher-order needs (i.e., individual autonomy, self-actualization, recognition), more effective contraception methods, the postponement of parenthood, rising symmetry in gender roles, and flexible family models (Lesthaeghe and van de Kaa, 1986; Lesthaeghe, 2011; Lesthaeghe, 2014).

Indeed, the assumption of fertility rates stabilizing at replacement level did not stand the test of time. As the OECD observed in 2019, 34 out of 36 countries have a fertility rate well below the level that ensures population replacement. According to the demographic projections, this will be the new equilibrium for the next 40 years. In the organization's words:

> *"The fall in fertility rates reflected changes in individuals' lifestyle preferences, in family formation, and in the constraints of everyday living, such as those driven by labour-market insecurity, difficulties in finding suitable housing and unaffordable childcare"* (OECD, 2019a, p. 170).

The OECD (2019a), as well as the European Commission (2020), expressed their worry on multiple occasions regarding the adverse consequences of the demographic decline on the economy, which should pressure the public sector by shrinking their budgets and increasing the demand for high-quality and accessible long-term healthcare services. Both organizations see innovation as an opportunity to solve or at least reduce these negative effects (OECD, 2019a; European Commission [EC], 2020).

2.1. Defining Innovation

Innovation in the public sector has been gaining increasing attention from scholars of public administration (de Vries et al., 2018). As Walker (2014) and Demircioglu (2020) observe, studies have demonstrated that public agencies are concerned with increasing innovativeness, as they are pressured by both citizens and politicians to raise user satisfaction, performance, efficiency, and legitimacy. Innovation can also be a catalyst for pursuing social and economic outcomes typically associated with public objectives, such as poverty reduction, wealth redistribution, improved education, and better health (Kelly et al., 2002; Demircioglu, 2020).

While there is generally an agreement on the effects of innovation, debates about its definition go back to 1934 (Suzuki et al., 2020). Damanpour and Schneider (2009, and reference therein) observe that *"researchers have generally defined innovation as the development (generation) and/or use (adoption) of new ideas or behaviors"* which may pertain to a product, service, technology, system, or practice. Similarly, and following specifically Rogers (2003) and Walker (2014, p. 23, and reference therein), here innovation is defined as an idea, practice, or behavior that is perceived as new and is implemented by an organization. The implementation and use of the innovative item are of critical importance (Walker, 2014, p. 24), as it is assumed that the objective is to raise the organization's performance or accountability, which is possible only by putting into practice the innovative idea (Damanpour and Schneider, 2009). Furthermore, the innovation must be new, or at least perceived as new, only in the specific unit of the administration where it is implemented, and not in the entire public sector (Rogers, 2003; Damanpour and Schneider, 2009; Walker, 2014; Demircioglu, 2020)

Given the broadness of the definition, it is becoming increasingly common to make a distinction between different types or dimensions of innovation (de Vries et al., 2018). The focus of this thesis is on a specific type that is known in the literature as *technological process innovation,* or more commonly as '*digitalization*' or '*e-government*' (Edquist et al., 2001; Damanpour et al., 2004; Walker, 2014; De Vries et al., 2016; de Vries et al., 2018). Technological process innovation ('digitalization' or 'technological innovation' henceforth) consists in the implementation of information and communication technologies (ICT) by public administrations to provide services and interact with citizens and businesses (Damanpour et al., 2004; Arduini et al., 2010; Walker, 2014;). The e-government literature is dedicated to the study of the implementation and usage of ICTs in the public sector, which is regarded by scholars in the field as a dimension of innovation (de Vries et al., 2018). In this view, innovation is driven by technological development, whose implementation and usage are seen as enhancing access, transparency, efficiency, and quality of public services (Bekkers and Homburg, 2007; De Vries et al., 2018) and decreasing costs (Walker, 2014). Digitalization has been used as a proxy of public sector innovation in many studies, including Meijer (2015), Lindgren and van Veenstra (2018), and Criado (2021).

2.1.1 Defining digital public services

There are different classifications of public services, depending on which aspect is emphasized. The OECD provides a summary of often used public services classifications, according to their function, provision, cost, target population, and geography of consumption, as reported in Table 1.

In this thesis, the focus lies on the geography of consumption of public services (last row of Table 1). According to OECD (2019b), point-specific services need the consumer to travel to the place of use and include airports, recreation centers, and healthcare, whereas services requiring continuous connection (or networks) are those that require roads, water pipes, power lines, and so forth. Digital services, instead, are defined by two characteristics: a) there is no travel on behalf of the consumer, and b) they require no network beyond digital connectivity (OECD, 2019b).

Table 1: Different classification of public services with key references

Categories	Sub-Categories	Key Source
Function	• Services to guarantee basic physical conditions • Services to guarantee basic social conditions • Services supporting quality of life • Services to enterprises	OECD, 2010
Provision	• Fully public • Association or non-profit • Private • Mixed	Klenk and Lieberherr, 2015
Cost	• Open access • Fee Based	European Commission, 2019
Target Population	• Universal • Targeted	OECD, 2019b
Geography of Consumption	• Point-specific consumption of public services • Public services requiring continuous connection (line or network) • Digital Consumption	DeVerteuil, 2000

Source: re-elaborated from OECD, 2019b

This classification can be further simplified by distinguishing public services that can (potentially) be supplied *fully* digitally from those that, by nature, require either travel time or a different network from digital connectivity. The first category includes education, paying taxes, and requesting benefits or similar forms of assistance. The second category includes healthcare, nursing assistance, waste management, public transport, and so forth. These services can benefit from digital technologies in various ways (for healthcare, see Kohlbacher et al., 2015) but cannot be provided exclusively through digital connectivity.

2.2. Digital Transformation and Demographic Decline

Scholars have identified several antecedents of innovation in the public sector, such as the complexity of the innovative idea, internal features of an organization (e.g., culture, structure, etc.), managerial and employees' characteristics, and changes in the external environment (Walker, 2014; De Vries et al., 2016; De Vries et al., 2018). Demographic shifts belong to the latter category, but the relationship between demographic decline and governmental innovation remains unexplored. Most studies focus on innovative behavior driven by immigration, as the public sector responds to a change in the ethnic composition of the workforce (for a literature review on this topic, see Richter, 2014). Among them, a few investigate the relation between regional innovativeness and changes in the age structure of the population due to immigration (Richter, 2014). Results are mixed: some researchers find an inverted U-curve relationship, others find that a younger or older workforce enhances regional innovativeness (Frosch, 2011; Richter, 2014). To the best of my knowledge, only Suzuki et al. (2020) studied the relationship between demographic decline and public sector innovation. They assess whether there are changes in innovative behavior in response to expected population decrease, focusing on Japanese municipalities, and find a non-linear relationship in which too strong or too weak expected demographic decline leads to less visible innovation.

Similarly, this thesis focuses on the digitalization of major Italian municipalities in response to the demographic decline. According to the National Institute of Statistics (ISTAT) data, Italy is one of the countries most impacted by the demographic transition: the fertility rate has been at sub-replacement level since 1976, and depopulation began in 2014. By 2065, the population is expected to decline from 60 million to 53 million, and the median age to go from 45.7 to 50.2 (data refers to the last projections made by ISTAT, 2018).

Literature on the digitalization of Italian municipalities is also very limited. A thorough search has yielded only two related articles. Arduini et al. (2011) use statistical evidence provided by ISTAT on 1,176 municipalities and find a positive correlation between the level of digitalization and broadband availability, population size, and the presence of firms using or producing ICTs. Previtali and Bof (2009), instead, employ qualitative evidence on 49 small municipalities and find that the lack of competence and infrastructure prevent them from furthering their digitalization process.

According to Suzuki et al. (2020) "*the link between demographic shifts and innovation is well established. The widely accepted notion is that to guarantee the viability of administrative governments, jurisdictions have to innovate in terms of (a) nature and number of services; (b) types of arrangements for service provision (contracting out, collaboration, co-production, privatization, etc.); and (c) different administrative and organizational structures that guarantee cost-efficiency and effectiveness*". It follows that innovation can raise efficiency (i.e., the viability of the administration) in response to a demographic shift. It is important to highlight that this thesis focuses only on one aspect of innovation, i.e., digitalization, while Suzuki et al. (2020) manage to capture innovation *tout cour*. Consequently, it cannot be excluded that a municipality with a low level of digitalization is not highly innovative in some other way.

Population decrease and aging are expected to create professional shortages, shrink the size of the workforce, and generate an age-dependent demand structure, which will ultimately result in an increasing pressure on public administrations to provide more and better services for the elderly, such as health care and long-term care (Suzuki et al., 2020; EC, 2020; OECD, 2021). These services, given their nature, can benefit from innovation and digitalization (Kohlbacher et al., 2015; OECD, 2021) but cannot be *provided* digitally (OECD, 2021). Moreover, older people tend to invest less time in learning new technologies (Suzuki et al., 2020) and have a considerably lower digital literacy compared to the rest of the population (Githens, 2007; UNECE, 2021; OECD, 2021). Consequently, aging makes the pool of people that would benefit from a digitalized administration smaller. These considerations are coherent with the literature on the spatial diffusion of innovation, which argues that "*technological advancement tends to be more timely and intensive where a larger number of potential users are concentrated*" (Arduini et al., 2011). In other words, where the population shrinks and ages at a faster rate, the adoption of digital solutions is less attractive since the number of potential users is reduced. At the same time, it can also be expected that municipalities with an increasing and overall younger population face a rising demand for a variety of services, some of which may be provided digitally. Population growth may cause inefficiency resulting in increasing cost of providing public services or decreasing quality and user satisfaction (Ladd, 1992). These mechanisms may exert pressure on the local administration to adopt digital solutions. In light of these considerations:

> **Hypothesis:** The administration of municipalities that have experienced a more severe demographic decline lag behind in the digital transformation process. Conversely, municipalities that have been less affected by the demographic decline have a more digitalized administration.

3. Research Design

3.1. Case Selection

Italian municipalities are suitable cases to investigate the interaction between demographic decline and digitalization for two reasons. First, municipal administrations have similar powers and responsibilities across the peninsula. Second, Italy is one of the countries most affected by the demographic decline, and about 1400 small towns are at high risk of extinction (ANCI, 2019). Both points are illustrated in detail in the next sub-sections.

Given the limited availability of data on local government's digitalization in Italy (which is extensively documented in the next section), the analysis focuses on the 110 provincial capitals. I investigate whether there is a correlation between the demographic decline and the digital transformation of Italian municipalities. However, due to data unavailability, it is not possible to infer a causal relationship. The goal of this study is, therefore, exploratory.

3.1.1 The Italian administrative structure

Italy adopts a three-tier local government system. The first tier is constituted by 20 regions. Each region is further divided into provinces, for a total of 106. Since 2010, provinces have lost most of their powers, and their role has been limited to one of coordination among municipalities (Benettazzo, 2019). Finally, the smallest administrative unit is called *comune* (i.e., municipality), and there are 7.904 in total (ISTAT, 2021a). About 5.521 (70%) of them are small municipalities with less than 5.000 inhabitants (ANCI, 2019) and host roughly 10 million people. Across the peninsula, municipal administrations have homogeneous functions and responsibilities, such as providing social relief, basic public services (waste, water, public transport), nursing assistance, and so forth (Testo Unico Enti Locali, Part I, Title II, Art. 13).

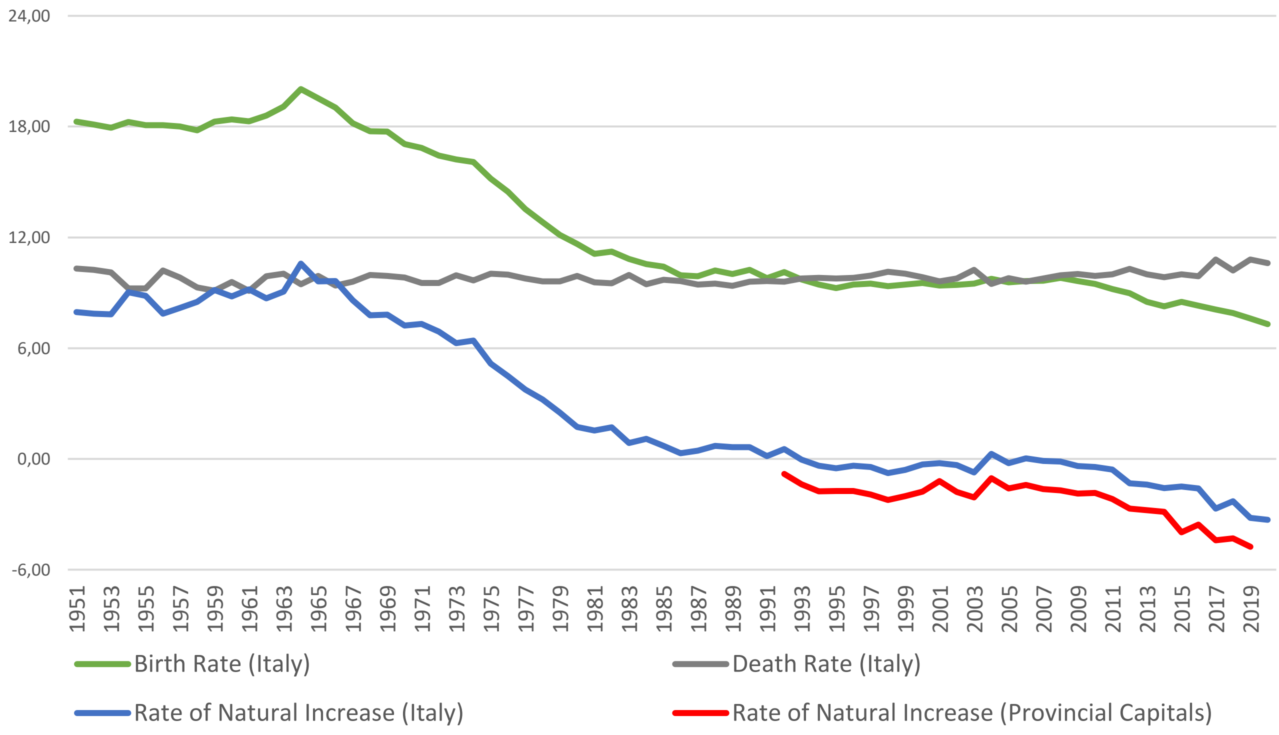
As previously mentioned, the analysis focuses only on the provincial capitals, which host about 28% of the total population (roughly 17 million people). The status of provincial capital is merely indicative and does not entail an extension of powers and responsibilities. Typically, it is attributed to a city where the provincial administration is located, which is usually the most populous city in the province. It must be noted that some provinces indicate more than one city as their capital. Therefore, the number of provincial capitals in the sample is 110 and not 106.

3.1.2 The demographic decline in Italy

The impact of the demographic decline was severe in Italy: in the last 20 years, the country recorded a fertility rate among the lowest in the OECD. Moreover, in 2019, the share of elderly people as a percentage of the total population was 23.06%, second only to Japan (OECD, 2021). As Figure 2 shows, birth rates decreased steadily from 1964, while mortality rates were overall stationary but started rising in 2014. Declining birth rates can be explained as the consequence of several phenomena typical of the SDT theory that have been observed in Italy, such as postponement of childbearing, fewer marriages, and increasing participation of women in the labor market (Aassve et al., 2019). The increasing mortality rate is instead the outcome of the structural and progressive aging of the population. In the words of ISTAT: "*The progressive rise of life expectancy, by favoring the aging of the population, extends year after year the number of elderly people in all age groups, ultimately resulting in a higher mortality rate*" (Translated from ISTAT, 2016).

The national Rate of Natural Increase (RNI, blue line in Figure 2) was negative for the first time in 1993. That is, the number of deaths exceeded the number of births. However, the phenomenon of depopulation was prevented until 2014 by a steady but decreasing international immigration. From then onwards, the country lost more than 1 million people. Figure 2 also shows that the RNI of the provincial capitals (red line) follows a pattern similar to the national one. Consequently, both birth rates and death rates of the municipalities in the sample evolved analogously to those of the entire population, as confirmed in Appendix A.

Figure 2: Birth rates, mortality rates, RNI in Italy from (1951-2020), and RNI in the sample of provincial capitals (1992-2019)



Data source: ISTAT database

Note: due to data unavailability, the RNI of the provincial capitals is shown only from 1992 onwards.

In the sample of provincial capitals, some municipalities still maintain a steady population growth, whereas most started depopulating way before 2014. This is explained by both international and internal migratory movements. In Italy, the latter are particularly relevant as they involve more than 1.2 million people every year (ISTAT, 2021b). According to ISTAT (2021c) and several academic studies (i.a., Lamonica and Zagaglia, 2013), there are two main migratory patterns: from less populated areas to major urban centers and from South to North, reflecting socio-economic differences in the peninsula. Importantly, these patterns are mostly attractive for the younger cohort of the workforce (ISTAT, 2018, pp. 3-5; ISTAT, 2019, p. 135). For instance, in 2019, 53% of the people who emigrated from South to North had an age between 18 and 35. In conclusion, while the RNI of a certain municipality may be negative, its population can still grow due to both international and internal migration.

3.2. Measuring Innovation

Researchers have adopted several ways to measure digital innovation in the public sector. Some studies focus on the ICT skills of the individuals involved in an innovation's implementation process, which can affect innovation adoption (de Vries et al., 2018).

Mossberger et al. (2021) employ data on broadband availability and internet subscriptions to measure digitalization in the US. Lindgren and van Veenstra (2018) point out that digitalization, in terms of digital provision of public services, is an important dimension of public sector innovation and a trigger for broad societal transformations. A few studies take all these aspects into account at once. For instance, Arduini et al. (2011) employ data on the number of services provided online, broadband availability, and ICT skills to measure the digitalization of local administrations in Italy. Other studies that follow this approach typically use the *Digital Economy and Society Index* (DESI), which measures EU member states' digital progress in terms of ICT skills, connectivity, integration of digital technologies, and the digitalization of public services (EC, 2021). DESI is widely used for cross-country comparisons (Nagy, 2019; Moroz, 2017) and explanatory studies, for instance, to observe the relationship between the digital economy and employment rate (i.a., Başol and Yalçın, 2021).

Public and accessible data on the digital transformation of Italian municipalities is very limited. ISTAT gathers data on the digitalization of all municipalities by measuring several indicators such as ICT training, the availability of public services online, internet speed, usage of social media, expenditure for ICTs, and others. This invaluable wealth of data, however, is published in aggregated form at the regional level, making it unpractical for a municipal-level analysis.

Another measurement is provided directly by the municipalities. Since 2009, every public agency must draft a three-year plan, indicating what objectives it will pursue to boost organizational performance. At the end of each year, the administrations must release to the public a report *(Relazione sulla performance*) where they self-assess the degree of achievement of such objectives. However, as the reports are not standardized, each local administration is free to make its own choices regarding how to draft them, what objectives to include, and how to measure them. As a result, not all municipalities include digitalization or any reference to innovation in their reports. Those who include it measure digitalization arbitrarily and sometimes fail to provide an exhaustive explanation of how the objective was achieved (Caporossi, 2021). Furthermore, some municipalities stopped reporting their performance altogether from 2016-2017. Because of these characteristics, the information that can be extracted from these reports is unreliable and not suitable for a large comparative study.

A few research institutes, associations, and companies try to measure municipal digitalization or other aspects related to it. In this thesis, I employ a composite index (*Ca.Re*) created by DedaGroup Public Services in collaboration with ForumPA (FPA). The *Ca.Re* index is inspired by the DESI and measures the degree of digitalization of Italian provincial capitals in terms of online provision of public services, integration of national digital infrastructures, transparency, and social communication (DedaGroup and FPA, 2019). By comparing the structure of both indexes, Ca.Re can be regarded as a subset of DESI: all the indicators considered by the former are included by the latter. The main difference is that Ca.Re does not include information on broadband availability and ICT skills.

3.2.1. *Ca.Re* Index: methodology and structure

The *Ca.Re* index measures the digital transformation of Italian provincial capitals' administrations. *Ca.Re* is composed by three "*dimensional indexes*" (or '*sub-indexes*'). *The Digital Public Service* index measures the online availability of 20 core public services typically provided by municipal administrations. One point is attributed when a service is available online, i.e., when citizens or companies can start a procedure (sending a file, requesting a document or certificate, accessing a service, making a payment, etc.) directly on the municipality's website. The score is subsequently normalized in a 0-100 scale. The list of services measured is available in Appendix B.

The *digital PA* index measures the level of integration of the main *enabling platforms*. Enabling platforms are national digital systems and infrastructures that standardize the access to and delivery of digital services across the country. The central government and the Agency for Digital Italy consider the integration of enabling platforms by all administrations a critical priority. These platforms relieve each public agency from the need to purchase and implement basic and necessary functions (i.e., prevents the phenomenon of *reinventing the wheel* and the subsequent waste of resources and time), and ensure greater IT security (Agenzia per l'Italia Digitale, 2017). In total, the index considers five enabling platforms. Three for the authentication of users on institutional websites: the Public Digital Identity System (SPID), the Electronic Identity Card (CIE), and the National Services Card (CIS). One platform is an electronic payment portal that allows businesses and citizens to carry out transactions to the public administration (PagoPA). The last system is the National Registry of Resident Population (ANPR): a national, fully digital population register that will replace local registry offices and related services.

Finally, the *digital openness* index measures the number and quality of open data published by each local government, as well as the level of communication with citizens through main social media channels. It is built on three indicators. The open data indicator measures the number of datasets released by municipal administration in open format. The interoperability indicator measures the open data's quality according to the Tim Berners-Lee scale. The digital communication indicator measures the level of interaction with citizens in terms of a) activation and usage of social media accounts and tools of instant messaging, b) social engagement, and c) the frequency of updates. The social media that are considered are Twitter, LinkedIn, YouTube, Instagram, Facebook, Messenger, and Telegram.

3.3. Dependent Variable

The dependent variable is the *Ca.Re* index, which measures the level of digital transformation achieved by each provincial capital in 2021. The *Ca.Re* index corresponds to the arithmetic mean of the dimensional indexes explained in the previous section and synthesizes information on a) the digital delivery of public services, b) the adoption of enabling platforms, c) the level of transparency and engagement in social communication.

3.4. Independent variables: operationalizing the demographic decline

The objective is to assess whether the *intensity* of the demographic decline has resulted in municipalities being more or less digitalized. The focus, therefore, lies not on the demographic indicators themselves but on how they changed over time. Two main independent variables are used: one measures population growth (or depopulation), and the other measures the aging rate. All data regarding the population of Italian municipalities are publicly available on ISTAT databases.

The first independent variable is the *population change rate* (or '*average rate of change of population size*'; World Health Organization, 2021). This variable measures how much a population grew (or shrunk) in each municipality between 2002 and 2020 (data refers to the 1st of January), which is arguably the most visible aspect of the demographic decline. To obtain this value, first, I calculated the rate of change of population size in each municipality for every year, according to the formula:

$$Population\ change\ rate = \frac{Population_{year(x)} - Population_{year(x-1)}}{Population_{year(x-1)}} \cdot 100$$

Then, I took the mean of these values for each municipality to synthesize the population change rate in a unique variable.

When measuring the aging of the population, it has been conventional for over a century to use the concept of population dependency ratio, which is the ratio of the number of people below the age of 15 and over 65, to the total working-age population (aged 15-64). However, studies in the last decades are diverging from this tradition. Sanderson and Scherbov (2015, p. 20) encourage researchers to use more accurate measures to conceptualize population aging. In their words: "*In the study of population aging, the dependency ratio and its components were developed in an era when far fewer data were available than they are today. Demographic methodology has also improved so that we can now conceptualize aspects of population aging separately from one another*." The researchers argue that the age cohorts considered by the dependency ratio are too broad and inaccurate. For example, the average retirement age is not 65 in all countries, and people in the 15-19 age group can hardly be regarded as financially independent given the increasing importance that education has gained in advanced economies. Nonetheless, following the tradition, the analysis of dependency ratio as the main independent variable is included in Appendix C.

Taking these considerations into account, I use the *rate of change of the active population age structure* (*'Workforce Aging Index'*, from here onwards) as a measure for aging. This indicator is often used by local and regional statistics offices in Italy and has also been employed in scholarly work (i.a., Lamonica and Zagaglia, 2013). The index captures the shifts in the age structure of the workforce. It is measured by the percentage ratio between the people aged 40-64 and those aged 15-39. A value of 100 would indicate that there is approximately the same number of people in both age cohorts. Higher values correspond to an older workforce. The average rate of change of this variable was calculated using the following formula:

$$Workforce\ ageing\ index\ \ (rate\ of\ change) = \frac{Workforce\ ageing\ index\ _{year(x)} - Workforce\ ageing\ index_{year(x-1)}}{Workforce\ ageing\ index_{year(x-1)}} \cdot 100$$

In the robustness check section, I rerun the same regression models employing the *Rate of Natural Increase (RNI) change,* which synthesizes information on the evolution of birth rates and death rates into one variable. As RNI is one of the two determinants of population change (the other being migration), it allows to check whether the results of *population change rate* are robust. Starting from data on birth rates and death rates between 2002 and 2019, I calculated the annual RNI change of each municipality according to the formula below, and then I took the mean of this variation as a variable.

$$RNI\ change = \left(Birth\ Rate_{year(x)} - Death\ Rate_{year(x)}\right) - \left(Birth\ Rate_{year(x-1)} - Death\ Rate_{year(x-1)}\right)$$

3.5. Control Variables

The validity of this approach is threatened if other factors are correlated with digital transformation outcomes. Therefore, I control for relevant geographic, demographic, financial, and socio-economic characteristics. A positive and statistically significant relationship between population size and the degree of digitalization in Italian municipalities was already found in the past literature (see Arduini et al., 2010). A larger population corresponds to a large number of potential users of new technologies, which makes the adoption of the innovative item more attractive (Arduini et al., 2010). Therefore, I control for *population size*. This variable is operationalized as the natural logarithm of the average population in each municipality between 2002 and 2020. The dimension of the municipality (*area size*) is also an interesting variable to explore. It mostly indicates those municipalities that have large farmlands or unused areas, and to a lesser extent, largely populated cities. For instance, the city of Andria has roughly 97 hundred citizens and an area of 402 km^2, whereas the city of Verona has 2.5 times the number of citizens (about 257 hundred), but half the area size (198 km^2).

Digital transformation requires a considerable financial investment by the municipality, which must adopt ICTs and train employees to use them. The relationship between budget size and innovation, however, is not straightforward. Several studies, mostly focused on the *New Public Management* reforms, find a negative and significant correlation between resource availability and innovation. For example, according to Bartos (2003, p. 10), budget cuts can "*encourage a higher degree of innovation and experimentation within the bureaucracy*". However, other studies find that budget has a positive effect since large budgets allow an organization to support innovative activities (i.a. Wynen et al., 2014). For these reasons, I control for the budget size per capita from 2016 to 2020. This data, available on *openbilanci.it,* considers all sources of income from both citizens (e.g., taxes) and other public administrations, such as the EU or the central state (e.g., redistribution schemes, disaster relief, funding for specific commitments and objectives). It must be noted that data before 2016 is not considered, as it is unsuitable for a comparative study since local administrations did not have a standardized accounting system and adopted different measurement methods and criteria (see *Legislative Decree 23 June 2011*). Furthermore, some municipalities have not published their budget sheets and financial statements at the end of 2018, 2019, or 2020[1]. I replaced missing values with data from yearly budget plans (which merely estimate the municipal's income during the year).

Finally, several studies reveal that worse social and economic conditions are associated with lower digital literacy, less usage and possession of digital devices, and lower internet access (i.a., Romeo, 2019; Zuddas, 2020). Moreover, people who live in critical social and economic conditions exert pressure on local governments to provide more and better social services. Consequently, socio-economic conditions can shrink or increase the pool of potential digital technology users, which, in turn, influences the decision of administrators to invest in digital solutions. Controlling for socio-economic conditions is also particularly important in Italy, as it is widely documented that Northern regions tend to have higher employment rates, GDP per capita, household income, and so forth (i.a. OECD, 2019c).

Since the availability of socio-economic data at the municipal level is very scarce, I follow a threefold strategy to control for these aspects. First, I control for latitude. Given that municipalities have the same powers and responsibilities, latitude should capture all other

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[1] Specifically: Foggia, in 2018 and 2019; Messina, in 2020; Isernia, in 2018 and 2020; Reggio Calabria, in 2020; Cosenza, in 2019 and 2020.

unobserved North-South differences, including socio-economic ones. Second, I include three socio-economic variables: income per capita, available at the municipal level from 2017 to 2019 (i.a. INTWIG, 2021); provincial GDP per capita from 2011 to 2018 (OECD, 2021); and provincial employment rate from 2011 to 2019 (ISTAT, 2021). Since the last two variables refer to the provincial level, they are not accurately descriptive of the socio-economic conditions of the municipality and, consequently, their explanatory power is weaker. Finally, as a robustness check, I employ dummy variables per region to investigate for possible inter-regional differences.

A list of all variables, along with their description, manipulation, and source is available in Appendix D.

3.6. Estimation Strategy and Descriptive Statistics

Given the cross-sectional nature of the data on digitalization, the goal of this thesis is not to infer causality but to investigate whether there is a correlation between the demographic decline and the digital transformation of Italian municipalities. To examine this relationship, I employ the statistical method of ordinary least squares (OLS). Several multiple linear regressions are conducted to investigate the hypotheses and the underlying research question.

The main regression model is expressed by the following equation:

$$Y_i = \alpha + \beta \cdot Population\ Change\ Rate + \gamma_i \cdot X_i + \varepsilon_i$$

Yi is the dependent variable, i.e., the *Ca.Re* index, which indicates the level of digitalization achieved by each municipality in 2021, whereas α is a constant intercept term. The main independent variable will be replaced first by the W*orkforce Aging Index* and, in the robustness check, by RNI change. Importantly, β is expected to be negative when the independent variable considered measures age (higher values of such variable indicates a population that is becoming increasingly older). X_i indicates the other variables that will be progressively included in the equation. These are both control variables for alternative explanations (i.e., confounders), fixed-time effects to be held constant (e.g., area size), and the various regional dummies that will be employed in the robustness checks to investigate the existence of regional differences. Finally, the error term ε_i indicates the variation from unobserved characteristics that I could not control for (e.g., employee's educational level).

Table 2 shows that the RNI decreased in most municipalities. A further inspection of both birth and mortality rates reveals that, in 2002, the RNI was positive in 32 municipalities. In comparison, from 2017 to 2019, all provincial capitals in the sample registered a negative RNI. Despite that, the population has grown in 70 municipalities from 2002 to 2019. These findings suggest that positive population growth is mainly explained by international and internal migratory movements, consistently with the analysis conducted in section 3.1.2. The aging variables (*dependency ratio change* and W*orkforce Aging Index*) are both positive, which correspond to a population that is becoming increasingly older in all municipalities. Table 3 reports the correlation matrix for all main variables. The matrix reveals that the *Ca.Re* index is positively correlated with population size: more digitalized administrations tend to be located in larger provincial capitals. At the same time, the aging indicators are negatively correlated with the *Ca.Re* index and all socio-economic variables. In other words, an older population is correlated with worse economic standards and lower levels of digitalization. Notably, the correlation between the demographic indicators and population size is weak, suggesting that the demographic decline in all its dimensions has affected municipalities independently from the amount of population.

Table 2: Descriptive Statistics

Variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**	**VIF**
Ca.Re	110	48.85	17.44	11.11	92.22	
Population change rate (2002-2019)	110	.12	.37	-.69	1.12	1.69
RNI change (2002-2019)	110	-.17	.11	-.44	.09	
Workforce ageing index (2002-2019)	110	2.11	.50	.94	3.36	
Dependency ratio change (2002-2019)	110	.95	.39	.12	2.37	
Area Size	110	179.90	170.94	20.9	1287.37	1.46
Population Size (log)	110	4.98	.36	4.33	6.42	1.52
Budget size per capita (2015-2020, log)	110	3.25	.16	2.86	3.81	1.26
Latitude	110	42.71	2.60	36.56	46.3	
Income per capita (log, 2017-2019)	110	4.32	.06	4.11	4.50	2.45
Avg. employment rate (provincial, 2011-2019)	110	57.54	10.04	37.21	72.18	2.60
GDP per capita (2011-2018, USD, PPP indexed, provincial, log)	110	4.11	.37	3.36	5.35	

Obs., observation; Std. Dev., standard deviation; VIF, variance inflation factor.

Table 3: Correlation Matrix

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
(1) Ca.Re	1.000										
(2) Population change rate (2002-2019)	.415*	1.000									
(3) RNI change (2002-2019)	.486*	.259*	1.000								
(4) Workforce ageing index (2002-2019)	-.490*	-.350*	-.722*	1.000							
(5) Area Size	.137	.221*	-.176	.192*	1.000						
(6) Population Size (log)	.583*	.133	.155	-.110	.374*	1.000					
(7) Budget size per capita (2015-2020, log)	.110	-.233*	.106	-.014	.018	.280*	1.000				
(8) Latitude	.382*	.444*	.556*	-.546*	-.272*	.003	-.131	1.000			
(9) Income per capita (log, 2017-2019)	.581*	.312*	.614*	-.584*	-.185	.294*	.161	.657*	1.000		
(10) Employment rate (provincial, 2011-2019)	.485*	.544*	.591*	-.577*	-.125	.049	-.137	.907*	.670*	1.000	
(11) GDP per capita (2011-2018, USD, PPP indexed, provincial, log)	.633*	.233*	.310*	-.376*	.137	.793	.303*	.298*	.685*	.309*	1.000

3.6.1. Diagnostics and multicollinearity

I ensured that the OLS assumptions were met. Specifically, the regression models and data show 1) no multicollinearity, 2) a linear relationship between all the independent variables and the dependent variable, 3) normal distribution of the residuals, 4) homoscedastic variance of errors, 5) no extreme outliers or highly influential and leverage points. It must be noted that some outliers and points of high leverage were identified. Their removal slightly favors the existence of a correlation between demographic decline and digitalization, but the results were not substantially different. Therefore, no outliers were removed from the empirical analysis. Some of the data and regression diagnostic methods employed are reported in Appendix E, whereas, for the remainder of this section, I focus on multicollinearity.

The descriptive statistics table (Table 3) shows the variance inflation factor (VIF) of the final regression specification with *population change rate* as the main independent variable. VIFs estimate how much the variance of a coefficient is affected because of linear dependence with other variables. A VIF higher than 5 indicates severe multicollinearity, whereas levels higher than 10 are critical (Hilmer & Hilmer, 2013). The final model of the regression has a mean VIF of 1.83, with e*mployment Rate* having the highest value of 2.60, sufficiently below the threshold for problematic collinearity. *Latitude* and *GDP per capita* are excluded due to multicollinearity. A look at the correlation matrix (Table 3) shows that latitude is strongly correlated to employment rate and moderately correlated with income per capita (column 8). Consequently, when socio-economic variables are included, latitude becomes uninformative and can be safely dropped without any loss of information. The variable for GDP per capita has a VIF of 7.19. Given that it is the least accurate among the socio-economic variables, it was dropped in the final specification.

To strengthen the validity of the results, I also employ a second method to deal with multicollinearity: Principal Component Analysis (PCA). PCA is a statistical technique able to extract the dominant patterns of two or more variables and create new variables (called *principal components*) based on such patterns (Jolliffe & Cadima, 2016). The principal components are obtained by linear combination of the original variables (Jolliffe, 1986). In the case at hand, through PCA, I obtained a new variable (called *Socio-Economic index)* that retains most of the variation of all three socio-economic variables. While this approach allows to simplify the analysis and to overcome multicollinearity, it may also make interpretability more complex since it is not clear which of the three original variables has the most influence. Still, including the *Socio-Economic Index* in the equation allows the observation of what would have happened to the coefficient of the main independent variables when all three socio-economic variables are included. The procedure I followed in STATA to obtain the principal components is described in Appendix F.

4. Regression results

In this chapter, the results of the main multiple regression models are presented, which show whether there is a correlation between the intensity of the demographic decline influenced the digital transformation of Italian provincial capitals. In the first section, demographic shifts are measured in terms of population change rate. In the second section, the demographic decline is operationalized in terms of changes in the age structure of the workforce through the variable W*orkforce Aging Index*. Both sections are essential to test the Hypothesis and address the research question of this thesis.

Figure 3 and Figure 4 display a scatterplot of the bivariate relationship between the two main independent variables and the *Ca.Re* index. The purpose of these graphs is to show in a visual way how *population change rate* and the W*orkforce Aging Index* are associated with digitalization. As Figure 3 shows, an increasing population is correlated with a higher score on the *Ca.Re* index. The relationship between the ageing of the workforce and the *Ca.Re* index is, instead, negative: a slower aging rate of the workforce corresponds to higher levels of digitalization.

Figure 3: scatterplot of Population Change Rate in relation to the Ca.Re index

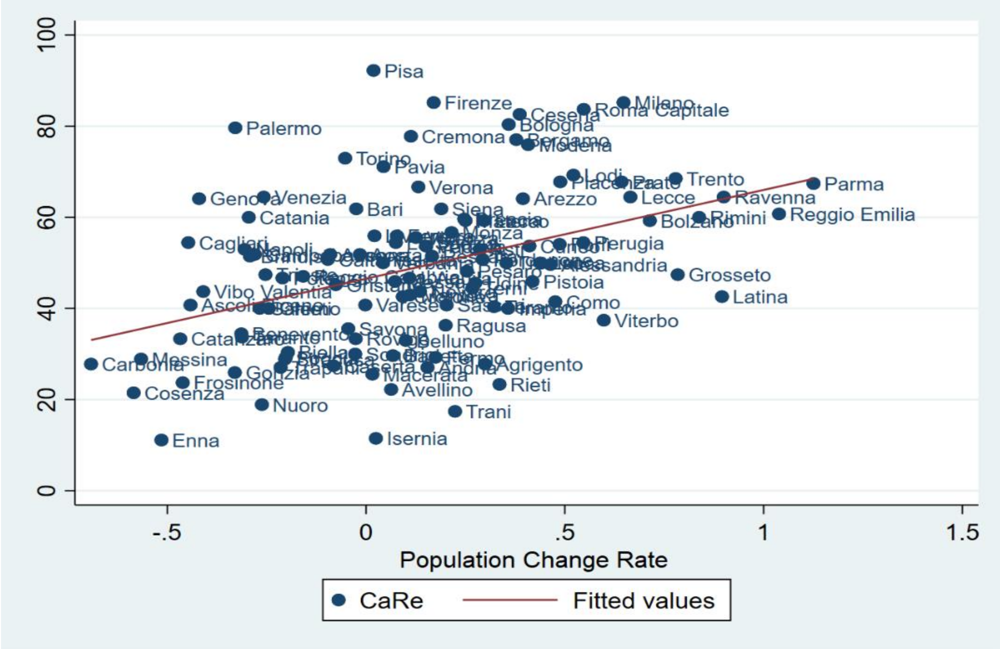
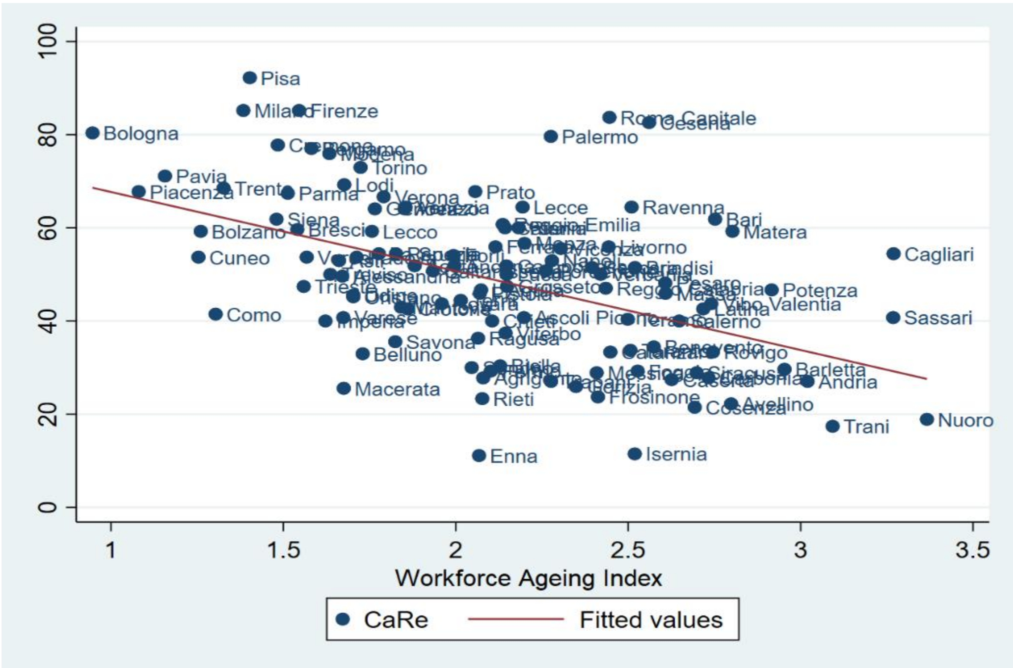


Figure 4: scatterplot of Workforce Ageing Index in relation to the Ca.Re index



4.1. Multiple regression (OLS) with population change rate

Table 4 presents the output of the regression, with *population change rate* as the main independent variable. Column (1) displays the result of the bivariate regression and shows that *population change rate* is highly statistically significant. A percentage point increase of the main independent variable corresponds to 19.4 *Ca.Re* index points. Controlling for *population size* and *area size*, as in column (2), reduces the coefficient of the main independent variable and its standard error. *Population size* is highly statistically significant in predicting municipal digitalization levels, coherently with past academic literature. New technologies tend to be adopted more intensively in cities where more potential users are concentrated (Arduini et al., 2011). At the same time, the digital provision of services represents a cost-effective and more efficient alternative to hiring new employees and opening new offices to improve the geographical distribution of services. In column (3), *latitude* is added in the regression, and it is statistically significant, indicating that municipalities in the North tend to be more digitalized than those in the South. The reasons for this contrast can only be ascribed to socio-economic differences across the peninsula, given that functions and powers are homogeneous across local administrations. Furthermore, *latitude* decreases the coefficient of the main independent variable by 6 points, reflecting the strong correlation between a positive *population change rate* (or at least less negative) and the geographic location of the municipalities. This finding confirms that migratory movements follow a South-to-North pattern, which is motivated by better economic conditions in the North (as reported in section 3.2.1). Column (4) documents that *budget size per capita* is positively correlated with more digitalization, but it is not statistically significant. This is not surprising, given that the central state allocates resources to poorer and smaller municipalities for redistribution purposes (Galli and Gottardo, 2020).

In columns (5) – (7), i*ncome per capita*, *GDP per capita (*2015, PPP indexed), and e*mployment rate* are added separately in the regression equation. *Latitude* is excluded to avoid collinearity issues (see section 3.6.1). All socio-economic variables are statistically significant. In particular, *income per capita* is highly statistically significant with a coefficient of 107. The coefficient of the main independent variable drops greatly in column (7) when e*mployment rate* is included in the equation, but it is still statistically significant at the 95% confidence interval. This would suggest that population change might be motivated by employment rates more than income levels. When both e*mployment rate* and i*ncome per capita* are included in the regression as in column (8), the coefficients and the significance of both socio-economic variables are reduced. The main independent variable remains statistically significant with a p-value of .045. In column 9, by including the socio-economic index based on all three variables, the coefficient increases by almost 1 point.

Regarding the explanatory power of the models, the adjusted R^2 increases considerably when other variables are included in the regression. The bivariate model shows an adjusted R^2 of .165, which peaks at .568 in column (8). In other words, once other explanatory variables are included, the model explains 56.8% of the *Ca.Re* index's variance. Interestingly, when the socio-economic index is employed, the explanatory power of the model is affected by -.008 points. Overall, the correlation between population shifts and digitalization is just statistically significant.

Table 4: Multiple Regression of Population Change Rate on Ca.Re index

	Ca.Re index								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Population Change Rate (2002-2019)	19.472*** (4.101)	17.539*** (3.365)	11.238** (3.837)	11.781** (3.941)	11.151** (3.501)	15.164*** (3.63)	7.933* (3.937)	7.808* (3.839)	8.729* (3.698)
Population Size (log)		28.445*** (3.588)	27.331*** (3.473)	26.577*** (3.677)	21.664*** (3.688)	16.18** (6.08)	26.393*** (3.509)	22.905*** (3.689)	18.026*** (3.975)
Area Size		-.018* (.008)	-.007 (.008)	-.006 (.008)	-.002 (.008)	-.011 (.008)	-.007 (.008)	-.001 (.008)	-.002 (.008)
Latitude			1.712** (.559)	1.724** (.561)					
Budget size per capita (2015-2020, log)				5.015 (7.852)	-2.323 (7.543)	.048 (8.155)	4.829 (7.505)	.193 (7.544)	-.981 (7.457)
Income per capita (log, 2017-2019)					107.008*** (22.361)			71.602* (28.322)	
GDP per capita (2011-2018, USD, PPP indexed, provincial, log)						14.019** (5.795)			
Employment rate (provincial, 2011-2019)							.631*** (.141)	.351* (.176)	
Socio-Economic Index									5.074*** (1.033)
_cons	46.527*** (1.597)	-91.739*** (17.437)	-160.529*** (28.042)	-173.73*** (34.899)	-515.05*** (89.699)	-89.46** (26.986)	-134.331*** (25.902)	-396.313*** (106.66)	-38.473 (27.726)
Observations	110	110	110	110	110	110	110	110	110
Adj. R-squared	.165	.467	.504	.503	.556	.487	.546	.568	.560

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

4.2. Multiple regression (OLS) with Workforce Aging Index

The output of the regression models with the rate of change of the active population age structure (W*orkforce Aging Index*) as the main independent variable is presented in Table 5. The pattern is the same followed in the previous section.

The bivariate regression displayed in column (1) shows that the W*orkforce Aging Index* is negatively correlated with digitalization and highly statistically significant. Specifically, a percentage point increase in the independent variable corresponds to -17 points in the *Ca.Re* index. This outcome lends support to the Hypothesis since higher values correspond to a workforce that ages at a faster rate. Including *population size* and *area size* as in column (2) reduces both the significance and the standard error of the independent variable. *Population size* is positive and statistically significant, which is in line with existing research. In column (3), *latitude* is statistically significant, indicating that socio-economic differences across the peninsula are important predictors of the digitalization level achieved by the municipalities. *Latitude* affects the coefficient of the main independent variable by 4 points, reflecting the strong correlation between these two variables. In line with the previous regression model, adding *budget size per capita* as in column (4) has a minimal impact on all coefficients, and it is not statistically significant. In columns (5) – (7), the three socio-economic variables are added separately in the regression equation. Only *GDP per capita* is not significant, while the other two variables are highly statistically significant and considerably affect the coefficient of the main independent variable. In column (8), the significance of *employment rate* and *income per capita* is very low. Moreover, the coefficient of the main independent variable drops to -7.47, but it is still statistically significant at the 99% confidence interval (p-value: .009). Finally, in column (9), the socio-economic index obtained through PCA is highly statistically significant and further reduces the coefficient of the independent variable by -.5 points.

As for the adjusted R^2, the explanatory power of the model goes from 23.3% in the bivariate regression to 58% in column (8). Once again, when socio-economic variables are replaced by their principal component as in column (9), the explanatory power seems to be slightly weaker.

The results document that there is a strong and negative correlation between the ageing rate of the workforce and local administrations' digitalization levels. In other words, the administration of municipalities where the active population aged at a faster rate is less digitalized. But before discussing the outcome and the limitations of these models, the robustness of these results must be investigated.

Table 5: Multiple Regression of Workforce Aging Index on Ca.Re index

	Ca.Re index								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Workforce Aging Index (2002-2019)	-16.962*** (2.901)	-15.072*** (2.41)	-11.199*** (2.725)	-11.234*** (2.741)	-9.402*** (2.729)	-13.221*** (2.688)	-8.787** (2.737)	-7.474** (2.802)	-8.123** (2.833)
Population Size (log)		25.097*** (3.503)	24.948*** (3.398)	25.199*** (3.584)	21.519*** (3.659)	18.808*** (6.002)	25.24*** (3.441)	22.918*** (3.637)	18.245*** (3.924)
Area Size		.002 (.008)	.006 (.008)	.006 (.008)	.008 (.007)	.003 (.008)	.002 (.007)	.006 (.007)	.007 (.007)
Latitude			1.469** (.531)	1.447** (.542)					
Budget size per capita (2015-2020, log)				-1.71 (7.425)	-7.794 (7.125)	-6.928 (7.561)	.05 (7.147)	-3.073 (7.277)	-5.514 (7.026)
Income per capita (log, 2017-2019)					90.493*** (24.206)			52.412* (28.917)	
GDP per capita (2011-2018, USD, PPP indexed, provincial, log)						8.831 (5.959)			
Employment rate (provincial, 2011-2019)							.547*** (.136)	.377* (.164)	
Socio-Economic Index									4.423*** (1.099)
_cons	84.659*** (6.294)	-44.697* (18.608)	-115.592*** (31.336)	-110.222** (39.171)	-405.744*** (103.183)	-31.386 (26.4)	-90.398** (28.799)	-288.86* (113.142)	-8.134 (25.486)
Observations	110	110	110	110	110	110	110	110	110
Adj. R-squared	.233	.511	.540	.536	.563	.514	.571	.580	.571

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

5. Robustness Check

In the following two sections, I assess the robustness of the results found in the main regression analysis by observing different aspects of both digitalization and demographic decline. Finally, in the last section, I investigate whether differences in digitalization follow a North-South pattern.

5.1. Alternative dependent variables: dimensional indexes comparison

The *Ca.Re* index, as already explained, is composed of three sub-indexes that synthesize information on different aspects of the digital transformation of local governments. In broader terms, the *Digital Service* index measures the availability of 20 services online; the *Digital PA* index measures the level of integration of national digital infrastructures, which are fundamental for the provision of said services. Finally, the *Digital Openness* index measures the transparency of the local government and the degree of interaction with citizens through social media. Clearly, ICTs have different applications and allow public agencies to pursue various objectives. Yet, in a more traditional view, the concepts of *e-government* and *digital administration* can be restricted to the provision of services online without accounting for other aspects such as social media or transparency (United Nations, 2021). It would be interesting to investigate whether the demographic indicators are stronger predictors when digitalization is operationalized according to such a restrictive view. Therefore, the dependent variable that is employed in the following two sub-sections is obtained by isolating the effect of the *Digital Openness* sub-index from the *Ca.Re* index. The result is a new dependent variable (called '*Digital Service+PA*') that exclusively measures the digitalization of services. The regression models with the *Digital Openness* index are displayed separately in Appendix G.

The academic literature suggests that population size is an important predictor of municipal levels of transparency for two reasons. First, governments of larger cities have stronger political competition and involvement of civil society, which pressures them to be more transparent (Bearfield & Bowman, 2016). Second, and to a lesser extent, larger cities tend to have more budget and are more likely to invest in transparency since it is an activity that yields no efficiency gain. In light of these considerations, I would expect that the demographic indicators are stronger predictors of digital services, whereas population size should be somewhat weaker.

5.1.1. Multiple regression (OLS) with population change rate

Table 6 shows the result of the multiple regressions model with *population change rate* as the main independent variable on the *Digital Services+PA* sub-index. The regression models in Table 6 are compared to their respective baseline models in Table 4 (section 4.1).

Table 6: Multiple Regression of Population Change Rate on the Digital Service+PA sub-index

	Digital Service + PA								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Population change rate (2002-2019)	21.005***	19.574***	13.825**	13.771**	12.517**	16.833***	9.748*	9.613*	10.377*
	(4.365)	(3.966)	(4.603)	(4.736)	(4.254)	(4.332)	(4.795)	(4.708)	(4.522)
Population Size (log)		23.918***	22.901***	22.976***	17.916***	13.565	22.733***	18.995***	14.571**
		(4.228)	(4.166)	(4.419)	(4.481)	(7.257)	(4.275)	(4.525)	(4.862)
Area Size		-.017*	-.007	-.007	-.001	-.011	-.007	-.001	-.002
		(.009)	(.01)	(.01)	(.01)	(.01)	(.009)	(.01)	(.01)
Latitude			1.562*	1.56*					
			(.67)	(.674)					
Budget size per capita (2015-2020, log)				-.498	-7.786	-4.994	-.631	-5.6	-6.275
				(9.437)	(9.166)	(9.733)	(9.142)	(9.253)	(9.12)
Income per capita (log, 2017-2019)					107.495***			76.742*	
					(27.173)			(34.739)	
GDP per capita (2011-2018, USD, PPP indexed, provincial, log)						12.689			
						(6.917)			
Employment rate (provincial, 2011-2019)							.605***	.305	
							(.172)	(.216)	
Socio-Economic Index									4.938***
									(1.263)
_cons	51.983***	-63.956**	-126.719**	-125.408***	-475.39***	-49.142	-91.471**	-372.26**	1.341
	(1.7)	(20.551)	(33.636)	(41.942)	(109)	(32.209)	(31.551)	(130.826)	(33.909)
Observations	110	110	110	110	110	110	110	110	110
Adj. R-squared	.169	.350	.376	.370	.424	.358	.408	.429	.422

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

The comparison of column (1) with the respective baseline model shows that the coefficient of *population change rate* in the bivariate regression is roughly 1.5 points higher when digitalization is operationalized only in terms of provision of services online. In column (2), the coefficient of *population size* is 23.9, which is considerably lower than 28.5 registered in the baseline model. Once again, the significance of latitude in columns (3) and (4) points at socio-economic differences that must be considered. In columns (5) to (7), all socio-economic variables, except GDP per capita, report a statistically significant value similar to the baseline model. When most variables are included, as in column (8), the main independent variable reaches the lowest coefficient of 9.613 (p-value: .044), which is just .7 points lower compared to column (9).

Notably, the coefficient of the main independent variable reports consistently higher values compared to the baseline models. By comparing columns (8) of both models, *population change rate* displays a higher coefficient when the effect of digital openness is isolated from the *Ca.Re* index. However, as the standard errors are also larger, the difference in p-values is negligible (from .045 in the baseline model to .044).

5.1.2. Multiple regression (OLS) with Workforce Aging Index

Similar to the previous section, Table 7 displays the regression output of *Workforce Aging Index* as the main independent variable on *Digital Service+PA* sub-index. The baseline models, in this case, are displayed in Table 5 (Section 4.2)

In the bivariate regression, the *Workforce Aging Index* reports a score of -18.876, which, in absolute terms, is 2 points bigger than the baseline model. The impact of *population* size in all models is considerably lower when the effect of digital openness is removed from the *Ca.Re* index. For instance, in column (2), *population size* reports a score that is 5 points lower compared to the baseline model. Still, the variable remains highly statistically significant. Interestingly, in columns (3) and (4), latitude is non-statistically significant. Accordingly, in columns (5) to (7), the socio-economic variables report lower values compared to the baseline models. Specifically, the statistical significance and the impact of the variables for *income per capita* and *employment rate* are considerably lower. Their significance is further reduced in column (8) when they are included together in the equation. Notably, in this specification, only the main independent variable and *population size* are statistically significant. In column (9), the S*ocio-Economic Index* results to be statistically significant, but its coefficient is smaller.

By comparing column (8) with the corresponding baseline model, it is possible to observe that the impact of population size is 4 points smaller, whereas the significance of the *Workforce Ageing Index* is slightly reinforced, with a p-value of .001 (compared to .009 in the baseline model).

Table 7: Multiple Regression of Workforce Aging Index on the Digital Service+PA sub-index

	Digital Service + PA								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Workforce Aging Index (2002-2019)	-18.87***	-17.653***	-14.518***	-14.692***	-12.615***	-16.456***	-12.264***	-11.057**	-11.806***
	(3.052)	(2.806)	(3.232)	(3.237)	(3.25)	(3.136)	(3.283)	(3.383)	(3.403)
Population Size (log)		19.939***	19.818***	21.081***	17.788***	17.447*	21.051***	18.917***	15.271**
		(4.078)	(4.03)	(4.232)	(4.358)	(7.003)	(4.128)	(4.391)	(4.713)
Area Size		.006	.009	.008	.01	.006	.005	.008	.009
		(.009)	(.009)	(.009)	(.009)	(.009)	(.009)	(.009)	(.009)
Latitude			1.189*	1.077*					
			(.629)	(.64)					
Budget size per capita (2015-2020, log)				-8.592	-13.449	-12.208	-6.765	-9.635	-11.448
				(8.768)	(8.485)	(8.823)	(8.573)	(8.785)	(8.439)
Income per capita (log, 2017-2019)					78.927**			48.167	
					(28.827)			(34.913)	
GDP per capita (2011-2018, USD, PPP indexed, provincial, log)						5.168			
						(6.953)			
Employment rate (provincial, 2011-2019)							.461**	.305	
							(.163)	(.198)	
Socio-Economic Index									3.66**
									(1.32)
_cons	94.337***	-8.611	-65.992	-39.017	-306.797*	19.671	-29.996	-212.384	38.95
	(6.622)	(21.663)	(37.162)	(46.253)	(122.882)	(30.804)	(34.543)	(136.602)	(30.61)
Observations	110	110	110	110	110	110	110	110	110
Adj. R-squared	.255	.418	.431	.431	.455	.419	.457	.462	.456

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

5.1.3. Summarizing the results

Coherently with the academic literature, *population size* is considerably more important in predicting local government's transparency rather than the digital provision of services. By comparing the regression models in Tables 6 and 7 to their respective baseline models, three conclusions can be drawn. First, *population size* loses some of its strength compared to the baseline models, but the correlation is still highly statistically significant. Second, socio-economic variables are weaker predictors, particularly when *Workforce Aging Index* is the main independent variable. Third, and most importantly, this approach shows that the demographic indicators are correlated with the digital provision of public services but are irrelevant in predicting the adoption of ICTs for communication or transparency purposes, as also confirmed in Appendix G.

Overall, both main independent variables are stronger predictors when *digital openness* is isolated from the *Ca.Re* index. However, only the robustness of W*orkforce Aging Index* comes reinforced from this analysis, while the significance of *population change rate* is unaffected.

5.2. Alternative independent variable: RNI change

Until now, the demographic decline was operationalized in terms of depopulation and aging, which are arguably the most visible aspects of demographic shifts. To test the robustness of these indicators, I investigate whether the underlying mechanisms of such phenomena, i.e., declining birth rates and rising mortality rates, are correlated with levels of local government's digitalization. To observe this relationship, a simple approach would consist in calculating the average rate of change of both birth rates and death rates in all municipalities and using this information as independent variables. However, these variables would not be very informative by themselves. For instance, a city may have increasing birth rates in a given period of time but may still experience depopulation due to higher mortality rates. In order to overcome this limitation, it is necessary to consider how the difference between birth rates and mortality rates evolved over time, which is exactly what the variable *RNI change* does. As population change is ultimately determined by the sum of RNI and net migration rate, this approach allows me to test the robustness of *population change rate.*

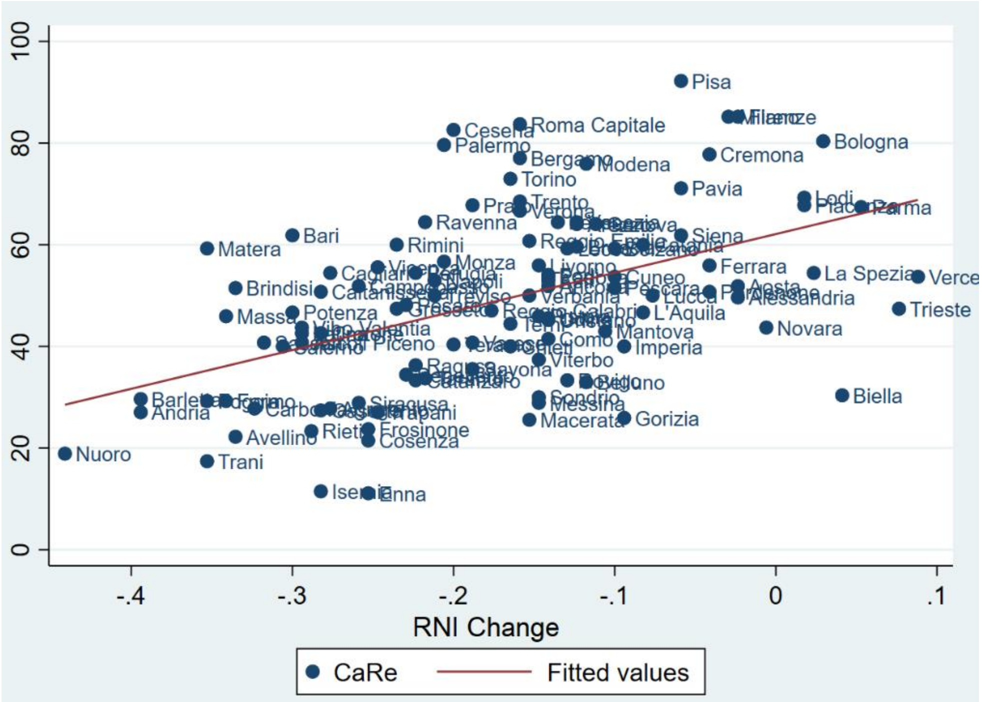
Table 8 displays the regression output with *RNI change* as the main independent variable. In column (1), the bivariate regression shows a coefficient of 76.1, positive and statistically significant. In other words, a "more positive" *RNI change* corresponds to a higher level of digitalization. Given the very small variation (from -.44 to .08, as shown in the descriptive statistics), the coefficient can be interpreted as follows: an increase of 0.1 of RNI change is associated with 7.6 *Ca.Re* points (see Figure 5 for a graphical representation). However, the high coefficient of the bivariate regression is vastly reduced as more controls are added.

Table 8: Multiple Regression of RNI Change on Ca.Re index (columns 1-9) and Digital Service+Pa (column 10)

	Ca.Re index									Digital Service+PA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
RNI Change (2002-2019)	76.099*** (13.16)	63.889*** (11.247)	44.271*** (12.795)	45.476*** (13.008)	36.581** (12.818)	56.686*** (11.281)	32.776* (13.043)	26.041 (13.319)	32.474* (12.691)	36.388* (16.249)
Population Size (log)		24.494*** (3.624)	24.644*** (3.503)	25.236*** (3.664)	21.369*** (3.719)	13.497* (5.811)	25.388*** (3.513)	22.874*** (3.696)	17.689*** (3.934)	18.887*** (4.509)
Area Size		.001 (.008)	.005 (.008)	.005 (.008)	.007 (.008)	.005 (.008)	.001 (.007)	.005 (.007)	.006 (.007)	.007 (.009)
Latitude			1.591** (.547)	1.516** (.564)						
Budget size per capita (2015-2020, log)				-4.382 (7.66)	-10.255 (7.214)	-11.388 (7.489)	-1.735 (7.38)	-4.732 (7.44)	-7.528 (7.089)	-11.948 (9.076)
Income per capita (log, 2017-2019)					95.895** (24.962)			57.543* (29.355)		56.973 (35.812)
GDP per capita (2011-2018, USD, PPP indexed, provincial, log)						14.895*** (5.491)				
Employment rate (provincial, 2011-2019)							.581*** (.142)	.397* (.169)		.344* (.206)
Socio-Economic Index									4.729** (1.08)	
_cons	62.097*** (2.716)	-62.26*** (18.106)	-135.128*** (30.568)	-120.315** (40.138)	-433.728*** (105.946)	-33.726 (26.155)	-99.905*** (29.242)	-317.7** (114.79)	-10.282 (25.636)	-261.806 (140.04)
Observations	110	110	110	110	110	110	110	110	110	
Adj. R-squared	.229	.487	.520	.517	.548	.518	.555	.567	.564	.434

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

Figure 5: scatterplot of RNI Change in relation to the Ca.Re index



Column (2) documents that *population size* is, as expected, statistically significant. *Latitude* is also statistically significant in columns (3) and (4), hinting that there are North-South differences in levels of digitalization. In columns (5) – (7), the socio-economic variables are added and, with the exception of *GDP per capita*, they are all highly statistically significant. When both *employment rate* and *income per capita* are added simultaneously in the regression equation as in column (8), *RNI change* is on the verge of statistical significance (p-value: .053). In column (9), using the socio-economic index increases the significance of the independent variable at the expense of some explanatory power. Finally, in column (10), I reproduce the model in column 8, employing the *Digital Service+PA* sub-index as the dependent variable, which exclusively measures the digitalization of services.

Overall, the correlation of *RNI change* with levels of digitalization is statistically significant, particularly when the latter is operationalized exclusively as the provision of services online (as in column 10). The results lend support, to some extent, to the robustness of the correlation between *population change rate* and digitalization levels.

5.3. Assessing geographic differences

In this thesis, the notorious "North-South" divide in Italy was mentioned several times, suggesting the possibility that digitalization may follow a geographic pattern that is determined by socio-economic differences. To further test this possibility, there are several possible approaches. Arduini et al. (2011) created four dummy variables, one per macro-area (North-East, North-West, Central Italy, and South), and found that there were no statistically significant differences in levels of local government digitalization in 2005. Instead, I created 20 regional dummy variables and tested them with multiple regressions. This approach allows to check for possible inter-regional unobserved differences, and the results can still be generalized for the four macro-areas previously mentioned.

Table 9 shows two multiple regression models. First, I illustrate the structure of the table, and then analyze the results of the dummy variables. In columns (1) – (4), the main independent variable is *population change rate*, which is replaced by the W*orkforce Aging Index* in columns (5) – (8). The region dummies are divided by macro-area. Sicily (*Sicilia*), a region belonging to the South macro-area, is treated as the omitted variable. In columns (2) and (6), *population size* and *area size* are added in the equations, the former being highly statistically significant. Columns (3) and (7) document that *budget size* is not statistically significant, equally to the main models in Chapter 4. Lastly, in columns (4) and (8), *income per capita* is included in the regression equations and it is significant in column (4), but non-significant in column (8). Interestingly, *population change rate* is statistically non-significant in all specifications, whereas the W*orkforce Aging Index* remains consistently highly statistically significant.

In the North-West area, municipalities in Lombardia and Piemonte seem to perform particularly better than those in Sicilia. However, when *income per capita* is added to the equation (Columns 4 and 8), the coefficients are not statistically significant, suggesting that socio-economic differences drive the considerably higher level of digitalization in these two regions.[2] In the North-East, only the provincial capitals in Emilia Romagna report a significantly higher level of digitalization than the baseline region. Even by controlling for *income per capita* as in Column (8), the Emilia Romagna dummy records a highly statistically significant coefficient (p-value: .010). This outcome indicates the presence of other factors beyond income per capita that influence such a high level of digitalization. The same applies to Tuscan provincial capitals in Central Italy, which have reached a higher digital level than the baseline model. Perhaps surprisingly, Lazio, which includes the city of Rome, does not differ significantly from the municipalities in Sicilia in terms of digitalization. Rome is the largest city in Italy in both population size and area size and is one of the most advanced in the digital transformation process (ranked 4th in the *Ca.Re* index). It follows that all other provincial capitals in Lazio have a digitalization level that is similar to the Sicilian average. All Southern regions, except for Basilicata, perform very closely to the baseline dummy. Basilicata, instead, has a statistically significant coefficient in most specifications, although the significance is lower in the models where *population change rate* is taken as the main independent variable.

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[2] The result of Valle d'Aosta is not considered in this analysis since it has only one provincial capital.

Table 9: Multiple Regression of Population Change Rate and Workforce Ageing index on Ca.Re

	Ca.Re							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Population change rate	5.107 (5.648)	5.419 (4.316)	6.029 (4.411)	5.31 (4.278)	-	-	-	-
Workforce ageing index	-	-	-	-	-13.202*** (4.198)	-10.433*** (3.121)	-10.433*** (3.174)	-8.689** (3.524)
Population Size		28.224*** (3.455)	27.242*** (3.726)	23.092*** (3.942)		26.478*** (3.293)	26.479*** (3.556)	23.516*** (3.825)
Area Size		-.002 (.009)	-.003 (.009)	.001 (.009)		.002 (.008)	.002 (.008)	.004 (.008)
Budget Size per capita			6.24 (8.705)	.133 (8.745)			-.011 (8.227)	-3.686 (8.332)
Income per capita				88.282** (33.852)				65.634 (34.09)
Regional dummy variables divided by macro-area								
North West								
Lombardia	18.068* (7.233)	20.3*** (5.805)	20.096*** (5.828)	7.524 (7.421)	12.681* (6.91)	17.471*** (5.332)	17.47*** (5.379)	8.816 (6.947)
Valle d'Aosta	12.025 (16.253)	25.953* (12.269)	24.627 (12.442)	16.591 (12.43)	8.491 (15.525)	23.68* (11.656)	23.682* (11.803)	18.025 (11.988)
Piemonte	10.181 (7.73)	13.504** (5.975)	13.167** (6.01)	6.181 (6.404)	6.43 (7.34)	11.56* (5.553)	11.56* (5.585)	6.837 (6.022)
Liguria	8.654 (9.306)	8.638 (7.099)	7.939 (7.185)	3.328 (7.176)	3.394 (9.032)	5.523 (6.791)	5.524 (6.848)	2.643 (6.907)
Northeast								
Veneto	7.76 (7.583)	9.12 (5.773)	9.078 (5.789)	-.073 (6.611)	6.24 (7.177)	8.741 (5.388)	8.741 (5.425)	2.125 (6.351)
Trentino Alto Adige	20.172 (13.145)	20.001 (10.041)	17.96 (10.464)	9.523 (10.632)	12.777 (12.103)	16.217 (9.01)	16.219 (9.178)	10.763 (9.471)
Friuli Venezia Giulia	7.459 (10.396)	8.236 (7.989)	7.469 (8.083)	-.996 (8.47)	4.013 (9.905)	6.838 (7.485)	6.839 (7.547)	.856 (8.055)
Emilia Romagna	23.9*** (8.398)	19.989** (6.34)	20.147*** (6.362)	12.46 (6.827)	23.384*** (6.897)	20.997*** (5.1)	20.996*** (5.23)	15.509* (5.886)
Central Italy								
Lazio	.285 (9.177)	-1.665 (6.834)	-1.625 (6.854)	-7.356 (6.988)	5.105 (8.203)	2.31 (6.176)	2.309 (6.224)	-2.384 (6.596)
Toscana	20.114* (7.628)	20.325** (5.775)	19.803** (5.837)	14.019* (6.069)	19.518** (6.815)	20.888*** (5.061)	20.889*** (5.092)	16.671** (5.471)
Umbria	7.459 (12.497)	5.399 (9.256)	4.716 (9.331)	.751 (9.158)	6.607 (11.533)	5.438 (8.518)	5.438 (8.572)	2.653 (8.564)
Marche	-.706 (8.64)	6.746 (6.552)	6.027 (6.647)	1.721 (6.642)	-1.15 (8.192)	6.829 (6.163)	6.83 (6.24)	3.619 (6.366)
South								
Abruzzo	4.273 (9.382)	9.815 (7.032)	8.311 (7.357)	4.987 (7.234)	6.382 (8.817)	11.957 (6.556)	11.959 (6.823)	9.064 (6.884)
Molise	-7.588 (12.037)	7.037 (9.16)	7.095 (9.186)	3.679 (8.987)	-5.724 (11.477)	8.65 (8.688)	8.65 (8.739)	5.909 (8.722)
Basilicata	12.955 (12.09)	19.929* (8.985)	19.086* (9.086)	15.606 (8.895)	22.517 (11.779)	27.32** (8.709)	27.321** (8.847)	23.468** (8.938)
Campania	-3.574 (8.585)	-5.558 (6.608)	-7.05 (6.946)	-9.959 (6.815)	1.344 (8.326)	-.648 (6.39)	-.645 (6.751)	-3.784 (6.844)
Calabria	-.717 (8.609)	4.05 (6.474)	3.367 (6.561)	3.062 (6.352)	1.591 (8.233)	6.111 (6.185)	6.112 (6.308)	5.423 (6.221)
Puglia	-.733 (7.587)	-1.525 (5.63)	-1.336 (5.652)	.622 (5.522)	6.749 (7.406)	4.815 (5.474)	4.815 (5.51)	5.344 (5.432)
Sardegna	-1.197 (8.592)	6.834 (6.428)	6.032 (6.543)	1.964 (6.522)	7.079 (8.626)	13.092* (6.408)	13.094 (6.593)	8.888 (6.85)
Sicilia (Omitted)	-	-	-	-	-	-	-	-
Observations	110	110	110	110	110	110	110	110
R-squared	.221	.573	.571	.598	.293	. 615	.610	.626

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001

The analysis conducted so far confutes the assumption that there is a North-South pattern in municipal levels of digitalization, coherently with past literature (see Arduini et al., 2011). Of course, as I have highlighted, the municipalities of some Northern regions, such as Lombardia and Piemonte, perform significantly better than the Sicilian ones in terms of digitalization. However, there are no significant differences that systematically follow a North-South pattern. This conclusion is supported by the existence of some virtuous cases in Southern and Central Italy, such as Basilicata and Tuscany, that report a higher level of digitalization than the baseline dummy. The results, instead, points to inter-regional differences as a topic to explore in future research.

6. Discussion

The analysis investigated whether there is a correlation between the intensity of the demographic decline and local governments' digitalization in Italy. I hypothesized that the demographic decline negatively affects the digital transformation process of municipal administrations. The study conducted so far confirms this Hypothesis. Specifically, the demographic decline was operationalized mainly in two dimensions: population change and aging. The correlation between *population change rate* and levels of digitalization is significant at the 95% confidence interval. This correlation, however, is also supported by the results of the robustness checks (specifically in sections 5.1 and 5.2). When the demographic decline is operationalized in terms of aging rate of the workforce, the results are highly statistically significant at the 99% confidence interval. In other words, a workforce that aged at a faster rate is correlated with lower levels of digitalization.

Overall, the outcome of the quantitative analysis is that demographic decline is negatively correlated with levels of municipal digitalization. These findings find resonance with the already mentioned literature on spatial diffusion of innovation: "*technological advancement tends to be more timely and intensive where a larger number of potential users are concentrated*" (Arduini et al., 2011). Accordingly, depopulation and aging shrink the number of potential users of digital services. Furthermore, the demographic decline can create an age-dependent demand structure (Suzuki et al., 2020) which may pressure local governments to invest less in digital solutions and focus on other areas. This, of course, can also mean that the local administration is innovative in ways different from digitalization.

Interestingly, when we consider only the provision of services online and exclude other aspects of digitalization (such as transparency and social media usage), the demographic decline assumes greater importance, whereas the impact of the other control variables is weaker. From the results in Appendix G, the *Digital Openness* dimensional index is explained mainly by population size and is uncorrelated with changes in the amount and age structure of the population. This finding reveals that municipal digitalization is multifaceted: ICTs can be applied for a variety of purposes and may, therefore, also have different triggers and antecedents.

This analysis, however, has some limitations. First, and as already mentioned, the variable for GDP per capita and employment rate are inaccurate since they refer to the provincial level. GDP per capita suffers from systematic measurement error (Toshkov, 2016, p. 118), i.e., the values of GDP are all overestimated. However, it is correct to assume that some measurements are "more overestimated" than others since some provinces host a considerably higher number of municipalities or total population than others. With the measurement of the employment rate at the provincial level, the situation is more complex. A certain provincial capital may have higher or lower employment than other municipalities in the same province, making the error non-systematic. These issues are particularly problematic for the variable *population change rate* since it is on the verge of being non-significant. In other words, it cannot be ruled out that, by taking the true measurement of these variables, *population change rate* would become non-statistically significant. Second, the sample is restricted to only 110 provincial capitals. Consequently, the results can be generalized to other municipalities with similar population sizes, but it would be harder to extend them to small municipalities (with less than 5.000 inhabitants), which are the majority in Italy. These villages typically face unique challenges, such as extreme travel times to providers of essential services (e.g., schools, hospitals, et cetera) or low broadband availability (UVAL, 2014).

Finally, the limited availability of data on digitalization, which refers only to one point in time, prevents me from inferring a causal relationship between demographic decline and digitalization. It may be, for instance, that municipalities that experience an intense demographic decline had fewer reasons for investing in digital technologies, to begin with. Given the limited academic literature and data availability, the goal of this study is exploratory and suggests that there is a negative correlation between the intensity of the demographic decline and digitalization levels.

7. Qualitative Study: Introduction and Methodology

To support the findings of the quantitative analysis and to illustrate how the demographic decline can influence the digital transformation of the public sector, I conducted a comparative study on two cases, following an inductive Most Similar System Design (MSSD). This comparison allows for an in-depth analysis of the cases involved using qualitative evidence on the commitment of the administration towards digital transformation. An inductive MSSD entails selecting at least two systems that are as similar as possible across all relevant background conditions but differ in the outcome of interest (Toshkov, 2016, pp. 265-266; Seawrigh and Gerring, 2008, p. 304). Then, these systems are compared in order to find a factor that varies across cases that can explain the different outcomes. The logic of this design lies in the fact that no variable that is similar across cases can be responsible for the difference in outcome (Toshkov, 2016, p. 265). In the context at hand, MSSD involves selecting two municipalities that are similar across all causal factors that can potentially influence the digitalization of local governments. However, despite this similarity, the cases must still display a different level of digitalization.

To ensure that background conditions and unobserved characteristics are similar, it is common practice in MSSD to select cases that are geographically and culturally close to each other (Anckar, 2008, p. 393). Therefore, the cases were selected according to three criteria. First, the municipalities must be in the same region and possibly at a minimal geographic distance. Second, they must have a similar population size. Third, the administration of the two municipalities must have a significantly different score on the Ca.Re index. The towns of Biella and Vercelli satisfy all these criteria: these towns are just 40km from each other, belong to the same region, and the population size is comparable. Yet, the administration of Vercelli achieved a considerably higher level of digitalization. Consequently, the objective is to identify a factor that differs across the two municipalities which can account for the different levels of digital transformation.

Given the similar population size and geographical proximity of the two municipalities, it is possible to assume that most background conditions are also similar. However, to confirm the validity of this assumption and further ensure that the two municipalities are suitable for the application of MSSD, in the next chapter, I compare them with respect to the relevant alternative causal factors that can influence local government digitalization. These factors correspond to the control variables identified in section 3.6. Particular attention, therefore, must be paid to the socio-economic conditions in the municipality and the budget size of the administration.

8. Analysis

In the next section of this chapter, the two systems are compared respectively by their background conditions and local government's digitalization, thus providing a detailed justification for the case selection and proving that MSSD is suitable for this study. In the third section, I investigate whether the demographic decline has affected disproportionately the two municipalities. The findings are discussed in the last section.

8.1. Preliminary Analysis

8.1.1. Background Characteristics

Biella and Vercelli are two cities in the region of Piemonte and are the capitals of their respective province. The demographic data available for the cases at hand goes from 1992 to 2019 (available on ISTAT's Demo-Geodemo database). The population of Biella went from 48.269 to 44.316, whereas the population of Vercelli went from 49.292 to 46.372. Overall, Vercelli and Biella have a similar population size, although the gap has been slowly widening over time.

The lack of data and information regarding socio-economic conditions at the municipal level affects this analysis as well. Given that the two municipalities have a similar population size and are close to each other, it can be assumed that living standards also similar. This is also confirmed by data on the average income per capita (2017-2019): which is 21.686€ in Vercelli and 22.257€ in Biella. Data on employment rate is available for both cases at the municipal level only in 1991, 2001, and 2011 (available on the *8milacensus* archive, ISTAT). According to this data, the average employment rate was 45% in Vercelli and 45.9% in Biella[3], which is sufficiently close.

To further validate the assumption that economic conditions are similar, I can compare the provincial-level data already employed in the quantitative analysis. However, for this comparison to be effective, the provincial context of the two capitals should also be comparable. The province of Vercelli includes 82 municipalities and hosts about 170 thousand people. Excluding Vercelli, only six towns have a population between 5.000 and 15.000, whereas the rest have less than 5.000 inhabitants. Very similarly, the province of Biella has 74 municipalities for a total of 175 thousand inhabitants. Apart from Biella, only four towns have a population slightly higher than 5.000, while the rest are even smaller. It follows that the provincial context is also comparable, and I can inspect how GDP and employment rate change across provinces. The average provincial GDP per capita (2011-2018) is equal to 6.389$ in Biella and 6.370$ in Vercelli. The average provincial employment rate (2011-2019) is also very similar: 64% in Biella and 65% in Vercelli. In conclusion, socio-economic conditions are similar across the two cases.

The two capitals also display a sufficient similarity when they are compared by their budget size (2015-2020). By considering all sources of income, including re-allocation from the central state or the EU, on average, Vercelli collects about 52€ million per year, 4 million more than Biella. By simplifying the analysis further, the income from taxes and other forms

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[3] Employment rate in Biella: 45.3% in 1991, 46.9% in 2001, 45.7% in 2011; In Vercelli: 45% in 1991, 45,9% in 2001, and 45,6% in 2011.

of direct contribution from citizens and businesses: on average, Biella collects 28€ million (643€ per capita), and Vercelli collects 30€ million (662€ per capita).

8.1.2. Digital transformation

Both Biella and Vercelli established an office to enable the digital transformation of the administration. The offices have exactly the same responsibilities: to foster e-government projects, manage the municipal ICT infrastructures, and provide online services to citizens and businesses by employing innovative ICT solutions (Comune di Biella, 2021; Comune di Vercelli, 2021). Yet, a look at the main index reveals that Vercelli is 46 positions over Biella in terms of digitalization. In particular, Vercelli seems to do considerably better in providing services online.

This difference is even more striking when the websites of the two municipalities are inspected. Vercelli created an ad-hoc web portal to access online services (‘*SportelloOnLine*’) and book appointments with six municipal offices. These services include enrollment to public nurseries, school transportation payment, booking an appointment for the renewal of the electronic identity card (CIE), waste tax payment (TARI), services to businesses (SUAP), and downloading registry and building certificates. The pool of services provided digitally in Biella is considerably smaller, and it includes downloading registry certificates, services to businesses, and registering students for services related to schools (e.g., school cafeteria). During the second half of 2021, the administration of Biella had been working on a digital platform (*Sportello Unico Digitale*) where citizens can access digital services or apply for careers in the public sector. Despite being released to the public in October 2021, to the best of my knowledge, the platform is currently non-operative.

By analyzing the yearly performance plans and reports (2017, 2018, 2019) of both municipalities, it becomes clear that they have different priorities regarding digitalization. Biella sees digitalization and e-government as mainly correlated to privacy protection, digitization of information (i.e., transforming a document from a paper to digital), and the extension of broadband availability. The only mention of online services is in the performance report of 2018, where Biella includes the search engine optimization of the services that are already being provided digitally. Interestingly, every yearly plan mentions increasing the digital literacy of the population as an objective. For this purpose, the municipality, in collaboration with the private sector and other public agencies, holds courses to transmit basic digital skills. These classes target primarily people over 55 years of age, and to a lesser degree, people under 30 (Agenda Digitale Biella, 2021). The end goal is to reduce the digital divide, raise employability, foster social inclusion, and extend the number of people that can interact digitally with the public administration (Agenda Digitale Biella, 2018; Magnani, 2018). According to the digital agenda, Biella will expand the pool of services digitally provided in the future. It is unclear, however, when and which services will be offered online (Agenda Digitale Biella, 2021).

The performance plans and reports of Vercelli (2017-2019) reveal a stronger commitment to digitalization. Every year, one of the objectives is "*to ensure the functionality of informative systems through the provision, management, and maintenance of the municipal informatic system*" (Relazione Sulla Performance, 2019, p.41). To that end, Vercelli monitors several factors, including the number of services provided online, the cost of connectivity and cloud services, customer satisfaction, and hardware maintenance cost. The expansion of the number of services provided online is also mentioned as an objective in some of the 2018 plan.

8.1.3. Summary

The analysis so far shows that Biella and Vercelli are optimal cases for the application of MSSD analysis (See table 10). The two cities have a similar amount of population, socio-economic conditions, provincial context, and budget size. However, they followed two different paths towards digitalization: while Vercelli has been focusing on expanding the pool of digitally provided services, Biella has prioritized increasing the digital literacy of the older cohort of the population. As a result, the digitalization level achieved by the administration of Biella is among the lowest in the sample of provincial capitals. Instead, the administration of Vercelli is considerably more digitalized and excels in the provision of services online. Given that population size, socio-economic conditions, and budget size are similar, a question remains unanswered: what can explain the difference in digitalization levels? I will try to find an answer to this puzzle in the next section.

Table 10: Simplified representation of an inductive Most Similar System Design

Variables	Biella	Vercelli
Main explanatory variable	?	?
Population Size	1	1
Socio-economic conditions	1	1
Budget Size	1	1
Outcome: digital transformation of the administration	0	1

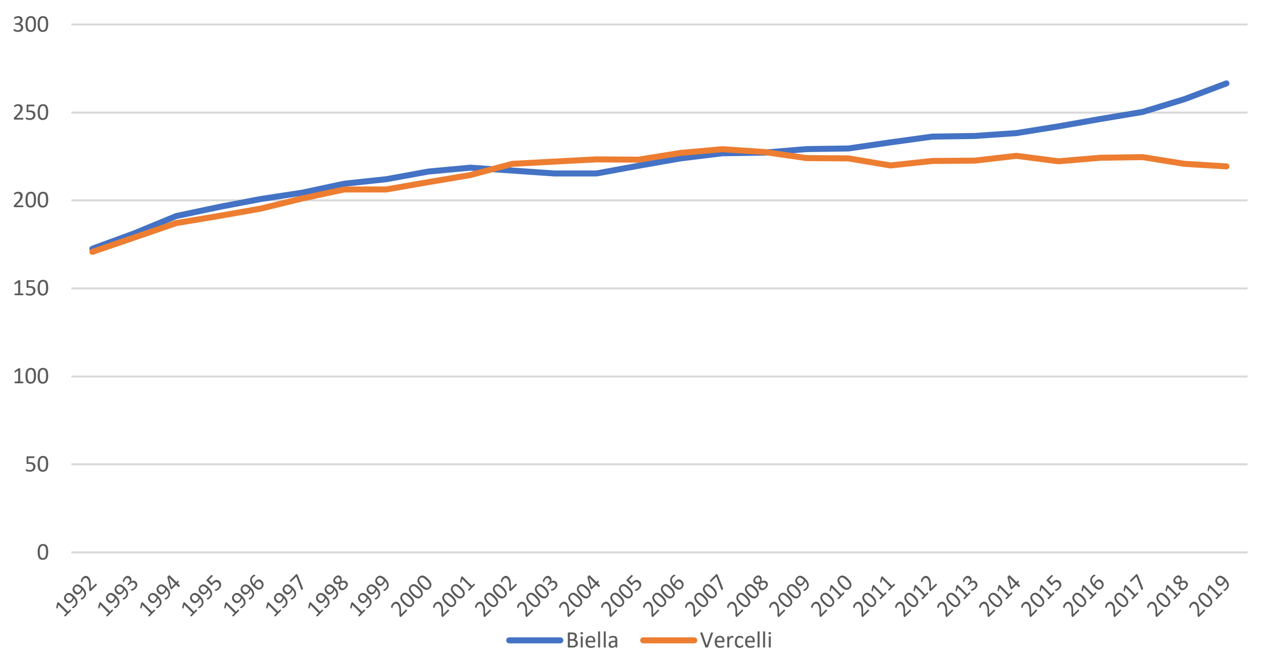
Note: the variables were codified in binary terms for simplicity. Their purpose is to show which factors are similar.

8.2. Demographic Decline

As already illustrated in the quantitative analysis, there are various ways to conceptualize and measure the demographic decline. The focus, again, is on two different dimensions: population change and aging. As already mentioned, both the population of Biella and Vercelli have shrunk, going from 48.269 to 44.316 and from 49.292 to 46.372, respectively. Clearly, the drop in population is slightly stronger in Biella. By processing this information in terms of population change rate, Biella lost -.31% of the population every year, while Vercelli lost only -.22%. Overall, this difference is not wide enough to justify possible differences in digitalization.

The difference in aging is more remarkable. Figure 5 shows the population aging index in Biella and Vercelli from 1992 to 2019. This variable refers to the number of elderly (aged 65 years and over) per 100 individuals younger than 14 (Statista, 2021). The index is often used in the academic literature (i.a., Reynaud et al., 2018) and offers a straightforward measure of population aging. According to Reynaud et al. (2018, p. 239), this index is one of the most accurate measures of population aging and takes into account the two main determinants of aging: fertility reduction and life expectancy increase. In 1992, the index was very similar for both cities: 172.5 in Biella and 170.8 in Vercelli, and it increased at a similar rate until 2007. From then onwards, it is possible to observe two distinct trends. In Biella, the index started increasing at a faster rate, reaching the extreme value of 266.5 in 2019, one of the highest in Italy (La Provincia di Biella, 2021). In Vercelli, instead, it decreased slightly and remained stationary from 2010, reaching the value of 219.2 in 2019.

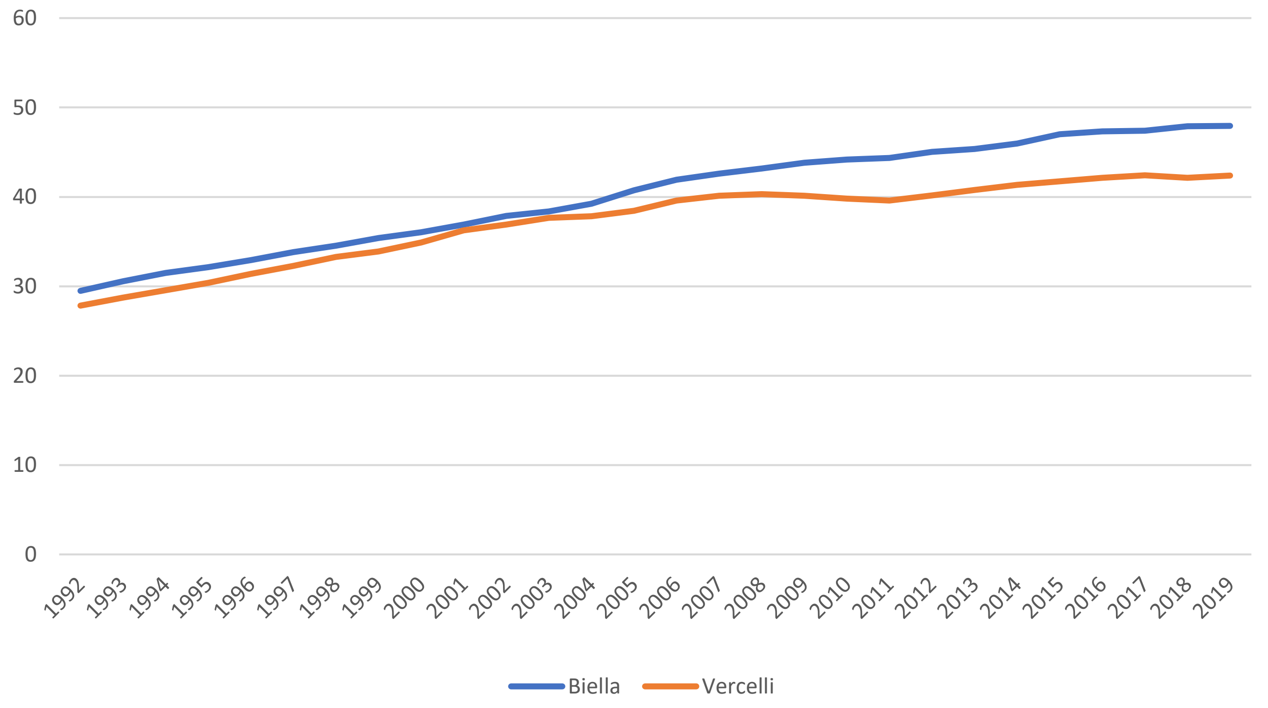
Figure 6: Population Ageing Index in Biella and Vercelli, 1992-2019



These trends reflect the different patterns of fertility among the two cases. In 1992, the birth rate was higher in Biella (7.5) than in Vercelli (7.0). However, after peaking at 8.6 in 2003, the birth rate in Biella started decreasing steadily, reaching the lowest value of 5.5 in 2019. The birth rate of Vercelli peaked at 8.9 in 2005 and started decreasing at a slower pace, reaching 7.8 in 2019. Noteworthily, there are more births in Vercelli in 2019 compared to 1992. As a result of these trends, the cohort of younger people (aged 0-14) has been increasing in Vercelli (from 11.3% of the total population in 1992 to 12% in 2019) and decreasing in Biella (from 11.7% of the total population in 1992 to 10.7% in 2019).

However, the decreasing birth rates alone are insufficient in explaining the enormous aging index in Biella and the difference in pattern with Vercelli. The share of elderly people (aged 65 and over) increased at a remarkable speed in Biella, as shown by the old-age dependency ratio (Figure 6). This indicator is a variant of the traditional dependency ratio, which was already introduced in section 3.4. It is obtained by the ratio of the number of elderly people (aged 65 and over) compared to the number of people of working age (i.e., 15-64 years old) (Eurostat, 2021). In 1992, the old-age dependency ratio was 29.5% in Biella and 27.5% in Vercelli. It increased in both municipalities at a similar pace until 2003. In 2019, this indicator reached 48% in Biella and 42.3% in Vercelli. By comparing the value reached by Biella to the national average (35.8% in 2019, ISTAT), it is clear that the old-age dependency ratio has reached an extremely high level, hinting that the number of dependent populations is nearing critical levels.

Figure 7: Old-age dependency ratio in Biella and Vercelli, 1992-2019



Finally, in the period considered, the workforce aging index in Biella rose at a rate of 1.54 per year, going from 103.8 to 156.4. In Vercelli, it increased by a rate of 1.40 per year, going from 99.6 to 145.1. By looking at the raw population data, it can be observed that the active population aged at a similar rate, but Vercelli had overall a larger workforce (by roughly 2 thousand units), which was also slightly but consistently younger. The table below (Table 11) summarizes the information on the demographic indicators.

Table 11: Demographic Indicators in Biella and Vercelli

	Biella			**Vercelli**		
Demographic Decline	1992	2019	Rate of Change	1992	2019	Rate of Change
Population change	48.269	44.316	-.31%	49.292	46.372	-.22%
Workforce Ageing Index	103.8%	156.4%	1.54%	99.6%	145.1%	1.40%
Old-Age Dependency Ratio	29.5%	48%	1.82%	27.5%	42.3%	1.57%
Ageing Index	172.5	266.53	1.6%	170.8	219.6	.95%
Birth Rates	7.5	5.5		7	7.8	

8.4. Discussion

In conclusion, the two municipalities are similar in all observed background conditions, with particular regard to those that can influence the digital transformation of local governments. Yet, they adopted a very different approach towards digitalization. While Vercelli has focused on digitalizing services, Biella has prioritized increasing the digital literacy of the population.

This difference in outcome and courses of action can only be ascribed to the demographic decline, which has affected the two municipalities disproportionately. In particular, the population of Biella aged at a faster rate than the population of Vercelli, and some of the aging indicators registered values that are critically high in Biella. This might have motivated the administration of Biella to increase the digital literacy of the population *before* investing in digitalizing the administration. According to Fulvia Zago, former President of Agenda Digitale (Digital Agenda) Biella: "*The (other) public agencies across the country have been investing for years in infrastructures and digital services, and even more will be invested in the future. However, these efforts risk being in vain if the root of the problem is not addressed, which is the unawareness of the opportunities that digitalization offers. For example, the average internet usage in Italy is below 60% against a European average of 75%*" (Translated from: Agenda

Digitale Biella, 2021). In other words, faced with an increasingly older population that implies a lower digital literacy and internet usage, Biella decided to prioritize spreading basic digital skills across the community. This is seen as a necessary step to increase the number of people who can use digital technologies and eventually benefit from the digital transformation of the economy and the public sector. This behavior is surely innovative, but it cannot be ascribed to the concept of *technological process innovation*. These findings are in line with the theory and lend support to the Hypothesis: the demographic decline (in the form of population aging) influences the choice of administrators regarding the digital transformation of local governments.

9. Conclusion

Although the literature on innovation in the public sector has grown considerably in the last decades, the link between demographic decline and innovation vastly remains unexplored. This thesis tries to fill the gap by empirically examining this understudied relationship in the Italian context and focusing on a specific dimension of innovation, i.e., digitalization.

According to the quantitative analysis, there is a statistically significant correlation between the demographic decline and local governments' digitalization in Italy. Specifically, the aging of the workforce is highly statistically significant, whereas population change rate and RNI change are consistently statistically significant at a lower confidence interval. The demographic indicators are better predictors when digitalization is operationalized only as the provision of public services online. Instead, they are unsuitable for predicting the usage of ICTs for transparency and communication purposes.

In conclusion, municipalities that were most affected by the phenomena of population shrinking and aging tend to have a less digitalized administration. This correlation may be explained in two complementary ways. First, according to the literature on the spatial diffusion of innovation, new technologies tend to be adopted more intensively where there is a higher concentration of potential users (Arduini et al., 2011). Consequently, a decreasing and aging population implies that the pool of potential users of ICTs shrinks, making digitalization less attractive. Second, population aging can generate an age-dependent demand structure (Suzuki et al., 2020) and budget constraints (OECD, 2019a). In turn, these phenomena may ultimately pressure local administrations to be innovative in other areas of municipal competence and in ways different from digitalization (e.g., telemedicine, better long-term care, et cetera).

The analysis, however, has some limitations that block the path to causality. Given the limited data availability, I can only observe the level of digitalization reached by local administrations at one point in time. In order to infer causation, it would be ideal to have information on how local administrations developed their digital infrastructures over time. Furthermore, the dataset includes only 110 municipalities, which results in limited generalizability. The results can be extended to all other municipalities with a similar size (>20.000 inhabitants), which account for more than half of the total population in Italy. However, I would expect the generalizability to become very low for smaller municipalities (<5.000 inhabitants) that represent the vast majority in Italy. These villages face different challenges from urbanized areas: both population decline and aging are at critical levels, sometimes threatening the very existence of small towns; employment rate and broadband availability are considerably lower; some of them are also extremely far from essential services (healthcare, education, mobility, et cetera), making the geographical distribution of services extremely inefficient (UVAL, 2014, p. 10).

To illustrate the interaction between demographic decline and digitalization, I complemented the quantitative analysis with a qualitative study following an inductive MSSD focusing on the cities of Biella and Vercelli. The two municipalities are equal in all observed background conditions and, given their similar population size and geographical proximity, it can be assumed that unobserved characteristics are also sufficiently similar. Yet, the administration of Vercelli focused on the digital provision of services, whereas Biella prioritized spreading basic digital competencies among the population. Given that all alternative causal factors are similar across the two cases, the difference in outcomes must be at least partly attributed to the demographic decline, which affected the two municipalities differently. Specifically, the population of Biella aged at a considerably faster rate compared to the one of Vercelli. Aging, as already argued, shrinks the pool of potential users of new technologies and creates age-dependent demand structures.

Given the status of the literature and the lack of data, the thesis contributes to the understanding of the interaction between demographic decline and digitalization by pointing at a statistical correlation between them. In light of the findings, and more importantly of the research of Suzuki et al. (2020), the demographic decline must be regarded as an external factor that can potentially influence public sector innovation. Future research can investigate the demographic shift-innovation nexus by analyzing different national contexts as well as through cross-country comparisons. If digitalization is taken as a proxy for public sector innovation, particular attention must be paid to its operationalization. As shown in section 5.1, ICTs can serve various purposes, and consequently, may have different drivers and antecedents. It follows that the demographic decline may influence some aspects of digitalization while leaving others unaffected. Regarding the Italian context, should more data on digitalization be available in the future, proper explanatory research should be conducted to infer causality. Future research should also investigate whether there are inter-regional and macro-area differences with a larger dataset.

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Appendix A: Comparison of birth rates, death rates, and RNI between the Italian population (blue) and the sample of provincial capitals (red)

Figure A1: Birth Rates in Italy and in the sample of provincial capitals (1992-2019)

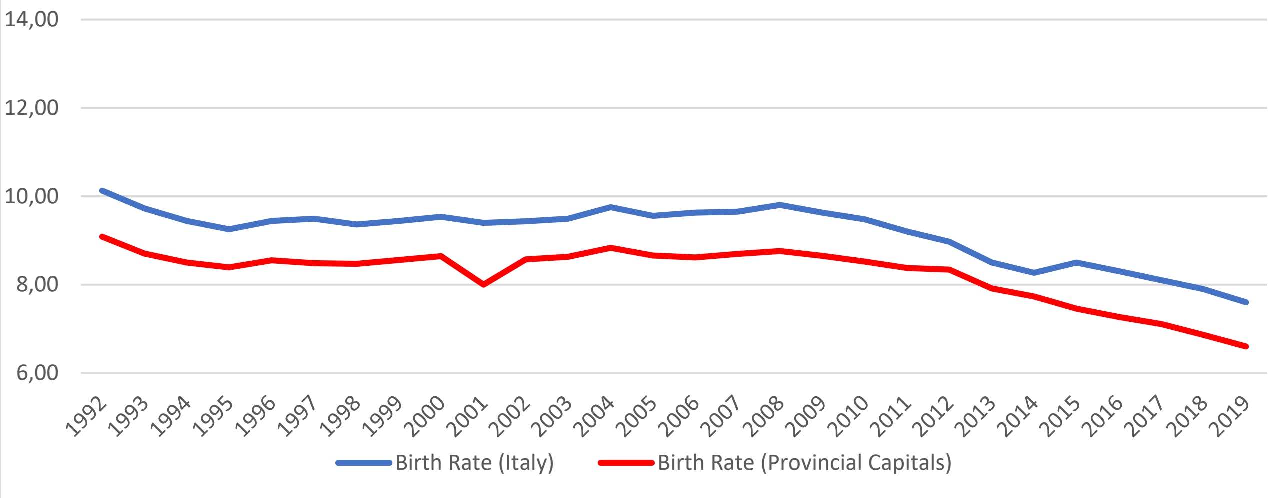


Figure A2: Death Rates in Italy and in the sample of provincial capitals (1992-2019)

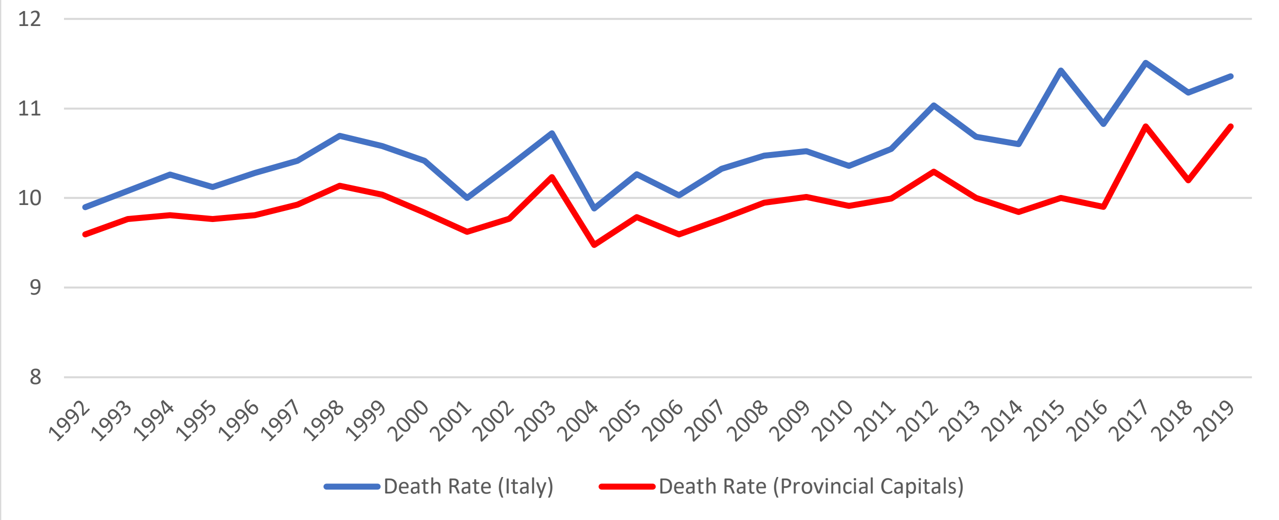
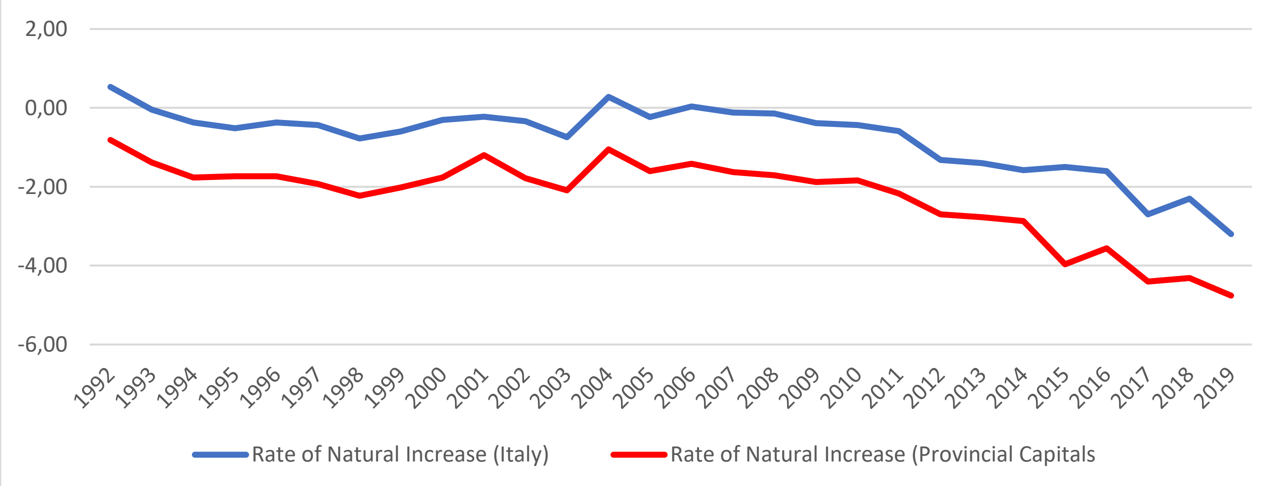


Figure A3: RNI in Italy and in the sample of provincial capitals (1992-2019)



Appendix B: list of services measured by the *Digital Services* sub-index

1. Registry certificates: request and/or download registry certificates (residence, family status, citizenship, et cetera).

2. Civil status certificates: request and/or download civil status certificates (birth, marriage, death).

3. Identity Card: request the renewal of the identity card (either fully online or by booking an appointment).

4. Change of residence: apply for the change of residence from a municipality to another

5. Electoral card: request a new electoral card in case of exhaustion, loss, deterioration, and theft.

6. EU Parking Card: apply for the EU parking card for people with disabilities.

7. Household allowance: request the allowance for households with limited assets and incomes and with at least three minors (*Assegno nucleo familiare;* law n. 448 of 23 December 1998).

8. Private building certificates: submit a building certificate or permit (Certified notice of commencement of works, certified notice of commencement of activity, building permit).

9. Certificate of urban planning (CDU): request the CDU digitally.

10. Nurseries: apply for municipal nursery schools and/or pay the correlated tuition.

11. School cafeteria: apply and/or pay the fee to access the school cafeteria.

12. School public transport: apply and/or pay the fee for school transport services.

13. Fines: see and/or pay a fine online.

14. Limited Traffic Zone (ZTL) permit: request and/or pay the permit to access the ZTL.

15. Towed vehicles: track towed vehicles and/or submit a request for the vehicle to be released.

16. Waste collection tax (TARI): submit related documents, report usage, view TARI position, pay the tax online (at least one of these options)

17. Permit for the temporary occupation of a public space (TOSAP / COSAP): submit related documents and pay the permit's fee online.

18. Unified Municipal Tax (IMU): submit related documents, check debt status, pay the tax online (at least one of these options).

19. Tourist Tax: manage and/or pay the tax online.

20. One-stop shop for businesses (SUAP): manage and send documents to SUAP (from the municipality's website, regional websites, or the *'impresainungiorno'* system).

Appendix C: Multiple Regression (OLS) with Dependency Ratio Change

Dependency ratios have been, for a long time, at the center of any discussion on the effects of population shifts. To measure the intensity of the demographic decline, this data might be operationalized as *dependency ratio change*, and it becomes an attractive tool to show how quickly the percentage of the dependent population is increasing. A higher dependency ratio change corresponds to a shrinking workforce and an overall older population, as well as a declining birth rate.

As shows by the descriptive statistics (Section 3.6), all municipalities experienced an increasing dependency ratio from 2002 to 2019. In other words, the percentage amount of the dependents over the working-age population increased in all provincial capitals. However, the variation and standard deviation of this variable is relatively small, which makes me assume that this variable is not appropriate given the data that is available and the Italian demographic context. First, the age cohorts considered by the classical dependency ratio indicator are too broad, as also argued by (Bearfield & Bowman, 2016). A related problem is that the time frame considered in this study is too limited. As it can be observed from Figure 2 (Chapter 3), the Italian baby boom goes from 1960 to 1964. Consequently, there is still a concentration of people in the workforce (aged 55-59 in 2019) that will change considerably the dependency ratio in the next 10 years. These people are constantly considered as part of the workforce in 2002-2019, and the variable does not account for imbalances that are expected to arise in the near future. A remedy to overcome these limitations would be extending considerably the time frame of the data, for instance by calculating dependency ratio change of each municipality from 1950 to 2019. Such data, however, is currently not available[4].

Dependency ratios for each year are calculated according to the formula:

$$Dependency\ Ratio = \frac{Total\ population\ aged\ 0{-}14\ and\ 65{+}}{Populationa\ aged\ between\ 15{-}65} \cdot 100 \qquad [D]$$

Table B1 displays the output of the regression with *average dependency ratio change* replacing the main independent variables of the model in Chapter 4. Higher values of this indicator correspond to a higher number of dependents. The bivariate regression in column (1) yields a negative coefficient of *dependency ratio change*, indicating that where the dependency ratio has increased less (and thus the ageing rate of the population is slower), there is a higher level of digitalization. However, this correlation is not statistically significant throughout the entire model. Even by removing the effect of the *Digital Openness* from the dependent variable (Column 10), *dependency ratio change* remains non-statistically significant.

[4] The National Institute of Statistics is working on creating population-estimates per municipality, but such wide amount of data is currently not available.

Table 1C: Multiple Regression of Dependency Ratio Change on Ca.Re index

	Ca.Re index								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependency Ratio Change (2002-2019)	-1.386 (4.239)	2.411 (3.483)	-.23 (3.159)	-.23 (3.188)	-1.794 (3.059)	1.17 (3.33)	-1.557 (2.997)	-2.44 (2.938)	-1.966 (2.977)
Population Size (log)		29.889*** (4.048)	27.193*** (3.66)	27.191*** (3.891)	20.832*** (3.962)	12.079 (6.578)	26.468*** (3.63)	22.601*** (3.836)	15.909*** (4.149)
Area Size		-.01 (.009)	.002 (.008)	.002 (.008)	.006 (.008)	-.002 (.009)	-.002 (.007)	.004 (.008)	.005 (.008)
Latitude			2.595*** (.497)	2.595*** (.509)					
Budget size per capita (2015-2020, log)				.011 (8.025)	-9.751 (7.488)	-11.009 (8.353)	2.006 (7.503)	-2.585 (7.517)	-6.002 (7.294)
Income per capita (log, 2017-2019)					139.147*** (21.894)			75.138* (28.982)	
GDP per capita (2011-2018, USD, PPP indexed, log provincial, log)						21.668*** (5.959)			
Employment rate (provincial, 2011-2019)							.806*** (.12)	.517** (.162)	
Socio-Economic Index									6.458*** (.932)
_cons	50.17*** (4.355)	-100.455*** (20.419)	-197.664*** (26.094)	-197.696*** (35.393)	-624.147*** (89.211)	-65.426* (28.804)	-134.096*** (26.461)	-408.334*** (108.871)	-9.928 (27.035)
Observations	110	110	110	110	110	110	110	110	110
Adj. R-squared	.008	.334	.466	.461	.514	.402	.529	.554	.539

Standard errors in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Appendix D: List of all variables including a short description, source, and scale manipulation.

Variables	Description	Manipulation	Source
Ca.Re Index	A composite index that measures the level of digitalization achieved by each provincial capital in 2021. It synthetizes information on a) the digitalization of services; b) the integration of enabling platforms; c) social media usage and transparency		DedaGroup Public Services
Digital Service+PA	An aggregate of the first two components of the Ca.Re index. The variable measures only the digitalization of public services, and it is employed in sections 5.1 and 5.2		DedaGroup Public Services
Digital Openness	Third component of the Ca.Re index. It measures social media usage of each local administration and the employment of ICTs for transparency purposes.		DedaGroup Public Services
Population change rate	Rate of change of the population from 2002 to 2019 obtained from population data for each municipality		ISTAT, demo-geodemo database
RNI change	Rate of natural increase change from 2002 to 2019. RNI is obtained by subtracting birth rates from mortality rates.		ISTAT, Data Warehouse; demo-geodemo
Workforce ageing index	Rate of change of the active population age structure from 2002 to 2019 obtained from demographic data for each municipality. The workforce age index is the ratio of the number of people aged 40-64 over those aged 15-39		ISTAT, demo-geodemo
Dependency ratio change	Rate of change of dependency ratio from 2002 to 2019 obtained from demographic data for each municipality. Dependency ratio is calculated by taking the number of people aged 0-14 and over the age of 65, divided by the number of people aged 15-64		ISTAT, demo-geodemo
Area Size	Total area in square kilometers under municipal administration.		ISTAT
Population Size	Average of the total population from 2002-2019	logged	ISTAT, demo-geodemo
Budget size per capita	Budget size per capita of each municipality from 2015 to 2020. All sources of entry are taken into account	logged	OpenBilanci
Latitude	Indicates the geographical position of a municipality. It is employed as a proxy for North-south socio-economic differences or other possible geographical differences		ISTAT
Income per capita	Average income per capita from 2017 to 2019 for each municipality based on the Ministry of Finances data. Expressed in euro.	logged	Intwig
Employment rate	Average employment rate at the provincial level from 2011 to 2019		ISTAT
GDP per capita	Average GDP per capita at the provincial level from 2222 to 2000. PPP Indexed, in 2015 USD	logged	OECD

Appendix E: Regression Diagnostics

Appendix E1: Preliminaries

I employed multiple formal methods to check the validity of several OLS assumptions. I ensured that all models had 1) no multicollinearity; 2) a linear relationship between all the independent variables and the dependent variables; 3) normal distribution of the residuals; 4) homoscedastic variance of errors; 5) no extreme outliers, or extreme influential and high leverage points.

In this appendix, I report the results of some regression diagnostics tools employed to show evidence that the conditions for applying OLS hold. Specifically, I will focus on the regression models shown in Column 9 of Tables 3, 4, and 7 (the only difference among these models is the main independent variable). I will verify the following conditions:

- The absence of unusual data: such as outliers or very influential data points
- Homoscedasticity:
- Normality of the residuals
- Absence of multicollinearity

To check for unusual data (outliers or very influential data points), I will show the results of a scatterplot with fit line of Cook's Distance by Cook's Distance. The name of the municipalities that exceed considerably the conventional cut-off points of 4/n (where n is the number of observation) is also reported in the graph. I also employ a scatterplot, that shows the leverage by the studentized residuals and displays outliers and points of high influence at the same time, through the STATA command .lvr2plot. I report here the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity. Further visual inspection of the residuals (and specifically the normal probability plots and quantile probability plots) confirms that it is not possible to reject the hypothesis that the errors are homoscedastic. The normality of the residuals is displayed via a resistant normality check and outlier identification test (via the command .iqr on STATA). If there are any severe outliers among the residuals, then it would be enough to reject normality at a 5% significance level. Mild outliers are common in samples of any size. I will also check the VIF of the models considered to exclude multicollinearity.

Appendix E2: Regression Diagnostics for Table 3

Identification of unusual data

Figure E2.1: Scatter with fit line of Cook's Distance by Cook's Distance

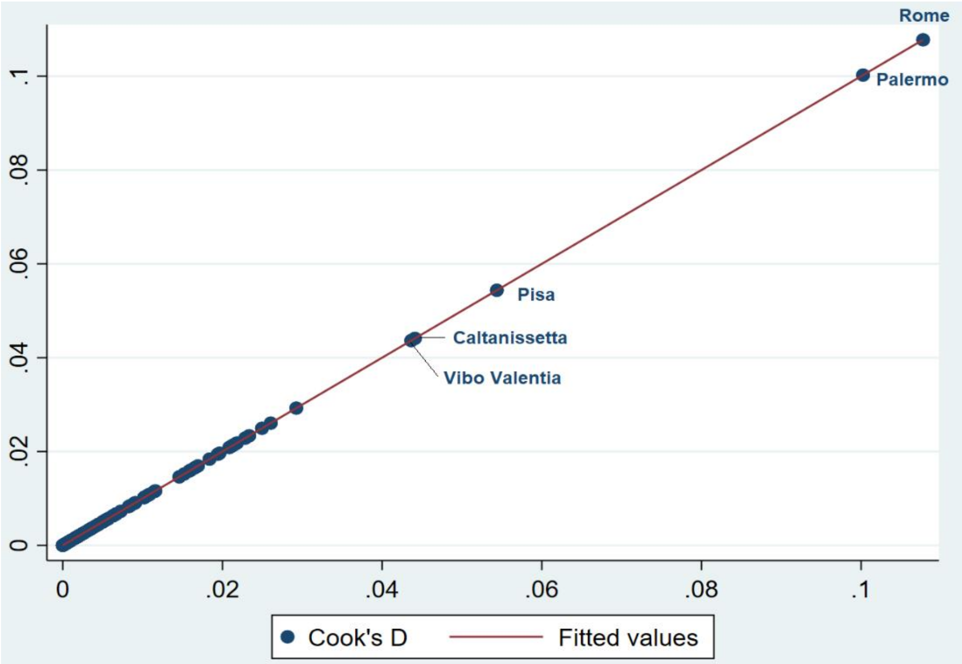
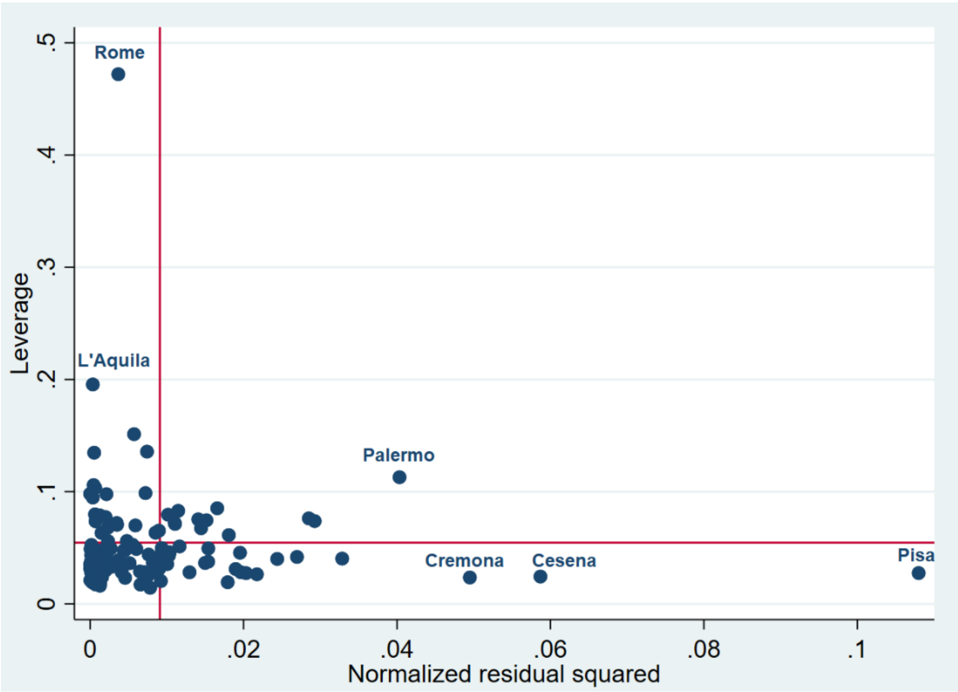


Figure E2.2: Leverage versus residual squared plot



Homoscedasticity Test

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of CaRe
chi2(1) = 0.96
Prob > chi2 = 0.3271

Normality of the residuals

Resistant normality check and outlier identification

```
   mean=   5.4e-08         std.dev.=    11.3          (n= 110)
 median= -2.303    pseudo std.dev.=   11.97        (IQR=  16.14)
10 trim= -.8772
                                                  low         high
                                                  -------------------
                                   inner fences   -33.14       31.43
                              # mild outliers     0            1
                              % mild outliers     0.00%        0.91%

                                   outer fences   -57.36       55.64
                              # severe outliers   0            0
                              % severe outliers   0.00%        0.00%
```

Collinearity Check

Variables	**VIF**
Socio-Economic Index	1.85
Population Size	1.74
Population Change Rate	1.54
Area Size	1.45
Budget Size	1.21
Mean VIF	1.56

Appendix E3: Regression Diagnostics for Table 4

Identification of unusual data

Figure E3.1: Scatter with fit line of Cook's Distance by Cook's Distance

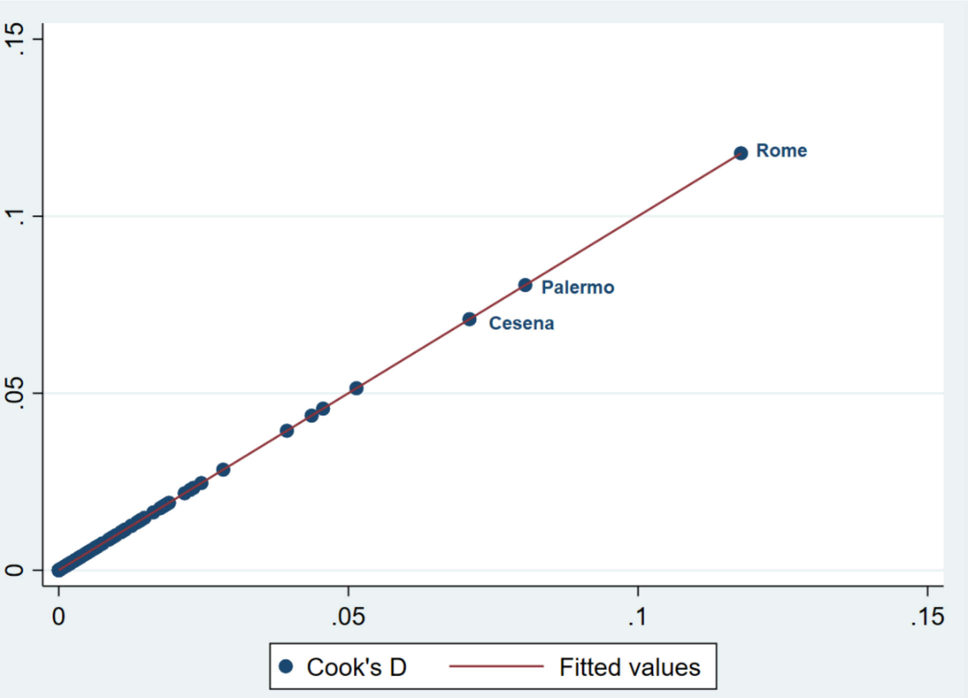
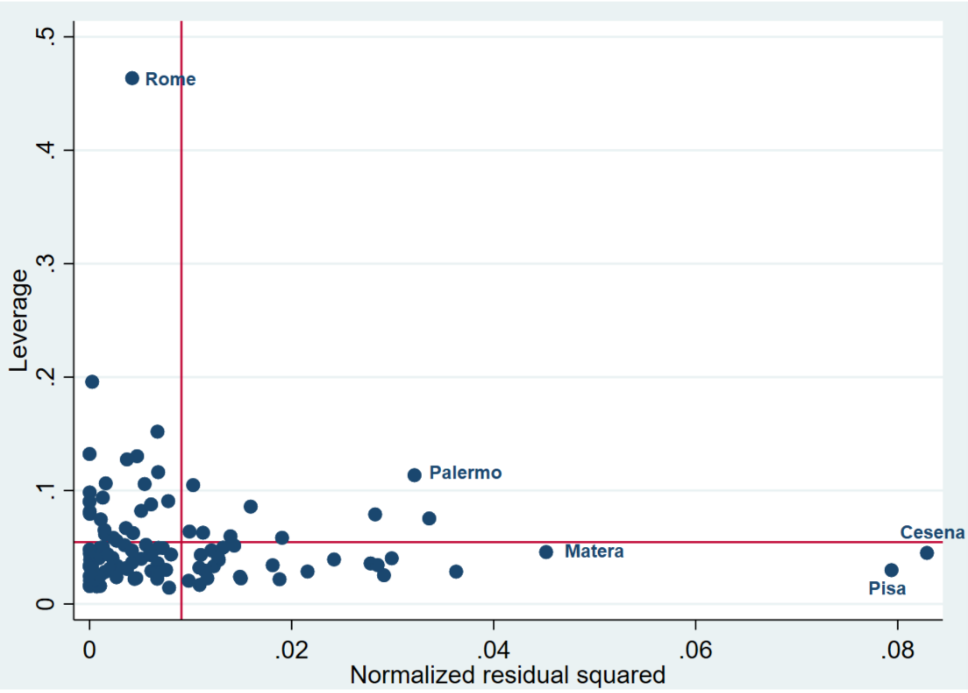


Figure E3.2: Leverage versus residual squared plot



Homoscedasticity Test

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of CaRe
chi2(1) = 0.34
Prob > chi2 = 0.5579

Normality of the residuals

Resistant normality check and outlier identification

```
   mean= -3.7e-08         std.dev.=  11.17          (n= 110)
 median= -.3406    pseudo std.dev.=   11.8        (IQR=  15.92)
10 trim= -.6542
                                                low         high
                                                -------------------
                                 inner fences   -31.87        31.8
                            # mild outliers     0           2
                            % mild outliers     0.00%       1.82%

                                 outer fences   -55.74       55.67
                            # severe outliers   0           0
                            % severe outliers   0.00%       0.00%
```

Collinearity Check

Variables	VIF
Socio-Economic Index	2.14
Population Size	1.73
Workforce Ageing Index	1.70
Area Size	1.30
Budget Size	1.10
Mean VIF	1.59

Appendix E4: Regression Diagnostics for Table 7

Identification of unusual data

Figure E4.1: Scatter with fit line of Cook's Distance by Cook's Distance

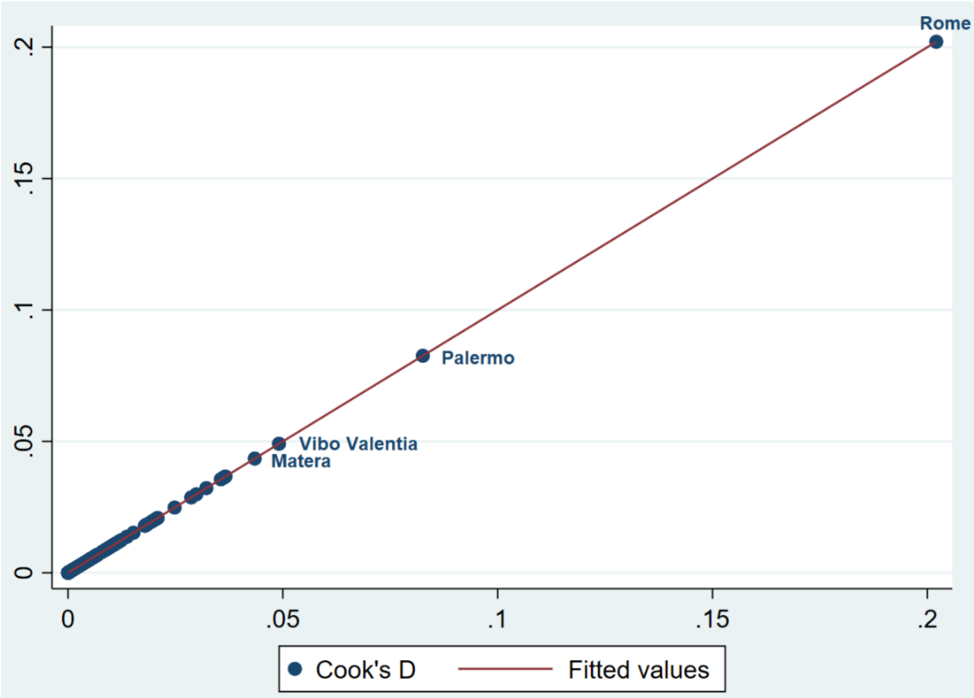
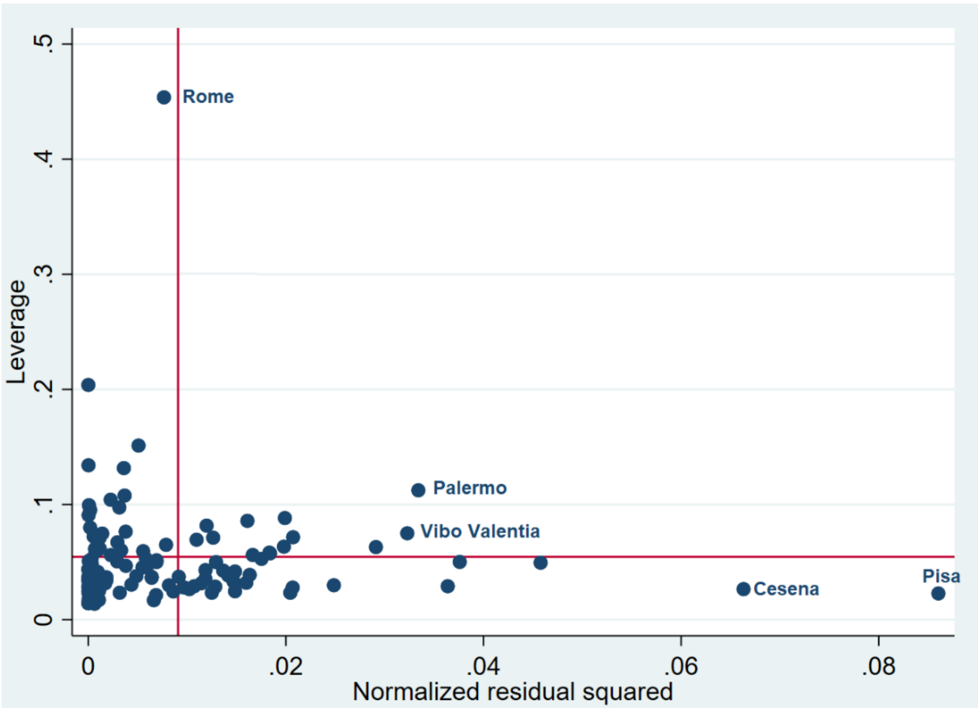


Figure E4.2: Leverage versus residual squared plot



Homoscedasticity Check

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of CaRe
chi2(1) = 0.32
Prob > chi2 = 0.5738

Normality of the residuals

Resistant normality check and outlier identification

```
   mean=  1.7e-08         std.dev.=   11.25         (n= 110)
 median= -.7121    pseudo std.dev.=   11.81       (IQR=  15.93)
10 trim= -.6377
                                                  low         high
                                                  -------------------
                                  inner fences    -32.59       31.12
                             # mild outliers      0            1
                             % mild outliers      0.00%        0.91%

                                  outer fences    -56.49       55.02
                             # severe outliers    0            0
                             % severe outliers    0.00%        0.00%
```

Collinearity Check

Variables	**VIF**
Socio-Economic Index	2.04
Population Size	1.72
RNI Change	1.64
Area Size	1.30
Budget Size	1.10
Mean VIF	1.56

Appendix E5: Summarizing the results from the Diagnostics

All regression models display low VIF values. The highest value reported across all models in all regression is 2.60, which is way below the conventional threshold of 5 for problematic collinearity. The models that were investigated in this appendix also show normal residuals as well as homoscedasticity.

There are, however, a few unusual data points, either because they are outliers or because they have a considerably higher leverage. Across the models, this behavior is displayed most often by Rome, Palermo, Pisa, and Cesena. Removing these municipalities from the dataset yields different results depending on the model. When the main independent variable is *population change rate*, the coefficient is 1 point higher whereas the standard error is substantially unaffected. This would confirm that the correlation between *population change rate* and levels of digitalization is statistically significant. The results of the two other models (with *Workforce Ageing Index* and *RNI change*) as independent variables, instead, are essentially unaffected. Because of these reasons, and after having ensured the absence of error outliers (i.e., outliers due to data inaccuracy), I decided to not remove any of the outliers that were identified. Their presence, in fact, does not prevent me from pursuing the exploratory goal that is the very purpose of this thesis.

Appendix F: Principal Component Analysis (PCA) procedure

To apply PCA, a precaution must be observed. Hair et al. (2018) suggests that variables that display a KMOs lower than 0.5 must be removed from the factorial/principal component analysis. The KMO (Kaiser-Meyer-Olkin) measure indicates the proportion of variance among the variables that can be derived from the common variance. A KMO closer to 0 indicates that there is a predominance of correlations of the variables that are problematic for the application of PCA.

As the table below shows, none of the variables selected shows a KMO below .5

Variable	KMO
Income per capita	.5138
GDP per capita	.5120
Employment Rate	.5145
Overall	.5134

Then, I proceeded to the calculation of the principal components with the command .pca on STATA.

```
Principal components/correlation                  Number of obs    =        110
                                                  Number of comp.  =          3
                                                  Trace            =          3
    Rotation: (unrotated = principal)             Rho              =     1.0000
```

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.12625	1.43603	0.7088	0.7088
Comp2	.690224	.506699	0.2301	0.9388
Comp3	.183525	.	0.0612	1.0000

As the figure shows, the first component explains roughly 71% of the total variation. According to Jolliffe and Cadima (2016) It is common practice to use components that show at least 70% (cumulatively) of total variability. I follow this practice and the Socio-economic index is, therefore, made only by the first component.

Appendix G: Regressions with Digital Openness as dependent variable

Table G1: Multiple Regression of Population Change Rate on the Digital Openness sub-index

	Digital Openness								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Population change rate (2002-2019)	16.406**	13.47**	6.065	7.8	8.42*	11.827*	4.305	4.198	5.434
	(5.464)	(4.498)	(5.181)	(5.272)	(4.864)	(4.84)	(5.386)	(5.35)	(5.109)
Population Size (log)		37.5***	36.19***	33.779***	29.159***	21.409**	33.714***	30.727***	24.936***
		(4.795)	(4.689)	(4.92)	(5.123)	(8.108)	(4.801)	(5.142)	(5.492)
Area Size		-.02*	-.007	-.006	-.004	-.011	-.007	-.003	-.002
		(.01)	(.011)	(.011)	(.011)	(.011)	(.01)	(.011)	(.011)
Latitude			2.012**	2.052**					
			(.755)	(.75)					
Budget size per capita (2015-2020, log)				16.042	8.602	10.132	15.75	11.779	9.607
				(10.505)	(10.478)	(10.874)	(10.268)	(10.515)	(10.304)
Income per capita (log, 2017-2019)					106.036***			61.321	
					(31.063)			(39.475)	
GDP per capita (2011-2018, USD, PPP indexed, log provincial, log)						16.68*			
						(7.727)			
Employment rate (provincial, 2011-2019)							.683***	.444	
							(.193)	(.246)	
Socio-Economic Index									5.348***
									(1.427)
_cons	35.614***	-147.307***	-228.149***	-270.373***	-594.371***	-170.097***	-220.052***	-444.417**	-118.101**
	(2.128)	(23.307)	(37.86)	(46.69)	(124.606)	(35.984)	(35.44)	(148.662)	(38.31)
Observations	110	110	110	110	110	110	110	110	110
Adj. R-squared	.069	.402	.434	.441	.461	.427	.466	.473	.472

Standard errors in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table G2: Multiple Regression of Workforce Ageing Index on the Digital Openness sub-index

	Digital Openness								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Workforce Aging Index (2002-2019)	-13.135**	-9.91**	-4.56	-4.317	-2.977	-6.752	-1.833	-.307	-.757
	(4.004)	(3.368)	(3.81)	(3.809)	(3.863)	(3.728)	(3.859)	(3.971)	(3.983)
Population Size (log)		35.414***	35.207***	33.434***	28.982***	21.53*	33.617***	30.919***	24.191***
		(4.894)	(4.752)	(4.98)	(5.18)	(8.325)	(4.852)	(5.154)	(5.516)
Area Size		-.006	0	.001	.003	-.001	-.004	0	.002
		(.011)	(.011)	(.011)	(.011)	(.011)	(.01)	(.01)	(.01)
Latitude			2.029**	2.185**					
			(.742)	(.753)					
Budget size per capita (2015-2020, log)				12.053	3.514	3.631	13.679	10.051	6.352
				(10.318)	(10.086)	(10.488)	(10.077)	(10.312)	(9.876)
Income per capita (log, 2017-2019)					113.625**			60.902	
					(34.266)			(40.981)	
GDP per capita (2011-2018, USD, PPP indexed, log provincial, log)						16.157			
						(8.265)			
Employment rate (provincial, 2011-2019)							.72***	.523**	
							(.192)	(.232)	
Socio-Economic Index									5.948***
									(1.544)
_cons	65.301***	-116.87***	-214.791***	-252.633***	-603.638***	-133.499***	-211.202***	-441.812**	-102.302**
	(8.687)	(25.997)	(43.816)	(54.43)	(146.067)	(36.617)	(40.606)	(160.344)	(35.824)
Observations	110	110	110	110	110	110	110	110	110
Adj. R-squared	.091	.416	.455	.462	.474	.439	.488	.499	.491

Standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001