The triangular relation of Digitization, GDP per capita, and Subjective well-being

To what extent and in what way do digitization and economic welfare affect subjective well-being in European regions?

Abstract This research investigates the relationship between Digitization, GDP per capita, and Subjective Well-Being (SWB). Data is used from 136 NUTS-2 regions in 15 EU countries. In combination with control variables for well-being, this research assesses how various aspects of digitization influence GDP per capita and how these aspects and GDP per capita affect SWB. Through multiple regression models, it is estimated that internet usage for public services, daily internet use, and broadband connection positively affect GDP per capita and subjective well-being. In contrast, participation in online social networks and weekly internet usage are expected to have negative impacts on GDP per capita. In addition, it is found that including control variables such as employment rate and education level refines these estimates. The results also suggest that fixed effects for countries significantly influence the variables and outcomes for possible relations, underscoring the importance of accounting for unobserved heterogeneity. Interaction variables for digitization and GDP per capita indicate possible mixed effects of digitization on GDP per capita's effect on subjective well-being. The findings contribute to the existing literature by providing a nuanced understanding of the multifaceted effects of digitization on economic and social outcomes.

Keywords Subjective Well-Being | Digitization | GDP per capita

Ian Buitenhuis (S4527216)
Rijksuniversiteit Groningen
Faculteit Ruimtelijke Wetenschappen
MSc Economic Geography
Supervisor: Björn de Kruijf
Date: 7-07-2024

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Introduction

Background

Digital devices are increasingly important in our lives, children grow up with them and older generations are using them more and more. Living without these devices seems nearly impossible or at least more complicated; e.g. almost all services presume that you own a smartphone. The increase in convenience following this development is undeniable. Communicating with someone or multiple persons at the same time; no matter the distance, finding an address, transferring money, and much more can be done within seconds nowadays. One could argue that the time and trouble saved by this development relieves worries and creates more freetime (Katz & Rice, 2002). Similar to other western countries, in The Netherlands this development has been going on for some decades, and now it is one of the most digitized countries in the world (European Commission, 2018). Although digitization is mainly seen as a positive development, some Dutch media warn for the flipside of digitization; recent research reported on online bullying, increase in stress, threats for mental well-being (Newcom, 2024), and increased loneliness as a result of digitization (Hertz, 2020). Though Newcom's (2024) findings are the result of social media, the latter can also be the result of other forms of digitization, for example self checkouts at stores (Hertz, 2020). In her book 'The Lonely Century' (2020), Hertz describes how digitization is one of the causes for this generation being the loneliest in history. With the rising awareness of well-being's importance, it is important to investigate and understand the possible relations there can be found related to this topic.

On the other hand, Elmassah and Hassanein (2022) present results indicating that life satisfaction increases by 0.84 units for every unit increase in digital connectivity. Furthermore there is evidence for a positive relation between digitization and organizational performance (Zheng et al., 2022) while economic welfare also influences well-being (Stevenson and Wolfers, 2008). These three concepts; well-being, economic welfare and digitization can differ strongly per country or within countries. Although these three concepts are fundamentally different, their broad influence makes them highly interrelated. However, research on their triangular relationship, especially involving all three, remains scarce.

Research on these relations is of significant theoretical and societal importance, particularly when examining self evaluation of life satisfaction. From a theoretical perspective, the relations between subjective well-being (SWB), economic welfare, and digitization in the context of European regions allows for a deeper understanding of the factors influencing SWB. It offers expansion of the scarce amount of literature on this subject. This knowledge can inform the development of theoretical frameworks on societal and economic patterns and contribute to more effective policies involving the interplay of SWB, economic welfare and digitization.

On a societal level, investigating these relations with SWB as dependent variables is crucial for creating more awareness on how different factors can influence one's mental state. Increased awareness in this context empowers individuals and communities to actively contribute to a more open environment and caring society.

Furthermore, research on this concept triangle highlights the social disparities and inequalities in European regions. It helps identify regions that possibly struggle with digitization, such as less economically strong countries, that may face barriers to adopting technologies, affecting SWB. Addressing these disparities through inclusive cross-border policies and targeted support programs can ensure that digital development is accessible and beneficial to all members of Europe.

This thesis addresses a notable research gap in the existing literature by examining the intersection of SWB, economic welfare, and digitization. While previous studies have explored SWB and its relation to digitization or economic welfare, there is a limited understanding of the possible interplay between these three concepts.

Research problem

The goal of this research is to research the effect the degree of digitization and the economic welfare have on a region's subjective well-being and if both independent variables also affect each other's relation to subjective well-being. To study these concepts in this triangular form, the research is based on the following research question: To what extent and in what way do digitization and economic welfare affect subjective well-being in European regions? Secondary questions zoom in on the different relations. These secondary questions are the base of the results section; 'To what extent does regional GDP affect subjective well-being?' 'To what extent does digitization affect subjective well-being?' and 'How does digitization affect GDP per capita's relation with subjective well-being?.' Based on these questions this research will work towards an answer to the central question.

To answer these questions this study takes the form of a quantitative research project and will be structured as follows: The first section analyzes relevant literature and the methodology for how all concepts are determined in this research, the second section will explain the methods. The third section analyzes the results, including statistical analyses.

Literature review and theory

The literature on links between SWB, economic welfare, and digitization is scarce; especially in this triangular form. This does not limit the extent to which these three concepts can be defined, based on the extensive literature that is available for them separately.

In line with this research, a growing body of research is dedicated to subjective well-being. This trend is partly the result of looking beyond GDP as an indicator for a country's overall performance (Coyle, 2014) (Hulten & Nakamura, 2022) and recent breakthroughs in spatial analysis, resulting in growing interest in applying geocomputation approaches to complex situations (Vaz, 2023). Spatial analysis has advanced to a new level due to this increase in computing power. A significant amount of this work has been done in an effort to improve decision-making, aimed to enhance social stability, economic growth, and life quality. Nonlinear modeling techniques along with stochastic modeling enable a better understanding of the geographical environment, which in turn promotes more precise decision-making. The main focus of this decision-making has been sustainable development, which would improve the quality of life (Vaz, 2023). Measured through many aspects, one part of quality of life is the subjective side; Subjective Well-Being. This trend in decision-making aligns with the many studies that followed in the aftermath of the European debt crisis. The crisis' result of recession and inherent job loss in Europe, led to a focus on economics of happiness. As also stated by John F. Helliwell, who studied the deeper effects of the monetary crisis; "*the largest declines in average life evaluations typically suffered some combination of economic, political and social stresses. (..) The losses were seen to be greater than could be explained directly by macroeconomic factors, even when explicit account was taken of the substantial consequences of higher unemployment.*" (Helliwell et al., 2015: pp. 33). The term happiness has been commonly used in social science research to refer to various measures that come from explicit questions about subjective life evaluations, which includes questions about happiness. These measures also entail subjective well-being, which includes hedonic (positive and negative), evaluative, and eudaimonic ('the good life') aspects (Ballas and Thanis, 2022). Well-being concerns health, happiness and prosperity, e.g. mental health, life-satisfaction and whether or not you feel a purpose in life. Within this concept, the subjective measures refer to all of the various evaluations that people make on their life, whether positive or negative (Morrison, 2020).

As already written by Helliwell et al., there is a link between economic welfare and SWB. They imply that macroeconomic factors are of great importance in the field of happiness economics. The most publicly known and used measure for economic welfare is gross domestic product (GDP). As a war-born product, GDP has an extensive history. Already in 1665, British scientist and official, William Petty was estimating England and Wales' resources and how to finance war by taxing these resources. In 1940 John Maynard Keynes published 'How to pay for the war.' In this essay he brought the deficiencies to light that were at that time still embedded in the economic war plans. Based on Keynes' essay, the first GDP was developed for the United Kingdom in 1941 (Coyle, 2014). This origin highlights the essence of GDP; a financial value seen as a country's most important indicator for development. Presently, GDP is seen as the standard when measuring a country's economy. Although in recent years GDP is increasingly doubted; some researchers plead for happiness or equality as measurements, it is still very much determining and highly valued as being the most important measurement on a country's overall (economic) performance and welfare.

The relation between economic welfare and happiness is thoroughly analyzed over the last decades. One key finding in this field is the 'Easterlin-paradox.' Richard Easterlin argues that there is no link between the level of economic development of a society and the overall happiness of its members, based on research both across countries and individual countries over time. Within these countries, however, there is evidence for a positive correlation of income and happiness (Easterlin, 2005). This is also endorsed by Layard: "*They want to keep up with the Joneses or if possible to outdo them"* (Layard, 2005, p. 45) i.e. the 'better than your neighbor effect.' Layard gives more nuance to his statement, by adding that for countries with a GDP per capita lower than $15.000, absolute income does influence happiness.

Contrary to the prior authors, Stevenson and Wolfers (2008) argue that more recent data and reanalysis of earlier data, indicate a robust and significant relation between subjective well-being and income across countries, within countries, and over time for all countries. The findings suggest that the subjective well-being income gradient is not only significant but also consistent, refuting previous claims that economic development does not raise subjective well-being and questioning the role of relative income comparisons. The text calls for a reassessment of stylized facts in economic analysis and emphasizes the strong relationship between subjective well-being and income worldwide. Although the authors connect GDP and well-being through correlation, they do not establish causality. Stevenson and Wolfers' research was on a far more large and diverse scale with more accurate data than Easterlin's, this explains the different outcomes in both researches.

Another aspect that possibly influences this relation is the new age of information; people's perception of life changes over time. This also links back to the prior mentioned 'looking beyond GDP as an indicator of a country's overall performance' (Stiglitz et al., 2019). Easterlin, Layard, Stevenson and Wolfers, and Stiglitz et al. all highlight the complexity and relevance for this possible relation.

A reason for this correlation between GDP and Well-being, that could explain the causes, could be the general state of a country based on its economic welfare, e.g. its (digital) infrastructure or benefit system.

With a higher GDP, countries are able to invest and thus develop more. This is also the case for the degree of digitization of a country, the higher its GDP, the more it is digitalized (Roy, 2022). With this development, ICT infrastructure strengthens, leading to an increase in use of internet services and broadband connections. Furthermore, a higher GDP per capita increases the affordability of digital devices. A more indirect effect comes from education. Countries with higher GDPs can invest more in education, leading to a higher level of general education. This then results in higher digital literacy (Mia et al. 2024). Katz et al. (2013) use a digitization index consisting of affordability, infrastructure reliability, network access, capacity, usage, and human capital to test the relation between economic growth and digitization. In their research they find strong evidence that economic growth positively influences the degree of digitization. The 184 countries in the research are subdivided in 4 types, based on their digitization development phase: Constrained, Emerging, Transitional, and Advanced. The development phase is determined by the value scored on the digitization index. This research establishes the pattern that these phases correlate with economic growth. All OECD- and middle-income countries score high in affordability and accessibility of digital services. The digital-divide that is still present in some of these countries can mainly be addressed to reliability and usage. Affordability and accessibility decrease promptly with decreasing GDP, explaining the global disparities in digitization worldwide (Katz et al. 2013).

For this research I zoom in on this possible relation between subjective well-being, economic welfare, and digitization. Sarangi and Pradhan (2021) and Elfafki and Ahmed (2024) come up with justification for this research direction in their articles. The prior conclude that the concept for speeding innovation efforts, improving systems infrastructure and, perhaps most importantly, disaster mitigation can be expanded with the help of improving ICT infrastructure (Sarangi and Pradhan, 2021). The latter explain how digital technology adoption promotes economic growth in Asian Pacific countries (Elfaki and Ahmed, 2024). Both the prior relations suggest links between well-being, economic welfare and digitization. This is underscored by Elmassah and Hassanein (2022). Using the self-reporting life satisfaction index published in the WHR, equal to as used for this research, and the Digital Economy and Society Index (DESI) published by the European Commission, Elmassah and Hassanein studied the relation between digitization and SWB. The life satisfaction index is on a scale from 0-10 and shows the weighted average of respondents' answers to a Self-Anchoring Striving Scale question. It is designed to measure the quality of current life compared to the best and worst possible life of the respondent. DESI is also a weighted average, it includes connectivity, human capital, internet usage, digital technology integration and digital public services. Through a regression analysis and the elasticities of the results, Elmassah and Hassanein (2022) present results indicating that life satisfaction increases by 0.84 units for every unit increase in connectivity. Furthermore, the results indicate that life happiness is negatively impacted by human capital and digital public service, but it is increased by internet use and integrated digital technology. Superfast broadband can benefit individual SWB in a number of ways, including an increasing number of entertainment alternatives that can be accessed through technology. Additionally, using the internet offers a wide range of services that both directly and indirectly assist people, and it helps people overcome feelings of loneliness and social exclusion. Furthermore, engaging in online activities might increase well-being through the expansion of social capital, which is recognized as the main indicator of happiness.

Based on the literature, the following theories arise; Digitization has a positive linear effect on Economic Welfare, Both Digitization and Economic Welfare have a positive linear effect on Subjective Well-being, and the positive effect of Economic Welfare on Subjective Well-being is strengthened when the degree of Digitization in a country is higher.

Methods

To test the hypothesis there are indicators needed for Subjective well-being, Economic state and for Digitization. Subjective well-being is defined as the value given for self evaluation of life satisfaction measured by the OECD based on the Gallup scale. For economic state the gross domestic product per capita, measured by Eurostat, is used. For Digitization multiple variables retrieved from Eurostat are used; Individuals who used the internet for interaction with public authorities, Individuals who used the internet per week and day, Internet use: participating in social networks (creating user profile, posting messages or other contributions to facebook, twitter, etc.), and Share of households with broadband access. These are all percentages of the total population. Taking multiple measures of Digitization creates a deeper understanding of the concept itself and its effect on the other concepts because it captures the multifaceted nature of digitization.

A famous measure of subjective well-being is Cantril's ladder, used for countless works of research in previous decades. Nowadays an adaptation of Cantril's ladder is prevalent for measuring subjective well-being; Gallup's ladder of life (Frijters, 2021). This measure is not only used by the OECD but in many other researches to measure the, by OECD called, 'Self evaluation of life-satisfaction,' (OECD, 2024). In Cantril's model the respondent is asked to imagine a ladder with values per step, 0 at the bottom and 10 at the top. The 0 represents the worst possible life for you and 10 the best possible. The respondent is asked to give a value for their current situation and the situation they think they will be in in 5 years (Cantril, 1965). The American research and consultancy organization Gallup revised the Cantril Self-Anchoring Striving Scale by combining present and future life satisfaction ratings and utilizing statistical analyses from global surveys to categorize respondents into three distinct well-being groups. (Gallup, 2021). For this research the values presented by the OECD are used, which is the scale from 0 to 10.

To test the hypotheses, multiple regression analyses were conducted. First, a multiple log-linear regression assessed the impact of digitization on Economic Welfare, using log-transformed GDP per capita to improve normality and interpretability. A positive and statistically significant coefficient for digitization would support the hypothesis that it enhances economic welfare. Second, multiple linear regression was employed to examine how digitization affects Subjective Well-being, controlling for relevant variables. Third, a multiple linear regression tested whether higher Economic Welfare positively influences Subjective Well-being. Finally, multiple linear regressions with an interaction term between GDP per capita and Digitization explored whether economic welfare's impact on subjective well-being varies with different levels of digitization. For all hypotheses the most complex test is also performed a second time, then with fixed effects for countries included, to test for unobserved heterogeneity between countries that could influence the variables and thus test-outcomes.

The measure for SWB is subtracted from the database 'Regional well-being,' created and used by the OECD for their research on regional well-being. Since the research is aimed at understanding regional well-being and its determinants, this database is also the source of the control variables used in for the tests with SWB as dependent variable. Variables used to control the relations triangle are; employment rate, unemployment rate, number of rooms per person, at least secondary education, life expectancy at birth, standardized mortality rate, air pollution, homicide rate, voter turnout in general election, perceived social network support, perception of corruption. What control variables are selected depends on the dependent variable; GDP per capita is only related to a selection of control variables, while

SWB is controlled for all variables, leaving out highly correlating variables like standardized mortality rate, which correlates with life expectancy at birth.

The tests are performed on Nuts2 scale data, since these are the basic regions for the application of regional policies (EuroStat). From the 244 Nuts2 regions in Europe, for 136 there is data available on all variables. The maps in this analysis also visualize missing regions; countries like Germany and Romania or regions within countries like Budapest or Oslo. This is the result of the OECD research that forms the basis of the data used in this research. This research is lacking values for these regions, either in general or on Nuts 2 level.

Results

Descriptive statistics

GDP per capita and Digitization

Knowledge spillovers have occurred extensively in European history and increasingly at the present day, nevertheless there can be substantial differences in certain developments within European regions, and even within particular countries, there is some great variance in minima and maxima. The variables used in this research are described in table 1, showing the descriptive statistics for the values of the regions. Figure 1 shows the values of GDP per capita in these regions. It can be seen that the values differ through the regions in the dataset. Absolute values range from 6700 euros (Northern Hungary), to 93100 euros a year per inhabitant (Luxembourg). Regarding spatial patterns in the map, GDP per capita is lower in the eastern areas of the dataset and southern Europe. Furthermore it can be seen that Switzerland and large parts of the Scandinavian countries have higher values for GDP per capita than the other regions in the dataset.

Table 1: Descriptive statistics

Variable	Mean	Std. Dev.	Median	Min	Max	N
Government	54.76	19.46	57.44	14.33	88.56	136
Week	76.31	11.87	76.72	48.4	95.22	136
Day	66.91	11.45	64.56	45.05	94.36	136
Networks	47.24	10.53	44.87	29.49	72.13	136
Broadband	77.62	9.21	77	53	98	136
Employment rate	65.66	10.21	65.75	31.3	86.5	136
Unemployment rate	11.04	6.78	8.95	2.5	34.8	136
Number of rooms pers person	1.77	0.27	1.8	1	2.2	136
Share of labor force with at least secondary education	75.47	13.34	79.1	33	97.7	136
Life expectancy at birth	81.36	2.17	81.9	74.2	84.8	136
Standardized mortality rate	7.74	1.41	7.4	5.8	12.5	136
Air pollution level of pm 2.5	11.43	4.57	10.9	2.2	26.8	136
Homicide rate	1.01	0.98	0.8	0	8.5	136
Voter turnout in general election	71.15	12.01	74.25	40.4	91.1	136
Perceived social network support	91.55	4.22	92.25	78.6	100	136
SWB	6.68	0.76	6.7	4.5	7.8	136
GDP per capita	30455.15	15459.37	28500	6700	93100	136

For all countries on a national scale there are disparities. The descriptive statistics for GDP per capita in table 1 show a mean of 30455.15 euros and a median of 28500 euros. Figure 2 shows the distribution of GDP per capita values over the regions. Figure 3 shows the distribution of log GDP per capita. These figures visualize the increase in normality when transforming the GDP per capita to logarithmic values.

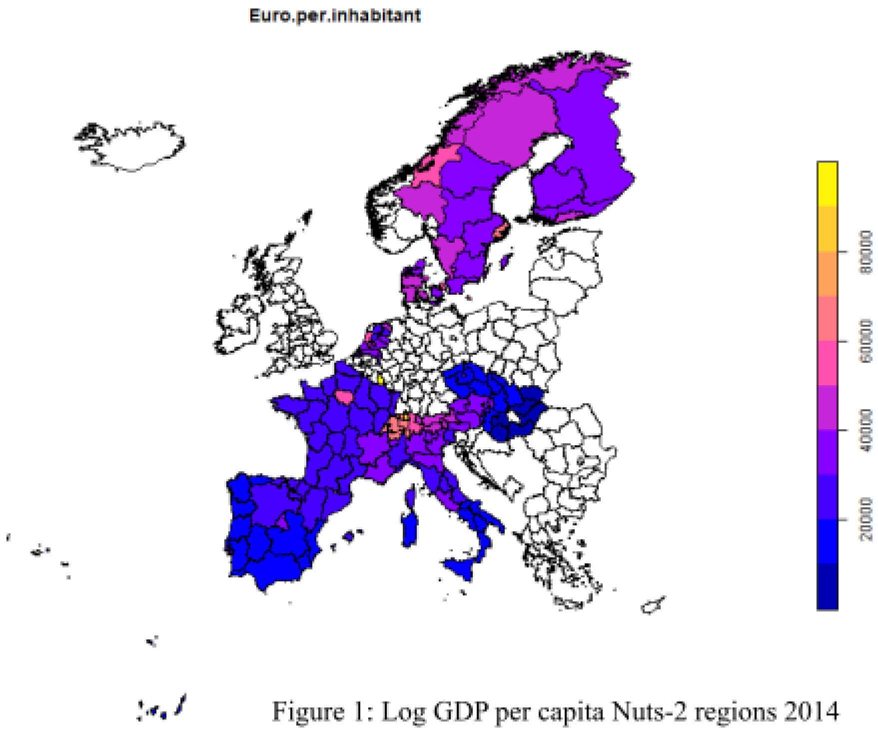


Figure 1: Log GDP per capita Nuts-2 regions 2014

Figure 2

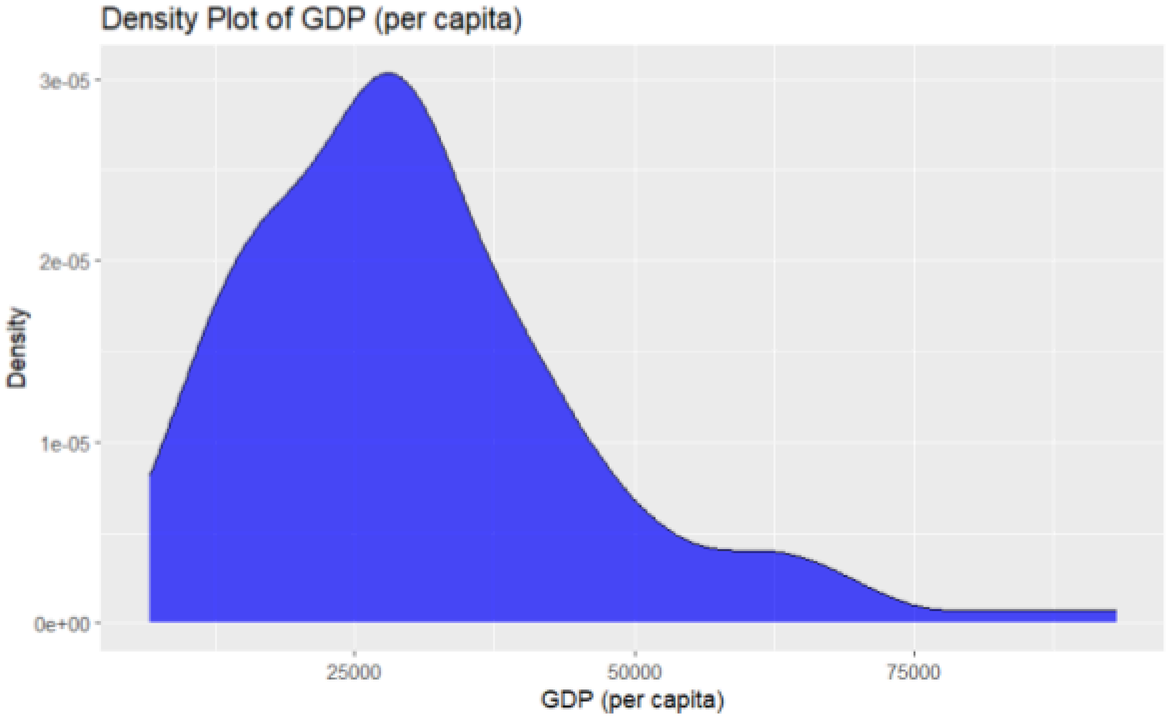
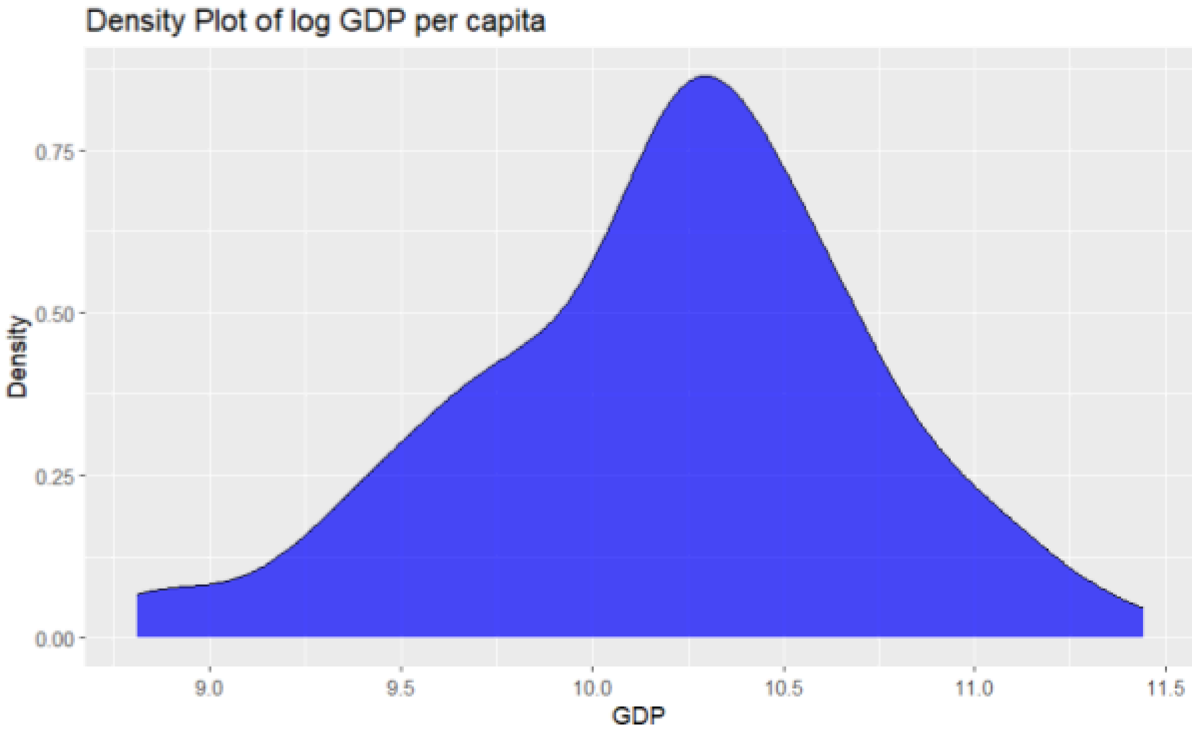


Figure 3



The 5 variables of digitization are visualized in figure 4. A pattern that can be seen for all variables is the high scores in Scandinavian countries and The Netherlands. Italy and Portugal stand out with low scores compared to the rest of the regions. For the other regions there is no straightforward spatial pattern. The great variance in digitization is also reflected in the descriptive statistics. The percentage of the population that uses the internet to use public services ranges from 14.33% (Puglia, Italy) to 88.56% (Capital Region, Denmark), the mean is 54.76%. Apart from more extreme lower values in internet use for public services the digitization variables show similar values for maximum, mean and median values. Table 2 shows how these variables correlate. The high correlation for weekly and daily internet usage can be explained by the construction of the weekly variable, which includes cases with daily internet usage. Apart from this correlation, the other digitization variables have high values for correlation, except for the usage of the internet for social networks. This value is still moderate positive but relatively lower than the other, high positive correlations, possibly due to culture or demography differences. As a result, including all digitization variables in the statistical models leads to multicollinearity. Including one of weekly/daily internet usage, internet usage for public services and broadband connection in combination with the variable for internet usage for social networks would therefore be representative for the concept of digitization. Statistical tests and results are explained in the ‘Regression analyses’ part of this research.

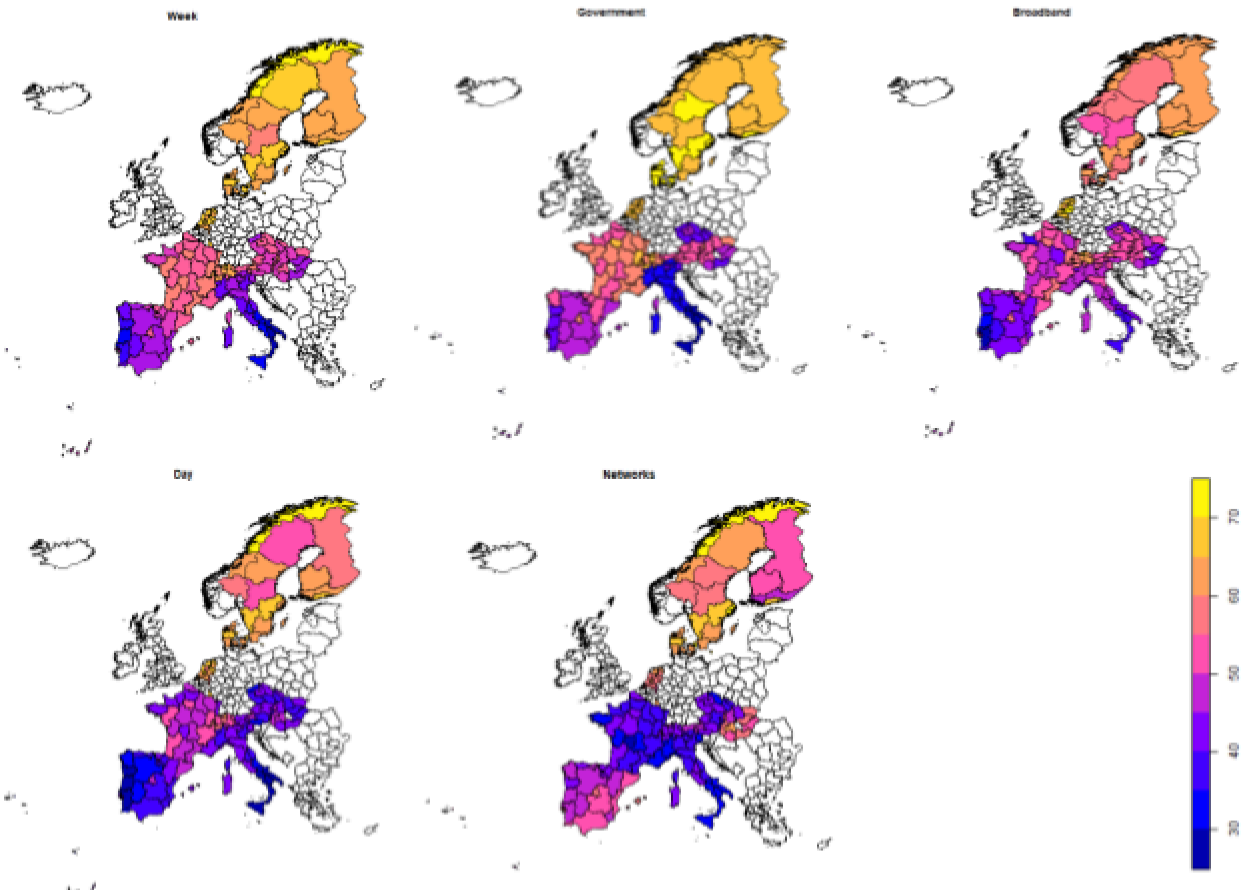


Figure 4: Percentage of population for digitalization variables

Table 2: Correlations matrix digitization variables

	Government	Week	Day	Networks	Broadband
Government	1				
Week	0.93	1			
Day	0.84	0.92	1		
Networks	0.63	0.60	0.64	1	
Broadband	0.76	0.87	0.89	0.55	1

Subjective Well-Being

In the OECD's research the question for determining the Subjective Well-Being variable is the following: Imagine a ladder with 11 numbered steps; 0-10. 0 being the worst possible life and 10 the best, on which step of the ladder would you say you personally feel you stand at this time? Descriptive statistics for SWB can be found in table 1. Based on the ladder question, values could range from 0 to 10. In practice this is not the case; on average, people do not rate their life the worst possible but also not the best possible. Figure 5 shows this distribution. The lowest values are around 4.5 and the highest approach a value of 8. Based on the descriptive statistics of the data, the lowest value is 4.5, which is the average SWB in Northern Hungary. It is noteworthy that the lowest scoring regions are all located in Hungary, all scoring less than 5.0, underscoring the importance of adding fixed effects models in the analyses to correct for possible heterogeneity between countries that influences the estimates. The mean value for SWB for the whole dataset is 6.68. East Switzerland, Central Switzerland and the Dutch province of Zeeland share the highest value; 7.8, possibly due to the high economic and social stability in these regions (Andreoni & Galmarini, 2016). The value distribution is left-skewed, higher values occur more often.

Figure 5

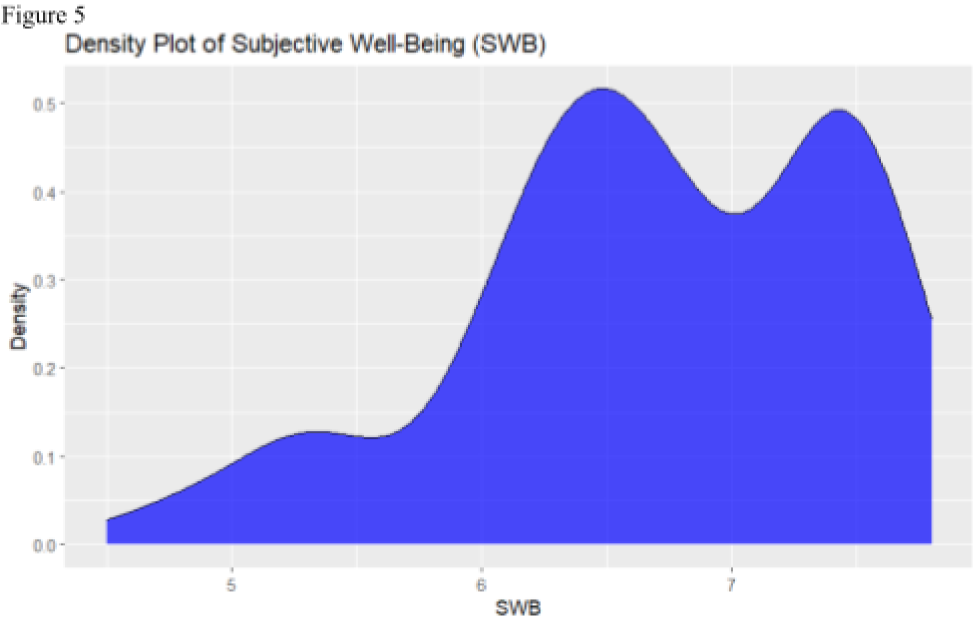


Figure 6 reflects the values on the map. In the map itself the highest values from the descriptive statistics can be recognized, in combination with generally higher values for the northern regions in the dataset, The Netherlands and Scandinavia. The low values in Hungary stand out, but also Portugal and southern Italy show low values. Overall, the most notable spatial pattern is the contrast between lower values in the southern regions and higher values in the northern regions.

Spatial patterns

In the maps visualizing the variables, some spatial patterns can be determined for all variables. Lower values for southern regions and Hungary can be observed, while Scandinavia, Switzerland and The Netherlands score high for (almost) all variables. Although the maps visualize these patterns very well, the possible interaction between Digitization and GDP per capita is not observable. The next section dissects these possible relations with statistical analyses.

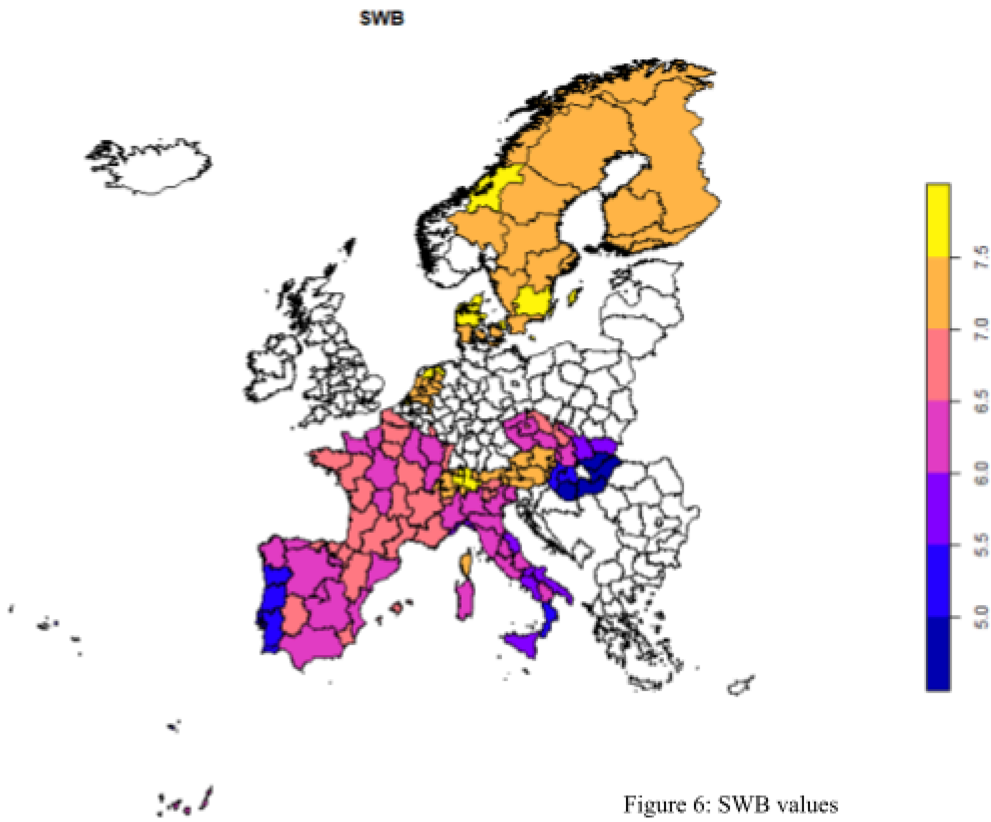


Figure 6: SWB values

Regression analyses

GDP per capita and Digitization

Although there are some patterns visible within the variables for Digitization and GDP per capita, connections between variables are hard to determine based on the maps. To test the sign, strength and significance of digitization's effect on economic welfare, I created multiple models. The first model is straightforward; log GDP per capita as dependent variable and usage of the internet for public services, weekly usage of internet, daily usage of internet, participating in social networks, and broadband connection as independent variables. The variables are indicated in the dataset as: GDP, Government, Week, Day, Networks, and Broadband respectively.

Table 3 shows the results of the first test. The test results suggest that a one unit increase in the percentage of the population that uses the internet for public services increases the GDP per capita in euros by 0.02%. The P value for this estimate is significant, therefore making claims on the positive relation of the government variable and GDP per capita is supported by statistical evidence. This can be said for all digitization variables in the test. Daily internet use shows a positive and significant effect. An increase of one unit in percentage of the population that uses the internet on a daily basis increases the GDP per capita by 0.05%. Participating in social networks and weekly internet usage also have significant effects, however, these effects are negative. The model suggests that a one unit increase in the percentage of the population that participates in social networks through the internet decreases the GDP per capita by 0.02% and an increase in the percentage of the population that uses the internet at least once a week decreases GDP per capita by 0.04%. The latter is contradicting with the earlier finding of a positive effect of an increase in daily internet usage, this could be the result of the high multicollinearity in the model. The adjusted R^2 for this model is 0.60. This value of R^2 is striking when working with 5 similar independent variables that are not directly linked to the dependent variable. A Variance Inflation Factor analysis (VIF), shows values around 10 for all independent variables except for Networks, confirming the earlier stated expectations regarding multicollinearity. After removing the correlating variables except daily use of the internet and adding variables from the dataset that can be added as control variables; Employment rate and Share of labour force with at least secondary education, a new model is created. The selected control variables are based upon relatedness to GDP per capita. The results of this model can be seen in the second column of table 3. It can be seen for the second model that the sign of the coefficients from both digitization variables do not change in the altered model. The strength does change for both variables; when daily internet use increases with 1 percent point, GDP is estimated to increase with 0.04% instead of the earlier estimated 0.05%. For participating in online social networks the decrease in GDP is estimated at 0.03% compared to 0.02% in the previous model. For the added control variables all are significant. The adjusted R^2 of the second model is 0.66 indicating a stronger predicting value for the second model.

The third estimate column in table 3 shows the results for when fixed effects for countries are added to the model. When accounting for the unobserved heterogeneity between countries, the sign for using the internet for social networks changes. It is now estimated that an increase in this variable has a positive effect on GDP per capita, but the results became insignificant. Daily internet usage is estimated to have a smaller effect. The model indicates significant values for country fixed effects; these countries are estimated to have a significantly different GDP per capita than the reference country Austria, even after controlling for the digitization and control variables. The adjusted R^2 of this third model is 0.92, which suggests a significant increase in predicatory power of this model compared to the previous models.

The results estimate a small but significant effect of Digitization on GDP per capita. In the most simple model usage of the internet for public services, daily internet usage and broadband connection are estimated to have a positive effect on GDP per capita, while Internet usage for social networks and weekly internet usage are estimated to have a negative effect on GDP per capita. When using just one of the highly correlating digitization variables, they are all estimated to have a positive influence on GDP per capita, except for Networks. Only when fixed effects for countries are added, an increase in this variable is also estimated to have a positive effect on GDP per capita, but it becomes insignificant. Between countries, the models suggest that when the degree of internet use for public services, daily and weekly internet use, and broadband access in a region is higher, GDP per capita is estimated higher, while GDP per capita in a region is estimated lower when internet use for social networks is higher. Within countries, a positive relation between digitization and GDP per capita is estimated for both online digitization (degree of- and reason for use) and digitization infrastructure; broadband, which is in line with findings in the literature review by Roy (2022) stating that the higher a region's GDP, the more it is digitalized.

Table 3: Log linear regression with GDP per capita as dependent

term	estimate	estimate	estimate
(Intercept)	8.99***	8.44***	7.44***
Government	0.02***		
Week	-0.04***		
Day	0.05***	0.04***	0.02***
Networks	-0.02***	-0.03***	0.004
Broadband	0.01*		
Employment rate		0.02***	0.01***
At least secondary education		-0.01***	0.01**
Country fixed effects			Yes
Adjusted R²	0.60	0.66	0.92
Number of observations	136	136	136

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

Subjective Well-Being and Digitization

To explore the possible relation between Digitization and Subjective Well-Being in European regions, multiple models are created. The first model is a simple model with SWB as the dependent variable and the variables for digitization as independent variables. Stated earlier is the finding of high correlation between most of the digitization variables; however, running a simple model with only the digitization variables is a good indicator of possible relations and for what variables to use in more complex models. Table 4 shows the results of this regression. Except for daily internet use, the digitization variables have significant values. Based on this model, a one unit increase in the variable for making use of public services through the internet, is estimated to increase SWB with 0.02. A one unit increase in Broadband connectivity has an estimate of 0.03 increase on SWB. For having an account on a social network platform, the sign is negative. A one unit increase in this variable is estimated to decrease SWB with 0.02. This model has an adjusted R^2 of 0.65 which is reasonably strong compared to earlier models, especially when considering the variables relation. Since this model shows high values for multicollinearity, the test is performed with a more complex model that excludes highly correlating variables and includes control variables.

Table 4: Regression with SWB as dependent variable

term	estimate	estimate	estimate
(Intercept)	3.38***	-10.41***	1.48
Government	0.02***		
Day	0.02 .		
Networks	-0.02***	0.002	-0.005
Broadband	0.03**	0.03***	0.006
Employment rate		0.01**	0.01**
Rooms per person		0.57**	-0.1
At least secondary education		0.01***	-0.007
Life expectancy		0.09***	0.03
Level of PM2.5		-0.003	0.001
Homicide rate		0.04	0.05*
Voter turnout		-0.0003	0.01 .
Perceived social network support		0.05***	0.02***
Country fixed effects			Yes
Adjusted R²	0.65	0.78	0.93
Number of observations	136	136	136
Signif. codes: 0 '***' 0.001'**' 0.01 '*' 0.05 '.'			

To determine what variables from the Well-Being dataset to use, without running into the same problem, correlations must be established. Table 5 shows the correlation matrix of all possible control variables. Employment- and unemployment rate and Life expectancy at birth and the standardized mortality rate highly correlate. A more complex model with control variables without correlation is created with the variables: Networks, Broadband, Employment rate, Number of rooms per person, Share of labor force with at least secondary education, Life expectancy at birth, Air pollution; level of PM2.5, Homicide rate, Voter turnout in general election, and Perceived social network support. The second column in table 4 shows these results. The results indicate that Networks, air pollution, homicide rate and voter turnout in general elections have no significant effect on SWB. Broadband connection, Employment rate, Share of labor force with at least secondary education, and Perceived social network support are all estimated to have a small positive effect on SWB. Number of rooms per person and Life expectancy at birth are estimated to have a bigger positive effect on SWB; 0,57 and 0,1 respectively. The adjusted R^2 for this test is 0.7823 which is a significant increase in prediction power compared to the more simple model. *[This test is performed multiple times with all digitization variables used separately, to prevent multicollinearity. 'Networks' was included in all tests. All outcomes had similar results for the digitization variables (table 1 in the appendix)]*

The third column in table 4 shows the results for the second model with fixed effects included. In this model the independent variables become insignificant. Furthermore France, Hungary, Portugal and Spain show negative significant values, indicating lower SWB compared to Austria. For Finland the value is positive, indicating higher estimated SWB compared to Austria. The adjusted R^2 of this model is 0.9277, indicating high predicatory strength.

Based on the results for the three models, a region's degree of digitization is estimated to have varying relations with SWB; Internet use for public services and having broadband connection are estimated to have a positive and significant relation with SWB, while participating in an online social network is estimated to have a negative and significant relation. In the simple model, frequency of internet usage is estimated not to have a significant effect on SWB. When control variables are added to the test and highly correlating values are deleted; the effect of digitization variables on SWB remains significant but small and contrary to the more simple model, a small positive effect of daily internet use on SWB is estimated and using the internet for social networks is estimated to have a positive effect but becomes insignificant. When fixed effects for countries are added to the model the independent variables become insignificant, indicating that unobserved heterogeneity between countries has an extensive impact on SWB. For subjective well-being between regions, digitization variables are estimated to have a positive relation with SWB for both online and broadband access percentages, when the digitization in a region is higher, SWB is also higher. These results are supported by findings in the literature review; Elmassah and Hassanein (2022) present results indicating that life satisfaction increases with an increase in connectivity. Within countries these patterns are not found, which is also inline with the literature findings.

Table 5: Correlation matrix digitization and control variables

	Government	Week	Day	Networks	Broadband	Emp. rate	Unemp. rate	Rooms per person	Share of labor force with at least secondary education	Life exp. at birth	Standardized mortality rate	Air pollution level of PM2.5	Homicide rate	Voter turnout in general election	Perceived social network support
Government	1														
Week	0.93	1													
Day	0.84	0.92	1												
Networks	0.63	0.60	0.64	1											
Broadband	0.76	0.87	0.89	0.55	1										
Emp. rate	0.62	0.70	0.66	0.36	0.63	1									
Unemp. rate	-0.39	-0.52	-0.52	-0.08	-0.48	-0.78	1								
Rooms per person	0.24	0.17	0.21	0.01	0.16	0.19	0.00	1							
Share of labor force with at least secondary education	0.43	0.57	0.45	0.06	0.46	0.49	-0.68	-0.32	1						
Life exp. at birth	0.01	-0.03	0.07	-0.27	0.07	0.02	0.16	0.65	-0.30	1					
Standardized mortality rate	-0.01	0.03	-0.05	0.31	-0.05	0.02	-0.17	-0.66	0.30	-0.99	1				
Air pollution level of PM2.5	-0.25	-0.09	-0.11	-0.30	0.06	0.08	-0.24	-0.43	0.32	-0.25	0.25	1			
Homicide rate	-0.23	-0.20	-0.23	-0.12	-0.22	-0.39	0.13	-0.32	-0.03	-0.23	0.20	-0.00	1		
Voter turnout in general election	0.25	0.26	0.35	0.03	0.22	0.11	-0.20	0.51	0.09	0.46	-0.46	-0.20	-0.23	1	
Perceived social network support	0.48	0.45	0.41	0.26	0.44	0.15	0.01	0.24	0.13	0.24	-0.25	-0.17	-0.10	0.16	1

Number of observations is 136

Subjective Well-Being and GDP per capita

To see how the prior established spatial patterns are translated in statistics, the correlation between the two variables is calculated. This value for SWB and GDP per capita is 0.798 which is high, this underscores the findings regarding the spatial patterns. Based on this relation I ran a regression model with SWB as dependent variable and only GDP per capita as independent variable. Table 6 shows these results. The effect of GDP per capita on SWB is a significant and positive value of 1.16. Figure 7 shows a scatterplot with a regression line for SWB and GDP per capita. In this figure this strong positive relation is visualized. Although the regression gives a large number; a one percent increase in GDP per capita leads to a 0.0116 increase in SWB. The model's strength offers room for improvement when looking at adjusted R^2, with a value of 0.63.

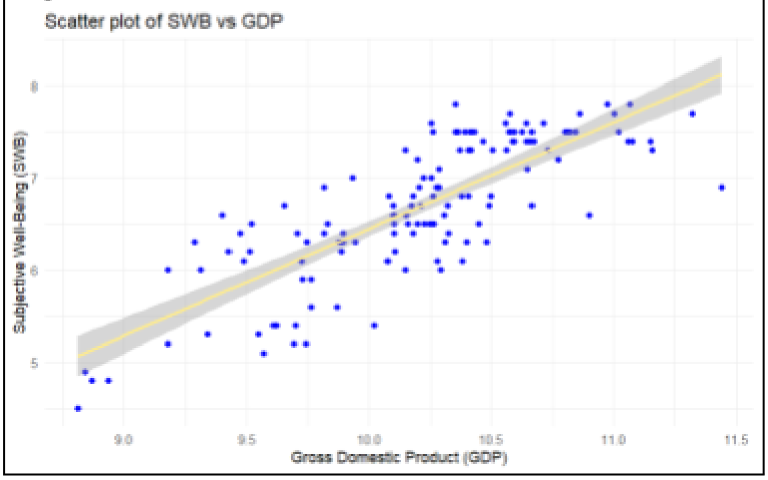
In a second model control variables are added. SWB is tested to GDP per capita, Employment rate, and Share of labour force with at least secondary education. The control variables are picked based on their connection with GDP and relative moderate/low values of correlation with GDP; 0.6 and 0.22 respectively. Table 4 shows the results of this regression in the second column. The estimated effect for GDP on SWB decreased, but still has a positive and significant value of 1.03. The control variables 'Employment rate' has a smaller and not significant estimated effect, while the positive weak estimated effect of percentage of the population with at least secondary education is significant. The adjusted R^2 for this model is 0.68, indicating a small increase in predicatory power compared to the prior model.

Table 6: Regression with SWB as dependent

	estimate	estimate
(Intercept)	-5.15***	-5.00***
GDP	1.16***	1.03***
Employment rate		0.01
Secondary education		0.01**
Adjusted R^2	0.63	0.68
Number of observations	136	136

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

Figure 7



I ran a third model with additional control variables to see the effect of GDP per capita on SWB when the predicatory strength of the model is greater. Added control variables are based upon significance in earlier models with SWB as dependent variable. The first column in table 7 shows the results of this regression. Striking is the change of strength for GDP per capita, now estimated to have an effect of 0.5 on SWB. All control variables are estimated to have a weak significant positive effect on SWB, except for life expectancy at birth. The model has an adjusted R^2 of 0.80, which indicates a strong predicatory power. The second column of table 7 shows the results for a fixed effects model. Certain countries in the dataset are estimated to have unobserved heterogeneity causing SBW to be lower than the reference country Austria, in relation to GDP per capita. GDP per capita, however, remains positive and significant, indicating that it is estimated to have a positive effect on SWB within countries. A one percent increase in GDP per capita is estimated to increase SWB with 0.004.

Based on the four models; simple, complex with related control variables, complex with strong predictor control variables and with fixed effects, the relation between GDP per capita and SWB is predicted to be strong. Within more simple models GDP per capita is estimated to have a large positive effect on SWB, while adding stronger control variables causes GDP per capita's effect to decrease but remain large and significant. The results suggest that a high GDP per capita is associated with a higher SWB, both for between all regions in the data as for within countries in the dataset. These findings are similar to Stevenson and Wolfers' (2008) who indicate a significant relation between subjective well-being and income across countries and within countries. Thus the findings are different than Easterlin (2005) and Layard (2005) who argued that this effect only occurs within countries.

Table 7: Regression with SWB as dependent

term	estimate	estimate
(Intercept)	-9.64***	-1.12
GDP	0.54***	0.38**
Broadband	0.02***	-0.002
Employment.rate	0.01*	0.01*
Secondary education	0.01**	-0.01 .
Life expectancy	0.04 .	0.03
Social network support	0.05***	0.03***
Country fixed effects		Yes
Adjusted R^2	0.80	0.93
Number of observations	136	136

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

Subjective Well-Being, GDP per capita, Digitization and interaction

To research that possible interaction, I created multiple statistical models. The first one is again simple: SWB tested to all digitization variables, GDP per capita, and the interaction between these independent variables. Table 8 shows the results of this test. Equal to the simple model with SWB tested to digitization variables, using the internet for social networks is estimated to have a negative effect on SWB. All other digitization variables are estimated insignificant. Furthermore GDP per capita is estimated to have a large positive effect on SWB, similar to earlier models. If we then look at the interaction terms, only the interaction between 'using the internet for social networks' and GDP per capita is estimated to be significant. The value of 0,026 indicates that it is estimated that when the percentage of people in a region using social networks increases with 1, the positive effect GDP per capita has on SWB increases with 0,026, from 2,078 to 2,103. Although the R^2 of 0.7962 indicates a strong model, multicollinearity is high due to the digitization variables. A second model with: just one of the highly correlated variables, GDP per capita, the interaction variables, and control variables is created.

Table 8: Linear regression with SWB as dependent

term	estimate	estimate	estimate
(Intercept)	-16.30*	-10.50 .	-10.26 .
Government	-0.10		
Day	0.19		
Networks	-0.27***	-0.22***	0.04
Broadband	0.28	0.21**	0.08
GDP	2.08*	0.99	1.31*
Broadband:GDP	-0.02	-0.02*	-0.01
Networks:GDP	0.03**	0.02***	-0.004
Day:GDP	-0.02		
Government:GDP	0.01		
Employment rate		0.01 .	0.003
Number of rooms		0.41**	0.17
Secondary education		0.01*	-0.01*
Life expectancy at birth		-0.005	0.03
Social network support		0.05***	0.02***
Country fixed effects			Yes
Adjusted R^2	0.80	0.84	0.93
Number of observations	136	136	136

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

The second column of table 8 shows these results. The negative effect of the networks variable decreases but is similar to the estimate in the simple model. The broadband variable has become significant in the second model, the control variables add enough evidence to estimate a possible positive effect of increased broadband connectivity on SWB. The interaction variables show different signs than the digitization variables themselves. The model estimates that an increase in broadband connectivity would decrease the positive effect GDP per capita has on SWB, while an increase in social networks would increase the effect GDP per capita has on SWB. When the models were run with Daily internet use the models showed similar results for all variables. The outcomes when using the public services variable were different but became not significant [Appendix table 2]. The last model created adds fixed effects to the second model. The third column in table 8 shows these results. GDP per capita, contrary to the previous models, is now significant. Implying that within the countries GDP per capita is estimated to have a positive effect on SWB. When looking at the digitization and interaction variables, they have become insignificant, indicating that differences between countries in unobserved heterogeneity has a significant effect on these variables.

Based on the three models it can be concluded that when comparing all regions, an increase in digitization is estimated to have different effects on the relation between GDP per capita and SWB: A higher percentage for internet usage for public services, daily internet use and/or broadband connection, is estimated to decrease the estimated positive effect of GDP per capita on SWB. A lower percentage of internet use for social networks, increases the effect GDP per capita has on SWB. When comparing per country, the results become insignificant, suggesting that unobserved heterogeneity for countries has a significant effect on SWB.

Conclusion

The results predict a small but significant effect of digitization on GDP per capita. In the simplest model, usage of the internet for public services, daily internet usage, and broadband connection are estimated to have a positive effect on GDP per capita, while internet usage for social networks and weekly internet usage are estimated to have a negative effect on GDP per capita. When using just one of the highly correlating digitization variables, they are all estimated to have a positive influence on GDP per capita, except for Networks. Only when fixed effects for countries are added, an increase in this variable is also estimated to have a positive effect on GDP per capita. The positive effect of digitization on GDP per capita aligns with Katz et al. (2013), who found economic growth boosts digitization, supported by Mia et al. (2024) and Sarangi and Pradhan (2021), indicating higher GDP improves ICT infrastructure, enhancing economic growth.

Based on the results for the three models, a region's degree of digitization is estimated to have varying relations with SWB; Internet use for public services and having broadband connection are estimated to have a positive and significant relation with SWB, while participating in an online social network is estimated to have a negative and significant relation. In the simple model, frequency of internet usage is estimated not to have a significant effect on SWB. When control variables are added to the test and highly correlating values are deleted; the effect of digitization variables on SWB remains significant but small and contrary to the more simple model, a small positive effect of daily internet use on SWB is estimated and using the internet for social networks is estimated to have a positive effect but becomes insignificant. When fixed effects for countries are added to the model the independent variables become insignificant, indicating that unobserved heterogeneity between countries has an extensive impact on SWB. For subjective well-being between regions, digitization variables are estimated to have a positive relation with SWB for both online and broadband access percentages, when the digitization in a region is higher, SWB is also higher. These results are supported by findings in the literature review; Elmassah and Hassanein (2022) present results indicating that life satisfaction increases with an increase in connectivity. Within countries these patterns are not found, which is also inline with the literature findings.

Based on the four models for SWB and GDP per capita (simple, complex with related control variables, complex with strong predictor control variables, and with fixed effects), it is suggested that the relation between GDP per capita and SWB is strong, both between and within countries. These findings are similar to Stevenson and Wolfers' (2008). In simpler models, GDP per capita is estimated to have a large positive effect on SWB, while adding stronger control variables causes GDP per capita's effect to decrease but remain large and significant. These findings align with the literature review; Helliwell et al. (2015) stated that life evaluations are significantly impacted by economic, political, and social concerns in addition to macroeconomic issues.

Based on the three models with interaction variables, it can be concluded that when comparing all regions, an increase in digitization is estimated to have different effects on the relation between GDP per capita and SWB: A higher percentage for internet usage for public services, daily internet use and/or broadband connection, is estimated to decrease the estimated positive effect of GDP per capita on SWB. A lower percentage of internet use for social networks, increases the effect GDP per capita has on SWB. When comparing per country, the results become insignificant, suggesting that unobserved heterogeneity for countries has a significant effect on SWB.

Discussion

This research adds to the extensive literature on digitization, GDP, and subjective well-being, and to the scarce literature on the connection between these three concepts. With data on 19 variables for 136 NUTS-2 regions from 15 different EU countries, the results are strong in representing similar countries. However, interpretability must be done cautiously since the last available data for all variables tested on a NUTS-2 scale is from 2014.

Recommendations for future research originate from the research process; the OECD collected values for 'perception of corruption.' Although this variable had some missing values and therefore is not included in the final version of this report, it was found to have a high negative correlation with all digitization variables. Future research on the underlying mechanisms in this relation would be an interesting addition to this field of research.

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Appendix

Table 1: Regression with SWB as dependent variable

term	estimate	estimate	estimate
(Intercept)	-10.41***	-11.77***	-10.63***
Government		0.01**	
Day			0.02***
Networks	0.002	0.01	0.003
Broadband	0.03***		
Employment rate	0.01**	0.02**	0.01*
Rooms per person	0.57**	0.58**	0.66**
At least secondary education	0.01***	0.02***	0.02***
Life expectancy	0.09***	0.12***	0.10***
Level of PM2.5	-0.003	0.02 .	0.01
Homicide rate	0.04	0.06	0.04
Voter turnout	-0.003	-0.001	-0.003
Perceived social network support	0.05***	0.05***	0.05***
Adjusted R^2	0.78	0.77	0.77
Number of observations	136	136	136

Signif. codes: 0 '***' 0.001'**' 0.01 '*' 0.05 '.'

Table 2: Regression with SWB as dependent variable

term	estimate	estimate	estimate
(Intercept)	-10.50 .	-6.76	2.23
Government			0.06
Day		0.21**	
Networks	-0.22***	-0.27***	-0.25**
Broadband	0.21**		
GDP	0.99	0.71	-0.30
Broadband:GDP	-0.02*		
Day:GDP		-0.02**	
Government:GDP			-0.01
Networks:GDP	0.02***	0.03***	0.02***
Day:GDP			
Government:GDP			
Employment rate	0.01 .	0.01 .	0.01 .
Number of rooms	0.41**	0.37*	0.29
Secondary education	0.01*	0.01**	0.01**
Life expectancy at birth	-0.005	-0.01	0.01
Social network support	0.05***	0.05***	0.05***
Adjusted R^2	0.84	0.83	0.82
Number of observations	136	136	136

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

Research Data Management Plan

1. General	
1.1 Name & title of thesis	Ian Buitenhuis The triangular relation of Digitization, GDP per capita, and Subjective well-being
1.2 *(if applicable)* Organisation. Provide details on the organisation where the research takes place if this applies (in case of an internship).	

2 Data collection – the creation of data	
2.1. Which data formats or which sources are used in the project?	Secondary data Collected by the European Commission and the OECD

2.2 Methods of data collection What method(s) do you use for the collection of data. (Tick all boxes that apply)	☐ Structured individual interviews ☐ Semi-structured individual interviews ☐ Structured group interviews ☐ Semi-structured group interviews ☐ Observations ☐ Survey(s) ☐ Experiment(s) in real life (interventions) ☒ Secondary analyses on existing data sets (if so: please also fill in 2.3) ☐ Public sources (e.g. University Library) ☐ Other (explain):
2.3. (If applicable): if you have selected 'Secondary analyses on existing datasets': who provides the data set?	☐ Data is supplied by the University of Groningen. ☒ Data have been supplied by an external party. Eurostat & OECD

3 Storage, Sharing and Archiving

3.1 Where will the (raw) data be stored *during* research?	☐ X-drive of UG network ☐ Y-drive of UG network ☐ (Shared) UG Google Drive ☐ Unishare ☒ Personal laptop or computer ☐ External devices (USB, harddisk, NAS) ☐ Other (explain):
3.2 Where are you planning to store / archive the data after you have finished your research? Please explain where and for how long. Also explain who has access to these data NB do not use a personal UG network or google drive for archiving data!	☐ X-drive of UG network ☐ Y-drive of UG network ☐ (Shared) UG Google Drive ☐ Unishare ☐ In a repository (i.e. DataverseNL) ☒ Other (explain): Personal computer The retention period will be 1 year.
3.3 Sharing of data With whom will you be sharing data during your research?	☐ University of Groningen ☐ Universities or other parties in Europe ☐ Universities or other parties outside Europe ☒ I will not be sharing data

<table>
<tr><td colspan="2">4. Personal data</td></tr>
<tr><td>4.1 Collecting personal data

Will you be collecting personal data?

If you are conducting research with personal data you have to comply to the General Data Privacy Regulation (GDPR). Please fill in the questions found in the appendix 3 on personal data.</td><td>No</td></tr>
<tr><td colspan="2">If the answer to 4.1 is ‘no’, please skip the section below and proceed to section 5</td></tr>
<tr><td>4.2 What kinds of categories of people are involved?

Have you determined whether these people are vulnerable in any way (see FAQ)?

If so, your supervisor will need to agree.</td><td>My research project involves:

☐ Adults (not vulnerable) ≥ 18 years

☐ Minors < 16 years

☐ Minors < 18 years

☐ Patients

☐ (other) vulnerable persons, namely (please provide an explanation what makes these persons vulnerable)

(Please give a short description of the categories of research participants that you are going to involve in your research.)</td></tr>
</table>

4.3 Will participants be enlisted in the project without their knowledge and/or consent? (E.g., via covert observation of people in public places, or by using social media data.)	Yes/no If yes, please explain if, when and how you will inform the participants about the study.
4.4 Categories of personal data that are processed. Mention all types of data that you systematically collect and store. If you use particular kinds of software, then check what the software is doing as well. Of course, always ask yourself if you need all categories of data for your project.	☐ Name and address details ☐ Telephone number ☐ Email address ☐ Nationality ☐ IP-addresses and/or device type ☐ Job information ☐ Location data ☐ Race or ethnicity ☐ Political opinions ☐ Physical or mental health ☐ Information about a person's sex life or sexual orientation ☐ Religious or philosophical beliefs ☐ Membership of a trade union ☐ Biometric information ☐ Genetic information ☐ Other (please explain below):

4.5 Technical/organisational measures Select which of the following security measures are used to protect personal data.	☐ Pseudonymisation ☐ Anonymisation ☐ File encryption ☐ Encryption of storage ☐ Encryption of transport device ☐ Restricted access rights ☐ VPN ☐ Regularly scheduled backups ☐ Physical locks (rooms, drawers/file cabinets) ☐ None of the above ☐ Other (describe below):
4.6 Will any personal data be transferred to organisations within countries outside the European Economic Area (EU, Norway, Iceland and Liechtenstein)? If the research takes places in a country outside the EU/EEA, then please also indicate this.	Yes/no If yes, please fill in the country.

5 – Final comments	
Do you have any other information about the research data that was not addressed in this template that you think is useful to mention?	No