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Bridging the Digital Divide in Europe: An Analysis of Fiber Adoption Drivers

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Abstract:

The adoption of fiber-to-the-home/building (FTTH/B) technology is critical for Europe's digital transformation, yet significant disparities in uptake persist across countries despite the availability of infrastructure. This thesis explores the key drivers influencing FTTH/B adoption in European countries from 2019 to 2023, employing a fixed-effects econometric model. The analysis highlights the importance of technological performance, pricing factors, demography and digitalization variables. By addressing an existing gap in the European literature, this research provides valuable insights for policymakers and stakeholders, emphasizing the need for targeted measures to enhance affordability, improve infrastructure quality, and promote demand for FTTH/B services, especially in rural areas.

Keywords:

Fiber-to-the-home; Fiber-to-the-building; Digital divide; EU Digital Decade; High-speed broadband connection; Broadband coverage; Broadband penetration; Infrastructure; Drivers of fiber adoption

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1. INTRODUCTION

The rapid advancement of digital technologies has reshaped how societies function, from economic activities to education and healthcare. Reliable and high-speed internet access is now essential for fostering innovation, competitiveness, and inclusion in a digital economy. In Europe, fiber-to-the-home/building (FTTH/B) is widely recognized as the cornerstone of this transformation, offering unique speed, reliability, and scalability compared to legacy technologies like cable or copper. Despite significant progresses in infrastructure rollout, the adoption of FTTH/B lags significantly behind, with this disparity being particularly pronounced in rural areas.

While considerable attention has been devoted to broadband coverage, a notable knowledge gap exists in understanding what are the drivers of FTTH/B adoption in Europe. This study seeks to address this gap by investigating these drivers and analysing how they affect adoption rates over time, considering both demand-side and supply-side factors. By employing a fixed-effect econometric model, this study provides evidence that goes beyond descriptive statistics and theoretical frameworks to offer actionable insights. The central research question guiding this study is: What are the factors driving changes in the adoption of FTTH/B over time in European countries? The results from the analysis highlight the relative importance of various adoption drivers, including technological factors (such as internet performance), socioeconomic variables (such as digital skills and demography) and market dynamics (such as prices of fiber and competing technologies).

The findings contribute to the scarce body of literature on this topic, aiming to stimulate further research. They also emphasize the need for targeted studies, particularly in rural areas, to achieve higher adoption rates and support the EU's connectivity goals.

The thesis is organised as follows: section 2 establishes the contextual background of high-speed broadband in Europe, reviewing the literature on FTTH/B deployment and adoption, its

economic and social benefits and the challenges of bridging the connectivity gap, particularly in rural areas. Section 3 outlines the methodological framework used to identify the drivers of FTTH/B adoption, categorizing them into four groups: technological, socio-economic, business digitalization and market & policy variables. Section 4 presents the hypothesis derived from the methodological analysis. Section 5 details the data sources and structure used for the study, which includes panel data covering 28 countries (EU27+Norway) over a five-year period (2019–2023). Section 6 analyses the drivers influencing FTTH/B adoption using a fixed-effect econometric model. Section 7 confirms or rejects the hypothesis elaborated. Section 8 discusses the limitations of the study. Section 9 concludes the study by summarizing the key findings and providing recommendations for future research.

2. LITERATURE REVIEW

Guaranteeing all households access to high-speed internet coverage by 2025 and gigabit connectivity by 2030 is one of the top priorities of the European Commission to digitize the region and reduce the digital gap. Specifically, the digital divide refers to the unequal access to digital technology, including the internet, and, therefore, access to high-speed broadband technologies (Ragnedda and Muschert, 2013).

As of September 2023, Europe faces a significant disparity between FTTH/B coverage and adoption rates. While approximately 68.78% of households in the EU32 region have access to FTTH/B broadband, only 37.46% of households have actively subscribed to and use these services (FTTH Council Europe, 2023). The adoption rate lags despite various EU initiatives and funding instruments aimed at stimulating fiber rollout, such as the Gigabit Infrastructure Act, CEF Digital, and the Connecting Europe Broadband Fund. This discrepancy highlights the critical need to understand the barriers to fiber adoption, particularly in rural areas, where deployment challenges and low digital awareness exacerbate the digital divide.

A significant body of literature has focused primarily on the rollout of fiber networks, analyzing infrastructure deployment and the associated regulatory, market, and technological factors. However, there is a notable gap in studies that explore fiber adoption drivers rather than rollout dynamics. Understanding what motivates households and businesses to subscribe to FTTH/B services once the infrastructure is laid out remains underexplored. Most existing studies examine adoption tangentially, often as a secondary outcome of coverage metrics, rather than focusing on the behavioural, economic, and policy-driven factors directly influencing adoption. This study draws inspiration from the “FTTH Adoption Drivers and Hurdles” report published by FTTH Council Europe in 2023, which provides a comprehensive overview of the factors that affect the adoption rate in Europe. While the report identifies key factors such as affordability, digital literacy and alternative technologies, it does not empirically investigate any of these drivers using econometric methods. This thesis seeks to expand on this groundwork by analysing the factors that drive FTTH/B adoption, using data and statistical methods to connect descriptive observations with quantitative findings.

FTTH/B represents a milestone in fixed broadband connectivity, offering superior bandwidth for high-demand applications, while ensuring greater reliability due to resistance to electromagnetic interference and signal degradation (Briglauer, Krämer, and Palan, 2023). Its future-proof infrastructure easily accommodates growing bandwidth demands and is cost-effective over time, thanks to the durability of optical fibre and reduced maintenance requirements compared to current technological alternatives (Briglauer, Krämer, and Palan, 2023). Beyond these technical advantages, recognizing the broader impact on society of this technology provides additional motivation to expand the research interest in this field.

The benefits of high-speed broadband are well-documented, particularly in economic growth, employment, and education. About economic growth, Briglauer et al. estimated that a 1% increase in FTTx connections leads to GDP growth of 0.002%-0.004% (Briglauer, Wolfgang,

and Klaus Gugler 2019). Similarly, De Clercq et al. found that a 1% increase in broadband coverage above 30 Mbps boosts GDP growth by 0.09% (Clercq, D'Haese and Buysse 2023). Employment is another area impacted: Firgo et al. discovered that digitalization increases high-skilled employment while reducing low-skilled jobs (Firgo, et al. 2018). Balsmeier et al. observed that a CHF 100,000 investment in digitalization creates 5.8 additional high-skill jobs while reducing 2.3 low-skill jobs, resulting in a slightly positive net effect (Balsmeier and Worter 2019). Moreover, fiber has also a positive effect on productivity: Cambini et al. found that ultra-fast broadband adoption in Italy increased total factor productivity by 2.9% and labor productivity by 3.9% (Cambini, Grinza and Sabatino 2023). Fabling and Grimes confirmed a similar impact on multifactor productivity over four years in Australia, although they noted a negative effect on employment, which contrasts with previous findings (Fabling and Grimes 2021). Concluding with education, Grimes et al. found that fiber availability in schools improves primary student grades by about 1% annually, with greater benefits for disadvantaged students (Grimes and Townsend 2018). However, Boeri highlighted contrasting effects, noting that high-speed broadband reduces disparities for low-performing students in supportive environments but challenges high-performing disadvantaged students (Boeri 2020).

Despite the clear benefits, an analysis of the EU broadband situation across different geographies highlights that one of the primary reasons for lower penetration rates is the connectivity gap between rural and urban areas. The high cost of deploying fiber in rural regions is primarily driven by geographic and demographic challenges, particularly the lower population density, which translates to significantly higher costs per premise passed. Based on a study of NUTS3 regions, Feijóo et al. (2018) estimated that, on average, FTTH/B deployment costs in rural areas in Europe are €2,609 per premise—rising to €6,711 in extremely rural areas—compared to €565 in urban areas, reflecting a fivefold increase. Furthermore, the lower profitability of rural deployments discourages private investment, making public subsidies an

essential tool to bridge the investment gap (Feijóo, Ramos, and Cristina Armuna 2018). While proper infrastructure is essential for delivering high-broadband connectivity (the supply side), it is equally important to address the demand side. Many rural areas lack basic digital skills and awareness of the potential benefits of digital technology. As a result, even when digital infrastructure is in place, it often remains underutilized due to low customer adoption. (European Network for Rural Development 2017).

3. METHODOLOGY

The next section introduces the process used to identify the relevant drivers for the demand of FTTH/B that have been later used in the regression model in section 6. Collectively, the factors analysed can be divided into 4 categories. Table 1 summarizes each category and the respective drivers. For each category, the respective driver is then presented.

Technological variables	• FTTH/B coverage • Urban-rural coverage gap • Average download speed • Average upload speed • Average latency
Socio-economic variables	• Gini equivalent disposable income • FTTH/B price as share of income • Urban density • Rural density • % of people living in rural areas • % individual with above digital skills • % people never do smartworking • %people usually do smartworking • Median population age • %people with tertiary education (5-8 levels) • Average households size • %people using internet banking • %people using telephoning, video calls or instant messages • %people playing or downloading games • %people using online learning material • %people watching internet streamed TV or videos • %people watching video content from commercial or sharing services
Business digital adoption	• %enterprises with 10 persons employed or more that uses at least one of the AI technologies

	• %enterprises with 10 persons employed or more who have ERP software package to share information • %enterprises with 10 persons employed or more that analyses big data internally • %enterprises with 10 persons employed or more that use cloud computing services
Market & Policy variables	• Fixed Fiber prices • Differential fiber-copper price • Differential fiber-mobile price • State aid expenditures in broadband technology

Table 1: Factors analysed against the adoption rate of FTTH/B

Fiber network coverage is essential for households to access high-speed broadband. Regressing the take-up rates against coverage ratios (Figure 3 in the appendix) shows a strong positive correlation, driven also by a “network effect,” where broader coverage boosts user adoption (Briglauer 2014). From figure 3, four country categories emerge: (I) Low coverage and low take-up (e.g., Belgium, Greece), where limited infrastructure suppresses adoption; (II) Low coverage but high take-up (e.g., Finland), which suggests strong demand once infrastructure exists; (III) High coverage but low take-up (e.g., Italy, Croatia), where customers hesitate due to adequate alternatives; and (IV) High coverage and high take-up (e.g., Spain, Sweden), reflecting robust infrastructure and consumer awareness. These findings underscore how coverage and take-up influence each other, as strong consumer demand may incentivize telecommunications companies to expand fiber network (World Broadband Associations 2024). This argument is particularly relevant for regions with a larger coverage gap - defined as the difference between the coverage rate in urban areas and that in rural areas. As illustrated in Figure 4, regions with wider gaps tend to exhibit lower adoption rates. This trend can be attributed to the limited infrastructure in remote areas, largely driven by the high costs of fiber deployment, as well as affordability challenges resulting from lower income levels.

Internet performance significantly influences consumers' adoption of fibre technology due to its impact on the online experience. To measure the internet performance, download speed, upload speed, and latency have been regressed against the fiber take-up (Figures 5, 6, 7)

revealing a strong association. Download speed measures how fast data is received, upload speed reflects how fast data are sent, and latency (or ping) indicates the response time (Speedtest 2024). Data from Ookla, covering various broadband technologies, show that higher download/upload speeds and lower latency correlate with increased adoption. These findings highlight the importance of fast and reliable internet in driving consumer preferences for Fiber. Moving to the social-economic category, the relationship between income inequality and fiber adoption was first examined by regressing the Gini equivalent disposable income¹ against take-up rates, but a weak positive correlation suggests that inequality does not significantly impact adoption (Figure 8). To assess the household financial availability, the annual price of the least expensive offer for fibre divided by the median equivalised income was regressed against the adoption rates. This revealed a modest negative effect, suggesting that higher relative fibre costs could reduce the adoption level (Figure 9).

Demographic factors were considered by regressing the adoption rate against the percentage of rural population revealing a surprisingly positive relation, which can be justified by the fact that telecom companies may prioritize urban areas for fiber infrastructure due to higher population density and lower deployment costs. A similar positive relationship is observed when regressing coverage rates against urban population proportion (Figure 11). Other demographic variables analysed include the average household size and median population age, both of which show a minor negative effect on the take-up rate (Figures 12 and 13).

In contrast, educational level, measured by the percentage of people who have completed tertiary education, appears to positively impact the take-up rate (Figure 14). This relationship may be explained by a greater awareness of the benefits of high-speed broadband, as well as a higher need for reliable and fast internet to meet professional and educational needs. To analyse

¹ The equivalent disposable income is a measure of household income that accounts for differences in household size and composition. (European Commission 2024)

the digital behaviour in the professional sphere, variables such as digital literacy and the percentage of people working remotely were examined for their correlation with the take-up rate. Digital literacy was assessed using the European Commission's Digital Skills Indicator, which categorizes individuals aged 16–74 into seven skill levels based on five digital areas: information and data literacy, communication, content creation, safety, and problem-solving (Eurostat 2024). Considering the proportion of individuals with above basic digital skills, a slight positive correlation suggests that higher digital proficiency may stimulate greater demand for fiber (Figure 15). However, Eurostat notes that recent revisions to the framework have been applied, which may limit its ability to fully account for factors relevant to fibre adoption, such as key activities like video streaming or video conferencing (European Commission 2024). For this reason, to investigate the relationship between internet usage patterns and fiber adoption, a series of additional variables were analysed. These include 1) the proportion of people using internet banking; 2) the proportion of individuals engaging in telephoning, video calls, or instant messaging; 3) the proportion of people playing/downloading games; 4) the percentage of users accessing online learning materials; 5) the proportion of people watching internet-streamed TV or videos; 6) the proportion of individuals viewing video content from commercial or sharing platforms; and 7) the proportion of people using cloud services. These variables represent some of the most common activities performed by average internet users and are hypothesized to positively correlate with fiber adoption, despite not all of them are highly dependent on high-speed internet. When these variables were regressed against the take-up rate of fiber, only a slight positive correlation was observed (Figures 16–22). To simplify the model and reduce the number of variables, a Digital Behavior Index was created by aggregating the mentioned variables. This index also displayed a positive correlation with fiber adoption (Figure 23). The limited correlation observed may be explained by the fact that many of these activities do not necessitate high-speed broadband and can be adequately supported by traditional mobile and

fixed broadband technologies, such as 3G/4G or copper networks. As a result, the added value of fiber may not be perceived as essential for these activities. Unfortunately, no additional individual-level indicators that could better capture digital behaviours were available to my knowledge. It is possible that the European Commission will introduce more relevant indicators in the future, particularly as the use of artificial intelligence continues to grow.

According to the definition provided by the FTTH Market Panorama, a premise is defined as any “Single Dwelling Unit (SDU), Multi-Dwelling Unit (MDU), commercial, or non-residential building that can be connected to an FTTH/FTTHB network” (FTTH Council Europe, 2023). This definition implies that the take-up rate includes a proportion of businesses connected to fiber networks, and for this reason, a category of variables related to business adoption was considered in the analysis. To summarize business adoption, an index was created integrating enterprises with more than 10 employees. The index includes the following variables: 1) the percentage of firms using at least one AI technology; 2) the percentage of firms utilizing ERP software; 3) the percentage of firms analyzing big data; and 4) the percentage of firms using cloud computing services. Each variable was regressed individually against the take-up rate and later aggregated into the index, which was also regressed (Figures 24–28). The results indicate that the business adoption index does not exhibit a strong effect on the take-up rate. This outcome may be attributed to the relatively small proportion of business premises compared to households and other types of buildings included in the category of premises. Even though the activities considered in the index are all data-intensive, the limited representation of businesses within the premises category might dilute their overall impact on the take-up rate. Finally, the last category of variable is the one from the market and the policies adopted. For the market, the first consider the differential prices between fiber and mobile, and the differential prices between fiber and copper, were assessed to understand if they influence the adoption of fiber. Regarding the first variable, a lower differential price between fiber and

mobile seems to boost the adoption rate (Figure 29), which means that the countries analyzed that have an higher adoption rate experience a lower difference in prices between fiber and mobile. This might suggest that after a certain value in this difference fiber-mobile, clients might prefer a cheaper mobile solution. The same experiment in correlation works with the delta between the price of fiber and copper, where a higher difference in prices between fiber and copper is associated with a lower take-up rate (Figure 30). The effect might be not as high as expected because the existing quality in performance of alternative technologies might hinder the potential of fiber, despite the infrastructure in place. It's the example for several countries including Italy, Ireland, Czechia where despite the least expensive price offer for copper is as expensive as the least expensive price for fiber, the adoption of fiber is lower compared to the average of the other countries. A last consideration has been made regarding the policies; this factor proved to be challenging to address for 3 key reasons: the first one is related to the accountability of the policy. Quantify the effect of a policy in a reasonable way is not an easy task, especially when the effects of different policies must be compared to draw general conclusions: the heterogeneity of countries play a key role in influencing a specific measure or investment made by a government, preventing a logical mathematical conclusion. A second reason, closely related to the scope of this study, is that even if governments introduce policies for high-broadband connection (such as schemes or vouchers), most of the times these measures do not address the demand side, hence the adoption rate which is our variable of interest, but cover the supply side to stimulate the deployment of the infrastructure, especially in white areas where the broadband network coverage is absent. Last consideration, the effects of a policy in the adoption rate might be visible after years. This lag poses a problem in the identification of the true effects of a policy, further requiring additional data for time series. As a result, it is difficult to capture the effect of the policies on the demand side. An attempt has been made by

considering the amount of total expenditure made by the countries on fixed broadband infrastructure between 2003-2018. (Figure 31).

4. HYPOTHESIS TO BE TESTED

Based on the relations analysed in the methodology part, this study tests the following hypotheses:

Technological variables

- H1: Higher FTTH/B coverage rates are positively associated with adoption.
- H2: Improved internet performance (e.g., download/upload speeds, lower latency) is positively associated with adoption.

Socioeconomic variables

- H3: Greater individual engagement in digital activities is positively associated with adoption.
- H4: A higher proportion of individuals living in rural areas is negative associated with adoption.

Business digitalization variables

- H5: A higher integration of advanced digital technologies (e.g., AI, ERP, big data, cloud computing) by enterprises positively affects adoption.

Market & Policy variables

- H6: A smaller price differential between fiber and mobile is negatively associated with adoption.
- H7: A smaller price differential between fiber and copper is negatively associated with adoption.

5. DATA COLLECTION AND STRUCTURE

The data for this study were sourced from a combination of publicly available and proprietary datasets to ensure comprehensive coverage of the factors influencing FTTH/B adoption across Europe. Data on fiber adoption and fiber coverage, including urban and rural areas, were

obtained from the FTTH Council Europe, an industry association dedicated to advancing full fiber connectivity in the region for over 20 years. Information on network quality metrics—download speed, upload speed, and latency—was sourced from the Ookla Global Fixed and Mobile Network Performance Maps, an open dataset aggregating millions of user tests conducted via the Ookla Speedtest platform. This dataset, updated quarterly since 2018, provides a detailed overview of internet performance metrics across countries and regions.

Prices for mobile and fixed broadband connections were gathered from the European Commission's annual report, "Mobile and Fixed Broadband Prices in Europe," which offers comprehensive data on consumer broadband offers across EU27 countries and Norway. Socioeconomic variables, including demographic indicators (median age, education level, average household size, rural population share, and digital skills), business digitalization metrics (e.g., adoption of AI, ERP systems, big data analytics, and cloud computing), and internet usage behaviours (e.g., internet banking, video calling, online learning, streaming, and gaming), were retrieved from Eurostat. Finally, data on state aid expenditures for broadband infrastructure were obtained from the Centre on Regulation in Europe (CERRE), a European think tank focused on improving regulation across media, tech, and telecom industries.

The dataset included in the final econometric model is a panel data covering 28 countries (EU27+Norway) across a period of 5 years (2019-2023). The countries represent the primary unit, with datapoints aggregated annually for the variables related to technological, socioeconomic, business digitalization and market & policy variables. The total number of observations of the dataset is 140. Table 2 provides the key descriptive statistics for the variables introduced.

Variable	Description	Average	Standard deviation	Median	Min	Max
<i>age</i>	Median Age (years)	42.93	2.40	43.00	37.70	48.40
<i>bigdt</i>	Businesses Analyzing Big Data (%)	15.06	8.01	12.07	3.10	40.90
<i>cloud</i>	Cloud Usage by Individuals (%)	41.09	12.28	38.48	17.64	72.99
<i>cover</i>	FTTH Coverage (%)	58.78	24.09	64.25	2.90	96.50
<i>digsk</i>	Individuals with Above-Basic Digital Skills (%)	28.32	10.68	27.76	7.73	54.53
<i>dload</i>	Average Download Speed (Mbps)	111.59	51.19	101.98	20.96	259.19
<i>entai</i>	Businesses Using AI (%)	7.82	5.11	7.20	0.40	32.60
<i>entcl</i>	Businesses Using Cloud (%)	41.46	18.38	38.50	4.42	78.30
<i>enter</i>	Businesses Using ERP (%)	36.37	11.68	36.73	6.60	67.30
<i>fcde</i>	Price Delta Fiber-Copper (EUR)	6.86	10.59	4.27	-5.38	88.73
<i>fmde</i>	Price Delta Fiber-Mobile (EUR)	14.78	11.89	14.07	-9.50	59.55
<i>fthpr</i>	FTTH Price (EUR)	27.96	14.24	25.52	8.29	118.62
<i>ftthr</i>	FTTH Take-up Rate (%)	46.74	0.20	47.50	0.80	85.80
<i>games</i>	Playing/Downloading Games (%)	30.33	10.43	28.61	9.66	53.12
<i>gini</i>	Gini Equivalent Disposable Income	29.29	3.90	29.20	20.90	40.80
<i>hhsiz</i>	Average Household Size (persons)	2.34	0.27	2.30	1.90	3.10
<i>ibank</i>	Internet Banking Usage (%)	64.65	20.58	66.85	8.36	96.85
<i>laten</i>	Average Latency (ms)	16.51	9.14	14.07	5.56	47.40
<i>learn</i>	Online Learning Usage (%)	22.10	9.28	20.63	4.58	47.57
<i>nesmt</i>	Individuals Never Smartworking (%)	11.63	7.50	9.73	1.00	33.53
<i>rural</i>	Households in Rural Areas (%)	28.60	10.20	30.05	2.73	43.63
<i>urds</i>	Rural Density (people/km2)	72.13	60.68	58.00	5.00	275.53
<i>stata</i>	State Aid (million EUR)	78.72	197.24	6.23	0.00	869.47
<i>stream</i>	Watching Internet-Streamed Content (%)	69.60	15.76	70.70	26.13	94.59
<i>techq</i>	Tech Quality Index	57.92	30.66	51.27	8.45	152.08
<i>tered</i>	Tertiary Education (%)	32.13	7.58	33.50	16.00	46.60
<i>tvcm</i>	Telephony/Video Calls/Messages Usage (%)	78.83	8.93	79.04	55.45	97.72
<i>upload</i>	Average Upload Speed (Mbps)	62.09	44.79	51.19	4.35	203.21
<i>urban</i>	Urban-Rural Coverage Gap (%)	22.61	12.96	24.45	-13.00	56.20
<i>urds</i>	Urban Density (people/km2)	903.94	826.78	690.50	86.00	3436.00
<i>usmt</i>	Individuals Usually Smartworking (%)	77.14	13.15	80.55	46.10	97.20
<i>vidsh</i>	Watching Video Content from Sharing Services (%)	65.41	16.44	67.20	21.27	90.33

Table 2: Key descriptive statistics

During the data collection process, several limitations were encountered. A first limit of the dataset is the high-level aggregation at the country level, which restricts the ability to draw detailed comparison between rural and urban areas due to the limited number of observations that are available. For instance, the take-up rate is only available at the national level, making it challenging to account for regional variations.

A second limitation involves missing data for specific years, particularly for some socioeconomic variables reported by Eurostat, which are not consistently available on an annual basis. This constraint required forecasting some of these missing series. Additionally, as Eurostat has noted, certain indicators have been revised and updated over time, resulting in inconsistencies that prevent direct comparisons across years. To address these gaps, some estimations were made to complete the dataset.

Furthermore, variables related to internet usage are sourced from self-reported surveys conducted by Eurostat, which may introduce biases, especially concerning digital behaviours. The software used for the study included Excel, which was utilized to aggregate and organize the dataset and perform initial correlation analyses for each independent variable against the adoption rate. For running regressions and testing the hypotheses, Stata was employed, offering robust tools for econometric analysis.

6. ECONOMETRIC MODEL

This chapter analyses the principal drivers influencing the adoption rate of FTTH/FTTB within the countries included in the study, using an econometric model based on panel data. The model has two goals: to confirm or reject the hypotheses formulated in the previous section and to uncover additional relationships among the variables included in the model.

The econometric approach employed is a fixed effects (FE) model, chosen for its ability to control for unobservable, time-invariant differences across countries. These differences may include country-specific regulations and policies, structural economic conditions, or cultural factors that could influence the chosen dependent variable. The FE model eliminates these cross-country differences, focusing exclusively on the effects of variables that change over time. This approach ensures more accurate estimations, reducing the risk of bias caused by unobservable cross-country differences. Robust standard errors were used in all regressions to address potential issues of heteroskedasticity and autocorrelation, which are common in panel data. Lastly, all the independent variables included in the following models were standardised to make the coefficients better interpretable.

The remaining chapter describes the process of how the final econometric model was developed, introduces the final regression model, and concludes with an analysis of the regression results.

6.1 Initial Model Setup (Model v1)

The first regression model was estimated by including all the variables listed in Table 2 before. This initial model produced a "within" R-squared of 55.23%, indicating that the model explained a significant portion of the variation in the FTTH/FTTB adoption rate. However, only 7 out of 31 variables were statistically significant, suggesting that many predictors were either irrelevant or redundant. Additionally, the variable *stata* (State Aid) was automatically excluded due to perfect collinearity.

Given the large number of non-significant variables and potential concerns about multicollinearity among other variables, a Variance Inflation Factor (VIF) test was conducted (Figure 32). The test revealed a severe multicollinearity between variables *stream* (Watching Internet-Streamed Content) and *vidsh* (Watching Video Content from Sharing Services), as both capture overlapping video consumption behaviours. A moderate multicollinearity was also found between *dload* (Average download speed) and *upload* (Average upload speed) - both related to internet performance – and also between *fthpr* (FTTH price) and *princ* (FTTH price as share of income), both measuring fiber costs.

6.2 Adjustment for “problematic variables” (Model v2)

To address the multicollinearity issues, a second regression model was estimated after removing the most problematic variables (*stream* and *vidsh*). The results of this adjusted model confirmed the significance of the same variables from the initial regression and showed a "within" R-squared of 55.08% (Table 4). Moreover, the VIF values improved significantly, with an average VIF of 7.27 (Figure 33), and coefficients for the remaining variables became more stable.

6.3 Refinement for non-significant variables (Model v3)

Since the non-significant variables in Model v1 remained non-significant in the second model, a third regressions was run by excluding all variables with a p-value greater than 0.1.

This version included 10 independent variables and 2 additional variables - *urlds* (urban population) and *rurlds* (rural population) - became statistically significant and robust. The "within" R-squared slightly decreased to 50.24%, reflecting a more parsimonious model without unnecessary variables. A subsequent VIF test (Figure 34) showed a further reduction in multicollinearity, with all variables falling within acceptable ranges.

6.4 Adding composite indices

Despite the positive results, three additional dynamics were tested in the model by constructing indices to capture apparent trends influencing the fiber adoption: internet performance, digital behaviour of individuals, and business digitalization. Each index was defined as follows:

- $techx = \frac{dload + uload + (\frac{1}{laten})}{3}$
- $digbx = \frac{ibank + tvcms + games + learn + stream + vidsh + cloud}{7}$
- $busix = \frac{entai + entcl + enter + bigdt}{4}$

After regressing these indices against the third model, only the technology index (*techx*) was found to be significant, while *digbx* and *busix* did not have a statistically significant impact. The results of these regressions, using each index individually, are presented in Table A in the appendix.

6.5 The econometric model (vFinal)

Considering the previous considerations, the final econometric model is expressed by the following equation:

$$ftthr_{it} = B_0 + B_1 fmdel_{it} + B_2 fthpr_{it} + B_3 digsk_{it} + B_4 nesmt_{it} + B_5 urlds_{it} + B_6 rurlds_{it} + B_7 techx_{it} + u_i + u_t \in_{it}$$

Where:

- u_i represents the factor that captures country-specific characteristics.
- u_t represents the factor that captures time-fixed effect.
- ϵ_{it} is the idiosyncratic error term that account for random disturbances that are not explained by the model.

Overall, the results from this version indicate that all 7 variables included in the model are statistically significant, contributing to explaining the changes in the adoption rate during the period considered within these countries. Although the model shows a lower R-squared compared to previous models (44.46%), this reduction is minimal given the robustness of the variables, the addition of the internet performance index, and the inclusion of only statistically significant variables. Furthermore, an additional comparison across models was conducted by examining the difference between the R-squared and adjusted R-squared (Delta R-squared). The model vFinal is revealed to be the most efficient, balancing satisfactory explanatory power with the parsimony principle, thereby avoiding overfitting of the data (Table 3).

Table 3: R-Squared metrics across models

	(v1)	(v2)	(v3)	(vFinal)
R^2	0.552	0.551	0.502	0.434
adj. R^2	0.429	0.437	0.464	0.404
ΔR^2	0.123	0.114	0.038	0.030

Table 3: R-Squared metrics across models

The findings confirm that price-related factors strongly influence the adoption rate. The absolute price of fiber (*fthpr*) exhibits a significant negative relationship with the take-up rate, indicating that higher fibre prices discourage consumers from adopting this technology. Specifically, the model suggests that for every unit increase in the standardized price of fiber, the adoption decreases by 7.34%. This aligns with the expectation that affordability remains a

critical barrier to adoption in broadband markets. Conversely, the price differential between fiber and mobile (*fmdel*) shows a positive relationship with adoption, suggesting that consumers view fiber as a premium option when compared to mobile services. For every unit of standard deviation increase, the adoption increases by 5.69%. This result underscores that fiber and mobile services are not perceived as substitutes, but rather as distinct offers targeting different needs. While mobile connectivity may suffice for basic or casual use, fiber is favoured for applications requiring higher performance and reliability.

Indeed, the technical performance of internet connections, captured by the composite index *techx*, also emerges as a significant driver. While the magnitude is smaller, a one standard deviation improvement in technical performance (i.e. better download/upload speed and lower latency) is associated with a 0.18% increase in the fiber adoption, reflecting a growing demand for high-quality connections, especially in a digital economy increasingly reliant on remote and streaming services.

The role of behavioural and skill-based factors provides further insights. Advanced digital skills (*digsk*) exhibit a counterintuitive relationship: a one standard deviation increase in the proportion of individuals with advanced digital skills corresponds to a 5.32% decrease in fiber adoption rates. This result likely reflects that digitally proficient individuals might prioritize flexibility and mobility, opting for technologies such as advanced mobile networks or satellite connections instead of fiber. In contrast, the lack of smartworking experience (*nesmt*) has a negative coefficient, indicating that a one standard deviation increase in individuals who have never worked remotely leads to a 6.91% decrease in fiber adoption. This finding reinforces the idea that remote work environments drive demand for stable, high-performance broadband connections.

Finally, the urban-rural divide also plays a crucial role. Urban density (*urbd*) has a positive coefficient effect on the adoption, as a one standard deviation increase in urban density is

associated with a 5.66% increase in fiber adoption rates. This reflects the advantages of urban areas, especially regarding better infrastructure. Conversely, rural density (*urds*) has a negative impact, indicating that a one standard deviation increase in rural density is associated with a 1.11% decrease in fiber adoption. The negative effect likely stems from demand-side factors (such as lower awareness about the benefits or affordability) and the quality of existing alternatives, including copper and mobile technologies.

Below, Table 4 summarizes the results from all the regression models described.

7. RESULTS

This chapter links each hypothesis formulated in section 4 to the results of the final version of the econometric model. Based on the empirical findings, each hypothesis is classified as confirmed, rejected or unsupported.

Table 4: Regression Results across Models

	(v1) ftthr	(v2) ftthr	(v3) ftthr	(vFinal) ftthr
cover	-0.003 (0.558)	-0.003 (0.506)		
urban	-0.010 (0.371)	-0.010 (0.401)		
fmdel	0.077*** (0.000)	0.079*** (0.000)	0.065** (0.001)	0.057** (0.001)
dload	0.051 (0.308)	0.055 (0.228)	0.007 (0.585)	
upload	-0.052 (0.397)	-0.055 (0.335)		
laten	0.025 (0.339)	0.020 (0.450)		
gini	-0.010 (0.766)	-0.010 (0.750)		
urbds	0.060 (0.107)	0.060 (0.105)	0.055*** (0.000)	0.057*** (0.000)
urds	-0.011 (0.133)	-0.012 (0.083)	-0.009** (0.009)	-0.011*** (0.000)
ftthr	-0.063 (0.055)	-0.065* (0.045)	-0.072*** (0.000)	-0.073*** (0.000)
princ	-0.026 (0.356)	-0.025 (0.337)		
fcdel	-0.003 (0.909)	-0.005 (0.829)		
rural	-0.042 (0.411)	-0.044 (0.398)		
digsk	-0.069*** (0.000)	-0.066*** (0.000)	-0.051* (0.036)	-0.053* (0.011)
usmrt	0.024 (0.613)	0.024 (0.624)		
nesmt	-0.052* (0.021)	-0.053* (0.019)	-0.067*** (0.000)	-0.069*** (0.000)
tered	-0.017 (0.835)	-0.015 (0.844)		
age	0.032 (0.745)	0.020 (0.830)		
hhsiz	0.035 (0.383)	0.038 (0.323)		
ibank	-0.037 (0.414)	-0.039 (0.360)		
tvcms	0.057 (0.085)	0.051 (0.134)	0.036 (0.066)	
games	0.027 (0.388)	0.020 (0.336)		
learn	-0.041* (0.029)	-0.042* (0.038)	-0.036 (0.050)	
stream	-0.048 (0.720)			
vidsh	0.032 (0.775)			
cloud	-0.014 (0.443)	-0.015 (0.377)		
entai	0.010 (0.629)	0.009 (0.640)		
enter	0.001 (0.959)	0.000 (0.998)		
bigdt	0.046 (0.586)	0.053 (0.502)		
entcl	-0.061 (0.184)	-0.064 (0.134)	-0.026 (0.091)	
stata	0.000 (.)	0.000 (.)		
techx				0.002** (0.002)
_cons	0.467*** (0.000)	0.467*** (0.000)	0.467*** (0.000)	0.467*** (0.000)
N	140	140	140	140
R ²	0.552	0.551	0.502	0.434
adj. R ²	0.429	0.437	0.464	0.404

p-values in parentheses
 * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Regression results across models

H1: Higher FTTH/B coverage rates
are positively associated with adoption.

The hypothesis is unsupported. FTTH/B coverage rates were excluded from the model due to lack of significance in the preliminary regression analysis. A temporal variability test confirms that much of the variation in coverage rates is attributable to cross-country differences rather than temporal changes within each country (Figure 36). Since the FE model controls for all time-invariant differences across countries, the explanatory power of the coverage rate in this context is effectively absorbed by the fixed effects, rendering it statistically insignificant.

H2: Improved internet performance (e.g., download/upload speeds, lower latency)
is positively associated with adoption.

The hypothesis is confirmed. A one standard deviation improvement in internet performance is associated with a 0.18% increase in adoption. This reflects the importance of high-speed, reliable internet connections in driving the uptake.

H3: Greater individual engagement in digital activities
is positively associated with adoption.

The hypothesis is unsupported. The composite index *digbx*, measuring digital activities, was excluded due to lack of statistical significance in the model. This suggests that digital engagement alone does not strongly influence the fiber adoption.

H4: A higher proportion of individuals living in rural areas
is negative associated with adoption.

The hypothesis is confirmed. A one standard deviation increase in rural density reduces adoption by 1.11%. This result supports the literature, which suggests that despite the infrastructure being in place, customer adoption in rural areas lags, primarily due to a lack of basic digital skills and awareness about the benefits of high-speed broadband.

H5: A higher integration of advanced digital technologies (e.g., AI, ERP, big data, cloud computing) by enterprises positively affects adoption.

The hypothesis is unsupported. Variables related to business digitalization were excluded from the final model due to lack of significance, suggesting they do not directly drive consumer-level fibre adoption in the dataset.

H6: A smaller price differential between fiber and mobile is negatively associated with adoption.

The hypothesis is rejected. Contrary to expectations, a larger price differential is associated with a 5.69% increase in adoption. This result has an important implication: consumers may view FTTH/FTTB as a premium option compared to mobile, and higher price differentials may reinforce its perceived value.

H7: A smaller price differential between fiber and copper is negatively associated with adoption.

The hypothesis is unsupported. The variable *fcdel* was excluded from the final model due to a lack of significance. As discussed in the methodology section, the effect might not be significant, unlike the case of mobile, due to the existing quality and performance of alternative technologies (example copper) that are perceived as a competitive option.

8. LIMITATIONS OF THE STUDY

Despite the model's ability to test the formulated hypotheses and provide insights into the drivers of adoption rates, certain limitations must be acknowledged. These limitations may affect the interpretation of the results while also suggesting directions for future research.

A first limitation of the model is the exclusion of policy and regulatory factors. Broadband subsidies, rural infrastructure investment programs, or regulatory frameworks could have a significant influence on adoption rates. Three key reasons made the inclusion of these variables challenging: 1) the difficulty in finding a quantifiable metric. An attempt was made by incorporating the level of investment in high-broadband initiatives reported by countries over a 15-year period. 2) The challenge to impute the effects of past investments on current adoption

rates. A lagging effect is expected, as investments made today might only show results in the next years. 3) Understanding how much these measures effectively target the demand side is even more complex, yet crucial to identifying their real effect on adoption.

A second limitation of the analysis lies in the availability of data, particularly for variables that could capture differences in infrastructure quality within a country due to regional disparities. Improving data collection, such as incorporating regional-level data or collaborating with telecom providers for granular infrastructure metrics, could enhance the model's robustness and the significance of certain variables.

Another consideration is the choice of employing a fixed-effects model. While this approach has the advantage of removing cross-country differences that are constant over the study period (as seen with the variable *stata*), it may exclude important drivers, such as long-standing structural differences embedded in the culture, GDP pro capita or variables with significant cross-country variability but low temporal variability, such as FTTH/B coverage, are deemed insignificant within the FE model. Supplementary models or mixed-effects frameworks could be employed to better capture the effects of these variables.

Finally, although the model controls for time-invariant heterogeneity, there remains the potential for endogeneity in certain variables, which could lead to over/underestimation of the coefficients. For instance, if adoption rates increase, operators might respond by either decreasing prices to attract more customers (particularly in highly competitive markets) or maintaining high prices in areas with strong demand. This could create a loop in which the price of fiber (*fthpr*) not only influences adoption, but is also influenced by it. Future studies could incorporate lagged variables to mitigate endogeneity concerns and avoid bias in coefficient estimates.

While these limitations do not undermine the validity of the hypotheses successfully tested, they highlight areas where the model could be improved, underscoring the need for continued exploration.

9. CONCLUSIONS

This study aimed to explore the key factors driving changes in FTTH/B adoption over time within European countries, addressing a notable knowledge gap in the existing European literature. Through an econometric analysis of panel data, the study identified several critical drivers influencing adoption rates, including technological performance (download speed, upload speed, and latency), pricing factors (absolute FTTH/B price and price differentials between FTTH/B and mobile), demographic factors (proportion of people living in rural areas), and digitalization levels (digital skills and smart working). Surprisingly, advanced digital skills showed a negative association with adoption, suggesting a preference for alternative technologies among digitally proficient individuals.

These findings hold practical implications for policymakers and stakeholders, highlighting the importance of targeted measures to improve affordability, enhance broadband quality, and raise awareness of the potential benefits of FTTH/B technology, particularly among users in rural areas.

However, the study faced limitations due to the lack of granular data for some variables and the absence of regional or individual-level information, which may obscure additional drivers of adoption. Future research should address these gaps by collecting more detailed data and employing advanced models, such as mixed-effects frameworks, to better capture the nuanced effects of these variables.

By advancing the understanding of FTTH/B adoption drivers, this research contributes to bridging the digital divide and supporting Europe's transition to a fully connected digital economy.

Appendix

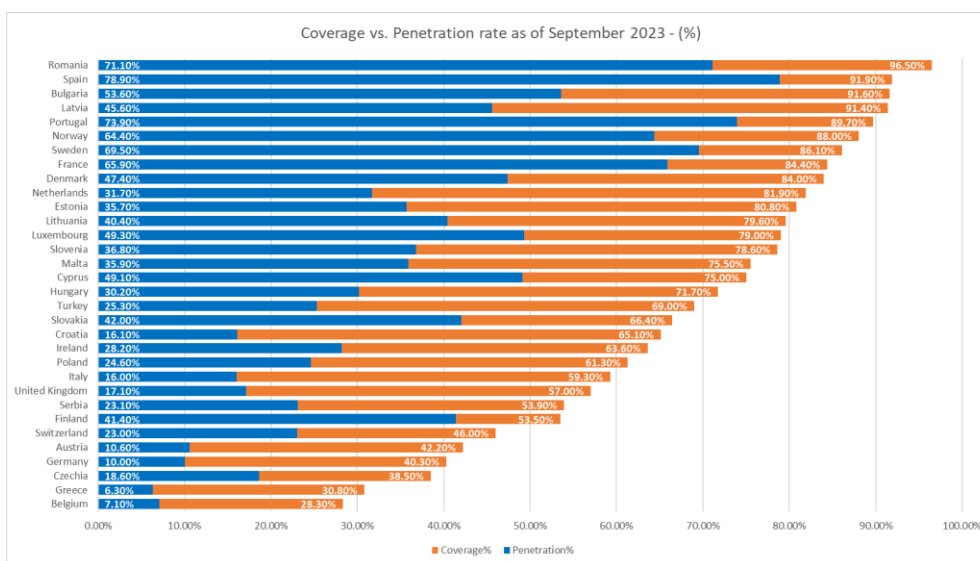


Figure 1: Personal elaboration based on "FTTH Market Panorama - Report by Country - September 2023."

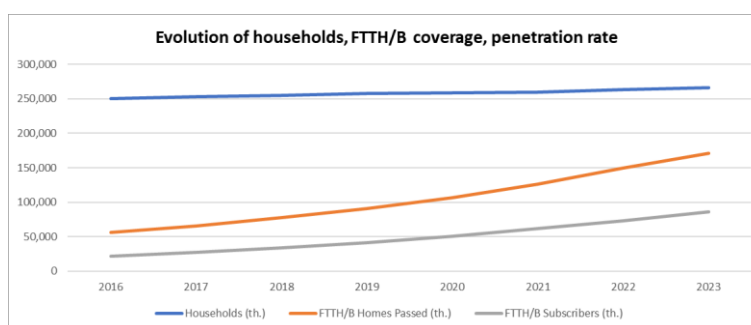


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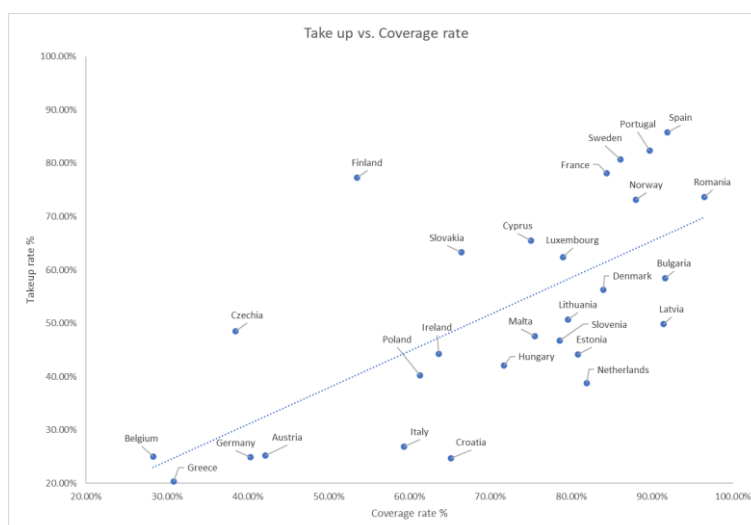


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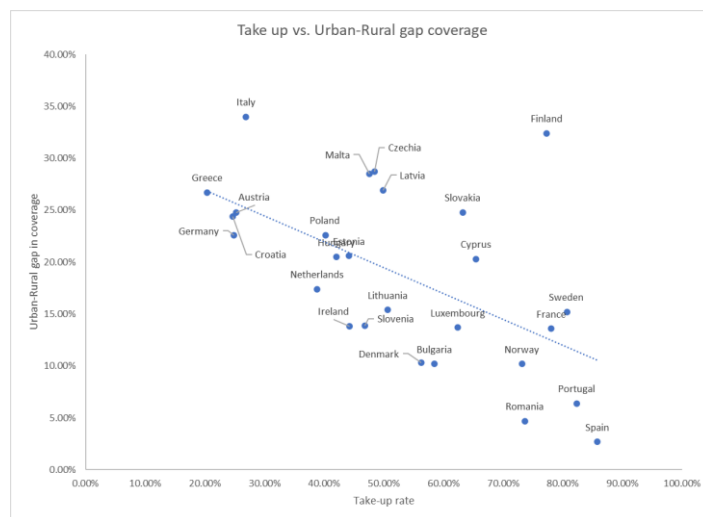


Figure 4: Personal elaboration based on “FTTH Market Panorama - Report by Country - September 2023.” and “Eurostat”

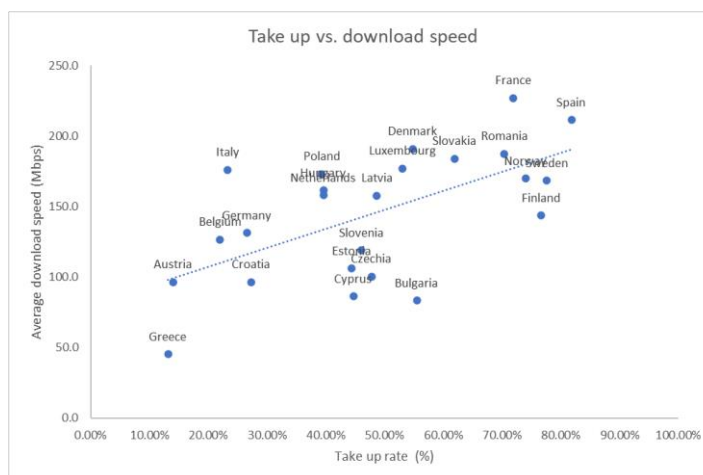


Figure 5: Personal elaboration based on “FTTH Market Panorama - Report by Country – Sept. 2023” and “Ookla Open Data”

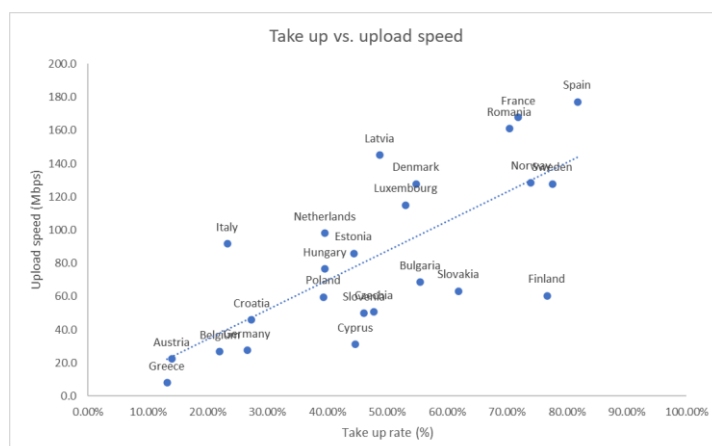


Figure 6: Personal elaboration based on “FTTH Market Panorama - Report by Country – Sept. 2023” and “Ookla Open Data”

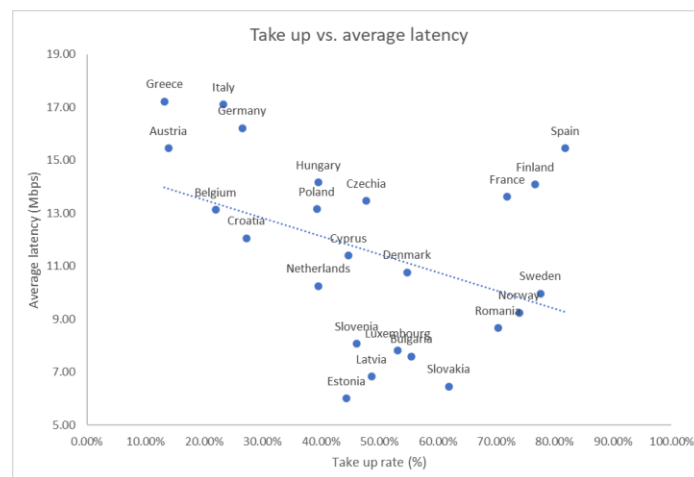


Figure 7: Personal elaboration based on “FTTH Market Panorama - Report by Country – Sept. 2023” and “Ookla Open Data”

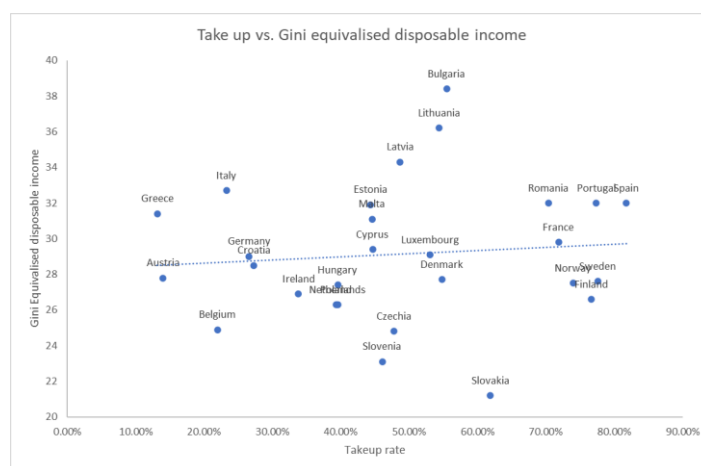


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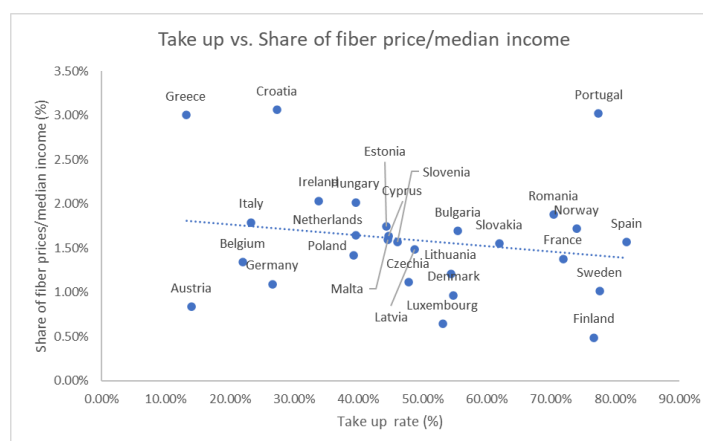


Figure 9: Personal elaboration based on “FTTH Market Panorama - Report by Country - September 2023.” and “Eurostat”

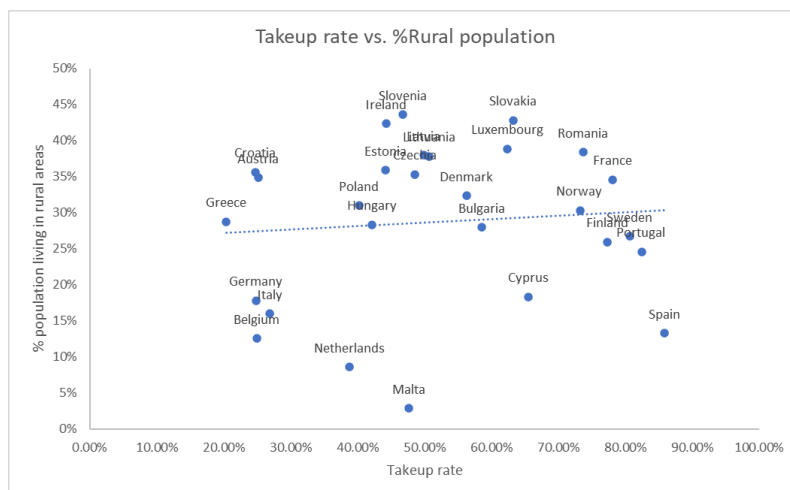


Figure 10: Personal elaboration based on “FTTH Market Panorama - Report by Country - September 2023.” and “Eurostat”

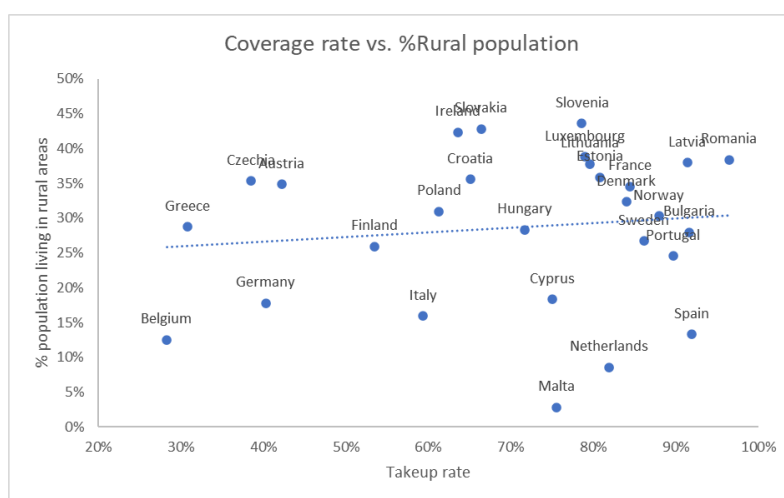


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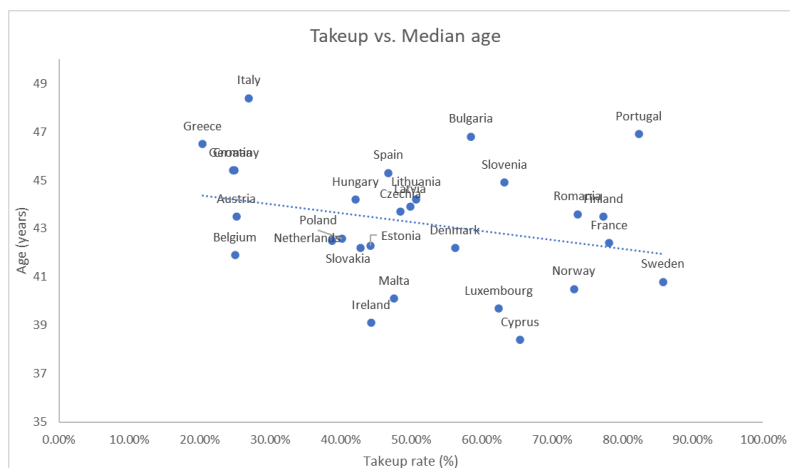


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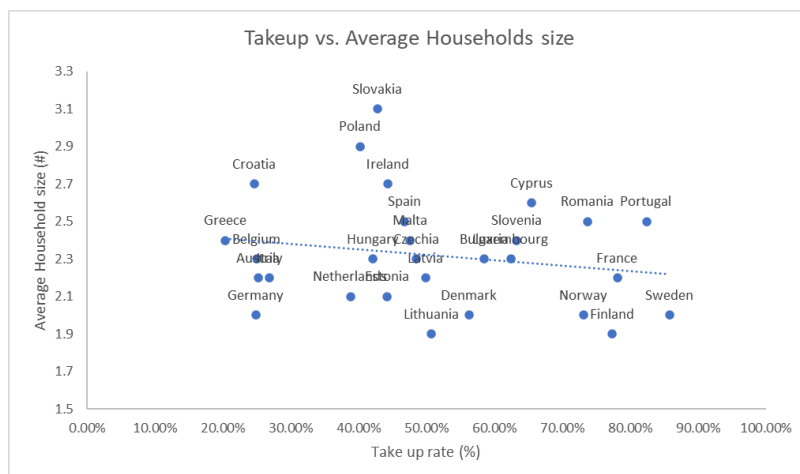


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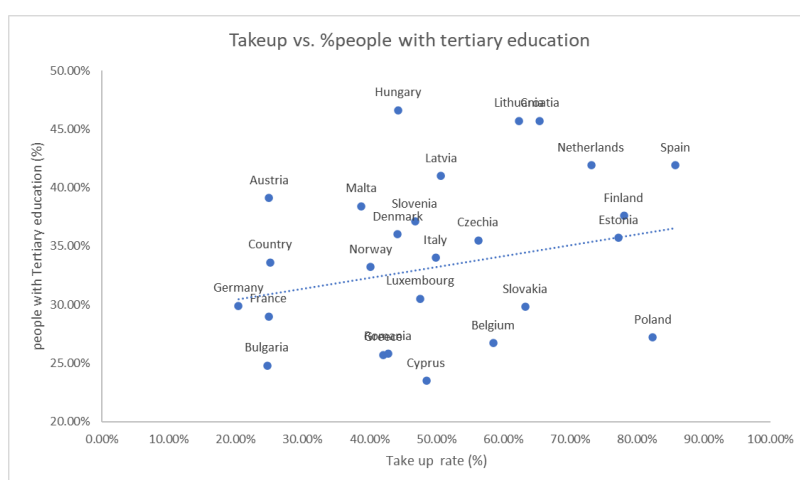


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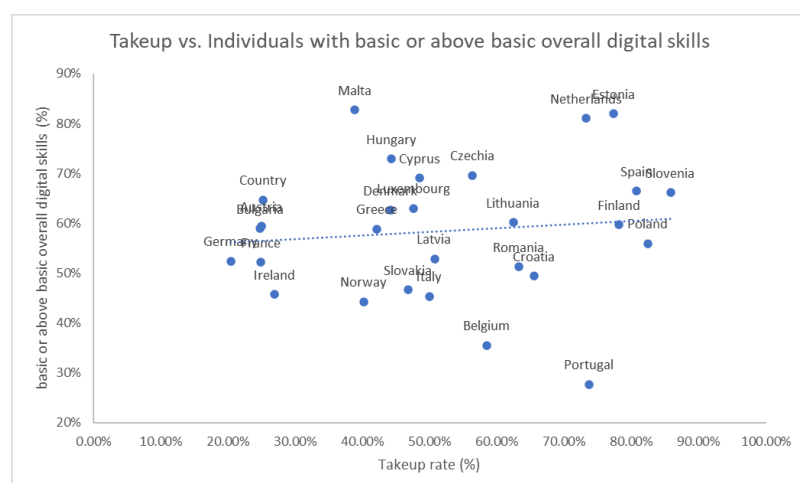


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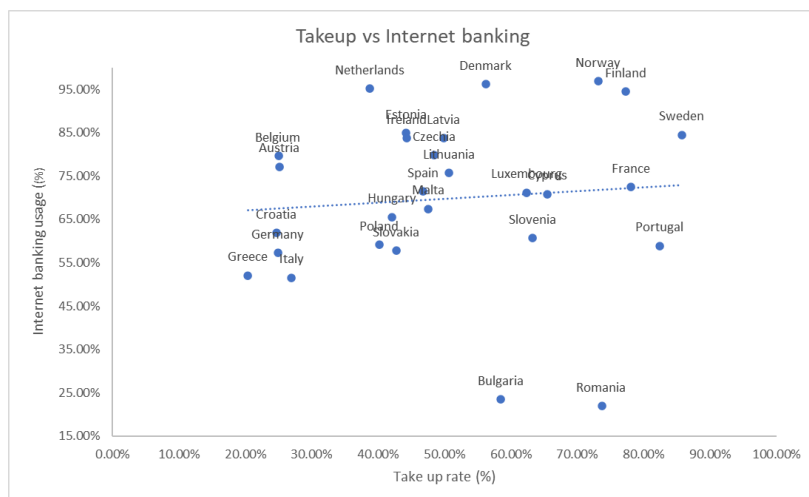


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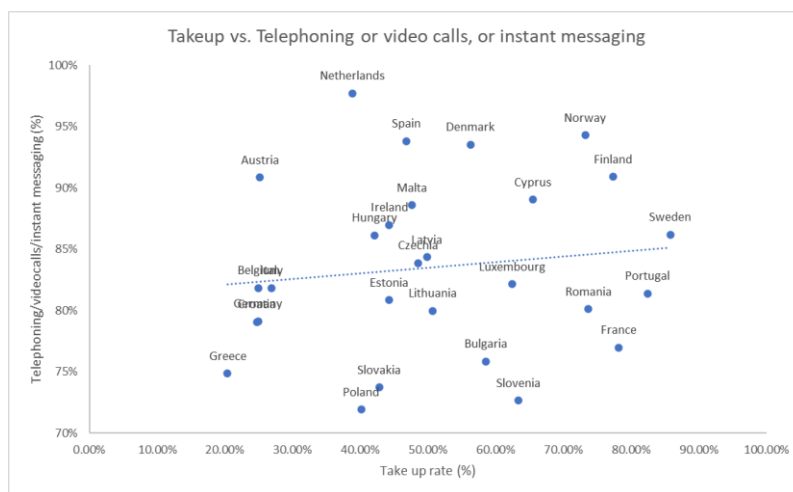


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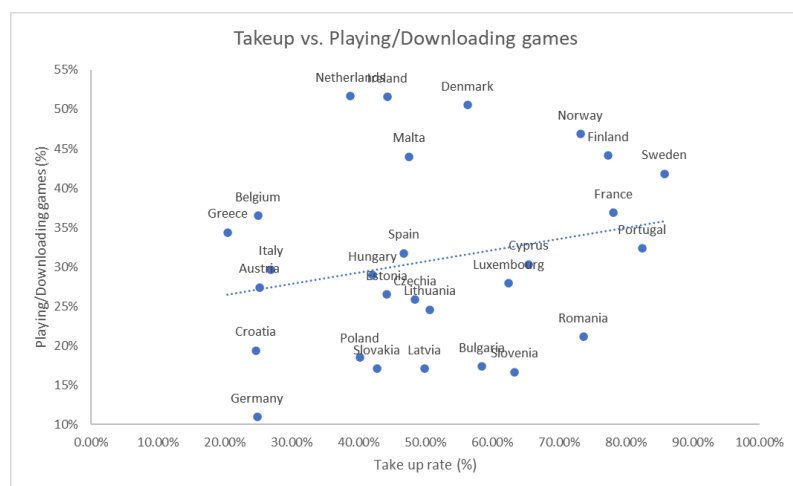


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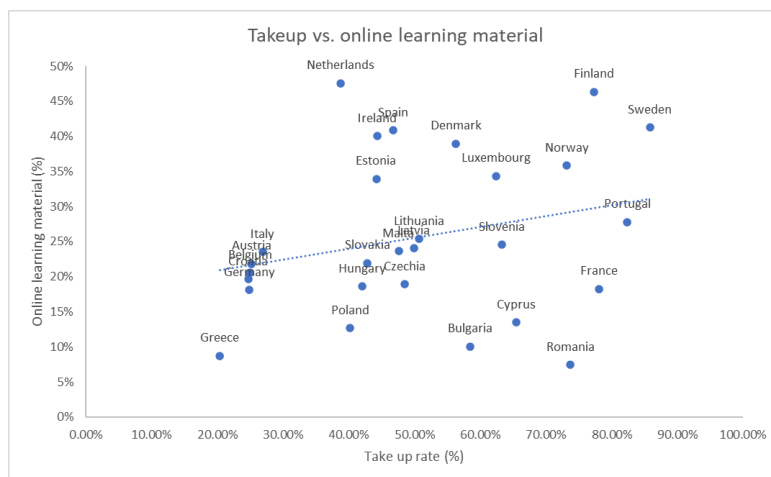


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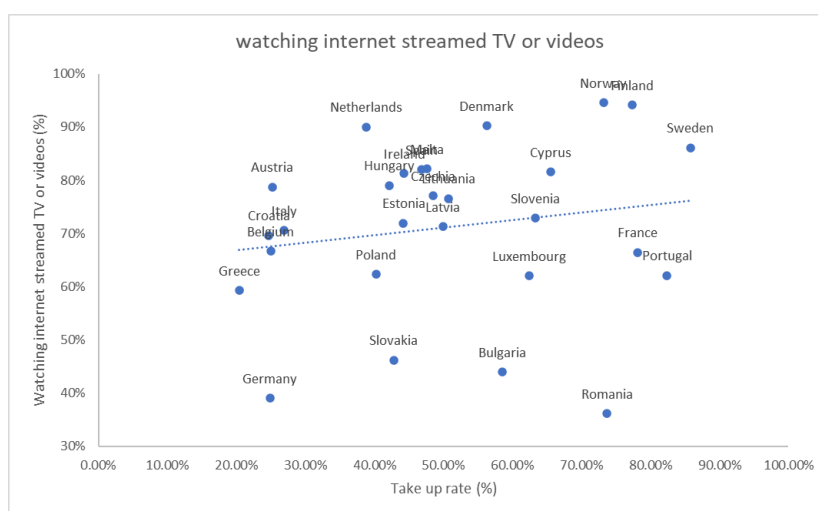


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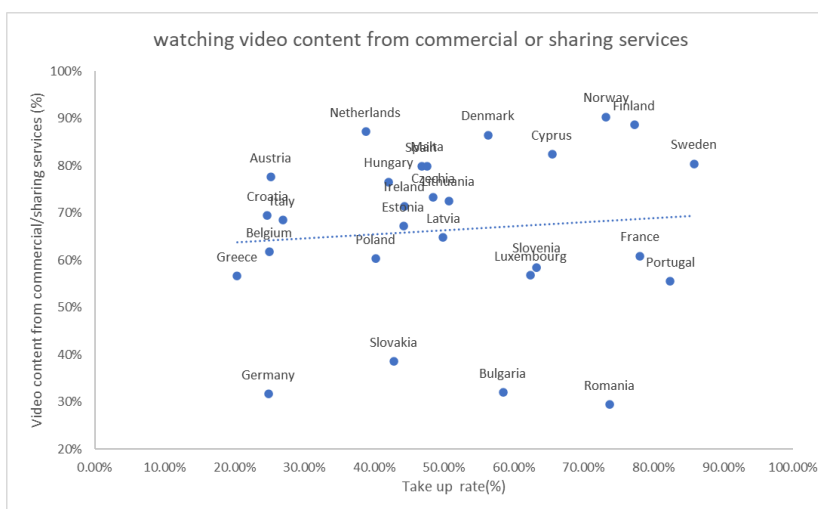


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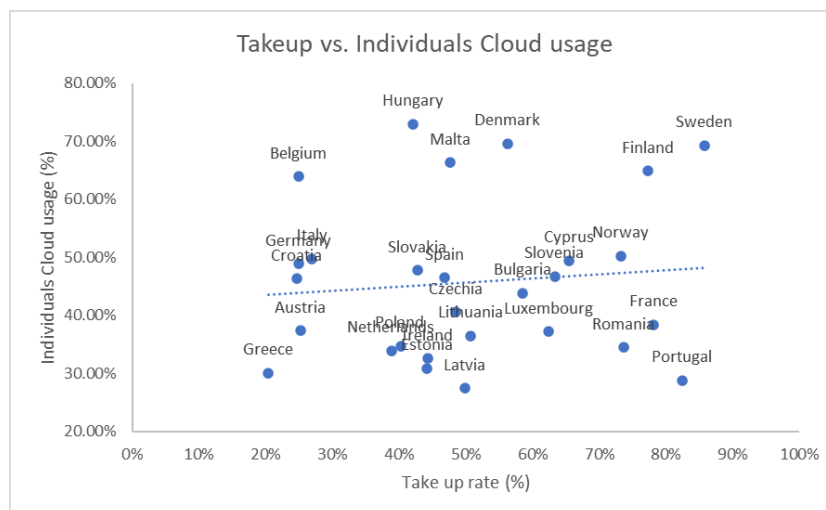


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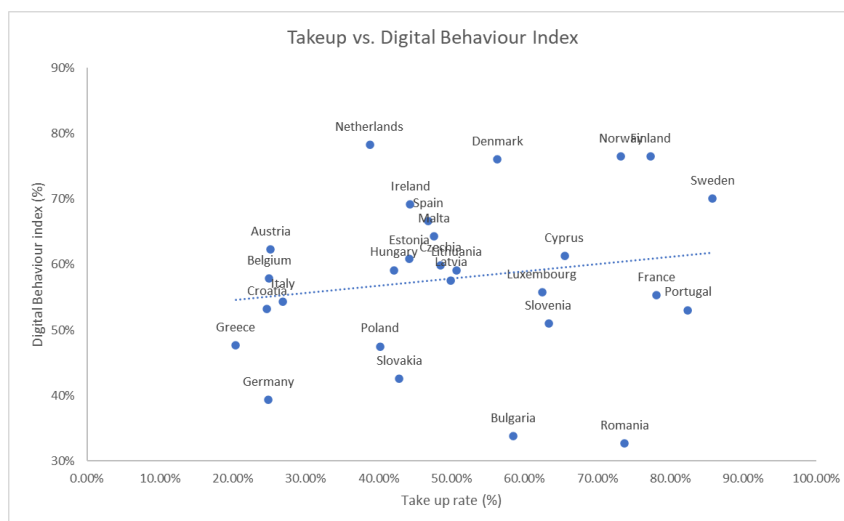


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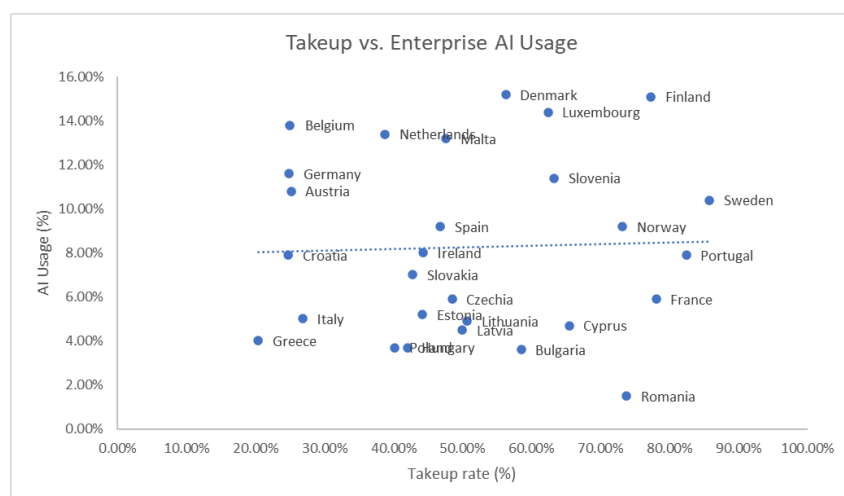


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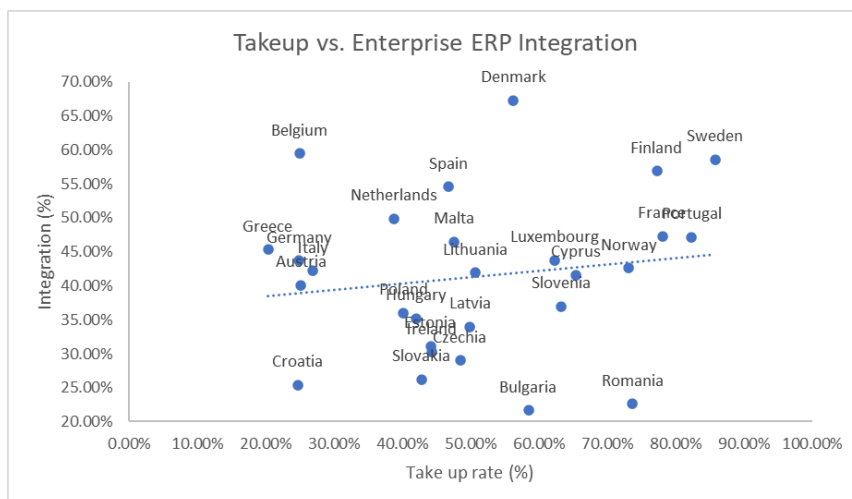


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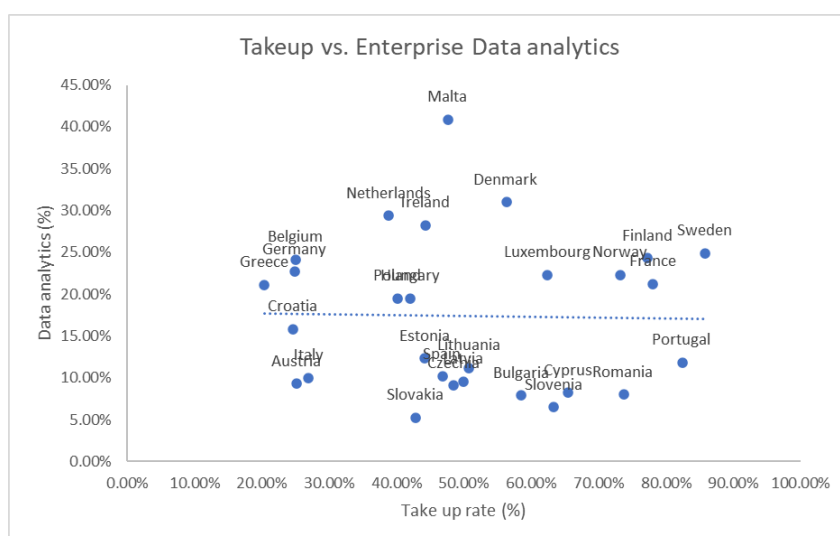


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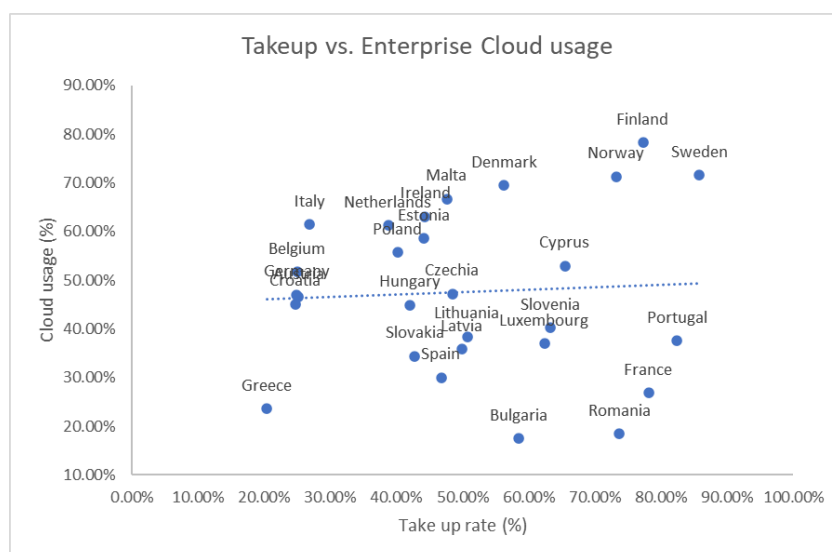


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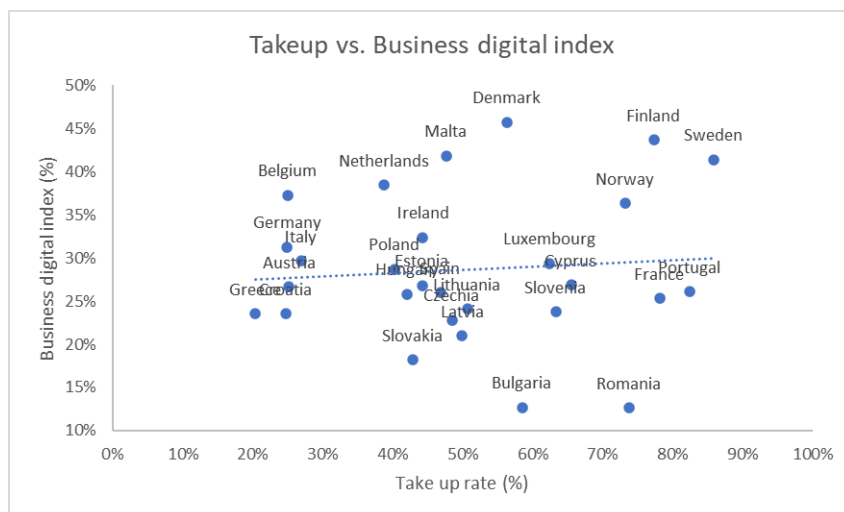


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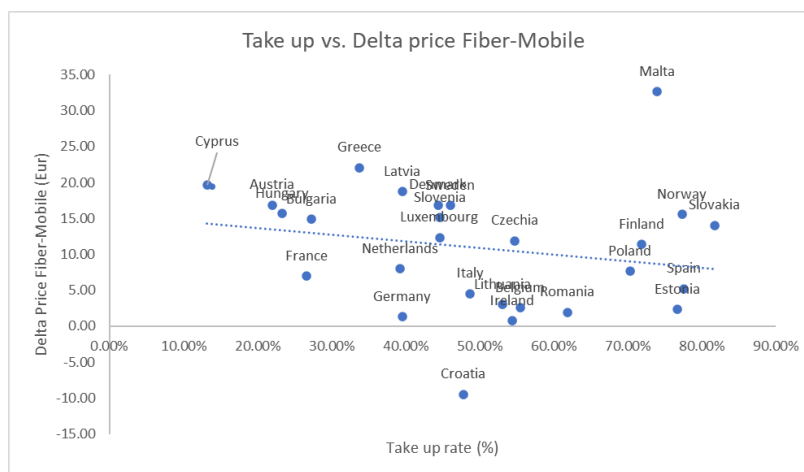


Figure 29: Personal elaboration based on “FTTH Market Panorama - Report by Country - September 2023.” and “European Commission”

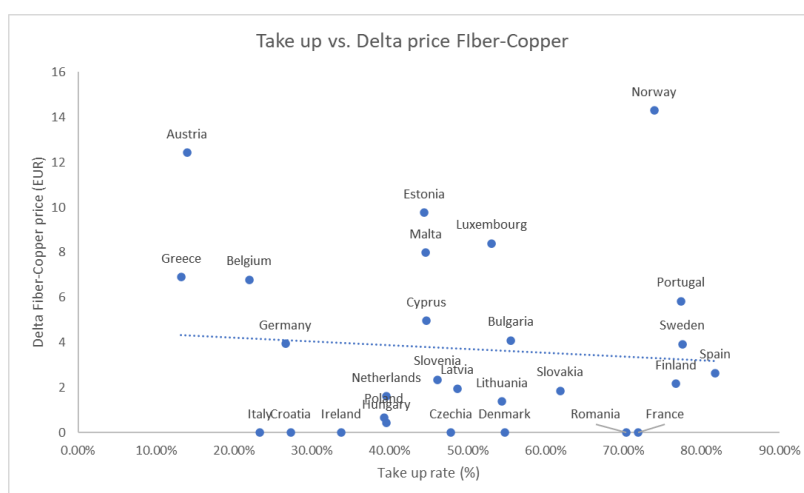


Figure 30: Personal elaboration based on “FTTH Market Panorama - Report by Country - September 2023.” and “European Commission”

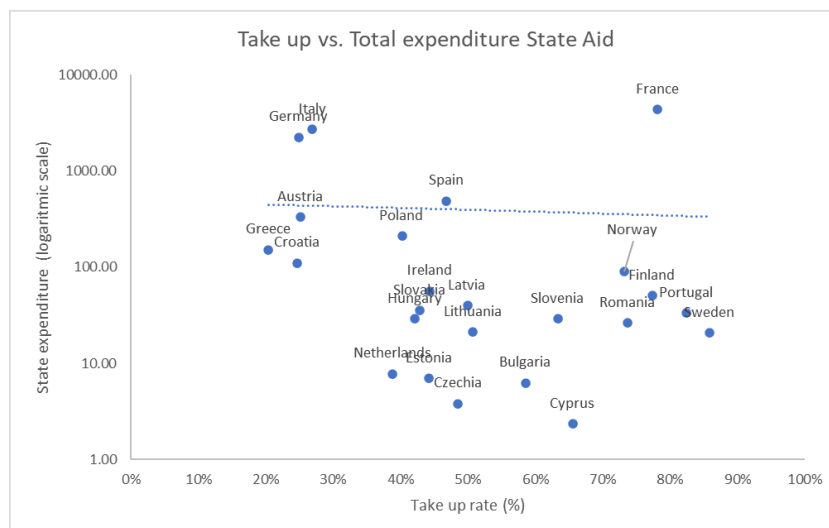


Figure 31: Personal elaboration based on “FTTH Market Panorama - Report by Country - September 2023.” and “European Commission”

Variable	VIF	1/VIF
stream	144.54	0.006919
vidsh	117.07	0.008542
fthpr	19.48	0.051330
ibank	16.46	0.060769
usmt	13.82	0.072385
princ	12.59	0.079435
dload	12.49	0.080095
upload	11.35	0.088105
tered	10.98	0.091088
fcdel	9.78	0.102234
digsk	9.67	0.103368
age	9.27	0.107914
games	8.50	0.117618
gini	7.78	0.128466
bigdt	7.59	0.131739
entcl	7.46	0.134028
fdcl	7.19	0.139085
tvcm	6.46	0.154871
bhsiz	6.31	0.158515
learn	5.50	0.181951
cloud	5.16	0.193947
nesmt	5.05	0.197860
entai	4.54	0.220250
laten	3.77	0.265310
rural	3.15	0.317128
enter	2.88	0.347317
urbds	2.80	0.357083
rurds	2.79	0.358103
cover	2.49	0.400832
urban	2.17	0.461285
Mean VIF	15.97	

Figure 32: VIF Calculation – Model V1

Variable	VIF	1/VIF
fthpr	22.81	0.043845
dload	14.92	0.067011
ibank	14.08	0.071035
usmrt	13.39	0.074700
princ	12.33	0.081119
upload	11.24	0.088982
fcdel	10.43	0.095848
digsk	8.65	0.115600
tered	7.97	0.125412
age	7.34	0.136276
entcl	6.90	0.144825
hhsiz	6.89	0.145140
bigdt	6.54	0.152795
tvcm	6.43	0.155522
gini	6.35	0.157503
games	6.28	0.159235
fmdel	5.68	0.176125
learn	5.67	0.176298
nesmt	5.48	0.182545
cloud	5.09	0.196577
entai	4.51	0.221555
laten	3.63	0.275568
stata	2.88	0.347252
rural	2.86	0.349560
urbds	2.77	0.361356
enter	2.69	0.371490
urds	2.52	0.397477
cover	2.40	0.416177
urban	2.20	0.454779
Mean VIF	7.27	

Figure 33: VIF Calculation – Model v2

. estat vif

Variable	VIF	1/VIF
fthpr	4.14	0.241515
fmdel	3.65	0.274310
digsk	3.41	0.292898
learn	3.28	0.304860
tvcm	2.85	0.350686
entcl	2.43	0.410955
nesmt	1.97	0.507227
dload	1.67	0.597121
urds	1.24	0.807293
urbds	1.15	0.866113
Mean VIF	2.58	

Figure 34: VIF Calculation – Model v3

Variable	VIF	1/VIF
fmdel	3.64	0.274987
fthpr	3.53	0.283313
nesmt	1.61	0.619314
digsk	1.58	0.631437
urds	1.11	0.902555
techx	1.06	0.944454
urbds	1.06	0.947359
Mean VIF	1.94	

Figure 35: VIF Calculation – Model vFinal

Variable		Mean	Std. dev.	Min	Max	Observations	
cover	overall	-9.68e-16	1.003591	-2.133293	5.361605	N =	140
	between	.7969336	-1.713967	1.13402		n =	28
	within	.6247939	-1.849662	5.365437		T =	5

Figure 36: Temporal variability test of coverage rate

Table A: Regression Results			
	(Technology index)	(Digital index)	(Business index)
	ftthr	ftthr	ftthr
fmdel	0.062** (0.001)	0.058** (0.003)	0.061** (0.002)
fthpr	-0.077*** (0.000)	-0.072*** (0.000)	-0.076*** (0.000)
digsk	-0.047* (0.024)	-0.055* (0.023)	-0.047* (0.023)
nesmt	-0.078*** (0.000)	-0.073*** (0.000)	-0.077*** (0.000)
learn	-0.019 (0.219)	-0.030 (0.107)	-0.020 (0.218)
urbds	0.064*** (0.000)	0.065*** (0.000)	0.064*** (0.000)
rudrs	-0.011*** (0.000)	-0.009** (0.001)	-0.011*** (0.000)
techx	0.001* (0.020)		
digbx		0.044 (0.086)	
busix			0.004 (0.832)
cons	0.467*** (0.000)	0.467*** (0.000)	0.467*** (0.000)
N	140	140	140
R ²	0.447	0.471	0.447
adj. R ²	0.413	0.439	0.413

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A: Regression results with composite index

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