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Executive Summary of the Thesis

Digitalization and Socioeconomic Inequality in the European Union: A Multidimensional Index-Based Analysis

Laurea Magistrale in Management Engineering - Ingegneria Gestionale

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1. Research Context and Scope

Digitalization has become a central feature of contemporary economic, social, and institutional change across the European Union, with wide-ranging implications for development and governance. Therefore, digital development has moved to the core of European policy agendas, most notably through the Digital Decade Policy Programme. This programme constitutes the European Union's main strategic framework for digital transformation, combining a harmonized system of indicators with binding targets for 2030 across four digital pillars: digital skills, digital infrastructure, digital transformation of businesses, and digital public services. By linking measurement, monitoring, and policy objectives, the Digital Decade serves both as a benchmark for assessing national digital performance and as a coordinated roadmap aimed at reducing digital gaps across Member States.

However, the distributional consequences of digitalization remain contested. While digital technologies are often presented as drivers of productivity growth, inclusion, and opportunity, a growing body of research suggests that digitalization, particularly when unevenly implemented, may also reinforce existing inequalities or generate new forms of exclusion. These concerns are especially relevant in the European context, where persistent socioeconomic and territorial disparities coexist with ambitious digital policy objectives.

Against this background, the present thesis analyzes patterns of digitalization and their relationship with socioeconomic inequality in the European Union. It adopts a multidimensional perspective on digitalization, consistent with the Digital Decade framework, and moves beyond income-only measures of inequality. The analysis pursues three objectives: (i) to describe current trends in digitalization across Member States, comparing country performances and identifying digital divides through the construction of a revised composite digitalization index, (ii) to extend the analysis to the Italian case by examining Italy's digital performance in comparison with the EU and by analyzing its subnational dimension through the development of an original Regional Digitalization Index, which enables a systematic assessment of territorial disparities, and (iii) to empirically investigate the relationship between digitalization and socioeconomic inequality, with the aim of deriving policy-relevant insights on how digital develop-

ment strategies can support inclusive and balanced growth.

2. Conceptual Foundations: Digitalization and Inequality

Digitalization is increasingly understood as a multifaceted process unfolding across several interrelated dimensions, rather than as a single technological phenomenon. This view is reflected in recent measurement efforts, most notably the Digital Economy and Society Index (DESI) and its evolution into the Digital Decade monitoring framework, which organizes digital development around four core pillars: digital infrastructure, digital skills, digital transformation of businesses, and digital public services.

The literature provides extensive evidence on each of these dimensions, though they are often examined in isolation. Research on digital infrastructure highlights its foundational role in enabling connectivity and access, while studies on digital skills emphasize the importance of individual capabilities for effective technology use and participation. Firm-level digitalization is shown to affect productivity, organizational structures, and labor demand, with potentially uneven distributional implications. More recently, digital public services have received increasing attention due to their relevance for access to education, healthcare, and administrative procedures. These strands offer valuable insights, but accounting for the coexistence and interaction of different dimensions helps clarify how they shape socioeconomic outcomes.

This recognition has motivated a growing use of composite indicators to measure digital development in a more comprehensive manner. Multidimensional indices provide a useful tool for capturing the complexity of digitalization in descriptive analyses and for studying its relationship with inequality. Their effectiveness, however, depends critically on the availability of harmonized indicators that are consistently defined and collected across countries and over time, a condition that remains only partially satisfied in existing frameworks.

A similar issue characterizes much of the literature on inequality. Empirical research has traditionally focused on income inequality as the primary outcome of interest. While income disparities remain central, recent contributions increasingly recognize that inequality is inherently multidimensional, encompassing education, labor market exclusion, social participation, and well-being. Asmar et al. (2022) conceptualize digital inequality as a process that co-evolves with income, education, agency, and well-being, highlighting the limitations of narrow, income-based measures and the need for broader analytical perspectives. Building on these insights, the present thesis adopts a composite measure of socioeconomic inequality that integrates multiple dimensions of disadvantage.

By combining a multidimensional framework for digitalization with a multifaceted conception of inequality, this study moves beyond isolated analyses of single digital domains or narrow inequality indicators. This integrated approach enables a more nuanced assessment of which dimensions of digitalization matter most for inequality and under which conditions digital development may support more inclusive growth.

3. Data Sources and Index Construction

The empirical analysis is based on a newly constructed dataset combining indicators of digitalization and socioeconomic inequality for European Union Member States over the period 2021–2024. Digitalization indicators are drawn from the EU Digital Decade framework, while inequality indicators are primarily sourced from Eurostat, ensuring harmonized definitions and cross-country comparability.

A central methodological contribution of the thesis is the construction of a revised composite digitalization index that preserves the four-pillar structure of the Digital Decade while restricting the underlying indicators to those that are relevant, comparable, and consistently available across countries and over time. This selection strategy improves measurement reliability and facilitates longitudinal analysis. In addition, the index distinguishes between enabling factors, which capture potential digital capacity, and achieved results, which reflect effective usage and realized digital outcomes.

Socioeconomic inequality is likewise conceptualized as a multidimensional phenomenon. A composite inequality index is constructed by combining indicators capturing education-related, labor-market-related, and income-related di-

mensions of disadvantage. All indicators are standardized to account for differences in scale and measurement.

Beyond the EU-level analysis, the thesis introduces a Regional Digitalization Index for Italy, designed to mirror the European Digital Decade framework at the NUTS 2 level. This regional index is constructed using data from Istat, Agcom, and Eurostat, allowing for a systematic examination of sub-national digital divides within a consistent conceptual structure.

4. Descriptive Evidence

The descriptive analysis shows that the European Union as a whole is becoming progressively more digitalized, although the pace of improvement remains modest relative to policy ambitions. Between 2023 and 2024, the EU average level of digitalization increased from approximately 57 to 60 percentage points, reflecting a slight improvement across all four Digital Decade pillars. While this upward trend indicates continued progress, the magnitude of these changes remains limited when compared with the targets set for 2030.

This gap is particularly evident in the area of digital skills. The Digital Decade objective sets a target of at least 80% of individuals with basic digital skills by 2030. However, the share of individuals meeting this threshold increased only from just under 53% in 2021 to approximately 56% in 2024. Similar patterns emerge in other pillars, where incremental improvements fall short of the acceleration required to meet the stated policy objectives within the remaining timeframe.

At the same time, cross-country disparities in overall digitalization have narrowed slightly. The gap between the best-performing Member State, Denmark, and the worst-performing one, Romania, declined from approximately 24 percentage points in 2023 to around 20 percentage points in 2024. However, a more disaggregated analysis reveals that substantial disparities persist across individual pillars. In the business area, the most advanced countries display levels of digitalization that are more than twice those of the least-performing Member States. These patterns indicate that convergence in overall digitalization may mask persistent and significant imbalances across specific dimensions of digital development.

The Italian case further illustrates dynamics of divides and slow improvement. Italy ranks 23rd out of 27 Member States in overall digitalization and performs below the EU average across all four pillars. However, some indicators point to recent signs of catching up. Notably, access to electronic health records increased by more than 24 percentage points between 2021 and 2024, shifting Italy from below to above the EU average in this specific dimension. This marked improvement suggests that targeted top-down intervention in digital public services can close gaps more rapidly than the gradual evolution driven by market dynamics alone.

A regional perspective highlights persistent disparities within Italy. The Regional Digitalization Index reveals a clear territorial divide, with all southern regions performing below the national average, while all central and northern regions exceed it, with the exception of Valle d'Aosta. This spatial pattern is part of long-standing socioeconomic divides and underscores the importance of complementing national-level analysis with a sub-national perspective to fully capture the uneven geography of digital development.

5. Econometric Analysis and Main Findings

The empirical analysis examines the relationship between digitalization and socioeconomic inequality using panel data econometric techniques. Given the short time dimension of the dataset, the analysis focuses on contemporaneous associations between changes in digitalization and inequality within countries. Although the Hausman test does not reject the random-effects estimator, a fixed-effects approach is adopted to control for unobserved, time-invariant country characteristics, such as welfare state models, institutional structures, and long-standing socioeconomic conditions, that are likely to be correlated with both digitalization and inequality outcomes.

When digitalization is considered in aggregate terms, the results indicate that only realized digital outcomes are significantly associated with inequality reduction, whereas enabling factors such as infrastructure availability and formal ICT training do not display a statistically signif-

icant contemporaneous relationship. This result is partly explained by the fact that enabling factors typically require time to translate into observable societal effects, and more importantly by their focus on capturing potential capacity rather than actual use. This interpretation is in line with existing contributions in the literature, which emphasize that equity-increasing outcomes arise from the quality of digital interactions and actual engagement with digital services, rather than from the mere availability of digital resources.

To account for the heterogeneous nature of digital development, the analysis then considers the four Digital Decade pillars separately. Digital infrastructure, digital skills, and business digitalization do not display statistically significant associations with inequality when analyzed in isolation. This result may reflect the context-dependent nature of digitalization effects and motivates a further analysis based on interaction models. By contrast, the digitalization of public services emerges as the most robust and statistically significant dimension. Improvements in digital public services are consistently associated with lower levels of socioeconomic inequality, and this relationship remains stable after controlling for GDP per capita, governance quality, and public expenditure on social protection. To address potential endogeneity and reverse causality, the analysis complements fixed-effects estimates with a System GMM specification. The results, reported in Table 1, confirm a negative and statistically significant association between digital public services and inequality. Standard diagnostic tests indicate no evidence of second-order serial correlation and support the validity of the instrument set. While the short time horizon calls for caution in causal interpretation, these findings provide supportive evidence consistent with a causal channel running from public-sector digitalization to inequality reduction.

Building on these results, the analysis explores mechanisms through which digital public services may influence inequality outcomes. Literature on administrative burden highlights how learning costs, compliance requirements, and procedural complexity can disproportionately affect disadvantaged individuals and limit their effective access to public services (Moynihan et al., 2015). From this perspective, digital public services, when effectively designed and implemented, can reduce inequality by simplifying access to information and lowering procedural barriers, improving access to benefits and support mechanisms that are otherwise unevenly distributed across the population.

To better understand the channels through which digital public services may primarily operate, the analysis then examines their relationship with disaggregated inequality measures. The strongest and most consistent associations are observed for youth-related dimensions, particularly the share of young people not in employment, education, or training (NEETs). These results are consistent with perspectives that emphasize the role of public service quality in shaping youth-related inequalities. In particular, improvements in transparency can help ensure that public interventions aimed at supporting education reach their intended beneficiaries. At the same time, digital guidance and training systems can support young people in the early phases of their professional careers by reducing information asymmetries and improving access to opportunities.

Finally, the analysis investigates interaction effects between different dimensions of digitalization. In particular, the interaction between business digitalization and digital skills is positive and strongly statistically significant, indicating that the association between firm-level digital adoption and inequality becomes more positive as the level of digital skills in the population increases. On average, business digitalization is associated with lower levels of inequality in low-skill contexts, while this association weakens and shifts in a positive direction as digital skills increase. Although the estimated marginal effects of business digitalization at specific points of the skill distribution are imprecise, the overall pattern is clear and statistically supported by the interaction term: the potential equalizing role of business digital transformation gradually attenuates in higher-skill environments and may even reverse. This pattern is consistent with theoretical contributions on skill-biased technological change, which suggest that in contexts with high levels of skills, business digitalization may disproportionately benefit already skilled workers and, if not adequately balanced, con-

tribute to widening inequality. These findings reinforce the importance of approaching digitalization as a multidimensional process and highlight the need for carefully considered policy responses.

	System GMM
Digital public services	−3.491
	($p = 0.013$)
AR(1) test (p-value)	0.020
AR(2) test (p-value)	0.623
Sargan test (p-value)	0.169
Hansen test (p-value)	0.238
Number of instruments	8

Table 1: System GMM estimate and diagnostics

6. Conclusions

This thesis examines the relationship between digitalization and socioeconomic inequality in the European Union through a multidimensional and comparative approach. By constructing a revised composite digitalization indicator aligned with the Digital Decade framework and extending the analysis to the regional level in Italy, the study contributes to the literature by offering a more integrated view of digital development across countries and territories.

The empirical results indicate that digitalization does not generate uniform distributional effects. When digital development is considered in aggregate terms, realized digital outcomes are significantly associated with reductions in inequality, whereas enabling conditions alone do not display the same relationship. This suggests that the effective use and implementation of digital technologies play a more immediate role in shaping distributional outcomes than the mere expansion of digital capacity.

One of the most robust findings concerns the role of digital public services. Across multiple specifications and robustness checks, higher levels of public-sector digitalization are consistently associated with lower levels of socioeconomic inequality. This relationship is particularly pronounced for youth-related outcomes, supporting the interpretation that digital public services may contribute to inequality reduction by lowering administrative burdens and improving access to education, guidance, and labor market services. Other digital pillars, by contrast, display weaker or more context-dependent associations, underscoring the heterogeneous nature of digitalization processes.

At the same time, the interaction between business digitalization and digital skills highlights that digital transformation can also produce uneven effects when contextual factors are taken into account. The results suggest that firm-level digital adoption may be associated with more equal outcomes in low-skill environments, while its distributional benefits weaken and may even reverse in high-skill contexts. This pattern is consistent with the logic of skill-biased technological change and points to the importance of considering how different dimensions of digital development evolve jointly rather than in isolation.

Several limitations should be acknowledged. The short time horizon of the dataset restricts the analysis of dynamic effects and limits the scope for strong causal inference, despite the use of complementary estimation techniques. Moreover, the construction of composite indicators necessarily involves methodological choices related to indicator selection, normalization, and aggregation, which may affect measurement. The analysis also highlights some limitations of the current Digital Decade framework, particularly with regard to the definition and monitoring of policy targets. While the framework represents an important step toward a harmonized assessment of digital development, it would benefit from a greater number of realistic targets, greater consistency in indicator definitions across years, and more frequent data collection for key dimensions. These considerations point both to avenues for future research, including the use of longer panels and more consistent data, and to potential improvements in EU digital monitoring tools.

From a policy perspective, the findings suggest that achieving an inclusive digital transformation requires more than expanding average digitalization. In particular, the results emphasize the central role of digital public services in translating digital progress into more equitable outcomes. Given that digital public services represent one of the areas in which governments can intervene most directly, the findings support greater policy attention to improving their quality and accessibility to reduce administrative

burdens and improve access to education and welfare opportunities. Beyond significant technological investments in service quality, policies should include campaigns to ensure effective adoption among disadvantaged groups, complementary measures to develop digital skills, and non-digital support measures.

At the same time, the results indicate that policies aimed at promoting business digitalization should be carefully coordinated with the broader skill environment. In contexts characterized by high levels of skills, business digitalization may disproportionately benefit already highly qualified workers, as its returns tend to be concentrated among them. This highlights the need for complementary policies on skills and training, alongside targeted support measures for affected workers in order to facilitate transitions and mitigate adjustment costs. In conclusion, this work supports a nuanced interpretation of the Digital Decade agenda and provides a foundation for further research aimed at understanding how to realize the full potential of digitalization in delivering inclusive benefits.

References

Asmar, A., Mariën, I., & Van Audenhove, L. (2022). No one-size-fits-all! Eight profiles of digital inequalities for customized inclusion strategies. *New Media & Society*, *24*(2), 279–310. https://doi.org/10.1177/14614448211063182

Moynihan, D. P., Herd, P., & Harvey, H. (2015). Administrative burden: Learning, psychological, and compliance costs in citizen-state interactions. *Journal of Public Administration Research and Theory*, *25*(1), 43–69. https://doi.org/10.1093/jopart/muu009