

Industrial Clusters, Digital Transformation, and Returns to Labour: A Spatial Perspective

Introduction

Digital transformation is increasingly reshaping regional economic performance, yet its effects remain spatially uneven and strongly conditioned by regional industrial structures. While firm-level studies often document productivity gains associated with technology adoption, less is known about how these processes translate into regional returns to labour. This study examines how industrial clusters, digital transformation, and regional competitiveness interact to shape labour returns from a spatial perspective, addressing a critical gap in understanding the mechanisms through which agglomeration economies generate tangible improvements in worker earnings.

Industrial clusters have long been associated with knowledge spillovers, dense networks, and localized externalities that enhance firm capabilities (Ketels & Protsiv, 2021). However, recent evidence suggests that cluster influence is increasingly mediated by technology-related mechanisms rather than operating through direct economic effects. Simultaneously, digital transformation has emerged as a key driver of competitive renewal, though its benefits do not materialize uniformly and depend on complementary regional resources such as human capital, institutional support, and innovation systems (Grashof et al., 2021).

This paper responds to this gap by examining the mediating roles of digitalization and competitiveness in the relationship between industrial clusters and earnings per worker across Spanish provinces. Spain offers a valuable empirical setting, presenting strong regional heterogeneity, long-standing cluster trajectories, and uneven patterns of digital adoption. By integrating cluster presence, technology adoption indicators, and a multidimensional competitiveness construct into a structural equation model, this research provides a comprehensive view of how territorial structures and technological capabilities interact to shape labour income.

Conceptual framework

The conceptual premise of the study is that agglomeration, digital transformation, and competitiveness are interdependent rather than independent drivers of regional economic performance. Clusters may provide favourable environments for technology diffusion by facilitating collective learning, coordination, and experimentation (Delgado et al., 2014). However, clustering alone does not guarantee improved economic outcomes, particularly in the absence of technological upgrading and supportive regional conditions.

Digital transformation, encompassing the adoption of ICT and Industry 4.0 technologies, plays a dual role. On the one hand, it can enhance productivity, innovation capacity, and organisational efficiency. On the other hand, its effects depend on the broader competitive environment in which firms and regions operate. Competitiveness is understood as a multidimensional construct capturing innovation capacity, productivity, human capital, institutional quality, and infrastructural foundations.

Within this framework, clusters are expected to promote digital adoption, digital adoption to strengthen competitiveness, and competitiveness to ultimately shape returns to labour (Corradini et al., 2021). The key proposition is not that clusters or digital technologies directly raise earnings, but that their effects unfold through sequential and mediated pathways. This perspective moves beyond linear models of agglomeration effects and aligns with recent calls in

regional science to adopt more systemic and mechanism-based explanations of territorial development.

Methodology

The analysis adopts a quantitative, descriptive, and exploratory approach based on a cross-sectional design. First, a cluster-mapping exercise is conducted using establishment-level data from 1,804,714 Spanish establishments to identify the spatial distribution and intensity of industrial clusters across regions. This mapping reveals pronounced territorial heterogeneity in cluster presence and specialisation, indicating that agglomeration advantages are highly uneven across space.

Second, the paper combines cluster indicators with regional measures of digital transformation, competitiveness, and innovation to explore their relationship with returns to labour. The empirical analysis uses regional and NUTS-3 level data for 50 Spanish provinces, combining establishment-based information on industrial activity with regional indicators of digital transformation (ICT Index and Industry 4.0 Index), competitiveness (Regional Competitiveness Index basic pillar, labour productivity, patent applications), and labour outcomes (earnings per worker) (D'Urso et al., 2022).

A partial least squares structural equation modelling (PLS-SEM) approach is employed to assess how digital adoption and regional competitiveness operate as complementary mechanisms linking industrial clustering to labour outcomes (Hair et al., 2022). All constructs are operationalized as formative composites, reflecting their multidimensional nature and the independence of their constituent indicators. The modelling strategy is intended to structure observed spatial relationships and identify mediating pathways rather than to establish causal identification.

Results

The results reveal several critical findings. First, industrial clusters exert a strong positive influence on technology adoption, confirming that agglomeration economies continue to foster conducive environments for ICT and Industry 4.0 diffusion. However, cluster presence does not directly enhance competitiveness or earnings per worker, challenging assumptions that clustering automatically generates regional advantages.

Technology adoption enhances competitiveness, and competitiveness strongly drives returns to labour. Yet neither technology nor competitiveness individually mediates the relationship between clusters and labour earnings. Instead, the analysis identifies a significant multi-stage pathway: Clusters → Technology Adoption → Competitiveness → Returns to Labour. This multi-stage pathway accounts for the vast majority of the indirect association between clustering and labour returns, highlighting that clusters contribute to higher labour income primarily when they enable technological upgrading that strengthens regional competitive conditions (Awad & Albaity, 2022; Usai et al., 2021).

The model explains substantial variance in the endogenous constructs: 27.2% of Technology Adoption, 59.6% of Competitiveness, and 67.5% of Earnings per Worker. Predictive relevance assessments confirm that the model generates meaningful out-of-sample predictions for regional competitiveness and labour outcomes, demonstrating medium predictive power when compared with linear regression benchmarks.

Discussion and Implications

The findings suggest that industrial clusters are positively associated with regional returns to labour, but only where digital transformation and competitive conditions jointly enable the translation of agglomeration advantages into labour-market outcomes. Clustered regions lacking

these complementary capacities exhibit weaker returns to labour, despite comparable levels of industrial concentration.

Technology adoption fully mediates the relationship between clusters and competitiveness, suggesting that clusters generate competitive advantages primarily when they enable the diffusion and assimilation of modern technologies. Similarly, competitiveness fully mediates the relationship between technology adoption and returns to labour, indicating that digital transformation enhances economic outcomes only when it improves underlying regional competitive conditions. These sequential dependencies underscore that neither clustering nor digitalization alone is sufficient; their contribution depends on how they reinforce regional competitiveness.

From a policy perspective, the findings underscore the importance of integrated place-based strategies. Cluster-based policies are insufficient on their own and must be coupled with explicit digital transformation and competitiveness-enhancing measures to improve wages and living standards. Regional development agendas should promote technology adoption through digital innovation hubs, fiscal incentives, and collaborative R&D programs while simultaneously investing in innovation capacity, human capital development, institutional quality, and business environment improvements. Strategies focused solely on technology supply without strengthening competitive framework conditions are unlikely to deliver meaningful wage gains.

Conclusions

This paper contributes to regional science by providing spatially explicit evidence on how industrial structure, digital transformation, and competitiveness jointly shape regional labour outcomes. The analysis demonstrates that the effects of clusters, technology, and competitiveness on labour returns are conditional, interdependent, and mediated rather than linear. Industrial clusters remain relevant as enablers of technological upgrading, and their positive effects on labour income materialize only through the dual channels of technology adoption and competitiveness enhancement.

The study reinforces that effective regional development strategies should recognize these interdependencies, supporting not only the spatial concentration of industry but also the technological and competitive capabilities that enable regions to convert agglomeration advantages into improved returns to labour. Future research should extend this framework to multi-country comparative settings, incorporate longitudinal designs to capture dynamic relationships, and complement PLS-SEM with spatial econometric approaches to better validate spillover effects and cluster heterogeneity.

Keywords

Industrial clusters; Digital transformation; Regional competitiveness; Labour market outcomes; Spatial heterogeneity.

JEL Codes

R11, R12, O33, O18

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