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Manufacturing Development and Regional Socioeconomic Outcomes in the Context of Hungary's Battery Industry Expansion

This paper examines the association between regional manufacturing development intensity and socioeconomic outcomes in Hungary in the context of the country's recent battery-industry expansion, using an EU27 NUTS2 benchmark panel over 2013–2022. Using a two-way fixed effects framework, it analyses employment, compensation per employee, and the tertiary employment share, while also testing the conditioning role of regional innovation capacity. The results show limited evidence of broad-based employment expansion, clearer wage upgrading, and no systematic upgrading in the tertiary employment share. Wage gains are stronger in regions with higher human capital and R&D effort, suggesting that innovation capacity strengthens the association between manufacturing development intensity and local wage outcomes. The findings suggest that manufacturing deepening in the context of Hungary's battery-industry expansion is associated with real but uneven regional socioeconomic outcomes.
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1. Introduction

The rapid diffusion of electric vehicles (EVs) has repositioned battery manufacturing as a strategic segment of industrial transformation and green transition (Foley et al., 2020; Barbosa et al., 2022). Batteries are central not only to EV performance and cost, but also to broader efforts aimed at decarbonizing transport and strengthening industrial competitiveness (Siebenhofer et al., 2021). Within the European Union, this transformation is closely linked to policy initiatives such as the European Green Deal and the European Battery Alliance, which treat batteries as key enabling technologies for low-carbon growth and industrial renewal (Haas & Sander, 2020).
However, at the same time, the geographic distribution of battery manufacturing indicates a highly concentrated and asymmetric industry, predominantly situated in East Asia; in contrast, Europe and North America remain underrepresented despite rapid growth (Yang et al., 2022). In 2023, China accounted for over two-thirds of global EV battery cell production, while South Korea and Japan held significant shares (IEA, 2024). Within the EU, notable disparities exist, where a select few member states—namely Germany, Poland, Sweden, and Hungary—dominate current and planned battery plant capacities, whereas others primarily engage in upstream material processing or downstream pack assembly (Asaba et al., 2022; Győrffy, 2024). The regional dynamics indicate a pronounced shift in investment patterns, particularly in CEE, identified as pivotal regions for new investments, where countries like Poland and Hungary are rapidly evolving into critical production hubs for traction batteries and their components (Kostecka-Tomaszewska & Czerewacz-Filipowicz, 2019; Ferraro & Garofalo, 2025).
Hungary, in particular, holds a prominent position in this evolving battery production landscape (Pavlínek, 2022). Leveraging its historical integration into the German automotive supply chain,

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the country has become a leading site for large-scale EV battery production since the late 2010s (Lechowski et al., 2025). Major investments such as Samsung SDI's factory in Göd and CATL's gigafactory in Debrecen highlight this shift, and the Hungarian government is actively positioning the country as a prospective European battery hub (Csomós et al., 2025; Ricz & Éltető, 2025; Kronstein, 2026). At the same time, the regional socioeconomic consequences of this manufacturing transformation remain uncertain.

Although existing studies document investment patterns, supply-chain shifts, and the strategic relevance of battery manufacturing, there is still limited evidence on the within-country socioeconomic consequences of manufacturing deepening in the context of battery-industry expansion, especially in Central and Eastern Europe. Employment, wage, and skill-composition outcomes are rarely analyzed jointly, and the moderating role of regional innovation capacity is more often assumed than directly tested.

This paper addresses these gaps by examining how regional manufacturing development intensity is associated with socioeconomic outcomes in Hungary during the period of battery-industry expansion, using an EU27 NUTS2 benchmark panel over 2013–2022. Because harmonized battery-specific employment and investment data are not available at this regional scale for the full study period, the analysis does not directly measure battery-sector effects. Instead, the battery industry provides the substantive context, while the empirical analysis focuses on broader regional manufacturing development intensity. The paper examines employment, compensation per employee, and the tertiary employment share, and tests whether these relationships vary with regional innovation capacity. It argues that the associated regional socioeconomic outcomes are uneven: compensation upgrading is more visible than employment expansion or increases in the tertiary employment share, while innovation-capable regions capture stronger wage-related benefits.

The remainder of the paper is structured as follows. Section 2 presents the theoretical framework and literature review. Section 3 introduces the data and methodology. Section 4 reports the empirical results. Section 5 discusses the main findings. Section 6 concludes.

2. Theoretical framework and literature review

2.1. FDI-led manufacturing development and regional upgrading

The relationship between manufacturing development and regional socioeconomic upgrading is often discussed through the lens of FDI-led industrial development. Foreign investment may contribute to productivity growth, export expansion, wage upgrading, and technological learning through capital inflows, supplier linkages, and knowledge transfer (Yao & Wei, 2007; Fu et al., 2011; Gyamfi et al., 2022; Tóth et al., 2024). However, these benefits are rarely automatic or spatially uniform. In transition and emerging economies, including Hungary, the local gains from foreign-led manufacturing expansion depend on the depth of domestic linkages, the position of local actors in value chains, and the capacity of regions to absorb external knowledge (Halpern & Muraközy, 2007; García et al., 2022; Liu et al., 2022).

A more critical strand of the literature emphasizes that FDI-led industrialization may also generate uneven or limited upgrading. Foreign manufacturing projects can create employment and wage gains, but they may also reinforce dependent development, production-oriented specialization, weak domestic supplier integration, and limited local control over strategic functions. These concerns are particularly relevant in Central and Eastern Europe, where manufacturing expansion has often been closely linked to multinational production networks. From a home-country perspective, foreign investors may locate production in Hungary not only because of host-country advantages, but also to access the EU market, reduce supply-chain risks, and serve European automotive producers. Therefore, the regional outcomes of manufacturing expansion should be assessed cautiously rather than assumed to be automatically inclusive.

2.2. Battery-industry expansion and manufacturing deepening in Hungary

Battery manufacturing represents a new phase of manufacturing transformation in Hungary. The country's historical integration into the German automotive supply chain has facilitated its recent positioning as a major location for battery-cell, component, and related manufacturing investments. This development reflects both EU-level green industrial transformation and Hungary's national strategy to become a battery-industry hub. However, the battery industry is not spatially or functionally homogeneous. Battery and EV value chains are geographically concentrated and functionally differentiated, with some regions specializing in innovation-intensive activities and others in large-scale production and assembly (Ferloni et al., 2024).

In this paper, Hungary's battery-industry expansion is therefore treated as the substantive context in which regional manufacturing development is examined. The empirical analysis does not directly measure battery-specific employment, investment, or output. Instead, it uses regional manufacturing development intensity as a broader indicator of manufacturing deepening during the period in which battery-related investments have become increasingly important in Hungary's industrial strategy. This approach is also supported by previous evidence from Hungary showing dynamic interactions between manufacturing production and battery-industry exports, suggesting that battery-sector expansion is embedded in broader manufacturing dynamics (Yang, 2024).

2.3. Regional absorptive capacity and heterogeneous socioeconomic outcomes

The socioeconomic outcomes of manufacturing development are likely to vary across regions. The literature on absorptive capacity and regional innovation systems argues that local benefits from industrial expansion depend on existing stocks of human capital, R&D effort, institutional capability, and the quality of local linkages (Rodríguez-Pose & Bilbao-Osorio, 2004; Rodríguez-Pose & Crescenzi, 2008; Grillitsch & Nilsson, 2015). Regions with stronger innovation capacity may be better able to translate manufacturing deepening into wage upgrading and higher-value activities, whereas regions with weaker capabilities may experience more limited or production-oriented gains.

This framework suggests that employment, wage, and skill-composition outcomes should not be expected to move uniformly. Manufacturing deepening may increase compensation without necessarily generating broad-based employment growth or a higher tertiary-educated employment share. In this sense, regional innovation capacity may condition the relationship between manufacturing development intensity and socioeconomic outcomes. The empirical analysis therefore examines three outcomes—employment, compensation per employee, and the tertiary employment share—and tests whether human capital and R&D effort moderate these relationships.

3. Data and methodology

3.1. Data

The empirical analysis uses an annual EU27 NUTS2 regional panel for 2013–2022. Although Hungary is the substantive focus, Hungarian regions are embedded in the broader EU benchmark to provide a reference distribution and increase panel variation. All variables are compiled from Eurostat regional datasets and harmonized by region and year.

The study period is determined by the availability of comparable EU27 NUTS2 data. It captures the early phase of Hungary's battery-industry expansion and related manufacturing restructuring, rather than the full post-operation effects of all major battery investments. Since some projects were announced, constructed, or expanded near the end of the period, their labour-market effects may appear only with a time lag.

Three socioeconomic outcomes are analysed: total employment, compensation per employee, and the tertiary employment share. Employment and compensation are used in logarithms, while skill composition is measured as the share of tertiary-educated employment in total employment. The key explanatory variable is regional manufacturing development intensity (ManuDev), measured as the share of manufacturing employment (NACE Rev. 2 Section C) in total employment.

ManuDev is not interpreted as a direct measure of battery-sector employment, investment, or output. Rather, it captures the broader manufacturing intensity of regional economies during the period in which Hungary has increasingly positioned itself as a battery-industry hub. Accordingly, the results are interpreted as associations between regional manufacturing development intensity and socioeconomic outcomes, not as direct causal effects of battery-sector activity.
To test whether regional innovation capacity conditions the socioeconomic associations of manufacturing expansion, the analysis uses two moderators: human capital and gross domestic expenditure on R&D (GERD) per inhabitant. Both variables are standardised for the interaction analysis. Baseline controls include GDP per capita, population, population density, and unemployment. Table 1 reports the definitions and sources of all variables.

Table 1. Variable definitions and data sources

Abbrev.	Variable full name	Definition / construction	Unit	Source
Emp	Total employment	Total employed persons of all NACE activities	thousand persons	Eurostat LFS
Wage	Compensation per employee	Compensation per employee (all NACE activities)	EUR	Eurostat
Skill	Tertiary employment share	Employed (ISCED 5–8) / total employed	%	Eurostat LFS
ManuDev	Regional manufacturing development intensity	Manufacturing employment share (NACE C) / total	%	Eurostat LFS
HC	Human capital	Tertiary attainment	%	Eurostat
GERD	R&D expenditure	Total gross expenditure on R&D per inhabitant	EUR	Eurostat
GDPpc	GDP per capita	GDP per capita (Purchasing power standard) per inhabitant in percentage of the EU27 (from 2020) average	%	Eurostat
Pop	Population	Total population	persons	Eurostat
Dens	Population density	Persons per square kilometre	persons/km²	Eurostat
Unemp	Unemployment rate	Unemployment rate	%	Eurostat

Source: Own construction.

3.2. Methodology

To examine how regional manufacturing development intensity is associated with socioeconomic outcomes in the context of Hungary's battery-industry expansion, the paper applies a two-way fixed effects (TWFE) panel model. This approach exploits within-region changes over time while controlling for unobserved time-invariant regional heterogeneity and common year shocks.
The baseline specification is:

$$Y_{it} = \beta_1 ManuDev_{it} + X_{it}\gamma + \mu_i + \lambda_t + \varepsilon_{it} \qquad (1)$$

where Y_{it} denotes one of the outcomes (log employment, log compensation per employee, or tertiary employment share), ManuDev_it is regional manufacturing development intensity, X_{it} is the vector of controls, μ_i are region fixed effects, and λ_t are year fixed effects.
To test whether innovation capacity conditions the association between industrial expansion and socioeconomic outcomes, the following specification is estimated:

$$Y_{it} = \beta_1 ManuDev_{it} + \beta_2 Innov_{it} + \beta_3 (ManuDev_{it} \text{ x } Innov_{it})$$

$$+X_{it}\gamma + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where $Innov_{it}$ represents either standardised human capital or standardised R&D effort. The interaction coefficient β_3 indicates whether the marginal relationship between industrial development intensity and the outcome varies systematically with innovation capacity.
Moreover, to highlight Hungary within the EU benchmark, a heterogeneity specification is also estimated:

$$Y_{it} = \beta_1 ManuDev_{it} + \beta_2(ManuDev_{it} \text{ x } HU_i) + X_{it}\gamma + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where HU_i is an indicator for Hungarian regions. Because HU_i is time-invariant, it is absorbed by region fixed effects, but the interaction term remains identified.
Table 2 reports descriptive statistics for the EU27 NUTS2 panel over 2013–2022. The variables display substantial cross-regional variation, while GERD has more limited coverage, reducing the effective sample size in some interaction models. For descriptive purposes, percentage-based variables are reported in percentage terms in Table 2. In the regression analysis, share variables such as ManuDev and the tertiary employment share are expressed as shares ranging from 0 to 1.

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Emp	2,412	787.98	680.42	13.8	5578.4
Wage	2,370	33,597.64	14,521.18	5,100	80,800
Skill	2,388	29.86	9.58	11.4	62.1
ManuDev	2,357	18.04	7.67	3.26	43.16
HC	2,380	29.80	9.53	11.4	62.1
GERD	1,585	457.20	596.77	4.16	5,776.65
GDPpc	2,369	94.48	37.24	27	282
Pop	2,420	1,840,384	1,610,715	28,501	1.24e+07
Dens	2,397	346.91	849.12	3	7,660
Unemp	2,385	8.67	6.19	1.2	36.2

Source: Own construction.

4. Empirical analysis

This section presents the empirical results on the associations between regional manufacturing development intensity and its socioeconomic outcomes. Using the two-way fixed effects framework introduced in Section 3, the analysis proceeds in three steps. First, it estimates the baseline association between ManuDev and regional labour-market outcomes. Second, it examines whether these relationships vary with regional innovation capacity. Third, it benchmarks Hungarian regions against the broader EU27 distribution.

4.1. Employment outcomes

Total employment is measured as the logarithm of total employed persons (ln_emp), and ManuDev is defined as the manufacturing employment share (NACE Rev.2 C) in total employment at the NUTS2 level. All models include region fixed effects and year fixed effects, with standard errors clustered at the NUTS2 level. Results are reported in Table 3.
Before turning to the regression estimates, it is useful to position Hungary within the EU benchmark. Over 2013–2022, Hungarian NUTS2 regions display substantially higher manufacturing development intensity than non-Hungarian EU regions. The average value of ManuDev is 0.253 for Hungary, compared with 0.178 for the others, consistent with Hungary's increasingly manufacturing-intensive development path. As shown in Figure 1, Hungarian regions also exhibit a visibly higher distribution of ManuDev relative to the EU benchmark.

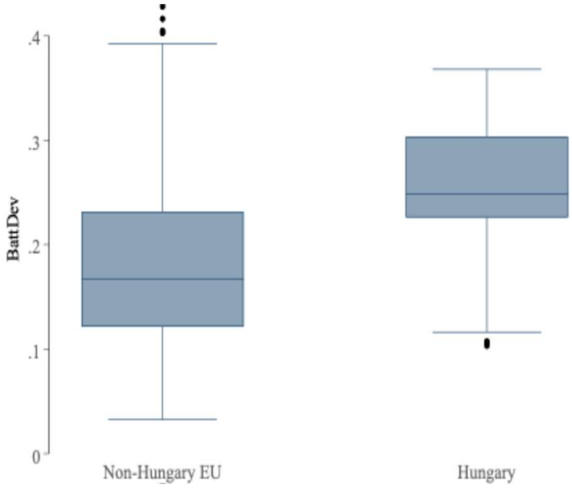

Figure 1. ManuDev distribution: Hungary vs non-Hungary EU regions (2013–2022)
Source: Own construction.

In the baseline specification shown in Column (1), ManuDev is negatively and significantly associated with total employment. In magnitude, a 0.10 increase in ManuDev, equivalent to a 10 percentage-point increase in the manufacturing employment share, is associated with approximately a 3.2% lower employment level in the baseline model. This suggests that rising regional manufacturing development intensity does not automatically translate into net employment expansion at the regional level. After introducing regional controls in Column (2), the coefficient on ManuDev remains negative but weakens in magnitude and statistical significance. This indicates that part of the baseline relationship reflects broader regional economic and demographic dynamics rather than a stable net job-creation effect of manufacturing development intensity.

Columns (3) and (4) test whether innovation capacity conditions the ManuDev–employment relationship. Human capital is positively related to employment, but the interaction term ManuDev × HC is statistically insignificant. Likewise, neither the main effect of GERD nor the interaction ManuDev × GERD is statistically significant. These results suggest that innovation capacity does not materially alter the employment association of regional manufacturing development intensity in the sample period.

Finally, Column (5) benchmarks Hungary against the broader EU27 distribution through the interaction ManuDev × Hungary. The interaction term is statistically insignificant, indicating that the within-region employment association of ManuDev does not differ significantly between Hungarian regions and the broader EU benchmark.

Taken together, the employment results provide limited support for a regional "job creation dividend" associated with rising regional manufacturing development intensity during 2013–2022. The ManuDev coefficient is negative and significant in the baseline specification, but the magnitude and statistical strength weaken after accounting for regional economic conditions and become indistinguishable from zero in the interaction models. These patterns are consistent with an interpretation in which manufacturing development in the context of Hungary's battery-industry expansion coincides with structural reallocation and increasingly capital-intensive production dynamics rather than broad-based net employment expansion. At the same time, this interpretation should remain cautious. The weak employment relationship may also be consistent with alternative mechanisms, including demographic change, sectoral crowding-out, broader regional restructuring, or measurement limitations associated with aggregate manufacturing employment shares.

Table 1. Employment outcomes and regional manufacturing development intensity

Variables	(1) Baseline FE	(2) + Controls	(3) + HC interaction	(4) + GERD interaction	(5) + Hungary interaction
ManuDev	-0.323** (0.158)	-0.173* (0.098)	-0.098 (0.100)	-0.080 (0.112)	-0.177* (0.101)
HC			0.027** (0.013)		
ManuDev × HC			0.000 (0.067)		
GERD				0.001 (0.008)	
ManuDev × GERD				0.026 (0.041)	
ManuDev × Hungary					0.094 (0.367)
ln GDPpc		0.080*** (0.025)	0.076*** (0.024)	0.110*** (0.031)	0.081*** (0.025)
ln Pop		0.851*** (0.128)	0.784*** (0.128)	0.771*** (0.141)	0.852*** (0.129)
ln Dens		0.270*** (0.057)	0.271*** (0.067)	0.321*** (0.082)	0.270*** (0.057)
Unemp		-0.01170*** (0.00070)	-0.01153*** (0.00069)	-0.01214*** (0.00070)	-0.01170*** (0.00070)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	2,357	2,281	2,277	1,528	2,281
Regions (NUTS2)	240	232	232	218	232

Notes: Coefficients reported with standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.
Source: Own construction.

4.2. Wage upgrading outcomes

Wage upgrading is proxied by compensation per employee, expressed in logarithms (ln_wage). All specifications follow the two-way fixed effects framework with region and year fixed effects, and standard errors clustered at the NUTS2 level. Results are reported in Table 4.

Table 2. Wage outcomes and regional manufacturing development intensity

Variables	(1) Baseline FE	(2) + Controls	(3) + HC interaction	(4) + GERD interaction	(5) + Hungary interaction
ManuDev	0.632** (0.285)	0.212 (0.180)	0.205 (0.189)	0.114 (0.241)	0.201 (0.188)
HC			-0.087*** (0.025)		

ManuDev × HC			0.445*** (0.117)		
GERD				-0.066*** (0.024)	
ManuDev × GERD				0.318*** (0.120)	
ManuDev × Hungary					0.273 (0.456)
ln GDPpc		0.758*** (0.120)	0.749*** (0.121)	0.990*** (0.065)	0.759*** (0.120)
ln Pop		-0.534** (0.260)	-0.335 (0.288)	-0.050 (0.283)	-0.532** (0.261)
ln Dens		0.032 (0.170)	-0.013 (0.228)	0.054 (0.258)	0.030 (0.170)
Unemp		0.00923*** (0.00154)	0.00843*** (0.00152)	0.00778*** (0.00144)	0.00923*** (0.00154)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	2,324	2,281	2,277	1,528	2,281
Regions (NUTS2)	234	232	232	218	232

Notes: Coefficients reported with standard errors in parentheses. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Source: Own construction.

In the baseline model, ManuDev is positively and significantly associated with compensation per employee. In magnitude, a 0.10 increase in ManuDev is associated with approximately a 6.3% higher compensation per employee in the baseline model. This indicates that regions experiencing increases in regional manufacturing development intensity also tend to record stronger wage dynamics over time.

Once regional controls are included in Column (2), the ManuDev coefficient remains positive but becomes statistically insignificant. This attenuation suggests that part of the baseline wage association reflects broader regional development conditions rather than a uniform unconditional effect of manufacturing intensity alone.

The interaction specifications reveal a more differentiated pattern. In Column (3), the interaction term ManuDev × HC is positive and highly significant, indicating that the wage association of manufacturing development intensity is stronger in regions with higher human capital. However, the negative main coefficient of HC should be interpreted cautiously, as it is estimated in an interaction specification with region and year fixed effects. In this setting, the substantive interpretation should focus on the interaction term, which indicates that the ManuDev–wage association becomes stronger in regions with higher human capital. In Column (4), the interaction ManuDev × GERD is also positive and significant, suggesting that regions with stronger R&D effort obtain larger compensation gains from increases in ManuDev. These findings are consistent with an absorptive-capacity mechanism, according to which innovation-capable regions are better able to translate industrial expansion into higher wages.

To visualise the interaction effect, Figure 2 plots the marginal effect of regional manufacturing development intensity on regional compensation across the observed range of human capital. The figure shows that the wage association of ManuDev strengthens monotonically with human capital and becomes clearly positive in more human-capital-rich regions.

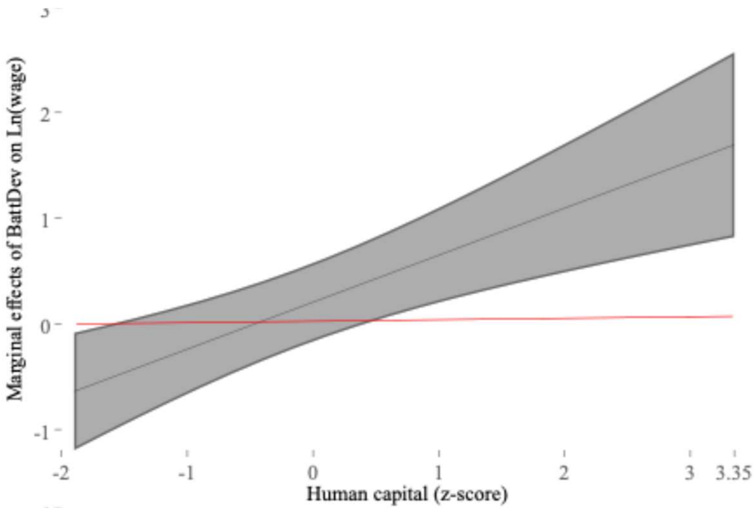

Figure 2. Marginal effect of ManuDev on ln(wage) across EU regional human capital (2013–2022)

Notes: The figure reports average marginal effects of ManuDev on ln(wage) estimated from the two-way fixed effects model with controls and year fixed effects (Table 4, human-capital interaction specification). Shaded areas denote 95% confidence intervals; the horizontal dashed line marks zero effect.

Source: Own construction.

The Hungary interaction reported in Column (5) is positive but statistically insignificant, indicating that the wage relationship between ManuDev and compensation does not differ systematically between Hungarian regions and the broader EU benchmark.

Overall, the wage results provide clearer evidence of upgrading than the employment results. While the unconditional association weakens after controls are included, both human capital and R&D significantly strengthen the ManuDev–wage relationship. This suggests that compensation gains from manufacturing development intensity are more pronounced in innovation-capable regions.

4.3. Skill composition outcomes

Skill composition is measured by the share of tertiary-educated employed persons (ISCED 5–8) in total employment at the NUTS2 level. All models include region and year fixed effects, and standard errors are clustered at the NUTS2 level. Results are reported in Table 5.

Table 3. Skill-composition outcomes and regional manufacturing development intensity

Variables	(1) Baseline FE	(2) + Controls	(3) + GERD interaction	(4) + Hungary interaction
ManuDev	-0.292*** (0.044)	-0.267*** (0.040)	-0.211*** (0.046)	-0.257*** (0.040)
GERD			0.015** (0.006)	
ManuDev × GERD			-0.074** (0.032)	
ManuDev × Hungary				-0.233 (0.260)

ln GDPpc		0.011 (0.010)	0.013 (0.012)	0.011 (0.010)
ln Pop		0.308*** (0.059)	0.276*** (0.062)	0.306*** (0.059)
ln Dens		-0.060 (0.051)	-0.011 (0.054)	-0.058 (0.052)
Unemp		-0.000992*** (0.000324)	-0.001075*** (0.000320)	-0.000996*** (0.000324)
Year fixed effects	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes
Observations	2,353	2,277	1,528	2,277
Regions (NUTS2)	240	232	218	232

Notes: Coefficients reported with standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.10.

Source: Own construction.

In the baseline specification, ManuDev is negatively and significantly associated with the tertiary employment share. This indicates that increases in manufacturing development intensity are accompanied by a decline in the regional share of tertiary-educated employment. After controlling for regional economic and demographic conditions in Column (2), the coefficient remains negative and highly significant, suggesting that the result is not mainly driven by contemporaneous co-movement with income, population, density, or labour-market slack.

To examine whether innovation capacity conditions this relationship, Column (3) introduces an interaction with GERD. The coefficient on ManuDev remains significantly negative, while GERD itself is positively associated with the tertiary employment share. However, the interaction ManuDev × GERD is negative and significant, implying that the negative association between manufacturing intensity and the tertiary employment share becomes more pronounced in more R&D-intensive regions.

A plausible interpretation is compositional. Regions with stronger innovation capacity may still experience manufacturing expansion through production-oriented job creation, which increases total employment faster than tertiary-intensive employment and thereby lowers the tertiary share. In this sense, wage upgrading and tertiary-share upgrading do not necessarily move together.

The Hungary interaction in Column (4) is statistically insignificant. Thus, although Hungary exhibits higher average manufacturing development intensity, the within-region relationship between changes in ManuDev and changes in skill composition does not differ significantly from the broader EU benchmark.

To sum up, the skill results contrast with the wage findings. ManuDev is consistently associated with a lower tertiary employment share, suggesting that manufacturing expansion is linked more closely to production-oriented employment growth than to a systematic increase in the tertiary employment share. The negative GERD interaction further indicates that this compositional pattern can persist even in innovation-oriented regions.

5. Discussion

5.1. Uneven patterns of regional upgrading

The results point to a differentiated pattern of regional socioeconomic associations linked to manufacturing development intensity in the context of Hungary's battery-industry expansion. There is little evidence of a robust regional employment dividend. Although the baseline employment specification shows a negative and significant association between ManuDev and total employment, this relationship weakens after regional controls are included and becomes statistically indistinguishable from zero in the extended models. This suggests that rising manufacturing intensity is better interpreted as part of structural reallocation and increasingly capital-intensive production than as a source of broad-based net job creation.

Wage upgrading emerges more clearly than employment expansion. ManuDev is positively associated with compensation per employee in the baseline model, and the broader pattern suggests that manufacturing deepening is linked to stronger income dynamics. However, the tertiary employment share does not increase in parallel. Instead, ManuDev is consistently associated with a lower tertiary employment share, indicating that manufacturing expansion is more closely linked to production-oriented employment growth than to a systematic increase in tertiary-intensive employment. Thus, upgrading in the context of Hungary's battery-industry expansion appears partial and multidimensional, with compensation effects more visible than employment expansion or increases in the tertiary employment share.

5.2. Innovation capacity and interpretation limits

Innovation capacity mainly conditions wage outcomes. The positive interaction terms between ManuDev and both human capital and GERD suggest that regions with stronger innovation-related capabilities are better able to translate manufacturing expansion into compensation gains. This supports the absorptive-capacity argument: where skill endowments and innovation effort are stronger, industrial deepening is more likely to be associated with higher-value tasks, productivity gains, and improved wage-setting conditions (Rodríguez-Pose & Crescenzi, 2008; Grillitsch & Nilsson, 2015).

At the same time, the results should be interpreted cautiously. ManuDev captures regional manufacturing employment intensity rather than battery-specific employment or investment. The estimated associations therefore cannot be read as direct evidence of the socioeconomic effects of the battery sector alone. Instead, they show how manufacturing deepening during a period of battery-related industrial transformation is linked to regional employment, wage, and skill-composition outcomes. This distinction is important because manufacturing employment may also reflect automotive, electronics, machinery, and supplier activities.

6. Conclusion

This paper examined the association between regional manufacturing development intensity and socioeconomic outcomes in Hungary in the context of the country's battery-industry expansion, based on the EU27 NUTS2 regional panel over the period 2013–2022. Using a two-way fixed effects framework, it analysed how within-region changes in manufacturing intensity are associated with employment, compensation per employee, and the tertiary employment share, and whether these relationships vary with regional innovation capacity.

The findings reveal uneven regional socioeconomic outcomes. ManuDev is not robustly associated with employment expansion, while wage upgrading is more visible, especially in regions with stronger human capital and R&D effort. By contrast, increases in manufacturing intensity are associated with a lower tertiary employment share, suggesting that industrial expansion is linked more strongly to production-oriented employment growth than to a systematic increase in tertiary-intensive employment.

The policy implication is that manufacturing development in the context of battery-industry expansion should not be treated as an automatic mechanism of inclusive regional upgrading. Policies should go beyond investment attraction and strengthen local skill formation, R&D capacity, supplier linkages, and cooperation between foreign investors, domestic firms, and regional institutions. Without such complementary measures, the benefits may remain uneven and concentrated in wage dynamics or production-oriented activities.

The paper has several limitations. ManuDev is based on the manufacturing employment share and does not directly measure battery-specific employment, investment, output, or plant-level activity; therefore, the findings should be interpreted as associations during Hungary's battery-related manufacturing transformation rather than as isolated effects of battery-sector expansion. The use of aggregate NUTS2 indicators may also mask sectoral, firm-level, occupational, and worker-level differences, while limited regional R&D data reduce the effective sample size in some interaction models. Future research should use plant-level battery-specific data and case studies of major sites such as Göd and Debrecen, possibly combined with event-study designs around investment announcements or production start dates.

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