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COST STICKINESS IN CROATIAN MANUFACTURING SMES: EVIDENCE FROM PANDEMIC AND POST-PANDEMIC PERIODS

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Abstract

This study analyses asymmetric cost behaviour in 3,399 Croatian manufacturing SMEs from 2018 to 2024 using an extended Anderson–Banker–Janakiraman model within a two-way fixed-effects panel with firm-clustered standard errors. Total operating costs show clear stickiness ($\beta_2 = -0.165$, $p < 0.01$), rising by 0.70% for a 1% increase in revenue but falling by only 0.53% for an equivalent decrease. Material costs exhibit the strongest asymmetry ($\beta_2 = -0.214$, $p < 0.01$). Personnel costs do not display systematic stickiness ($\beta_2 = 0.015$, $p = 0.764$), suggesting that labour market factors such as minimum wage increases, emigration-related shortages, and eurozone accession shaped their dynamics independently of revenue changes. Larger SMEs show lower cost rigidity than smaller ones. Sectoral analysis indicates that labour-intensive industries have the highest stickiness, resource-intensive industries show near-symmetric behaviour, and capital-intensive industries fall in between.

Keywords: Cost stickiness, SMEs, Manufacturing, Croatia, COVID-19 pandemic

1. INTRODUCTION

Effective cost management is a critical determinant of business competitiveness and financial sustainability, and understanding the dynamics of cost behaviour enables managers and investors to make more informed decisions (Drury, 2018). Traditional cost accounting theory assumes a symmetrical response of costs to changes in activity volume – costs should fall at the same rate as they rise for equivalent changes in sales. However, this theoretical assumption systematically fails when confronted with empirical reality. Since the seminal work of Anderson et al. (2003) establishing the concept of cost stickiness, this phenomenon has subsequently been confirmed in various geographical and institutional contexts, with the degree of stickiness showing significant heterogeneity across countries, industries and firm size categories (Calleja et al., 2006; Chen et al., 2019).

Although extensive research on asymmetric cost behaviour in developed economies has established a robust theoretical framework encompassing adjustment cost theory, agency theory and managerial expectations theory (Banker & Byzalov, 2014; Chen et al., 2012), evidence from the Central and Eastern European region remains fragmentary. Existing studies suggest that CEE countries should exhibit higher stickiness than Anglo-American economies due to traditions of continental law, stakeholder-oriented governance, and stronger employment protection (Calleja et al., 2006; Prabowo et al., 2018). Nevertheless, systematic evidence from this region, particularly in the small and medium-sized enterprise segment, remains limited. At the same time, the literature consistently identifies manufacturing as an industry with significant cost asymmetry due to the high share of fixed assets and inventories creating rigid structures (Weiss, 2010), while SMEs exhibit different patterns of behaviour than large firms due to more flexible structures and shorter decision-making chains (Dalla Via & Perego, 2014).

This article contributes to the existing literature by analysing asymmetric cost behaviour in 3,399 Croatian manufacturing SMEs over the period 2018–2024, covering both the COVID-19 pandemic shock and the subsequent post-pandemic recovery. Specifically, we examine the existence and degree of stickiness in three key cost categories: total operating costs, material costs, and personnel costs. Using an extended Anderson–Banker–Janakiraman model within a two-way fixed-effects panel framework with firm size control, we provide a comprehensive analysis of cost stickiness in an economically turbulent environment encompassing the COVID-19 pandemic, post-pandemic recovery, and eurozone accession. Our findings reveal significant heterogeneity in stickiness across cost categories and manufacturing sectors classified by factor intensity – with material costs exhibiting the strongest asymmetry and personnel costs showing no systematic stickiness, contrary to established theoretical predictions – as well as a significant moderating role of firm size within the SME segment.

2. LITERATURE REVIEW

Costs are a fundamental element of corporate financial management, and their effective management directly determines the competitiveness and long-term sustainability of a business (Drury, 2018). Traditional cost accounting theory assumes a symmetrical response of costs to changes in activity volume, but empirical studies repeatedly show that this symmetry systematically fails in the real business environment (Anderson et al., 2003).

2.1. Theoretical basis of asymmetric cost behaviour

Anderson et al. (2003) established the concept of asymmetric cost behaviour by analysing 7,629 US companies over a 20-year period. They found that SG&A costs increase by 0.55% for every 1% increase in sales, but decrease by only 0.35% for an equivalent decrease – an asymmetry of 0.20 percentage points that contradicts the traditional assumption of proportional cost behaviour. Since then, cost stickiness research has expanded significantly across different contexts, countries, and cost categories, with systematic reviews documenting 80 research articles examining this phenomenon globally (Ibrahim et al., 2022).

Five complementary theories explain this phenomenon:

- Adjustment cost theory – managers rationally maintain unused resources because the costs of eliminating and reacquiring resources (severance pay, recruitment, training, asset disposal) exceed the benefits of short-term reductions. Banker et al. (2013) demonstrated that stricter employment protection significantly increases cost stickiness in 19 OECD countries.
- Agency theory – Chen et al. (2012) documented that empire-building managers add resources too quickly during growth and reduce them too slowly during downturns. Strong corporate governance can mitigate this stickiness.
- Managerial expectations theory – Banker & Byzalov (2014) showed that optimistic managers expecting temporary downturns maintain spare resources (stickiness), while pessimistic managers expecting a permanent decline aggressively cut back (anti-stickiness).
- Behavioural theory (prospect theory and bounded rationality) – Kahneman and Tversky (1979) demonstrated that losses are psychologically perceived as more painful than equivalent gains; consequently, managers tend to frame layoffs and asset disposals as losses and are reluctant to execute them even when economically rational, a pattern that directly corresponds to the asymmetric downward adjustment of costs when sales decline. Simon (1997) and Cyert and March (1963) further emphasised that bounded rationality and organisational inertia cause managers to rely on standard operating

procedures rather than optimal resource adjustment, thereby reinforcing cost rigidity in the face of declining demand.

- Resource-based view (RBV) – Barney (1991) and Penrose (1959) argue that firms retain rare, inimitable resources because releasing them would destroy competitive advantage; adjustment costs represent only one component of this reluctance – the other is the strategic value embedded in the resources themselves. Balakrishnan and Gruca (2008) empirically demonstrated that costs associated with core competency activities exhibit significantly higher stickiness than costs in peripheral support areas, while Venieris et al. (2015) confirmed that firms with high organisational capital display greater SG&A cost stickiness, corroborating the RBV prediction that strategically valuable resources are particularly resistant to reduction.

Collectively, these five theoretical perspectives form a comprehensive explanatory architecture for asymmetric cost behaviour. Adjustment cost theory, agency theory, and managerial expectations theory constitute the established triangular foundation of the field (Banker & Byzalov, 2014; Chen et al., 2012), while behavioural theory and the resource-based view extend this foundation by incorporating the dimensions of cognitive limitations and strategic resource value, respectively. Although each theory emphasises different mechanisms, all five converge on the prediction that managers will hesitate to reduce resources when sales decline – yet the relative weight of each mechanism varies systematically with industry context, firm size, and institutional environment (Kahneman & Tversky, 1979; Barney, 1991). This theoretical pluralism underscores the importance of contextualised empirical investigation and motivates the multi-period, panel-based design adopted in the present study.

2.2. Determinants of asymmetric cost behaviour

Asymmetric cost behaviour is not a homogeneous phenomenon, but is systematically influenced by a wide range of factors, including firm characteristics, institutional arrangements, industry specifics and managerial decision-making processes (Chen et al., 2019). Empirical research has identified three main categories of determinants: structural factors related to capital intensity and firm size, financial factors including indebtedness and resource constraints, and behavioural factors reflecting managerial expectations and agency problems (Banker & Byzalov, 2014; Chen et al., 2012).

2.2.1. Firm size and capital intensity

Calleja et al. (2006) found that larger firms exhibit higher levels of asymmetric cost behaviour due to more complex structures, formal contracts and a higher proportion of fixed costs. Total assets serve a dual purpose in the models

– as a control variable and as a moderator through asset intensity (total assets/sales), which consistently predicts greater stickiness.

2.2.2. Specifics of SMEs

Dalla Via and Perego (2014) analysed Italian SMEs and found asymmetric cost behaviour only in labour costs, not in SG&A or COGS – in sharp contrast to the findings for large firms. SMEs have more flexible cost structures, shorter decision-making chains and fewer formal contracts, allowing for faster adjustments. Özkaya (2021) confirmed for Turkish SMEs across industries that asymmetric cost behaviour is positively associated with asset and employee intensity, while debt intensity is negatively associated with stickiness of total costs and cost of goods sold. Financial constraints reduce cost stickiness, as financially constrained firms adjust costs more aggressively when sales decline (Costa et al., 2021).

Among the macroeconomic and institutional determinants of cost stickiness, statutory minimum wage adjustments occupy a particularly important position. Survey evidence from eight CEE countries provided by Bodnár et al. (2018) reveals that firms respond to minimum wage increases primarily by raising output prices and reducing non-labour costs rather than through workforce reductions, implying that personnel costs remain rigid even when business activity declines. This finding is corroborated by Argilés-Bosch et al. (2023), who demonstrated on Spanish data that the liberalisation of labour legislation significantly reduces labour cost stickiness – a result that, by analogy, implies that tighter wage regulation, such as mandatory minimum wage increases, reinforces cost rigidity. The employment protection dimension of this mechanism is well established in the cross-country evidence of Banker et al. (2013). In the Croatian context of the period under investigation (2018–2024), several substantial minimum wage increases were legislated, which may have structurally reinforced the rigidity of personnel costs – particularly in labour-intensive segments of the manufacturing sector.

2.3. Asymmetric cost behaviour in the manufacturing industry

Manufacturing firms exhibit particularly pronounced asymmetric cost behaviour due to the high proportion of fixed assets and inventories that create rigid structures. The capital-intensive nature of manufacturing implies significant incremental costs – liquidation expenses, installation costs, losses from firm-specific investments (Weiss, 2010).

With respect to cost categories, COGS often exhibits stronger stickiness than SG&A in manufacturing. Labour costs show the most persistent stickiness – Golden et al. (2020) found that a one standard deviation increase in their Labor Skill Index is associated with 4.2 basis points of additional cost stickiness.

Regarding digital transformation, research from China (2011–2020) demonstrates that digital transformation significantly reduces cost stickiness by lowering adjustment costs and alleviating managerial over-optimism (Chen & Xu, 2023). Paradoxically, however, firm-level robot use increases labour cost stickiness, as robots shift the workforce towards more skilled positions with higher adjustment costs (Voshaar et al., 2022).

The manufacturing sector, however, is far from homogeneous, and research points to systematic differences in cost stickiness across labour-intensive, capital-intensive, and raw-material-intensive sub-industries. Anderson et al. (2003) and Özkaya (2021) demonstrated that asset intensity and employee intensity are the principal structural predictors of stickiness, implying that labour-intensive sub-sectors – such as textiles, clothing and food processing – will exhibit higher personnel cost stickiness, whereas capital-intensive sub-sectors – such as chemicals and automotive manufacturing – will display greater stickiness in depreciation charges and total operating costs. Subramaniam and Weidenmier (2016) confirmed that cost of goods sold is sticky for manufacturing but not for trading firms, and that the magnitude of stickiness varies systematically with the industry's cost structure. The international comparative evidence of Calleja et al. (2006) further underscores that institutional and sectoral factors interact in shaping stickiness patterns. Accordingly, an aggregate analysis of the entire manufacturing sector may obscure these within-sector heterogeneities, and the results reported in the present study should be interpreted as reflecting an average across a diverse group of firms with potentially divergent cost behaviour profiles.

2.4. The context of Central and Eastern Europe and asymmetric cost behaviour

Calleja et al. (2006) found that costs across their pooled four-country sample (US, UK, France, Germany) increase by 0.97% for every 1% increase in revenue but decrease by only 0.91% for an equivalent decline. Importantly, French and German firms exhibited significantly higher stickiness than their US and UK counterparts, a difference the authors attribute to continental law traditions, stakeholder-oriented governance, and stronger employment protection. This suggests that CEE countries, sharing similar institutional characteristics, should exhibit cost stickiness patterns closer to the French and German levels than to the Anglo-American ones. Prabowo et al. (2018) analysed 22 European countries and found that state-owned enterprises exhibit greater wage stickiness, which intensifies in election years and under left-wing governments. For CEE countries with a legacy of state-owned enterprises, this suggests structural sources of stickiness beyond economic considerations. Musil & Kocmanova (2025) documented that during COVID-19, SMEs in the Czech Republic, Slovakia and Poland (2018–2022) exhibited high stickiness, with company size significantly influencing cost behaviour patterns. Pervan and Pervan (2012) analysed approximately 334 firms per year (2,678 total firm-year observations) of Croatian

food industry companies (2003–2010). Material and labour costs increase by 0.85% for every 1% increase in sales, but decrease by only 0.68% for every 1% decrease. While the overall cost elasticities are notably higher than those reported for the United States (0.55%/0.35%; Anderson et al., 2003) and Brazil (0.59%/0.32%; De Medeiros & Costa, 2004), the degree of asymmetry (0.17 percentage points) is actually lower than in both the American (0.20 p.p.) and Brazilian (0.27 p.p.) contexts, suggesting that Croatian food industry companies exhibited relatively more symmetric cost behaviour despite higher overall cost responsiveness to sales changes.

Škuflić and Novinc (2024) offer a complementary perspective on the cost environment of the Croatian manufacturing industry. Using panel data from the Orbis database, they show that the relationship between unit labour costs and sales is heterogeneous across sectors of the Croatian manufacturing industry, with more productive firms exhibiting lower sensitivity of sales to changes in these costs and firms with a higher share of labour costs being more sensitive. These findings have direct implications for research on asymmetric cost behaviour, as a higher share of labour costs in a firm's cost structure simultaneously increases the rigidity of these costs when demand falls – laying off skilled employees generates adjustment costs in the form of severance pay, loss of firm-specific human capital and future recruitment costs (Anderson et al., 2003; Banker et al., 2013). Similarly, Tomas Žiković et al. (2024) confirmed on a sample of Croatian companies that internal company characteristics, including cost efficiency, are stronger predictors of profitability than external macroeconomic conditions, which corresponds to the theory of adjustment costs, according to which managers' decisions to adjust resources reflect internal motives and barriers rather than external demand shocks (Banker & Byzalov, 2014).

2.5. Methodological evolution in cost stickiness research

The methodological foundations of cost stickiness research were established by Anderson et al. (2003), who applied pooled cross-sectional ordinary least squares (OLS) estimation with a piecewise log-log specification – regressing the logarithmic change in costs on the logarithmic change in revenue and an interaction term capturing downward sales movements. While this approach constituted a significant methodological advance, it is subject to several well-documented limitations. Pooled OLS ignores serial correlation of residuals within firms across time, resulting in underestimated standard errors and inflated test statistics. Furthermore, the estimation is vulnerable to omitted variable bias arising from unobserved firm-level heterogeneity: time-invariant firm characteristics correlated with both cost levels and revenue dynamics – such as management quality, organisational culture or technology endowments – are absorbed into the error term, biasing the slope estimates. Balakrishnan et al. (2004) further highlighted that capacity utilisation, typically unobserved in

archival datasets, constitutes a material omitted variable that may confound the estimated degree of stickiness.

Subsequent methodological development sought to address these shortcomings through a variety of approaches. Weiss (2010) departed from regression-based coefficient estimation and instead developed a firm-level measure of cost stickiness defined as the difference between the cost-to-revenue ratio in periods of falling versus rising revenue, thereby enabling firm-specific characterisation without imposing a common slope across the sample. Chen et al. (2012) introduced instrumental variable (IV) approaches to address the potential endogeneity inherent in the revenue–cost relationship: rigid cost structures, particularly in capital- and labour-intensive firms, may themselves constrain pricing flexibility and output decisions, so that past cost behaviour feeds back into current revenue realisations. This reverse causality implies that revenue changes cannot be treated as strictly exogenous regressors in the standard OLS framework, and IV estimation using lagged revenue as an instrument provides a partial remedy.

The field's methodological consensus was substantially advanced by Banker and Byzalov (2014), who formally demonstrated that pooled OLS estimation of the ABJ model suffers from omitted variable bias and provided theoretical and simulation-based evidence in favour of firm fixed effects combined with year fixed effects as the preferred estimation strategy. Firm fixed effects absorb all time-invariant unobserved heterogeneity, while year fixed effects control for macroeconomic shocks common to all firms in a given year – such as business cycle fluctuations, changes in interest rates, or economy-wide demand shifts. The necessity of this two-way approach was further validated in an international panel context by Banker et al. (2013), who applied country and year fixed effects across 19 OECD countries to isolate the effect of employment protection legislation from confounding country-level characteristics. Independently, Petersen (2009) demonstrated through Monte Carlo simulation that panel datasets in corporate finance and accounting typically exhibit both firm-level and time-level clustering of residuals, and that failure to cluster standard errors at the firm level leads to severe underestimation of coefficient standard errors and corresponding over-rejection of null hypotheses.

In line with the methodological recommendations of Banker and Byzalov (2014) and the best-practice standards identified in the systematic literature review by Ibrahim et al. (2022), the present study employs a two-way fixed effects panel regression framework incorporating both firm fixed effects and year fixed effects, with standard errors clustered at the firm level. This specification controls simultaneously for unobserved time-invariant firm characteristics – such as managerial style, ownership structure, or technology endowment – and for macroeconomic shocks affecting all firms uniformly within a given year, including pandemic-related demand disruptions and post-pandemic inflationary pressures. By addressing the principal sources of bias identified in the prior methodological literature, this approach yields more reliable and

conservative estimates of the degree of asymmetric cost behaviour in Croatian manufacturing SMEs than would be obtainable through pooled OLS.

Based on the literature review, the following hypotheses were established:

H1: The total operating costs of Croatian manufacturing SMEs show significant signs of asymmetric cost behaviour, i.e. they increase more when sales increase than they decrease when sales decrease by an equivalent amount ($\beta_2 < 0$).

Anderson et al. (2003) demonstrated the existence of stickiness in aggregate costs. Total operating costs include a combination of cost components with varying degrees of flexibility, with adjustment costs associated with resource reduction during sales declines motivating managers to maintain part of their capacity (Banker & Byzalov, 2014). In the context of Croatian SMEs, we expect stickiness due to rigid labour regulations, a shortage of skilled workers, and managerial optimism associated with economic growth following EU accession (Pervan & Pervan, 2012).

H2: The material costs of Croatian manufacturing SMEs show significant signs of asymmetric cost behaviour ($\beta_2 < 0$).

Material costs in the manufacturing industry include not only direct input materials but also inventories that firms maintain as a buffer against fluctuations in demand. Although material costs are traditionally considered relatively variable, empirical evidence suggests asymmetry due to: (1) long-term supply contracts with minimum purchase requirements, (2) storage costs versus urgent order costs, (3) anticipation of future demand growth (Pervan & Pervan, 2012). Pervan and Pervan (2012) also confirmed material stickiness in Croatian food industry companies with a revenue elasticity of approximately 0.85 and an asymmetry coefficient of approximately -0.17.

H3: The personnel costs of Croatian manufacturing SMEs show significant signs of asymmetric cost behaviour ($\beta_2 < 0$).

Personnel costs are the most persistent source of stickiness across all studies and contexts (Golden et al., 2020; Dalla Via & Perego, 2014). Reasons include: (1) high dismissal costs (severance pay, legal procedures), (2) costs of losing firm-specific human capital, (3) costs of future recruitment and training, (4) impact on the morale of remaining employees, (5) social and political pressure to avoid layoffs. In the Croatian context, the Labour Code requires written contracts, severance pay after 2 years, 42 days of sick leave paid by the employer, and strong collective bargaining, which creates significant adjustment barriers (Prabowo et al., 2018; Banker et al., 2013).

H4: The depreciation and amortisation costs of Croatian manufacturing SMEs show significant signs of asymmetric cost behaviour ($\beta_2 < 0$).

Depreciation and amortisation represent committed costs arising from past capital investment decisions and are therefore expected to exhibit the strongest degree of stickiness among all cost categories (Anderson et al., 2003;

Banker & Byzalov, 2014). Once tangible and intangible assets are acquired, depreciation charges continue regardless of short-term fluctuations in output and sales. In manufacturing firms, machinery, production equipment and technology represent substantial sunk commitments whose disposal during revenue downturns would entail significant transaction costs and irreversible loss of productive capacity (Banker et al., 2013). Moreover, managers facing temporary demand declines are reluctant to dispose of specialised assets because replacement costs upon demand recovery would be considerably higher than the savings from divestment (Prabowo et al., 2018). In Croatian manufacturing SMEs, where EU-funded investment programmes and tax incentives have encouraged capital deepening in recent years, the stock of committed fixed assets is expected to reinforce asymmetric cost behaviour through the depreciation channel. Additionally, Croatian accounting standards prescribe systematic depreciation methods (predominantly straight-line) that are insensitive to short-term revenue changes, further contributing to the rigidity of this cost component (Golden et al., 2020; Dalla Via & Perego, 2014).

H5: The other operating costs of Croatian manufacturing SMEs show significant signs of asymmetric cost behaviour ($\beta_2 < 0$).

Other operating costs encompass a heterogeneous mix of cost items – including external services, energy, maintenance, rent, insurance, logistics, and administrative expenses – that vary in their degree of flexibility and contractual commitment. Although individually some of these items may appear discretionary, empirical evidence suggests that in aggregate they exhibit asymmetric behaviour due to several reinforcing mechanisms: (1) multi-period contractual obligations with external service providers that cannot be terminated without penalties (Banker et al., 2013), (2) energy costs with fixed capacity charges and minimum consumption thresholds that do not decrease proportionally with output (Anderson et al., 2003), (3) maintenance programmes that managers prefer to sustain during downturns to preserve asset reliability and avoid costly breakdowns upon recovery, and (4) managerial empire-building and reluctance to reduce overhead spending that signals organisational contraction (Chen et al., 2012). In the context of Croatian manufacturing SMEs, other operating costs are further rigidified by the reliance on outsourced logistics and specialised services where the supplier market is thin and switching costs are high (Pervan & Pervan, 2012). The composite nature of this category means that even if individual sub-components show limited stickiness, the aggregate effect is expected to be significantly asymmetric due to the cumulative impact of multiple small adjustment frictions.

3. RESEARCH METHODOLOGY

3.1. The data sample

Data for the research on asymmetric cost behaviour was collected from the Orbis Europe database. The following filters were applied in the data collection process:

- Geographical scope – companies legally domiciled in Croatia were selected.
- Sectoral classification – entities assigned NACE Rev. 2 codes corresponding to manufacturing activities (Section C, divisions 10–33) were selected.
- Temporal coverage – companies with available financial data for the period 2018–2024 were selected.
- Firm size – only small and medium-sized enterprises (SMEs), as defined by EU Commission Recommendation 2003/361/EC, were retained.

Based on these filters, 3,399 companies from Croatia were selected to form the data sample for this research, yielding a maximum of 20,394 firm-year observations across the six-year observation window.

The data are organised in a data matrix containing the following information: company identifier, company name, company size category, turnover (revenue), EBIT, material costs, personnel costs, depreciation and amortisation, and total assets. To mitigate the influence of extreme values and data entry errors inherent in commercial databases, all continuous variables were winsorised at the 1st and 99th percentiles prior to model estimation.

3.2. Transformation of variables and calculation of year-on-year changes

For research into asymmetric cost behaviour, total operating costs "TOC_n " are calculated, where "n" is the relevant period. These costs are calculated (Eq.1) as the difference between TURNOVER and EBIT.

$$TOC_n = TURNOVER_n - EBIT_n \quad (1)$$

where

- TOC_n is the Total operating costs of the nth year
- EBITn is the EBIT of the nth year
- TURNOVERn is the Turnover of the nth year.

Subsequently, year-on-year changes in all components entering the regression model are calculated – year-on-year changes are logarithmised. Logarithms allow for a direct interpretation of regression coefficients as elasticities, i.e. percentage changes in costs for a percentage change in sales (Anderson et al., 2003; Banker & Byzalov, 2014). This specification corresponds to the natural way of managerial thinking about the relationship between costs

and activities and at the same time addresses the heteroscedasticity typical of financial data from companies of different sizes (Weiss, 2010). The log-log transformation also converts multiplicative relationships to additive ones, which allows the use of standard OLS regression while maintaining an economically meaningful interpretation (Calleja et al., 2006).

To calculate year-on-year changes in individual economic variables, a general equation (Eq.2) is used, which expresses the logarithmic year-on-year change in a general economic variable ("EV")

$$\Delta \ln(EV_{t,t-1}) = \ln(EV_t) - \ln(EV_{t-1}) \quad (2)$$

where

- $\Delta \ln(EV_{t,t-1})$ = difference in economic variable (natural logarithm) between years t and t-1
- $\ln(EV_t)$ = natural logarithm economic variable in year t
- $\ln(EV_{t-1})$ = natural logarithm economic variable in year t-1

This transformation is applied to the following economic variables: (i) total operating costs, (ii) turnover, (iii) material costs, (iv) personnel costs, (v) depreciation and amortisation, and (vi) other operating and personnel costs.

3.3. Basic form of the regression model

A regression model is used for the research – also referred to as the ABJ model (Anderson et al., 2003), whose basic specification (Eq. 3) includes year-on-year changes in the cost component (explained variable), year-on-year changes in sales (explaining variable) and a dummy variable that takes the value 1 in the event of a year-on-year decline in sales.

$$\Delta \ln(C_{i,t,t-1}) = \beta_0 + \beta_1 \Delta \ln(R_{i,t,t-1}) + \beta_2 DEC_{i,t,t-1} \cdot \Delta \ln(R_{i,t,t-1}) + \varepsilon \quad (3)$$

where

- $\Delta \ln(C_{i,t,t-1}) = \ln(C_{i,t}) - \ln(C_{i,t-1})$ = logarithmic change in costs
- $\Delta \ln(R_{i,t,t-1}) = \ln(R_{i,t}) - \ln(R_{i,t-1})$ = logarithmic change in revenues (Turnover)
- $DEC_{i,t}$ = 1 if $\Delta \ln(R_{i,t,t-1}) < 0$ and 0 otherwise
- Regression coefficient:
- β_0 = constant, intercept
- β_1 = cost elasticity with respect to revenue increases
- β_2 = coefficient measuring the degree of cost stickiness
- ε = error term

Although the basic model by Anderson et al. (2003) provides a robust framework for measuring cost stickiness, a literature review has identified a number of factors that systematically moderate the degree of cost asymmetry.

Ignoring these determinants can lead to omitted variable bias and misinterpretation of the observed stickiness (Banker & Byzalov, 2014).

Firm size, measured by total assets, is one of the most important structural determinants of cost behaviour, as evidenced by extensive empirical evidence. Calleja et al. (2006) explicitly tested the effect of firm size using total assets on samples from the US, the UK, France and Germany and found that larger firms exhibit significantly higher cost stickiness than smaller firms.

3.4. Extended form of the regression model

The baseline ABJ specification is estimated within a two-way fixed-effects (FE) panel framework that simultaneously incorporates firm-level fixed effects (αi) and year fixed effects (γt). Firm fixed effects absorb all time-invariant unobserved firm heterogeneity – including managerial style, organisational structure, contractual rigidity, and technological endowment – that could otherwise confound the stickiness estimate. Year fixed effects control for common macroeconomic shocks affecting all firms in a given period, such as business cycle fluctuations, aggregate demand shocks, or economy-wide regulatory changes. Standard errors are clustered at the firm level throughout, which accounts for within-firm serial correlation of residuals across years and yields inference that is robust to both heteroscedasticity and temporal dependence (Petersen, 2009). Estimation is performed in R using the *plm* package for panel fixed-effects estimation and the *sandwich* and *lmtest* packages for cluster-robust inference.

The extended panel model (Eq. 4) additionally controls for asset growth as a proxy for firm-level investment dynamics and size changes over time:

$$\Delta ln(C_{i,t,t-1}) = \alpha_i + \gamma_t + \beta_1 \cdot \Delta ln(R_{i,t}) + \beta_2 \cdot DEC_{i,t} \cdot \Delta ln(R_{i,t}) + \beta_3 \cdot DEC_{i,t} \cdot \Delta ln(R_{i,t}) \cdot \Delta ln(TOAS_{i,t}) + \varepsilon_{i,t} \quad (4)$$

where

- α_i = firm fixed effect
- γ_t = year fixed effect
- $\Delta \ln(C_{i,t,t-1}) = \ln(C_{i,t}) - \ln(C_{i,t-1})$ = logarithmic change in costs
- $\Delta \ln(R_{i,t,t-1}) = \ln(R_{i,t}) - \ln(R_{i,t-1})$ = logarithmic change in revenues (Turnover)
- $DEC_{i,t}$ = 1 if $\Delta \ln(R_{i,t,t-1}) < 0$ and 0 otherwise
- $\ln(TOAS_{i,t,t-1}) = \ln(TOAS_{i,t}) - \ln(TOAS_{i,t-1})$ = logarithmic change in total assets (asset growth)

Regression coefficient:

- β_0 = constant, intercept
- β_1 = cost elasticity with respect to revenue increases
- β_2 = coefficient measuring the degree of cost stickiness
- β_3 = interaction effect of asset growth on cost stickiness
- ε = error term

3.5. Sector Disaggregation

Established classifications of manufacturing industries by factor intensity include Lall (2000), who distinguished resource-based, low-technology (labour-intensive), medium-technology, and high-technology manufactures, and UNIDO (2013), which classifies sectors into 'early' (labour-intensive), 'middle' (resource-processing), and 'late' (capital-intensive) industries. Rather than imposing an external taxonomy, the present study classifies sectors based on the observed average cost structure of Croatian manufacturing SMEs in the sample, computed at the two-digit NACE level. This data-driven approach directly aligns the classification criterion with the dependent variables of the regression models. The resulting grouping is broadly consistent with the established taxonomies cited above. Aggregate analysis of the manufacturing sector risks masking substantial heterogeneity in cost structures across industries with fundamentally different production technologies (Banker & Byzalov, 2014; Weiss, 2010). To examine whether cost stickiness varies systematically with production factor intensity, firms are classified into three mutually exclusive groups based on the dominant cost component at the two-digit NACE sector level, computed as the average share of each cost category in total operating costs across the full observation period.

The classification procedure operates as follows. For each two-digit NACE division, three ratios are computed: personnel cost share (personnel costs / TOC), material cost share (material costs / TOC), and depreciation share (depreciation / TOC). Each sector is then assigned to the group corresponding to its highest-ranking cost component relative to the cross-sector distribution:

1) Labour-intensive sectors – divisions where the personnel cost share exceeds the 66th percentile of the sector-level distribution. Representative divisions: wearing apparel (NACE 14), leather products (15), furniture (31), and repair and installation of machinery (33). These sectors face the most direct exposure to minimum wage increases and labour shortages.

2) Resource-intensive sectors – divisions where the material cost share exceeds the 66th percentile. Representative divisions: food and beverages (10–11), wood products (16), paper (17), and basic metals (24). Cost adjustment in these sectors is shaped primarily by commodity market dynamics and supply contract flexibility.

3) Capital-intensive sectors – divisions where the depreciation share exceeds the 66th percentile, or where neither personnel nor material costs dominate. Representative divisions: chemicals (20), machinery and equipment (28), electrical equipment (27), and motor vehicles (29). The high proportion of sunk costs in fixed assets theoretically predicts pronounced mechanical stickiness.

4. RESEARCH RESULTS

4.1. Descriptive Statistics and Correlation Analysis

Table 1 presents descriptive statistics for the key variables for the full sample. The data comprise 20,375 firm-year observations for most variables.

Table 1 Descriptive statistics of variables

Variable	N	Mean	Median	SD	Min	Max
Δln(TOC)	20 394	0,039	0,043	0,330	−6,164	3,195
Δln(OPRE)	20 375	0,036	0,043	0,421	−7,519	4,700
Δln(MATE)	20 394	0,026	0,030	0,457	−6,481	5,437
Δln(STAFF)	20 367	0,059	0,062	0,330	−4,759	5,558
Δln(DEPRE)	20 298	0,052	0,020	0,767	−6,535	6,751
Δln(OOPI)	19 120	0,063	0,067	0,880	−8,344	10,187
ln(TOAS)	20 394	5,682	5,737	1,497	−2,409	10,040
D_DECR	20 394	0,424	0,000	0,494	0	1
INT_SALES_DECR	20 375	−0,110	0,000	0,286	−7,519	0

Source: own processing by authors.

The average logarithmic change in operating revenues (Δln OPRE) is positive (+0.036), reflecting overall nominal revenue growth during the period under study. The share of observations with revenue decline is 42.4% (mean of the dummy variable D_DECR = 0.424), indicating that nearly half of all firm-year observations recorded a year-on-year decline in revenues. Personnel costs exhibit the highest average growth (+0.059) and relatively the lowest variability (SD = 0.330), whereas other operating costs (OOPI) display the highest variability (SD = 0.880). Depreciation (DEPRE) has a median substantially lower than the mean (0.020 vs. 0.052), indicating a right-skewed distribution.

The average firm size in the sample is ln(TOAS) = 5.68, corresponding to total assets of approximately 294 000 EUR (e^5.68 ≈ 294).

Table 2 characterizes the sample structure by sector type.

Table 2 Sample structure by sector type

Sector type	Number of firms	Observations	Share with revenue decline (%)
Labour-intensive	1 277	7 662	44,2
Resource-intensive	1 314	7 884	40,5
Capital-intensive	808	4 848	42,6

Source: own processing by authors.

The labour-intensive sector exhibits the highest share of observations with declining revenues (44.2%), whereas the resource-intensive sector exhibits the lowest (40.5%). Differences in the shares of revenue declines reflect

differences in sectoral cyclical sensitivity – labour-intensive sectors (textiles, apparel, furniture) are more sensitive to demand fluctuations than resource-intensive sectors (food processing, paper, chemicals).

Table 3 Correlation matrix of key variables

	Δln TOC	**Δln OPRE**	**Δln MATE**	**Δln STAFF**	**INT_SD**	**ln TOAS**
Δln TOC	1,000	0,815	0,831	0,453	0,627	−0,017
Δln OPRE	0,815	1,000	0,700	0,338	0,812	−0,031
Δln MATE	0,831	0,700	1,000	0,254	0,535	−0,016
Δln STAFF	0,453	0,338	0,254	1,000	0,281	−0,008
INT_SALES_DECR	0,627	0,812	0,535	0,281	1,000	0,020
ln TOAS	−0,017	−0,031	−0,016	−0,008	0,020	1,000

(INT_SD = INT_SALES_DECR)

Source: own processing by authors.

The correlation matrix of the key variables (Table 3) shows that the logarithmic change in revenues (Δln OPRE) is most strongly correlated with Δln TOC (0.815) and Δln MATE (0.700), confirming a strong empirical relationship between revenues and these cost categories. The correlation of Δln OPRE with Δln STAFF (0.338) is substantially lower, suggesting a weaker link between personnel costs and short-term revenue changes. The interaction variable INT_SALES_DECR is strongly correlated with Δln OPRE (0.812), as it captures the same variable – but only for observations with revenue decline. Correlations between ln(TOAS) and the other variables are low ($|r| < 0.06$), indicating the absence of a substantial multicollinearity problem.

4.2. Baseline ABJ Model

Table 4 presents the results of the baseline ABJ models with two-way fixed effects for five cost categories estimated on the full sample. The research findings are structured according to the individual hypotheses.

Table 4 Baseline ABJ models – two-way FE, clustered SE

	(1) TOC	**(2) MATE**	**(3) STAFF**	**(4) DEPRE**	**(5) OOPI**
dLn_OPRE (β_1)	0,697***	0,850***	0,213***	0,320***	0,674***
	(0,026)	(0,037)	(0,021)	(0,039)	(0,056)
INT_SALES_ DECR (β_2)	−0,165***	−0,214***	0,015	−0,151***	−0,070
	(0,036)	(0,049)	(0,050)	(0,057)	(0,078)
$\beta_1 + \beta_2$	0,532	0,636	0,228	0,169	0,604
Decline/growth ratio	76 %	75 %	107 %	53 %	90 %
N	20 375	20 375	20 350	20 281	19 101
Within R^2	0,644	0,468	0,084	0,017	0,089
Adj. R^2	0,572	0,361	−0,100	−0,181	−0,105

Source: own processing by authors.

H1: Total operating costs (TOC) of Croatian manufacturing SMEs exhibit significant asymmetric cost behavior ($\beta_2 < 0$).

Model (1) explains 64.4% of the within-firm variation in changes in total operating costs (within-$R^2 = 0.644$; Adj. $R^2 = 0.572$) and is estimated on 20,375 observations from 3,399 firms. A 1% increase in operating revenues is associated with a 0.697% increase in total operating costs ($\beta_1 = 0.697$; $p < 0.01$). A 1% decrease in operating revenues is associated with only a 0.532% decrease in total operating costs ($\beta_1 + \beta_2 = 0.697 - 0.165 = 0.532$). The coefficient $\beta_2 = -0.165$ ($p < 0.01$) is negative and highly statistically significant, confirming the presence of cost stickiness. Costs decline by 0.165 percentage points less rapidly than they rise. For the same 1% change in revenues, the cost response to a decline is 76% as strong as the response to an increase (0.532/0.697 = 0.76). Hypothesis H1 is confirmed.

H2: Material costs (MATE) of Croatian manufacturing SMEs exhibit significant asymmetric cost behavior ($\beta_2 < 0$).

Model (2) explains 46.8% of the within-firm variation in changes in material costs (within-$R^2 = 0.468$; Adj. $R^2 = 0.361$). A 1% increase in revenues leads to a 0.850% increase in material costs ($\beta_1 = 0.850$; $p < 0.01$). A 1% decrease in revenues leads to a 0.636% decrease in material costs ($\beta_1 + \beta_2 = 0.850 - 0.214 = 0.636$). The coefficient $\beta_2 = -0.214$ ($p < 0.01$) is negative and highly statistically significant. Material costs decline by 0.214 percentage points less rapidly than they rise. The response to a decline is 75% as strong as the response to an increase (0.636/0.850 = 0.75). The higher elasticity $\beta_1 = 0.850$ relative to TOC (0.697) reflects the more direct linkage between material costs and production volume. At the same time, the greater stickiness ($|\beta_2| = 0.214$ vs. 0.165) suggests that long-term supplier contracts, minimum order quantities, and inventory management practices impede rapid downward adjustment. Hypothesis H2 is confirmed.

H3: Personnel costs (STAFF) of Croatian manufacturing SMEs exhibit significant asymmetric cost behavior ($\beta_2 < 0$).

Model (3) explains only 8.4% of the within-firm variation in changes in personnel costs (within-$R^2 = 0.084$; Adj. $R^2 = -0.100$). The very low R^2 suggests that the ABJ framework captures only a minimal share of the variability in personnel costs. A 1% increase in revenues is associated with a 0.213% increase in personnel costs ($\beta_1 = 0.213$; $p < 0.01$). The coefficient $\beta_2 = 0.015$ ($p = 0.764$) is positive but statistically insignificant. The panel FE model therefore finds no evidence of systematic asymmetric behavior in personnel costs relative to revenue changes. The dominant drivers of personnel cost dynamics in Croatian manufacturing SMEs during 2018–2024 are likely increases in the minimum wage, collective bargaining, labour market tightness driven by emigration, and institutional changes associated with eurozone accession – factors captured by year fixed effects or operating independently of revenue movements. Hypothesis H3 is rejected.

H4: Depreciation and amortization (DEPRE) of Croatian manufacturing SMEs exhibit significant asymmetric cost behavior ($\beta_2 < 0$).

Model (4) explains only 1.7% of the within-firm variation (within-R^2 = 0.017; Adj. $R^2 = -0.181$). The extremely low R^2 is expected, as depreciation costs are determined by past investment decisions. A 1% increase in revenues is associated with a 0.320% increase in depreciation ($\beta_1 = 0.320$; $p < 0.01$). A 1% decrease in revenues is associated with a 0.169% decrease in depreciation ($\beta_1 + \beta_2 = 0.320 - 0.151 = 0.169$). The coefficient $\beta_2 = -0.151$ ($p < 0.01$) is negative and statistically significant. The response to a revenue decline is only 53% as strong as the response to a revenue increase (0.169/0.320 = 0.53), reflecting the irreversibility of investment decisions. Hypothesis H4 is confirmed, albeit with the caveat of the model's very low explanatory power.

H5: Other operating costs (OOPI) of Croatian manufacturing SMEs exhibit significant asymmetric cost behavior ($\beta_2 < 0$).

Model (5) explains 8.9% of the within-firm variation (within-R^2 = 0.089; Adj. $R^2 = -0.105$). A 1% increase in revenues is associated with a 0.674% increase in OOPI ($\beta_1 = 0.674$; $p < 0.01$). The coefficient $\beta_2 = -0.070$ ($p = 0.369$) is negative but statistically insignificant. The baseline ABJ model therefore does not provide sufficient evidence to confirm cost stickiness in other operating costs. This insignificance may reflect the heterogeneous composition of this category (rent, insurance, repairs, marketing), whose subcomponents may exhibit conflicting adjustment dynamics. Hypothesis H5 is rejected on the basis of the baseline model.

4.3. Extended ABJ Models

Table 5 presents the results of the extended ABJ models, which augment the baseline specification with the firm-size interaction term.

Table 5 Extended ABJ Models

	(1) TOC	(2) MATE	(3) STAFF	(4) DEPRE	(5) OOPI
dLn_OPRE (β_1)	0,700***	0,852***	0,213***	0,320***	0,678***
	(0,026)	(0,037)	(0,021)	(0,039)	(0,054)
INT_SALES_DECR (β_2)	−0,450***	−0,402**	0,075	−0,216*	−0,425**
	(0,139)	(0,187)	(0,123)	(0,124)	(0,212)
INT_SALES_DECR_TOAS (β_3)	0,050**	0,033	−0,011	0,012	0,063*
	(0,024)	(0,031)	(0,021)	(0,020)	(0,038)
N	20 375	20 375	20 350	20 281	19 101
Within R^2	0,648	0,469	0,085	0,017	0,090
Adj. R^2	0,578	0,362	−0,099	−0,181	−0,104

(two-way FE, clustered SE. *** p<0,01; ** p<0,05; * p<0,10)

Source: own processing by authors.

TOC − extended model. Revenue elasticity $\beta_1 = 0.700$ ($p < 0.01$) is virtually unchanged relative to the baseline model. The baseline stickiness coefficient $\beta_2 = -0.450$ ($p < 0.01$) is substantially larger in absolute value than in the baseline model (−0.165), because it represents stickiness for a hypothetical firm of zero size (ln TOAS = 0). The firm-size interaction $\beta_3 = 0.050$ ($p = 0.034$) is positive and statistically significant at the 5% level, confirming that larger firms exhibit lower cost stickiness. For a firm at the sample mean ln(TOAS) = 5.68, effective stickiness is: $\beta_2 + \beta_3 \times 5.68 = -0.450 + 0.050 \times 5.68 = -0.166$, which closely approximates the aggregate estimate from the baseline model (−0.165).

MATE − extended model. The model confirms material cost stickiness ($\beta_2 = -0.402$; $p = 0.031$). The size interaction $\beta_3 = 0.033$ ($p = 0.287$) is not significant—firm size does not moderate the degree of stickiness in material costs. This suggests that the rigidity of material costs is driven by supply chain factors affecting firms of all sizes.

STAFF − extended model. The coefficient $\beta_2 = 0.075$ ($p = 0.541$) remains insignificant, consistent with the baseline model. The ABJ framework has limited explanatory power for personnel costs (within-$R^2 = 0.085$).

DEPRE − extended model. The coefficient $\beta_2 = -0.216$ ($p = 0.081$) is significant only at the 10% level, weaker than in the baseline model ($p = 0.008$). Decomposition into a baseline and size-moderated component leads to wider standard errors. The size interaction $\beta_3 = 0.012$ ($p = 0.555$) is insignificant.

OOPI − extended model. The finding of the extended model is the coefficient $\beta_2 = -0.425$ ($p = 0.045$), which is significant at the 5% level, whereas in the baseline model $\beta_2 = -0.070$ ($p = 0.369$) was insignificant. The extended model reveals that smaller firms exhibit strong OOPI stickiness, which was masked by size heterogeneity in the aggregate baseline model. The interaction $\beta_3 = 0.063$ ($p = 0.100$) is marginally significant at the 10% level. Effective stickiness at the mean value ln(TOAS) = 5.68 is: $-0.425 + 0.063 \times 5.68 = -0.067$, which corresponds closely to the aggregate baseline estimate $\beta_2 = -0.070$.

4.4. Sectoral Disaggregation

To obtain a deeper understanding of sectoral heterogeneity in asymmetric cost behavior, the baseline and extended ABJ models were estimated separately for three sector types: labour-intensive (Labour), resource-intensive (Resource), and capital-intensive (Capital). Table 6 summarizes the results of the baseline sectoral models.

Table 6 Summary results of baseline ABJ models by sector

Sector / Cost	β_1	β_2	p(β_2)	$\beta_1+\beta_2$	Ratio	R^2w	Stickiness
Labour / TOC	0,768	−0,250	<0,001	0,518	67 %	0,691	Yes***
Labour / MATE	0,943	−0,300	0,002	0,644	68 %	0,471	Yes***
Labour / STAFF	0,240	−0,011	0,913	0,229	95 %	0,084	No
Labour / DEPRE	0,418	−0,310	0,006	0,109	26 %	0,020	Yes***
Labour / OOPI	0,765	−0,196	0,112	0,569	74 %	0,094	No
Resource / TOC	0,652	−0,074	0,128	0,578	89 %	0,626	No
Resource / MATE	0,775	−0,100	0,113	0,675	87 %	0,460	No
Resource / STAFF	0,223	+0,065	0,476	0,288	129 %	0,094	No
Resource / DEPRE	0,322	−0,018	0,850	0,304	94 %	0,025	No
Resource / OOPI	0,645	−0,042	0,710	0,602	93 %	0,064	No
Capital / TOC	0,660	−0,155	0,011	0,505	77 %	0,611	Yes**
Capital / MATE	0,817	−0,226	0,007	0,592	72 %	0,477	Yes***
Capital / STAFF	0,169	−0,001	0,980	0,168	99 %	0,077	No
Capital / DEPRE	0,192	−0,093	0,291	0,100	52 %	0,008	No
Capital / OOPI	0,601	+0,041	0,794	0,642	107 %	0,127	No

Ratio = $(\beta_1+\beta_2)/\beta_1$. R^2w = within-R^2.,*** p<0,01; ** p<0,05; * p<0,10

Source: own processing by authors.

4.4.1. Labour-intensive sector (Labour)

The labour-intensive sector exhibits the strongest and most consistent pattern of cost stickiness among the three sectors. Statistically significant stickiness is confirmed for three of the five cost categories: TOC ($\beta_2 = -0.250$; $p < 0.001$), MATE ($\beta_2 = -0.300$; $p = 0.002$), and DEPRE ($\beta_2 = -0.310$; $p = 0.006$). Personnel costs and OOPI are insignificant.

Depreciation exhibits the highest stickiness ($\beta_2 = -0.310$), where the response to a revenue decline is only 26% as strong as the response to a revenue increase (0.109/0.418). This reflects the high share of machinery and equipment in labour-intensive manufacturing, whose depreciation cannot be adjusted in the short run. Material costs exhibit near-unit elasticity during revenue growth ($\beta_1 = 0.943$) combined with pronounced stickiness ($\beta_2 = -0.300$), suggesting that material inputs are very tightly linked to revenues during expansion, but respond much more slowly during contraction. TOC as an aggregate category reflects a combination of sticky material and depreciation costs with more flexible other components.

In the extended models for the labour-intensive sector, the most interesting result concerns other operating costs (OOPI): baseline stickiness $\beta_2 = -0.834$ ($p = 0.003$) is very high, with significant moderation by firm size $\beta_3 = 0.118$ ($p = 0.027$). Smaller labour-intensive firms therefore exhibit extreme OOPI stickiness, whereas larger firms are able to adjust these costs more efficiently.

4.4.2. Resource-intensive sector (Resource)

In the baseline model, the resource-intensive sector does not exhibit statistically significant cost stickiness in any cost category. All β_2 coefficients are statistically insignificant ($p > 0.1$), and their absolute values are substantially lower than in the other sectors ($|\beta_2|$ ranging from 0.018 to 0.100). The decline/growth response ratios range between 87% and 94% (with the exception of STAFF, where a mildly anti-sticky pattern appears), indicating approximately symmetric cost behavior.

This result is consistent with the hypothesis that resource-intensive firms (food processing, paper, chemicals, basic metals) have more flexible cost structures due to commodity-linked sourcing on spot markets, lower labour intensity, standardized production processes, and lower dependence on specialized labour.

The extended models, however, reveal an important hidden pattern: for TOC, baseline stickiness $\beta_2 = -0.490$ ($p = 0.001$) is highly significant, with significant size moderation $\beta_3 = 0.073$ ($p = 0.007$). Smaller resource-intensive firms thus exhibit pronounced stickiness, whereas larger firms effectively eliminate it. A similar pattern appears for MATE ($\beta_2 = -0.572$; $p = 0.025$; $\beta_3 = 0.083$; $p = 0.054$). The insignificance in the baseline model was therefore caused by masking due to size heterogeneity − the stickiness of small firms was offset by the flexibility of large firms.

4.4.3. Capital-intensive sector (Capital)

The capital-intensive sector exhibits significant stickiness in two cost categories: TOC ($\beta_2 = -0.155$; $p = 0.011$) and MATE ($\beta_2 = -0.226$; $p = 0.007$). Personnel costs, depreciation, and OOPI are insignificant. Somewhat surprisingly, the capital-intensive sector does not exhibit significant depreciation stickiness ($\beta_2 = -0.093$; $p = 0.291$), despite its larger capital base. This may suggest that capital-intensive firms actively manage their asset portfolios through leasing, asset sales, or accelerated depreciation in order to preserve flexibility, or alternatively that the short panel (6 years) is insufficient to capture the long-term dynamics of depreciation.

In the extended models for the capital-intensive sector, none of the interaction terms β_3 is statistically significant ($p > 0.1$ in all cases). Likewise, the β_2 coefficients lose significance relative to the baseline models (TOC: $p = 0.124$; MATE: $p = 0.141$), probably due to the smaller sample (808 firms), which limits the statistical power of the decomposition.

4.5. Summary Evaluation of Hypotheses

Table 7 summarizes the results of the research hypotheses based on the panel FE models.

Table 7 Summary assessment of research hypotheses

Hypothesis	Cost category	β_2 (baseline)	p-value	Conclusion
H1	TOC	−0,165	<0,001	**Confirmed**
H2	MATE	−0,214	<0,001	**Confirmed**
H3	STAFF	+0,015	0,764	**Rejected**
H4	DEPRE	−0,151	0,008	**Confirmed with reservations**
H5	OOPI	−0,070	0,369	**Rejected / confirmed with reservations**

Source: own processing by authors.

Overall, the panel FE models confirm that asymmetric cost behavior (cost stickiness) is a statistically significant phenomenon for total operating costs and material costs among Croatian manufacturing SMEs. Depreciation exhibits stickiness in the baseline model, albeit with limited robustness in the extended specification. Personnel costs and other operating costs do not exhibit systematic asymmetry in the baseline model, although for OOPI the extended model reveals heterogeneity moderated by firm size.

The sectoral analysis yields three key findings: (1) the labour-intensive sector exhibits the strongest and most consistent stickiness (TOC, MATE, DEPRE); (2) the resource-intensive sector exhibits symmetric cost behavior in the baseline model, but the extended models reveal hidden stickiness among smaller firms, offset by the flexibility of larger firms; and (3) the capital-intensive sector exhibits significant stickiness only in TOC and MATE, without significant moderation by firm size.

Firm size emerges as a significant moderator of cost stickiness for total operating costs ($\beta_3 = 0.050$; $p = 0.034$) and marginally for OOPI ($\beta_3 = 0.063$; $p = 0.100$) at the level of the full sample. In the resource-intensive sector, size moderation is particularly strong (TOC: $\beta_3 = 0.073$; $p = 0.007$).

5. DISCUSSION

This study provides a comprehensive analysis of asymmetric cost behavior among Croatian manufacturing SMEs over the period 2018–2024, employing a two-way fixed effects model (firm FE + year FE) with firm-level clustered standard errors. The estimated coefficients control for unobserved firm heterogeneity (management quality, technological level, rigidity of labor contracts, organizational structure) as well as common macroeconomic shocks (inflation, minimum wage changes, pandemic-related measures, and eurozone accession). The discussion interprets the empirical findings through multiple

theoretical lenses − adjustment cost theory, behavioral theory, the resource-based view (RBV), and institutional theory.

5.1. Cost stickiness of total operating and material costs

The panel FE model confirms significant cost stickiness in total operating costs ($\beta_2 = -0.165$; $p < 0.01$) and material costs ($\beta_2 = -0.214$; $p < 0.01$). A 1% increase in revenues leads to a 0.697% increase in TOC, whereas a 1% decrease in revenues results in only a 0.532% reduction − a response ratio of 76%. For material costs, the corresponding values are 0.850% (increase) versus 0.636% (decrease), yielding a ratio of 75%. These within-firm estimates represent the average structural degree of cost asymmetry over the entire 2018–2024 period, after controlling for all time-invariant firm characteristics and common annual shocks.

From the perspective of adjustment cost theory (Anderson et al., 2003; Banker & Byzalov, 2014), these findings are consistent with the prediction that downward cost adjustments involve explicit costs − contractual penalties, supplier search costs, and reputational costs − that do not arise during upward adjustments. The particularly strong stickiness of material costs ($\beta_2 = -0.214$) likely reflects post-pandemic disruptions in global supply chains (Handfield et al., 2020; Sodhi & Tang, 2021), which compelled firms to enter into long-term contractual commitments with minimum order requirements as insurance against input shortages. From an RBV perspective (Barney, 1991; Peteraf, 1993), strategic supplier relationships constitute valuable, rare, and difficult-to-imitate resources that enhance competitive advantage through supply chain reliability, albeit at the cost of reduced short-term flexibility.

Behavioral theory provides a complementary explanation. Managers who experienced severe input shortages in 2020–2021 are likely to form pessimistic expectations regarding future material availability (Banker & Byzalov, 2014; Cyert & March, 1963), leading them to maintain supplier relationships even during demand downturns. This “pandemic memory effect” generates asymmetric adjustment that persists beyond the original shock. A comparison with prior research (Pervan & Pervan, 2012: $\beta_2 \approx -0.17$ for Croatian food companies) suggests that the post-pandemic period has intensified material cost rigidity relative to earlier, more stable periods.

5.2. Absence of systematic asymmetry in personnel costs

The panel FE model yields an insignificant coefficient for personnel costs ($\beta_2 = 0.015$; $p = 0.764$), with a very low within-$R^2 = 0.084$. After controlling for firm heterogeneity and common time effects, no systematic asymmetric relationship exists between revenue changes and adjustments in personnel costs. This null result represents the most theoretically significant finding of the study

and directly challenges the established literature, where personnel costs have consistently been identified as the primary source of cost stickiness in large corporations (Banker et al., 2013; Golden et al., 2020).

From the perspective of institutional theory (DiMaggio & Powell, 1983; North, 1990), the Croatian labor market during 2018–2024 was subject to extraordinary institutional pressures: a cumulative 69% increase in the minimum wage (from EUR 498 to EUR 840), eurozone accession on January 1, 2023, and persistent outmigration of skilled labor to Western EU member states. These institutional forces exerted upward pressure on personnel costs irrespective of firm-specific revenue trajectories, effectively decoupling personnel cost dynamics from the demand-driven mechanism captured by the ABJ framework. These common time-varying factors are absorbed by year fixed effects, explaining the insignificance of β_2.

From an RBV perspective, the null result can be interpreted through human capital as a strategic resource: in a labor market characterized by chronic shortages and emigration, firm-specific human capital becomes increasingly valuable and difficult to replace. Rational managers therefore prioritize employee retention regardless of short-term revenue fluctuations (Wernerfelt, 1984; Barney, 1991). Behavioral theory complements this view: according to prospect theory (Kahneman & Tversky, 1979), managers facing labor shortages frame employee departures as losses, which are weighted disproportionately relative to the cost savings from workforce reductions.

Evidence from other SME contexts supports this interpretation. Dalla Via and Perego (2014), analyzing Italian SMEs over 1999–2008, find asymmetric behavior only in personnel costs and not in other categories − the exact inverse of our findings. Together, these contrasting patterns demonstrate that personnel costs in SMEs are primarily determined by country-specific institutional factors rather than the revenue–cost relationship.

5.3. Depreciation and other operating costs

The panel FE model confirms stickiness in depreciation ($\beta_2 = -0.151$; $p = 0.008$), with an expectedly low within-$R^2 = 0.017$, reflecting the irreversibility of investment decisions (Williamson, 1985). For other operating costs (OOPI), the baseline model does not confirm stickiness ($\beta_2 = -0.070$; $p = 0.369$); however, the extended model reveals significant baseline stickiness ($\beta_2 = -0.425$; $p = 0.045$), moderated by firm size ($\beta_3 = 0.063$; $p = 0.100$). Smaller firms exhibit significant OOPI stickiness, whereas larger firms do not − heterogeneity that is masked in the baseline model.

5.4. Firm size and cost stickiness

The extended model confirms that firm size significantly moderates the stickiness of total operating costs ($\beta_3 = 0.050$; $p = 0.034$), with larger SMEs exhibiting lower stickiness. This finding is consistent with Özkaya (2021) for Turkish SMEs, but contradicts Calleja et al. (2006) and Weiss (2010). From an RBV perspective, larger SMEs possess more developed dynamic capabilities (Teece et al., 1997) − professional financial management, monitoring systems, and bargaining power with suppliers − which enable them to reconfigure their resource base more effectively during revenue declines. In contrast, the smallest micro-enterprises lack these organizational capabilities, leading to higher cost rigidity not as a result of deliberate resource allocation, but due to limited managerial capacity. These findings suggest a potentially nonlinear, U-shaped relationship between firm size and cost stickiness across the full spectrum from micro-enterprises to large corporations.

5.5. Sectoral disaggregation

Sectoral disaggregation by factor intensity reveals three distinct patterns. The labor-intensive sector exhibits the strongest and most consistent stickiness (TOC: $\beta_2 = -0.250$; MATE: $\beta_2 = -0.300$; DEPRE: $\beta_2 = -0.310$, all $p < 0.01$), reflecting higher adjustment costs associated with workforce management and labor protection legislation. The resource-intensive sector displays approximately symmetric cost behavior across all categories in the baseline model, consistent with more flexible cost structures based on commodity-linked sourcing. The capital-intensive sector occupies an intermediate position, with significant stickiness only in TOC and MATE.

In the extended model, the resource-intensive sector reveals hidden TOC stickiness ($\beta_2 = -0.490$; $p = 0.001$) with highly significant size moderation ($\beta_3 = 0.073$; $p = 0.007$). Smaller resource-intensive firms face substantial cost rigidity, whereas larger firms adjust costs almost symmetrically. The insignificance in the baseline model was driven by size heterogeneity masking the effect. These sectoral patterns challenge the implicit assumption in the ABJ literature that cost stickiness is a universal property. Our results suggest that stickiness is fundamentally conditioned by cost structure and factor intensity.

5.6. Model performance

Within-R^2 ranges from 0.644 for TOC to 0.017 for depreciation. Models for personnel costs (0.084), depreciation (0.017), and OOPI (0.089) explain less than 10% of within-firm variability. In the context of a two-way FE model, within-R^2 reflects the explanatory power of regressors only (revenue changes and asymmetry interactions), not fixed effects, which absorb most of the variation. For cost categories primarily driven by institutional factors (STAFF), past

investment decisions (DEPRE), or heterogeneous contractual obligations (OOPI), it is expected that firm-specific revenue changes explain only a marginal portion of cost dynamics. Negative adjusted R^2 values (STAFF: −0.100; DEPRE: −0.181) arise from penalization for a large number of fixed-effect parameters and do not invalidate the model.

5.7. Limitations and implications

The confirmed stickiness of total operating and material costs implies that cost structures adjust asymmetrically to revenue changes − managers should anticipate that cost reductions during downturns will lag behind revenue declines. Strong sectoral heterogeneity suggests that cost management strategies should be tailored to firms' factor intensity. Labor-intensive firms should prioritize flexible employment arrangements and variable compensation components. Resource-intensive firms, particularly smaller ones, should focus on diversifying their supplier base. The decoupling of personnel costs from revenue changes implies that employee retention strategies should be designed with respect to labor market conditions rather than short-term revenue fluctuations.

The study has several limitations. Its focus on Croatian manufacturing SMEs limits the generalizability of findings to the Croatian context. Coefficient estimates and sectoral patterns reflect country-specific institutional conditions − labor market structure, minimum wage trajectory, migration patterns, and the timing of eurozone accession − which may differ substantially from other Central and Eastern European countries. Generalization to the broader CEE region would require cross-country analysis. Furthermore, the six-year panel covers an exceptionally turbulent period; the absence of firm-level data on employment and average wages prevents construction of the Kaitz index for more precise measurement of minimum wage exposure; and the low explanatory power of models for STAFF, DEPRE, and OOPI indicates that the ABJ framework captures only a marginal aspect of the dynamics of these cost categories.

A promising avenue for future research emerges from this study. Qualitative research focused on managerial decision-making processes in SME cost adjustment could shed light on the mechanisms underlying the observed patterns. Investigation of threshold effects across the full firm-size distribution could test the hypothesis of a U-shaped relationship.

6. CONCLUSION

This study presents a systematic analysis of asymmetric cost behavior (cost stickiness) among Croatian manufacturing SMEs over the period 2018–2024, employing a two-way fixed-effects framework with cluster-robust standard errors on a panel of 3,399 firms and approximately 20,375 firm-year observations

drawn from the Orbis Europe database. The analysis covers five cost categories for the full sample and for three sectoral groups classified by factor intensity.

The key findings are as follows. Total operating costs exhibit statistically significant cost stickiness ($\beta_2 = -0.165$; $p < 0.01$), thereby confirming Hypothesis H1. Material costs also display significant stickiness ($\beta_2 = -0.214$; $p < 0.01$), confirming Hypothesis H2; they show the highest revenue elasticity among all cost categories ($\beta_1 = 0.850$) and are consistent with pronounced contractual rigidities. Depreciation is sticky in the baseline specification ($\beta_2 = -0.151$; $p = 0.008$), providing qualified support for Hypothesis H4.

In contrast, personnel costs do not exhibit systematic asymmetric behavior ($\beta_2 = 0.015$; $p = 0.764$), leading to the rejection of Hypothesis H3. Interpreted through the lenses of institutional theory and the resource-based view (RBV), this result indicates that personnel costs in Croatian manufacturing SMEs during 2018–2024 were driven primarily by labor-market institutions − such as increases in the statutory minimum wage, collective bargaining dynamics, labor shortages, and euro area accession − rather than by firm-level revenue fluctuations. Other operating costs are not sticky in the baseline model; however, the extended specification reveals significant baseline stickiness moderated by firm size. Accordingly, Hypothesis H5 is rejected in the baseline model but supported − with caveats − in the extended specification.

Firm size is confirmed as a statistically significant moderator of stickiness in total operating costs ($\beta_3 = 0.050$; $p = 0.034$). Sectoral disaggregation further indicates that the labor-intensive sector exhibits the strongest stickiness, the resource-intensive sector shows approximately symmetric cost behavior (while still displaying “hidden” stickiness among smaller firms), and the capital-intensive sector occupies an intermediate position.

This study contributes to the cost stickiness literature in four principal ways: (i) it offers the first comprehensive panel fixed-effects analysis of asymmetric cost behavior in Croatian manufacturing SMEs; (ii) it demonstrates that, in SMEs, personnel costs may be structurally decoupled from the revenue–cost relation due to institutional labor-market forces; (iii) it confirms the moderating role of firm size within the SME segment; and (iv) it shows that sectoral factor intensity generates substantial heterogeneity in cost behavior. These contributions are embedded in a multi-theoretical framework integrating adjustment cost theory, behavioral theory, the RBV, and institutional theory.

The findings are specific to the context of Croatian manufacturing SMEs during the turbulent period 2018–2024 and should not be directly generalized to other Central and Eastern European economies without careful consideration of country-specific institutional differences. Nevertheless, the theoretical framing, methodological approach, and sectoral classification strategy developed in this study are transferable and provide a foundation for future comparative research in the CEE region.

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NEELASTIČNOST TROŠKOVA U HRVATSKIM MALIM I SREDNJIM PODUZEĆIMA U PROIZVODNOM SEKTORU: DOKAZI IZ RAZDOBLJA PANDEMIJE I POSTPANDEMIJSKOG RAZDOBLJA

Sažetak

Ova studija analizira asimetrično ponašanje troškova na uzorku od 3.399 malih i srednjih poduzeća u hrvatskom proizvodnom sektoru u razdoblju 2018.–2024., primjenom proširenog Anderson–Banker–Janakiraman modela u dvosmjernom panelu s fiksnim efektima i standardnim pogreškama grupiranima po poduzećima. Ukupni operativni troškovi pokazuju značajnu neelastičnost ($\beta_2 = -0{,}165$; $p < 0{,}01$): rastu za 0,70 % na svaki 1 % povećanja prihoda, ali se pri padu smanjuju tek za 0,53 %. Najizraženija asimetrija uočena je kod troškova materijala ($\beta_2 = -0{,}214$; $p < 0{,}01$). Troškovi osoblja ne pokazuju sustavnu neelastičnost ($\beta_2 = 0{,}015$; $p = 0{,}764$), što upućuje na snažan utjecaj institucija tržišta rada. Veća MSP pokazuju manju krutost troškova, suprotno nalazima za velike korporacije. Sektorska analiza otkriva najveću ljepljivost u radno intenzivnim industrijama.

Ključne riječi: neelastičnost troškova; mala i srednja poduzeća; proizvodnja; Hrvatska; pandemija bolesti COVID-19.

JEL klasifikacija: M41, D22, D24, L11, L60, L26.