MARITIME FREIGHT COST SHOCKS AND SME FINANCIAL PERFORMANCE IN THE VISEGRAD REGION DURING AND AFTER COVID-19

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Resume

In this paper is analysed how the maritime freight costs fluctuations (2020-2024) affected the small and medium sized enterprises (SMEs) across the Visegrad Group using firm-level panel data and fixed-effects regressions. Four financial indicators were examined: turnover, gross margin, inventory stock, and cost of goods sold (COGS), with the Shanghai containerized freight index (SCFI) as the key explanatory variable. Higher freight costs are associated with increased turnover, inventories, and COGS, and with reduced gross margins, though the within-firm explanatory power is low. Overall, shipping price shocks leave measurable but modest effects on SME finances, indicating partial cost pass-through and strong resilience. Supporting supply-chain adaptability and digital logistics tools may further reinforce this resilience.

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1 Introduction

Global maritime shipping is the backbone of international trade, carrying roughly 80% of goods worldwide [1]. The COVID19 pandemic, however, caused unprecedented disruption to this sector [2]. Pandemic related shocks - from lockdowns and labour shortages to port closures, severely disorganized supply chains and curtailed maritime trade in 2020 [3]. By mid2020, as consumer demand for goods rebounded while containers and vessel capacity were in short supply, ocean freight costs began surging to historic highs. For example, the Shanghai Containerized Freight Index for China-Europe routes jumped from under $1,000 per TEU in mid2020 to about $4,000 by late 2020 and then reached $7,395 by mid2021 [4]. By 2021, many freight indices hit record levels, contributing to rising commodity prices and even inflationary pressure worldwide [5]. These soaring maritime shipping prices quickly became a focal point for researchers and policymakers given their far-reaching economic impact in the post COVID period. Importantly, this paper focuses on Central Europe, in particular the Visegrad (V4) countries (Poland, Czechia, Slovakia, and Hungary) - which are landlocked, except Poland, and therefore rely on seaborne trade indirectly via major European ports [4]. This geographic characteristic makes the V4 region a distinctive case for assessing how global maritime disruptions is transmitted inland to small businesses.

A critical concern arising from the logistics turmoil is how such elevated transportation costs affect businesses, especially small and medium sized enterprises (SMEs). The SMEs account for a large share of economic activity, for instance, about 47% of formal sector jobs and over half of output in developing countries, yet they typically lack the scale and resources of large firms to absorb external shocks [6]. The recent freight cost spike was no exception. Rapidly rising transportation expenses squeezed many businesses' operations, in some cases forcing smaller firms out of the market and compelling drastic adjustments to inventory and sourcing strategies. Evidence suggests that most firms had to respond by raising prices: a 2021 OECD business survey found that most retailers in Europe reported higher logistics costs, and approximately three quarters had partially passed these costs on to consumers [7].

Such cost pressures are especially perilous for SMEs that operate on thin margins. Indeed, during the pandemic many SMEs were at risk of bankruptcy due to collapsing demand coupled with surging input and logistics costs [8]. Sudden spikes in freight rates tend to have a disproportionate impact on smaller businesses' profitability and viability, since SMEs often have limited cash buffers, less bargaining power with shippers, and fewer options to reroute shipments compared to large corporations [9]. While some larger firms managed to negotiate long-term contracts or alternative shipping methods, smaller enterprises frequently faced the full brunt of spot market rate increases and shipping delays. This dynamics has raised debate over whether the logistics cost shock was largely passed through to end consumers (thereby "sharing" the burden via higher retail prices) or absorbed at the firm level, eroding SMEs' financial performance. Both scenarios occurred: many SMEs did implement price hikes (at the risk of losing price sensitive customers) even as their profit margins shrank due to portions of the costs that could not be fully passed on.

A growing body of literature has documented the pandemic's impact on supply chains and transportation costs. However, relatively few works were focused on the firm level consequences for SMEs. Many scholars examine COVID19's effect on freight rates and import costs broadly, but often with limited attention to the real economic impact on smaller enterprises [10]. This is a notable gap given the essential role of SMEs and their apparent vulnerabilities. Moreover, most of the available evidence comes from Asian contexts or global aggregates, while there is very limited empirical research on Europe's landlocked economies. To our knowledge, no study has systematically examined the relationship between the global maritime freight costs and the financial performance of SMEs in the V4 countries. Filling this gap is particularly important because these economies depend heavily on imported intermediate goods, which makes them indirectly exposed to maritime price shocks despite their geographic distance from ports [10].

Considering the above, it is crucial that the effect of maritime shipping price fluctuations on SMEs' financial indicators in the post COVID-19 era is investigated. Key financial performance metrics analysed include:

- Operating revenue
- Profit margins
- Costs of goods sold
- Inventory levels.

These indicators together capture firms' ability to generate revenue, the cost pressures they face, and their operational resilience. The goal is to quantify and contextualize how the extreme volatility in ocean freight rates since 2020 has translated into financial stresses or changes for small businesses. Particular attention is paid to contentious viewpoints in the literature. For instance, whether the shipping costs shock should be seen as a transient logistical inconvenience or as a catalyst for long term structural adjustments in SMEs' business models. By analysing firm level data and industry trends, it is determined to what extent SMEs absorbed the increased shipping costs (thereby impacting their profitability) versus passed them on to customers (potentially impacting sales volumes or customer retention) [11]. Ultimately, it is imperative to fill the research gap on the microeconomic impacts of freight rate swings in Central Europe, thereby complementing the broader macrolevel analyses and informing strategies to bolster SME resilience in the face of volatile logistics markets.

1.1 Literature overview

The COVID19 crisis caused unprecedented swings in ocean freight rates. After early 2020, when carriers sharply cut capacity via blank sailings and freight rates initially fell, the trend reversed dramatically later that year. From late 2020 onward, container shipping costs surged to record highs, as demand outstripped available capacity. Industry indices show that container spot rates effectively quadrupled in 2021 compared to pre pandemic levels. Rates remained high through 2022 and much of 2023, with intermittent spikes linked to unforeseen events (e.g. disruptions around the Red Sea in late 2023) and by early 2024, freight rates had eased from their peak, but were still well above pre pandemic norms [1]. The Shanghai Containerized Freight Index presented in Figure 1 and other benchmarks more than four folded during 2020-2021 and remained extremely elevated through much of 2022. UNCTAD reported that on some Asian export routes (such as Shanghai-Europe), rates saw especially sharp spikes - in one late 2023 instance, Asia-Europe spot rates jumped by roughly $500 within a single week, a record weekly increase [12]. Multiple shipping price indices (SCFI, CCFI, etc.) confirm that rates on major trade lanes (Asia-Europe, Asia-North America) in 2021-2022 stayed far above their 2019 levels, reflecting an extraordinary degree of volatility [13]. In contrast, the freight rates on a few less profitable routes rose relatively less (for example, some Asia-East Coast North America rates were up ~63% versus 2019, whereas China-Latin America routes saw over 4 times increases).

European importers felt these surges acutely. The critical Asia-Europe trade lanes suffered severe congestion and escalating costs. For instance, port waiting times in key hubs (Singapore, Jebel Ali, Port Klang) lengthened in 2021-2022, further raising costs and causing delays. An analysis by the European Central Bank noted that transportation costs on routes from Asia to Europe climbed sharply beginning in mid-2021, contributing to higher landed import prices in Europe [13]. Although few studies are isolating freight rate impacts specifically on the V4 countries, the general

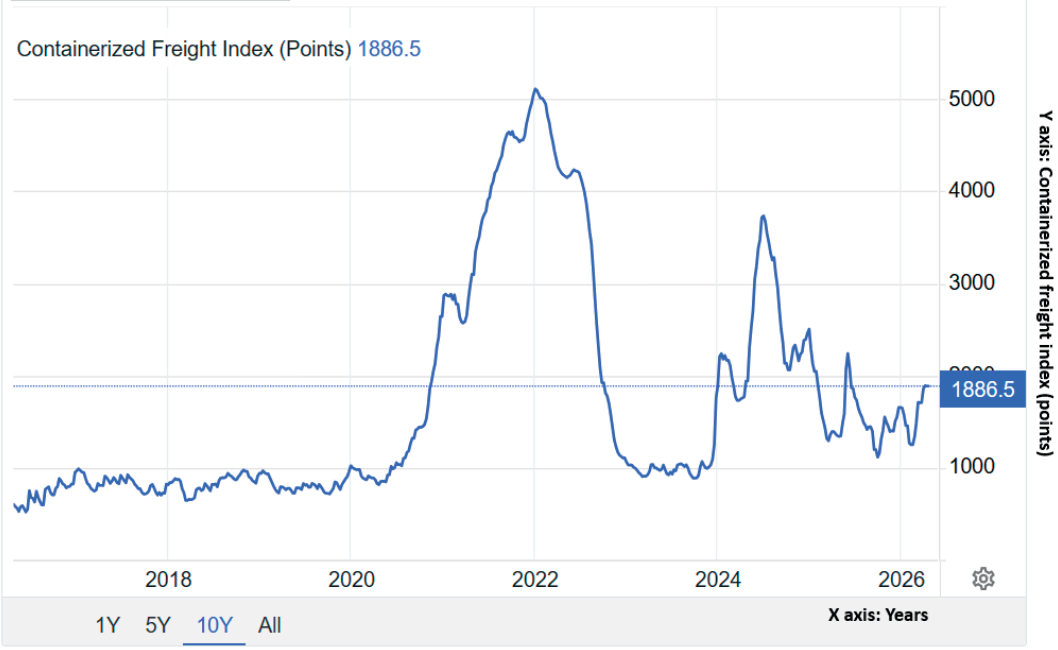

Figure 1 *Containerized shipping index from 2020 to 2025, source: [14]*

pattern undoubtedly applied: Poland, Czechia, Slovakia, and Hungary rely heavily on imports from Asia and thus faced these international price shocks indirectly. In other words, firms in the V4 region experienced the global freight costs boom along with the rest of Europe, despite being geographically distant from the ports where the disruptions originated [15].

Research has identified multiple factors behind the extreme freight rate swings of the pandemic era. Broadly, these causes can be grouped into demand shocks, supply constraints, logistical bottlenecks, and other industry specific factors [16].

The pandemic (and subsequent recovery) induced large shifts in demand for goods. Explosive growth in consumer spending on merchandise (especially home electronics, appliances, and other stay-at-home goods) collided with previously downsized shipping capacity. As manufacturing orders rebounded sharply in late 2020, delivery times lengthened and input costs, including freight, spiked. In essence, a strong demand resurgence, coupled with limited short term capacity elasticity' meant shipping carriers could charge much higher prices. In one modelling study was found that mere increases in operating costs could not explain the post2020 freight rate explosion; instead, a shift in market equilibrium (e.g., reduced competition among major carriers and more collusive pricing) magnified the spike [17].

On the supply side, deliberate capacity reductions and equipment dislocations aggravated the situation. In the first half of 2020, as global trade initially collapsed, carrier alliances responded by cancelling over a hundred Asia-Europe sailings, idling ships to save costs. These widespread "blank sailings" temporarily reduced available capacity. When the demand roared back later in 2020, the shipping system struggled to catch up. The U.S. International Trade Commission reported that by late 2020 U.S. exporters were experiencing a shortage of empty containers, inventories of usable export containers were depleted, which in turn drove up the cost of leasing containers for shipment [18]. A similar phenomenon hit Europe: empty containers languished in inland depots or import heavy ports, while exporters in Asia and elsewhere desperately needed them. Carriers had to spend time and money repositioning containers (often paying premiums to rush empties back to origin markets), costs which then fed into freight rate increases.

Surges of vessels arriving off schedule overwhelmed port infrastructure and labour availability as dozens of ships waited at anchor off major ports (Los Angeles/Long Beach, Shanghai, Rotterdam, etc.), port throughput slowed and shipping schedules unravelled. One study enumerated causes of the congestion, from labour shortages and infrastructure limitations to weather events and sudden demand swings, all of which tend to increase shipping turnaround times and costs. UNCTAD observed that by mid2024 roughly 8.4% of the global container ship fleet (approximately 2.5 million TEU of capacity) was stuck waiting at anchorages worldwide due to port bottlenecks, putting continued upward pressure on freight rates, for example, demurrage charges for containers stuck in port and peak season surcharges [18].

Several ancillary factors contributed to shipping costs inflation as well. Bunker fuel prices rose sharply from late 2020 into 2022, increasing carriers' operating costs, which were then reflected in higher freight

tariffs. Climate related events hindered certain routes for example, an El Nino related drought in late 2022 reduced Panama Canal capacity and forced some ships onto longer routes, adding transit time and expense.

The outbreak of war in Ukraine and periodic instability around the Red Sea and Suez corridor (e.g., missile scares in 2023) created uncertainty and occasional spikes in rates on those routes. Finally, the market structure of container shipping evolved during this period in a way that favoured carriers. The industry analysis noted that the container shipping sector effectively transitioned from a highly competitive (near Bertrand) market pre2020 to a more oligopolistic or coordinated pricing environment by 2021-2022, as major carrier alliances exercised newfound pricing power. Multiple sources conclude that without all these factors occurring together, the enormous rate increases of 2021 would not have been nearly as severe.

Elevated freight costs have broad implications for trade and prices in the global economy. In essence, higher transportation costs act like a tax on trade, raising the delivered price of imported goods. The World Trade Organization reported that after the steep collapse in 2020, global merchandise trade volumes rebounded by about +9.7% in 2021, but this recovery came at significantly higher costs - global export and import price indices rose by roughly +15% in 2021 alone [19]. The gap between the resurgence in trade volumes and the even larger increase in trade values suggests that the higher shipping and input costs were a major factor driving up prices. In purchasing managers' indexes (PMIs) at the time, businesses consistently cited supply chain bottlenecks and soaring freight rates as key contributors to rising input prices.

An analysis by the International Monetary Fund found that spikes in global shipping rates (as measured by indicators like the Baltic Dry Index) lead to statistically significant increases in import prices and producer price indices and eventually put upward pressure on consumer price inflation across many countries [20]. Similarly, the OECD has documented that inflation in container shipping costs feeds into higher inflation for imported goods, and to a lesser extent raises core consumer price index (CPI) inflation over time [21]. In practical terms, as firms faced drastically higher costs for ocean transport, many were forced either to accept lower profit margins or to raise the prices of final goods. Case studies underscore this dynamics: for example, the central bank of Chile estimated that the jump in freight costs during 2019-2021 accounted for roughly 14% of total inflation in Chile over that period. In addition, UNCTAD's modelling exercises have warned that if severe shipping disruptions persist (for instance, a protracted crisis on a major route like the Red Sea corridor), global consumer price levels could end up about 0.6 to 1.5 percentage points higher by 2025 than they would otherwise be [22].

In the short run, rising transport costs and longer transit times tend to dampen trade volumes because some transactions become less profitable or face fulfilment delays. UNCTAD projected that global maritime trade growth would slow to only around 1.4% in 2022 (down from the higher pre pandemic growth rates). The WTO similarly noted that ongoing supply frictions "weighed on trade" through 2021-2022, even as overall demand remained robust. Nonetheless, since the consumer and industrial demand was very strong during the recovery, the global trade volumes did continue to grow; it was the efficiency of trade that suffered, as evidenced by the much higher costs and prices. From a macroeconomic perspective, the surge in shipping costs acted like a negative supply shock to the world economy. General equilibrium models (for example, simulations using the GTAP framework) indicate that the shipping disruptions of 2020-2021 likely reduced real GDP and increased price levels in many regions, with especially pronounced effects on small, import dependent economies, particularly those that rely heavily on imported goods, such as many developing island states experienced larger inflationary effects from the shipping crunch. In summary, elevated transport costs during the pandemic likely trimmed global trade growth modestly and added on the order of 0.5-1 percentage point to global consumer inflation during 2020-2024. Import dependent regions like Central Europe would have felt these effects even more. Notably, OECD analysts in 2025 underscored that recent volatility (e.g., the late2023 shipping disruptions) means freight costs shocks remain "relevant for policymakers" due to their significant inflationary spillovers.

The surge in shipping rates effectively raised the costs of obtaining goods, components, and raw materials, directly increasing input costs for firms [23]. The SMEs that import intermediate goods from Asia or other distant markets saw their delivered materials costs skyrocket, which immediately squeezed their profit margins. Smaller firms, with typically low negotiating power on shipping, often had to pay the going spot rates, unlike some larger importers who might have locked in lower rates via contracts. A broad survey of SMEs in the U.S. reported that higher material and transport costs were "compressing profit margins," forcing firms to cut expenses elsewhere and search for process innovations just to stay afloat. In many cases, the steep increase in freight costs was partially passed through to final prices (contributing to inflation in consumer goods) - an action necessary for survival that nonetheless risked reducing customer demand. In Central Europe, where many SMEs rely on imported inputs, companies faced difficult choices: absorb the higher logistics expenses and accept lower margins, seek alternative suppliers (e.g., closer to home), which might be costly, or raise output prices. The Czech/Slovak business survey mentioned earlier confirms that pandemic era border closures and logistics breakdowns led to shortages of raw materials and goods, implying that SMEs sometimes had to pay more for

scarce inputs or find expensive workarounds [15]. All of these factors put intense upward pressure on small firms' costs of goods sold.

The tumult in global shipping forced changes in how the SMEs manage inventories and procure goods. During 2020-2021, many firms depleted their inventories to unusually low levels (for instance, a U.S. small business index showed inventory to sales ratios hitting record lows) because restocking became slower and costlier. Fearful of stockouts and further delays, some SMEs began ordering larger quantities or critical supplies earlier than usual, effectively increasing their buffer stocks when possible. In other cases, companies paid premiums for faster shipping or guaranteed space. Longer lead times, due to port congestion, container scarcity, and route deviations, meant that just in time inventory models became risky; instead, firms had to carry more just in case inventory, which ties up working capital. UNCTAD noted examples of carriers offering "premium" ocean services at higher rates to secure container space, meaning shippers (including smaller companies) sometimes paid twice for a single shipment (a standard rate plus a surcharge for priority) to ensure delivery. These disruptions upended the inventory management of SMEs and could have led to higher warehousing costs and cash flow challenges, as money was locked into goods in transit or sitting in stock as a hedge against uncertainty.

Inflationary supply shocks like a freight surge tend to hurt SMEs' profitability more than that of larger firms. Empirical surveys indicate that rising input costs and inflationary pressures squeezed SMEs' margins disproportionately [24]. According to an EU Commission review, the inflationary spike during the pandemic eroded small firms' profit margins by an estimated ~0.6 percentage points on average, a significant hit relative to typical SME margins - whereas larger firms generally managed to weather cost increases better. The fundamental issue is that many SMEs have limited ability to raise their own prices quickly or to a sufficient extent. Smaller businesses often compete on thin price differences and hesitate to risk losing customers; they may also lack the market power to pass on cost increases without demand suffering. As a result, input costs inflation translated more directly into reduced gross margins for these firms. A report by Visa surveying small businesses noted that 90% of SMEs worldwide experienced supply chain disruptions in 2021 and expected these issues to continue, suggesting that the majority were bracing for sustained pressure on their costs and earnings. In Central Europe, it is common for SMEs to operate with single digit profit margins, so any additional freight surcharges posed a serious dilemma: either accept a hit to earnings or increase prices (and potentially drive away price sensitive buyers) [25]. In practice, many did a mix of both, but either way their financial position deteriorated compared to the precrisis norm.

Ultimately, the combination of higher costs, logistical delays, and pricing challenges undermined many SMEs' overall performance and threatened their survival. A survey of SMEs in Slovakia and Czechia concluded that a large share of firms found themselves with "low liquidity, nonnegligible fixed costs and resulting financial problems" as the COVID crisis unfolded [26]. Although that study examined the pandemic's impact broadly (including demand shocks and lockdowns), supply chain disruptions and rising input costs were among the key difficulties contributing to those financial strains. Across Europe, inflationary shocks in 2021-2022 led numerous SMEs to scale back operations, defer investments, or even exit the market. For example, one European survey reported that small businesses experienced record increases in costs, and many anticipated a decline in profits moving forward. The cited Slovak/Czech study also emphasized that SMEs in that region had very limited financial buffers; notably, a large fraction of those firms chose not to take on available emergency loans, fearing debt amid the uncertainty, which implies that they largely absorbed the higher costs by depleting their own cash reserves rather than risking new liabilities [26]. The European Commission's 2023 report on SMEs likewise identified supply chain challenges as a major constraint on small firms' growth and viability in 2021-22. In sum, while no single study has isolated the specific effect of freight costs on V4 SMEs, the converging evidence suggests that these landlocked businesses bore substantial fallout from the global shipping crisis. Steep freight surcharges fed into higher input costs at the firm level, which translated into squeezed margins, operational hurdles, and in some cases business closures or consolidations. This underscores the importance of building greater resilience among SMEs to withstand such external logistic shocks in the future.

Several recent peer reviewed studies have examined how logistics and maritime transport systems and especially small and medium enterprises (SMEs), responded to pandemic induced supply chain disruptions. Below are key examples, highlighting their methods, data, findings, and noted research gaps.

Research on logistics disruptions and SMEs during and after COVID19 has employed a wide range of methodological approaches. For example, Veselovska [27] used a largescale survey of firms in Central Europe (including Czechia, Poland, and Slovakia) to examine the earlystage responses to supply chain shocks, finding that operational adjustments and new partnerships improved resilience. Gurbuz et al. [26] combined a qualitative case study of a Turkish SME with simulation modelling of supply chain network configurations, showing that diversified sourcing and customer bases mitigated disruption risks. Li et al. [28] applied a Threshold Vector Autoregression (TVAR) to longitudinal data from nearly 600 Chinese SMEs, identifying nonlinear effects of successive pandemic waves on supply chain disruptions,

costs, and customer losses. Burinskas, Cohen, and Drozdz [29] employed a gravity model with a difference in differences specification to analyse the Central and Eastern European trade flows, demonstrating that supply shocks reduced imports of intermediate goods and highlighted vulnerabilities in manufacturing supply chains. In contrast, Grzelakowski [30] adopted a qualitative, descriptive approach based on industry and institutional data to assess maritime and logistics sector responses, emphasizing structural weaknesses and the need for digitalization and regionalization. Together, these studies show that existing research employs both quantitative and qualitative designs, but few integrate firm level panel data in the V4 context, leaving a gap that this study addresses.

2 Methodology

In this study is employed a panel data approach to examine how maritime freight costs have affected the financial performance of small and medium sized enterprises (SMEs) in the Visegrad (V4) countries (Czechia, Hungary, Poland, and Slovakia) during the period 2020-2024. The guiding research question (RQ) is:

How have fluctuations in maritime freight costs since 2020 affected SMEs' selected company financial indicators in the V4 region?

The COVID19 pandemic created a unique setting in which global shipping costs surged to historic highs, introducing an external shock that plausibly influenced SME operations. A panel data approach allows to exploit both cross sectional variation between firms and timeseries variation across years, while controlling for firm specific unobserved heterogeneity. This strengthens the analysis by accounting for differences between firms that do not change over time (e.g. industry or country factors), isolating the impact of freight cost fluctuations on financial outcomes.

2.1 Data source and sample protection

Firm level data were obtained from the ORBIS database (Bureau van Dijk), covering active private companies in the four V4 countries from 2020 through 2024. The initial dataset contained approximately 13.3 million firm year observations across the four countries. To focus on comparable businesses, the sample was gradually narrowed through filtering steps.

SME Definition: The study targets SMEs as defined by the EU. Firms were restricted to those with 11-250 employees and annual operating revenues between €2 million and €50 million. This ensures a focus on true small and medium enterprises (excluding microenterprises and large firms).

Only companies with recent and complete financial statements for all the years in the 2020-2024 period were included. Public authorities and state-owned entities were excluded to focus on private sector SME performance.

The final sample is a balanced panel of 8,371 SMEs, meaning each of these firms has complete data for every year from 2020 to 2024. By requiring a balanced panel, the analysis avoids distortions from entry or exit of firms and ensures sufficient longitudinal coverage for each firm. Data was exported on date 15.08.2025.

By concentrating on firms of comparable size and excluding very small firms with potentially atypical accounting, the dataset provides a representative and reliable sample of the SME segment in the V4 region. This careful sample selection improves comparability and robustness of the results. Overall, out of 8,371 companies, 921 are from Czechia (11 %), 2,323 from Hungary (28 %), 1,611 from Poland (19 %) and from Slovakia 3,516 (42 %).

2.2 Variables and measures

The impact of shipping costs is analysed on several aspects of firm performance. Four dependent variables are chosen to capture different dimensions of SME financial performance (all monetary values are harmonized in euros and reported on an annual basis):

Operating Revenue (Turnover, € thousands): Total sales revenue, reflecting the scale of operations and market activity of the firm each year. Higher turnover indicates growth in business activity. Turnover captures the demand-side response to a cost shock. If firms pass higher transport costs into output prices, demand may decline, particularly for SMEs facing elastic demand, making revenue an indicator of market adjustment to freight-cost inflation.

Gross Margin (%): A profitability ratio calculated as gross profit divided by turnover (expressed as a percentage). Gross margin indicates the firm's ability to generate profit after accounting for the cost of production. A lower gross margin suggests margin compression (e.g. higher costs not fully passed on to customers). Gross margin reflects firms' pricing power and costs' pass-through ability. A decline following freight costs increases indicates incomplete transmission of higher input costs to customers and therefore margin compression typical for smaller firms in competitive markets.

Inventory (Stock, € thousands): Year-end value of inventories. This reflects the firm's working capital tied up in stock and can indicate supply chain adjustments. An increase in inventory might signal stockpiling in response to anticipated supply disruptions or cost changes. Inventory measures operational adjustment to supply-chain uncertainty. Rising shipping costs and delivery volatility often lead firms to precautionary stockpiling, making inventories a proxy for risk-mitigation behavior rather than production expansion.

Cost of Goods Sold (COGS, € thousands): The

direct costs of production (including materials, labour, and overhead associated with goods sold). The COGS is closely related to input cost pressures; higher COGS may reflect increased input prices, possibly due to higher freight and material costs. The COGS captures the direct cost channel of the shock. Higher maritime freight rates increase import prices of intermediate inputs, raising production costs even without changes in output quantity.

Together, these indicators provide a complementary view of firm performance - covering revenue generation, profitability, operational stock management, and cost structure. Changes in these variables can illuminate how firms respond to external cost shocks in both their topline (revenue) and bottom line (costs and margins).

Main Explanatory Variable - Shipping Cost Index: The key independent variable is the Shanghai Containerized Freight Index (SCFI) for the Europe route. The SCFI, published by the Shanghai Shipping Exchange, measures spot container shipping rates on the Shanghai-Europe trade route and is a widely recognized benchmark of global maritime freight costs [9]. Annual average values of the SCFI (Europe route) are obtained for each year 2020-2024 (sourced via Trading Economics from the Shanghai Shipping Exchange). This index serves as a proxy for worldwide shipping cost fluctuations that would affect import/export expenses for firms in Europe.

The SCFI is matched to each firm year observation by year. Since it is a global index, SCFI varies only across years (common to all firms each year) and not across individual firms. While this lack of cross-sectional variation in the index means firm differences in freight exposure are not directly observed, using a common index ensures we capture a common external shock faced by all firms in the region each year. The period of analysis includes dramatic swings in shipping costs, notably a sharp increase during 2020-2021 amid pandemic disruptions and subsequent normalization, providing a useful context to observe how such cost shocks correlate with firm financial metrics. Since individual SMEs cannot influence global container freight rates, changes in the SCFI can be treated as an exogenous macroeconomic cost shock affecting all firms simultaneously.

2.3 Hypothesis

Rising maritime freight costs represent an external cost-push shock affecting imported inputs and delivery reliability. Firms may respond through price adjustments, cost absorption, or operational adaptation. The following hypotheses test these distinct transmission channels within SMEs.

H1: Higher maritime freight costs are associated with increased SME turnover (operating revenue).

Under the cost-push inflation, firms may increase output prices to compensate for higher transport expenses. When demand remains relatively inelastic in the short run, nominal revenues rise even if quantities do not change, implying positive revenue adjustment.

H2: Higher maritime freight costs are associated with lower SME gross margins.

In competitive markets SMEs often have limited pricing power and cannot fully transmit higher logistics costs to customers. Economic theory therefore predicts margin compression when input costs rise faster than the output prices.

H3: Higher maritime freight costs are associated with increased SME inventory holdings.

Supply-chain uncertainty increases precautionary stockholding. Firms facing delivery delays or volatile transport prices accumulate inventories as a buffer against production disruptions and future price increases.

H4: Higher maritime freight costs are associated with higher SME cost of goods sold (COGS).

Transport costs are embedded in input prices; therefore, an increase in shipping rates directly raises production costs through more expensive imported materials and intermediate goods.

Together, these hypotheses test whether the global freight shocks propagate primarily through pricing behaviour, profitability pressure, operational risk management, or direct cost transmission in SME financial accounts.

2.4 Panel data and model specification

To quantify these relationships, a panel regression model with fixed effects (FE) was employed, estimated separately for each of the four dependent variables. The general specification can be written as:

$$Y_{it} = \alpha_i + \beta SCFI_t + \varepsilon_{it}, \quad (1)$$

where Y_{it} represents the financial outcome of interest for firm i in year t. The term SCFI is the Shanghai Containerized Freight Index value in year t, which serves as our independent variable capturing shipping prices. The coefficient β measures the impact of an one-unit change in the SCFI on the dependent variable. The term α_i denotes the firm specific intercept or fixed effect, which captures all time invariant characteristics of firm i that could affect its financial metrics (such as the firm's industry, inherent efficiency, or country specific factors). Finally, ε_{it} is the idiosyncratic error term for firm i at time t, representing all other unobserved influences

that vary over time. The inclusion of firm fixed effects means the coefficients are identified purely from within firm variation over time. In practice, the estimation uses the within transformation (demeaning each variable by that firm's average over 2020-2024), so that each firm serves as its own benchmark. This approach discards any between firm variation and thereby eliminates bias from omitted time invariant factors. Essentially, it is asked when a given firm experienced higher (or lower) shipping costs than its usual level (via yearly changes in SCFI), did it also exhibit changes in revenue, margin, inventory, or COGS relative to its usual levels.

Both fixed effects (FE) and random effects (RE) panel models in preliminary analysis are estimated. A Hausman test was then conducted to compare the two estimators. The Hausman test strongly indicated that the FE model is more appropriate, suggesting that unobserved firm characteristics are correlated with the shipping cost proxy (violating the RE assumptions). Therefore, all the main results are reported using the fixed effects specification.

Key aspects of the estimation strategy include these steps.

Fixed Effects over Random Effects: Choosing the FE estimator means each firm is allowed to have its own intercept. This accounts for unobservable factors (e.g., a firm's business model or sector) that could influence outcomes and potentially correlate with freight cost exposure. By using FE, biased estimates that might arise if, say, more globally oriented firms (with certain performance traits) also face different freight cost impacts are avoided.

Cluster Robust Standard Errors: To ensure reliable inference, the clustered standard errors are employed at the firm level. Clustering by firm accounts for potential heteroskedasticity (unequal error variance across firms) and serial correlation (errors for a given firm being correlated over time). This is important because the same firm's outcomes over years might be subject to persistent shocks or measurement issues. Diagnostic tests were performed: the Wooldridge test for autocorrelation in panel data indicated potential serial correlation, and the Breusch-Pagan test indicated heteroskedasticity. By clustering the standard errors on firms, we correct for both issues, making our statistics and confidence intervals more reliable.

Exogeneity of Shipping Cost Index: The SCFI is used as an external proxy for shipping costs because firm level freight expenditure data are not available (and if they were, they might be endogenous to firm performance). The SCFI is determined by global logistics market conditions and is plausibly exogenous to any single V4 firm. Using a global index mitigates endogeneity concerns -it is unlikely that an individual firm's performance could influence the global freight index. This strengthens the causal interpretation that changes in the SCFI reflect an external cost shock impacting firms, rather than the reverse.

2.5 Omission of additional controls

Other control variables, such as firm size, sector, or country dummies, are deliberately excluded in the regression.

This is for several reasons. All firms in the sample are constrained to the SME category by design, which ensures a relatively comparable scale. There is a limited variation in size by construction (e.g., micro firms with medium firms beyond the defined range are not mixed).

Sector and country differences are time invariant for each firm in this short panel and are thus already accounted for by the firm fixed effects. For example, if a firm is in manufacturing or located in Poland, that characteristics does not change over 2020-2024 and its average effect is absorbed by the fixed effect.

Including additional controls that do not vary (or vary very little) in this five-year period could introduce multicollinearity with the fixed effects or simply consume degrees of freedom without providing new information. Given the relatively short time dimension (5 years), parsimony is preferred to maintain statistical power.

By focusing on the core relationship between the SCFI and firm performance outcomes and using a rigorous fixed effects approach with robust errors, the estimation strategy aims to isolate the impact of maritime freight cost fluctuations on SMEs as cleanly as possible.

3 Results

The panel regression analyses revealed significant relationships between the maritime freight costs and key measures of SME financial performance in the Visegrad Group (V4). A Hausman specification test was first conducted to choose between random and fixed effects for the panel models. The test results presented in Table 1 strongly rejected the random effects model ($\chi^2 \approx 61.86$, $p < 0.001$), indicating that the firm specific effects are correlated with the regressors. Therefore, adopting a fixed effects specification for all subsequent models. This approach controls for time invariant differences across firms (such as size or industry), isolating the impact of time varying maritime freight costs on performance outcomes. Each model used the global freight cost index as the key independent variable and one financial performance indicator as the dependent variable, with n = 8,371 firms observed annually from 2020-2024 (total observations ranging from 41,673 to 41,695 depending on data availability). The freight costs index increased sharply during 2020-2021 and then moderated by 2023, providing a natural experiment to assess cost shock impacts on firms. Reported below the estimated coefficients (β) and significance levels for the freight index's effect on four performance metrics: operating revenue

Table 1 *Output from GRETL software*

Dependent variable	Coefficient index	Std. error	t-ratio	p-value	within R^2
Turnover	0.0545	0.0134	4.05	***	0.00049
Margin	-0.00011	2.32×10^{-5}	-4.75	***	0.00068
Stock	0.0334	0.00367	9.1	***	0.00248
COGS	0.0464	0.0096	4.85	***	0.0007

(Turnover), gross margin ratio (Margin), inventory holdings (Stock), and cost of goods sold (COGS).

Revenue and Cost Effects: Rising maritime transport costs were associated with higher operating revenues and higher cost of goods sold for V4 manufacturing SMEs. In the turnover model, the freight cost index showed a positive coefficient ($\beta \approx 0.054$, $p < 0.001$), implying that an upswing in global shipping rates corresponded to a modest increase in SME sales. Although the counterintuitive at first glance, this result suggests that firms were largely able to pass on elevated logistics expenses to customers in the form of higher prices, thereby inflating nominal revenues. The finding aligns with broader economic observations during the COVID19 pandemic: surging transport costs fed into output price inflation without necessarily suppressing demand. At the same time the SMEs experienced a substantial rise in input costs. The coefficient on the freight index in the COGS model was positive and sizable ($\beta \approx 0.0464$, $p < 0.001$), indicating that higher shipping rates led to significantly higher cost of goods sold. In other words, as maritime freight became more expensive, the cost paid by SMEs for imported materials and components rose commensurately, squeezing their cost structure. This evidence confirms that global logistics shocks were directly transmitted into firms' production costs, consistent with recent IMF analyses showing shipping cost spikes pass through to higher producer prices. It is important to note that while the revenue uptick suggests SMEs did not lose sales in aggregate, the cost increase was proportionally much larger. The net effect was a deterioration in profitability, as discussed next.

Profitability and Margin Effects: SME profit margins were noticeably eroded during periods of high freight costs. The gross margin ratio (gross profit as a percentage of sales) showed a negative association with the freight index. The fixed effects model estimates for Margin yielded €≈ -0.00011 ($p < 0.001$), indicating that each unit increase in the shipping cost index led to a slight but significant decline in gross margin percentage. Although the coefficient may appear small in absolute terms, its effect is nonnegligible given the large swings in freight rates over 2020-2021. For example, at the peak of the logistics crisis the global freight indices climbed several hundred points above their 2019 baseline; our estimate suggests that such a shock would cut the average SME's gross margin by a few tenths of a percentage point. This constitutes a meaningful reduction considering that the sample's mean gross margin was around 42%. The finding empirically confirms that soaring transport costs squeezed profit margins for manufacturing SMEs in Central Europe. The SMEs were forced to absorb part of the cost surge rather than fully transferring it to customers, resulting in margin compression. This result is in line with qualitative reports of firms' profitability being under pressure due to pandemic era supply chain disruptions. This analysis provides clear evidence of this effect in the V4 context - as transport costs rose, SME profitability declined, even though sales revenue rose, because cost of sales outpaced any price markups.

Inventory (Stock) Adjustments: The surge in freight costs was further associated with changes in inventory management. It is found that SME inventory levels (Stock) increased significantly in response to higher shipping prices. The freight index's coefficient in the inventory model was positive (€ ≈ 0.033, $p < 0.001$), suggesting that firms held greater stocks of inputs and products when transport became costlier. One interpretation is that V4 manufacturers adopted more of a "just in case" strategy: anticipating prolonged delivery times and future cost increases, they accumulated extra inventory as a buffer. This behaviour has been observed globally during the pandemic supply crunch, as companies built up safety stocks to hedge against logistics uncertainty. These findings corroborate this adaptation where SMEs increased their inventories in tandem with freight cost spikes, likely to avoid stockouts or lock in lower shipping costs before further rate rises. While such a stockpiling would amplify the short-term costs (tying up working capital in inventory), it was a rational response to unpredictable, expensive freight service. In summary, high maritime transport costs not only raised direct expenses but also induced firms to alter their operations (e.g., inventory policies), with potential knock-on effects on financial statements.

Across all these regressions, the effects of freight costs are statistically significant at the 0.1% level or better, underscoring a robust link between global transport prices and SME performance metrics from 2020-2024. However, the magnitude of these effects remains relatively small in economic terms when viewed against overall firm variability. The fixed effects models have very low within firm R^2 (on the order of 0.05% or less for the freight index alone), indicating that year to year fluctuations in freight prices explain only a tiny fraction of the variance in individual firms' financial outcomes. Most variation is driven by the firm specific factors and idiosyncratic shocks not captured by the

transport index. Thus, while a clear directional pattern exists - higher freight costs push up revenues and costs and compress margins - the transport cost factor by itself did not dominate firm performance during 2020-2024. This nuance is important for interpreting the practical significance of the results, as discussed below.

4 Conclusions

These results provide empirical support for the hypothesis that global logistics costs influence manufacturing SMEs' financial health, while also highlighting the limits of that influence. Each finding can be contextualized considering existing literature and economic theory. Overall, this study aligns with prior research on supply chain shocks and extends it by quantifying the impact of the 2020-2021 freight cost surge on firm level outcomes in Central Europe.

First, the positive revenue response to higher freight costs suggests a passthrough of cost inflation to customers. This observation is consistent with macroeconomic analyses that documented strong pricing power and inflationary passthrough during the COVID19 supply chain disruptions. Notably, the International Monetary Fund (2022) reported that the surge in shipping rates in 2021 added as much as 1.5 percentage points to global consumer price inflation in 2022. Firm level evidence [9] mirrors this macro trend: V4 SMEs raised their output prices (and hence revenues) alongside rising input costs. In the context of existing literature on SMEs, this finding nuances the commonly held view that small firms struggle to transfer cost increases to prices [9]. In fact, during an economywide shock that affected all firms, even SMEs could increase prices without losing customers, as the entire market faced the same cost pressures. This outcome might reflect a low elasticity of demand for certain manufactured goods in the short run or a general inflationary environment in which customers reluctantly accept higher prices. It may also indicate that V4 manufacturers benefited from strong post pandemic demand in Europe, allowing them to maintain sales volumes despite charging more per unit. Our findings here converge with the observations of OECD (2021) that post lockdown demand and supply bottlenecks jointly fuelled a sharp uptick in prices across many sectors.

Second, the erosion of gross margins under high freight costs conditions is firmly in line with theoretical expectations and prior studies of supply chain risk. When input costs rise rapidly, firms often cannot fully offset the increase through higher prices, especially if contracts or competitive pressures limit immediate price adjustments [31]. The SMEs in the sample experienced a squeeze in profitability, as evidenced by the significant drop in gross margin ratio. This result dovetails with the findings, which noted that SMEs during the pandemic faced margin pressures due to rising transportation and procurement costs [8]. It also complements the works, which emphasized that greater dependence on external suppliers can heighten SMEs' cost vulnerabilities and hurt their financial performance [9]. In this case, even without directly measuring supply chain dependence, the freight index serves as a proxy for an external cost shock that hit virtually all import reliant firms. The fact that margins fell across the board supports the view that SME profitability is tightly linked to supply chain conditions. When those conditions deteriorate (e.g., logistics become expensive and unreliable), small manufacturers see an immediate negative impact on their bottom line. This aligns with broader evidence that unexpected cost spikes disproportionately affect smaller firms, which lack the buffering capacity and economies of scale that large firms have in absorbing cost shocks [9]. The contribution is to quantify that impact for the maritime transport disruption: a major spike in shipping costs can measurably shave off SME profit margins, even within a short one-to-two-year window.

Third, the finding that inventory levels increased with freight costs offers insight into SME adaptive behaviour. Inventory buildup is a double-edged sword: it can safeguard production against delayed inputs, but it ties up cash and risks obsolescence. The positive association between the freight index and stock levels in data suggests that the extraordinary nature of the 2020-2021 shock pushed firms to prioritize resilience over efficiency. This behavior is strongly consistent with reports of a shift from "just in time" to "just in case" inventory management during the pandemic (e.g., firms holding more stock to guard against supply disruptions). Empirical evidence confirms that such a shift occurred among V4 manufacturers. This outcome is also in agreement with supply chain management research that highlights inventory as a key buffer in times of uncertainty [8]. Interestingly, the inventory increase observed may have exacerbated the cost issues discussed above by purchasing and holding more inputs in advance, SMEs likely incurred higher holding costs and possibly paid premium prices, which could further dent profitability. In essence, the SMEs traded off some financial efficiency for greater supply security. This adaptive strategy aligns with the notion of supply chain resilience found in recent studies [3, 5], wherein firms accept short term cost increases to mitigate the risk of stockouts and lost sales. Results thus contribute to the literature by illustrating this trade off in quantifiable terms: high transport costs led firms to accumulate inventories, reflecting a strategic response to external risk.

It is worth noting that the models capture a short run contemporaneous relationship rather than long term causation. The analysis cannot conclusively determine whether the higher freight costs caused these performance changes or merely coincided with other forces (such as the general economic rebound in 2021-2022). However, the fact that the freight index is

a significant predictor even after accounting for firm fixed effects suggests a meaningful link. The discussion above interprets the relationships in a causal narrative (for example, positing that freight cost shocks squeezed margins), consistent with theoretical expectations and timing of events. This interpretation finds support in external evidence and reports, as cited. Still, one must be cautious: the freight surge occurred alongside other pandemic related challenges (labour shortages, energy price spikes, etc.), and those factors likely also influenced SME performance [7]. Results, therefore, are best viewed as evidence of correlation in line with plausible causation mechanisms, reinforced by the concurrence of our findings with widely reported real world trends.

4.1 Implications

The study's findings carry several important implications for managers, policymakers, and researchers concerned with SME performance and supply chain management. Managerially, the results underscore the importance of developing strategies for cost passthrough and cost control in times of volatile logistics expenses. The ability of V4 SMEs to maintain or even increase revenue during a period of soaring freight prices suggests that agile pricing strategies and customer communication were critical; SMEs that quickly adjusted their prices could protect their topline revenue. However, the overall decline in margins indicates that such firms still absorbed part of the cost increases. This implies that managers should explore long term solutions to bolster margins against supply chain cost shocks, for example, by diversifying sourcing options, renegotiating supplier contracts to share logistics costs, or improving operational efficiency to reduce other expenses. The significant inventory buildup observed also highlights a strategic consideration: resilience vs. efficiency. Firms chose to hold more inventory to mitigate risk, accepting higher holding costs. Managers must weigh these trade-offs and perhaps invest in better demand forecasting and inventory optimization tools. In an environment where global transport costs can swing dramatically, SMEs may benefit from incorporating scenario planning for logistics expenses and considering instruments like freight insurance or hedging if available.

For policymakers and support institutions, these findings illustrate how the global supply chain disruptions can ripple down to small businesses in landlocked economies. The V4 countries, though not directly on seacoasts, were clearly not insulated from maritime cost shocks - a reminder of their integration in global trade networks [10]. Policymakers should therefore consider measures to help the SMEs manage such external shocks. For instance, governments might provide temporary freight subsidies or logistics support programs during extreme cost surges to prevent excessive damage to SME profitability. Investing in alternative transport infrastructure (such as improving rail connections to major ports or supporting regional distribution hubs) could also alleviate the reliance on distant maritime routes and reduce freight cost volatility for inland firms [10]. Additionally, disseminating market intelligence, e.g., early warnings about rising freight rates and guidance on adaptive strategies, could empower SME owners to respond proactively. From a financial perspective, the fact that SMEs' margins were squeezed suggests many may have experienced cash flow stress during the high freight cost period. This underscores the need for accessible financing solutions or emergency credit lines for SMEs when global shocks drive up working capital requirements (as when firms must pay more for inventory and shipping [10]. In summary, an implication for policy is that the SME's resilience in global supply chains can be strengthened through a targeted support, infrastructure investment, and information sharing to mitigate the impact of abrupt logistics cost swings.

For scholars and future research, this study provides a baseline quantification of freight cost impacts and points to several avenues for further investigation. The very low within firm explanatory power of the freight index indicates that most performance variation comes from other factors; future research could incorporate additional variables (such as input prices, exchange rates, or firm specific characteristics like liquidity and supply chain diversification) to build a more comprehensive model of SME performance under stress. Another implication is the importance of examining heterogeneous effects: our aggregate results show the average impact, but different industries or firms might have experienced varying degrees of pain or gain. Subsequent studies might segment the sample by industry (e.g., automotive vs. electronics manufacturing) or by firm size/maturity to see if certain groups were more vulnerable to freight cost shocks. Moreover, qualitative research could complement these quantitative findings by exploring how exactly the SMEs managed to pass through costs or why some could not, thereby shedding light on the mechanisms behind the observed statistical relationships. Overall, our work highlights that global logistics factors deserve greater attention in SME performance research and that integrating supply chain metrics (like freight indices) into firm level studies can enrich our understanding of business vulnerability and resilience in an interconnected world.

4.2 Limitations

While this study offers novel insights, several limitations must be acknowledged. First, this analysis relies on Orbis accounting data and a single global freight index. The financial data include only a few indicators over a relatively short five-year horizon,

excluding important dimensions such as net profit, cash flow, operating expenses, and debt. The SCFI, although a reasonable proxy, may not perfectly capture firm-specific freight costs, which vary by route, cargo, and contract type. Since the index is common across firms, it is collinear with year effects, preventing to include the time fixed effects; thus, the estimated coefficients may partially reflect other concurrent macroeconomic trends (e.g., post-pandemic recovery, fiscal stimuli, or general inflation).

Second, the model assumes a contemporaneous linear effect. It does not account for potential lags, nonlinearities, or thresholds despite the possibility that firms experienced delayed or disproportionate responses. The analysis also treats the effect as homogeneous, even though the SMEs differ in logistics contracts, bargaining power, or supply-chain flexibility. Sample bias is another concern: Orbis underrepresents microenterprises and financially weaker firms, meaning the smallest SMEs are not captured. Finally, the study is observational and examines an exceptional period; results should be generalized with caution.

It is shown that the extreme freight costs swings of 2020-2024 had detectable but modest impacts on V4 manufacturing SMEs. Higher shipping costs coincided with higher revenues, larger inventories, and significantly higher COGS, compressing gross margins. Firms appeared to respond adaptively, especially via inventory expansion, which helped mitigate supply-chain uncertainty but raised holding costs. Overall, the results indicate that the inland SMEs were exposed to global logistics turbulence, even if freight costs explained only a small share of within-firm variation.

The findings contribute to the literature by quantifying how a global cost shock permeated the SME financials and by underscoring their partial resilience: SMEs could pass on some costs but still experienced margin pressure. For policymakers, the evidence highlights the need to strengthen the supply-chain resilience and protect smaller firms from extreme logistics price volatility. The 2020-2024 period effectively served as a stress test, offering lessons for preparing SMEs for future disruptions in freight markets and other critical input channels.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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