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Information Asymmetry, Return, and Market Structure in Petrochemical Companies: A Dynamic Spatial Panel Method

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Highlights

- While information asymmetry in petrochemical companies has a positive but limited effect on observed retained earnings, it exhibits a significant negative effect on price return and total stock return.
- In terms of returns, the Iranian petrochemical industry follows a monopolistic competitive pattern; however, monopolistic behavior is evident in its dividend policy.
- Under conditions of information asymmetry, investors act more cautiously, particularly in response to price returns, while companies may accumulate additional profits to mitigate associated uncertainty.
- Financial decisions in the petrochemical industry are shaped by past corporate performance as well as the behavior of neighboring competitors.

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Abstract

This study employs spatial econometric and dynamic analyses to examine the temporal and spatial effects on three performance indicators of petrochemical companies listed on the Tehran Stock Exchange: price performance, retained earnings, and total performance. The target population includes all petrochemical companies that have been active on the Tehran Stock Exchange from the beginning of 2013 to the end of 2024. The findings indicate that, while information asymmetry positively influences retained earnings, it simultaneously exerts a negative effect on both price performance and total performance. An examination of the H-index further shows that the market structure of this industry is monopolistic. However, monopolistic behavior is specifically observed in the distribution of retained earnings, a pattern attributable to the centralized governance structure of the Iranian petrochemical industry.

Results related to financial structure demonstrate that high financial leverage and financing costs adversely affect returns, whereas investment in physical assets generates the most favorable outcomes. Moreover, the identification of significant spatial effects confirms that proximity and spillover effects among companies are substantial. Overall, this study provides robust empirical evidence that improving information transparency, optimizing financial structures, and reforming corporate governance mechanisms could enhance market returns and strengthen stock performance in the petrochemical industry.

Keywords: Dividend, Dynamic spatial panel, Information asymmetry, Market structure, Price return,

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1. Introduction

Financial markets, which function as platforms for optimal resource allocation, face various challenges, including information asymmetry. This phenomenon is particularly pronounced in capital-intensive industries such as the petrochemical sector, which is characterized by technical complexity, input price volatility, and political–economic risks (Blondeel and Bradshaw, 2022). Information asymmetry can lead to price deviations from intrinsic value (Alimoradi and Rajabdorry, 2018), reduced market efficiency (Akhtar and Asif, 2017), and changes in competitive structure (Mazaraki et al. 2020). In parallel, the spatial dependency of corporate activities in this industry—driven by factors such as shared supply chains, regional consumer markets, and macro-policy alignment—combined with the temporal dynamics of corporate returns, underscores the need to employ advanced econometric techniques, including the dynamic spatial panel model.

The petrochemical industry, a cornerstone of the Iranian economy, plays a pivotal role in generating added value, creating employment, and contributing to foreign exchange earnings (Shamsoddini and Akhlaghi, 2024). However, the performance of this industry depends heavily on capital market returns and information transparency. In recent years, challenges related to information asymmetry, optimal financial structure, and competitive behavior among petrochemical companies listed on the Tehran Stock Exchange have become critical concerns for policymakers, investors, and corporate managers.

This study applies a novel spatial econometric approach to thoroughly analyze the impact of information asymmetry on returns and market structure in the petrochemical sector. The dynamic spatial panel method enables more accurate measurement of cross-regional effects stemming from investment policies and exogenous shocks (Chen et al. 2025), such as oil price fluctuations, on industry performance. By incorporating spatial dependencies among geographic units and accounting for temporal dynamics, this method identifies both the spillover effects of regional policies on neighboring areas and the long-term effects of macroeconomic variables on firm profitability (Otieno, 2024). From a policy standpoint, this analytical framework assists decision-makers in designing industrial development strategies with enhanced returns by distinguishing between direct and indirect effects, including spatio-temporal effects, associated with policy implementation (Liang, 2024). Consequently, the application of the dynamic spatial panel in petrochemical industry research not only strengthens the validity of empirical findings but also serves as a powerful analytical tool for developing effective macro-level industrial policies. This methodology offers several key advantages: first, it facilitates the detection and quantification of spatial spillover effects; second, it enables the modeling of temporal dynamics; and third, it allows for controlling individual firm heterogeneity.

A review of the existing research literature indicates that, although numerous studies have examined factors affecting stock returns (Zhang and Sok, 2025; Mohanasundaram et al. 2024; Raei et al. 2022; Chhajer et al. 2020; Shamsoddini et al. 2017), relatively few have simultaneously analyzed the effects of information asymmetry and market structure using a spatial approach within the Iranian capital market. This research gap is particularly evident in the petrochemical industry, which exhibits distinctive structural and operational characteristics. Accordingly, this study integrates advanced econometric techniques with theoretical insights to provide a comprehensive assessment of market behavior among petrochemical companies.

The primary objective of this research is to address three key questions. First, the effect of information asymmetry on various dimensions of stock returns must be examined, including price return, retained earnings, and total return. Second, the competitive structure governing the petrochemical industry must be evaluated. Third, the role of spatial and temporal factors in explaining the return behavior of these companies must be clarified. Answering these questions contributes to a deeper understanding of the mechanisms that shape the Iranian capital market and supports the formulation of effective policies.

This study is significant for several reasons. Given the central role of the petrochemical industry in the Iranian capital market, a thorough understanding of the factors influencing stock returns in this sector enables more informed investment decisions. An in-depth analysis of the competitive landscape offers a clearer perspective on market returns. Moreover, the concurrent examination of temporal and spatial dimensions through a spatial dynamic panel model offers a more comprehensive understanding of market dynamics. The data employed in this study encompass financial and market information for petrochemical companies listed on the Tehran Stock Exchange from 2013 to 2024. The structure of the article is as follows: following this introduction, Section 2 reviews the theoretical literature and related research. Section 3 presents the research methodology. Section 4 provides the empirical findings, and Section 5 offers conclusions and policy recommendations.

2. Literature review and background

2.1. Theoretical foundations

The theoretical foundations of this study are further strengthened by examining the distinctive characteristics of the petrochemical industry. These characteristics—stemming from high capital intensity, long investment cycles, dependence on oil and raw material prices, and the significant role of the government (Al-Samhan et al. 2022)—influence the financial behavior and stock returns of companies operating within the sector. Such structural attributes necessitate modifications to traditional corporate finance theories.

In capital markets, information asymmetry refers to circumstances in which one party to a transaction, typically managers or major shareholders, possesses private information unavailable to other investors (Goldstein, 2023). This phenomenon can affect stock returns through several channels, including adverse selection and moral hazard (Salman, 2023). Information asymmetry, a foundational concept in financial economics, draws on seminal works such as Spence's signaling theory (1973) and Akerlof's adverse selection model (1970). Within these frameworks, disparities in information among market participants lead to inefficiencies (Alrashidi, 2022). In financial markets, the issue can be further analyzed through efficient market models (Fama, 1970) and agency theory (Jensen and Meckling, 1976). A comprehensive review of existing theoretical and empirical studies indicates that information asymmetry exerts a meaningful influence on stock returns and can lead to systematic deviations from intrinsic value as well as excessive market volatility.

The concepts of market structure and competitive behavior in the stock market hold central importance in the fields of finance and industrial economics. These concepts originate from theories of market competition and the Structure–Conduct–Performance paradigm (Kumar and Choudhary, 2024). Within this theoretical framework, market structure—shaped by factors such as the number of market participants, entry and exit barriers, and the degree of product differentiation—directly influences competitive behavior and ultimately market performance. In stock markets, these concepts manifest through competition among traders, market returns, and asset liquidity. Some researchers have incorporated transaction costs into this analysis, demonstrating that market structure directly affects pricing behavior and competition among liquidity providers (Frésard and Phillips, 2024). Conversely, market microstructure models emphasize that the competitive conduct of traders, reflected in pricing strategies and reactions to new information, can influence key indicators such as market depth and bid–ask spreads (Al Janabi, 2024). Competitive behavior in stock markets is also shaped by game theory

(Ullah et al. 2021), wherein traders, acting as rational players, select optimal strategies to maximize their payoffs. Among these theoretical perspectives, monopolistic competition and competition under information asymmetry have been identified as critical determinants of pricing behavior and trading volume. Empirical evidence indicates that in markets with centralized structures and a limited number of major traders, competitive behavior can lead to higher transaction costs and reduced liquidity (Üslü, 2019). In contrast, markets with more competitive structures exhibit higher efficiency and greater transparency in information disclosure. These findings align with efficient market theory, which underscores the essential role of competition in achieving fair prices.

Corporate governance, understood as the framework through which companies are directed and controlled, plays a pivotal role in reducing information asymmetry and improving stock returns. According to agency theory, conflicts of interest between shareholders and managers can heighten information asymmetry and ultimately reduce stock returns (Tekin and Polat, 2020). This perspective emphasizes that effective governance mechanisms—including concentrated ownership structures, independent boards of directors, and transparent information disclosure—can reduce agency costs. Stakeholder theory, in contrast, posits that addressing the interests of all stakeholders, including minority shareholders, contributes to reducing information asymmetry and enhancing transparency (Gyapong and Afrifa, 2019). Signaling theory further suggests that firms with strong governance practices send positive signals to the market through timely and accurate disclosure, thereby improving stock returns (Ahmed, 2023). Additionally, transaction cost theory highlights that robust corporate governance can mitigate transaction costs arising from information asymmetry, supporting more efficient resource allocation.

2.4. Research background

Recent studies have identified three distinctive characteristics of the petrochemical industry. First, the industry demonstrates high sensitivity to global oil and gas prices, as noted by Al Mestneer and Bollino (2024). Second, the impact of sanctions on the financial structure of petrochemical firms has intensified, as evidenced by Ghazanfari Shabankareh et al. (2024). Third, the government plays a significant role in determining dividend policies, as highlighted by Bhatti et al. (2023).

A substantial body of research has shown that information asymmetry affects stock returns through multiple mechanisms. The cost of capital channel indicates that an increase in the information gap raises the information risk premium (Cai, 2023), which subsequently increases financing costs for companies (Jansen, 2020). The market liquidity channel is influenced by declining transparency, which widens the bid–ask spread and reduces market depth (Daadaa, 2021). Furthermore, the investor portfolio selection channel contributes to this phenomenon; in this context, incomplete information may prompt investors to shift toward riskier or lower-yielding stocks (Saci et al. 2022).

The validity of these effects is further supported by empirical evidence. For example, the literature on informed trading demonstrates that informed traders can earn abnormal returns (Ahern, 2020). Similarly, Easley and O'Hara (2004) provide evidence of a positive relationship between information asymmetry and expected stock returns through the development of the Probability of Informed Trading index. These findings align with the Capital Asset Pricing Theory and more advanced asset pricing models, such as the Fama and French three-factor model, in which information risk is incorporated as an additional pricing factor.

Recent research in behavioral finance shows that information asymmetry in capital-intensive industries, such as petrochemicals, can exert nonlinear effects on stock returns. Xia and Liu (2021), in a study focused on emerging markets, report that in industries with moderate competition intensity, such as petrochemicals, the influence of information asymmetry on stock returns follows an inverted U-shaped pattern. This result is consistent with signaling theory, which posits that firms employ more sophisticated signaling mechanisms at moderate levels of information asymmetry.

In the petrochemical industry, characteristics such as entry barriers, substantial capital requirements, and variability in product quality create conditions similar to monopolistic competition. Recent research on the market structure of this industry suggests that, despite global trends toward perfect competition (Berk and Çam, 2020), monopolistic competition characteristics persist in emerging markets such as Iran (Khodadad Kashi et al. 2024). Empirical evidence also indicates that firms with strong corporate governance mechanisms experience lower levels of information asymmetry and higher stock returns (David et al. 2022). For example, Wang et al. (2020) show that transparent and timely disclosure of financial information can reduce information asymmetry and improve stock returns.

3. Methodological framework

3.1. Methodology

The methodological framework of this study is grounded in spatial econometrics and dynamic analysis. Anselin's (1988) contributions established the theoretical foundation for spatial models, which enable the examination of neighborhood effects and spatial spillovers. In contrast, the dynamic panel approach pioneered by Arellano and Bond (1991) facilitates the investigation of temporal dynamics in cross-sectional time series data. The integration of these two approaches in the form of a spatial dynamic panel model (Yu and Lee, 2012) allows for the simultaneous analysis of temporal and spatial effects. Recent advancements in spatial econometrics indicate that conventional SAR and SEM models are insufficient for analyzing spatial effects in capital markets. Otto et al. (2024) propose dynamic spatiotemporal models capable of identifying dynamic spatial correlations. These developments are particularly relevant to the petrochemical industry, as Gao et al. (2024) demonstrate that spatial spillover effects in energy industries account for a substantial portion of the variation in stock returns.

Given the geographical clustering of petrochemical companies and the existence of spatial spillovers in key variables such as technology and environmental performance, the use of spatial panel models enables explicit incorporation of spatial dependencies in the analysis. This approach is more accurate than traditional methods, such as linear panel models or the generalized method of moments, which do not account for spatial effects. Diagnostic tests conducted in this study confirm the presence of spatial autocorrelation in the data, thereby justifying the necessity of employing this methodology.

In this study, the generalized Panzar–Rosse framework, modified to incorporate spatial dynamics, is used to examine market structure and return fluctuations in the petrochemical industry. Considering the industry's distinctive characteristics—such as high investment intensity, dependence on energy inputs, and significant government involvement in pricing regulation—the application of the Panzar–Rosse H-index provides meaningful insights into the competitive behavior of firms operating within this sector.

The Panzar-Rosse H-index, a non-structural tool in industrial economics, measures the degree of market concentration by utilizing behavioral data and actual firm performance (Sohail et al. 2024). The theoretical foundation of this index is based on the analysis of the systemic relationship between firms' income and the prices of production inputs. Within this framework, a regression model of the summarized form of income is employed to examine the behavior of firms in different market environments. According to the fundamental assumptions of this model, each firm operates in the production process with the objective of maximizing profit. The fulfillment of these optimization conditions depends on the satisfaction of two primary criteria: the equality of total revenue and total cost, and the equivalence of marginal revenue and marginal cost.

The H-index, derived by taking the derivative of the revenue function with respect to the input price, enables the classification of markets based on the degree of competitiveness. Values of this index across various ranges indicate distinct market structures. When H=1, the market is competitive, and a decrease or increase in the input price results in a corresponding decrease or increase in both marginal cost and marginal revenue. Conversely, when 0<H<1, the market is monopolistic, occupying a position between competition and monopoly; a decrease or increase in the input price produces a greater decrease or increase in marginal cost than in marginal revenue. When $H \leq 0$, the market is monopolistic, and a decrease or increase in the input price leads to a decrease or increase in marginal cost. This change in marginal cost either has no effect on marginal revenue (H = 0) or causes a decrease in marginal revenue (H < 0) (Sanchez, 2020).

Subsequently, the dynamic spatial panel method, implemented within R software, is employed to examine the impact of information asymmetry on the volatility of returns and the market structure of petrochemical companies listed on the Tehran Stock Exchange, including Tabriz Oil Refinery, Bandar Abbas Oil Refining, Behran Oil, Isfahan Oil Refinery, Parsian Oil and Gas Development Group, Shazand Petrochemical, Pardis Petrochemical, Fan Avaran Petrochemical, Shiraz Petrochemical, and Kermanshah Petrochemical Industries. The data were collected from the Tehran Stock Exchange information website and were based on the financial statements, notes, and reports of the companies. It is important to note that these companies do not differ substantially in essence. The Parsian Oil and Gas Development Group is highlighted for two primary reasons: first, because the Tehran Stock Exchange is the focus of the study and the direction of stock value and return is significant; second, because this group owns numerous petrochemical plants whose shares are not publicly traded on the Tehran Stock Exchange, rendering it representative of these companies.

3.2. Model specification

Following Panda et al. (2016), the H-index is calculated based on the logarithmic linear relationship between marginal revenue and cost, as shown in Equations 1 and 2.

$$Ln(MR) = \alpha_0 + \alpha_1 Ln(S) + \sum \gamma_i Ln(EX_i) \tag{1}$$

$$Ln(MC) = \beta_0 + \beta_1 Ln(S) + \sum \delta_i Ln(W_i) + \sum \theta_i Ln(EC_i) \tag{2}$$

Where MR represents marginal revenue, MC denotes marginal cost, S indicates firm output, *i* is the number of firms in the market, EX is an exogenous variable that shifts the revenue function, W_i is the price of the production input, and EC is an exogenous variable that shifts the cost function. Under equilibrium conditions, firms operate in a situation where economic profit tends toward zero. Establishing this equilibrium requires equality between marginal revenue and marginal cost (MR=MC). The equilibrium production level can be derived by applying the optimization conditions and taking the logarithms of the revenue and cost functions, as shown in Equation 3.

$$Ln(S^*) = (\beta_0 - \alpha_0 + \sum \delta_i Ln(W_i) + \sum \theta_i Ln(EC_i) - \sum \gamma_i Ln(EX_i))/(\alpha_1 - \beta_1) \tag{3}$$

In Equation 3, S^* represents the firm's equilibrium output level. This equation indicates the point at which firms achieve equilibrium in the short run and base their production decisions accordingly. In this context, the presence of market entry barriers and exit obstacles significantly limits the ability of firms to enter or leave the market.

The model in this study is based on the reduced revenue function, which serves as the main theoretical framework for the analysis. This function is derived by inverting the product demand function and is defined in terms of two key variables: the firm's equilibrium production level and the price of production inputs. The mathematical expressions of this model are given in Equations 4 and 5.

$$Ln(P) = \vartheta + \mu Ln \sum_{i=1}^{n} S_i^* \tag{4}$$

$$Ln(TR) = \beta_0 + \beta_1 Ln(S^*) \sum \delta_i Ln(W_i) \tag{5}$$

Where P denotes the profit rate and TR represents the total revenue of the company. The petrochemical industry, characterized by its dependence on oil and gas resources, the influence of geographical and regional factors, and its critical role in national economies, requires sophisticated analytical methodologies capable of accurately modeling the complexities of this sector. The dynamic spatial panel method is particularly effective in this regard, as it integrates both spatial and temporal dimensions to enable a more comprehensive analysis. This approach considers not only the spatial dependencies between distinct regions but also the dynamic effects of variables over time.

Spatial dependence is frequently observed in cross-sectional data with a spatial component, indicating the presence of systematic relationships between geographically distinct observations. Specifically, if the value of a variable at a particular location (i) is influenced by the values of the same variable at neighboring locations (i≠j), spatial dependence is present. This property implies that measurements at a given location are closely associated with values at surrounding locations, rendering them inherently interdependent. Equation 6 illustrates spatial dependence.

$$E\left(Y_i \middle| Y_j\right) \neq E(Y_i) \tag{6}$$

Where the variable value at location *i* is denoted Y_i, and its value at neighboring locations *j* is denoted Y_j. This inequality indicates that the expected value of Y_i, conditional on the values of Y_j, differs from its unconditional value. This observation suggests the presence of spatial dependence in the data. Such spatial dependence is frequently observed in numerous economic and regional studies, including analyses of the performance of large industries such as petrochemicals. These industries are affected by spatial factors, including access to resources, infrastructure, and regional policies. Ignoring this phenomenon can lead to biased estimates and incorrect conclusions.

In spatial econometrics, the determination of spatial location is achieved through the application of various methodologies. In this study, following LeSage and Pace (2009), the geographical coordinates (latitude and longitude) of each company are determined, and the Euclidean distance between each pair of observations is calculated. Specifically, the distance of each point from a fixed reference, such as an industrial center or a focal point of economic activity, is used as a criterion for measuring spatial proximity. Theoretical foundations of spatial econometrics suggest that observations separated by shorter spatial distances will exhibit a higher degree of spatial dependence compared to observations that are farther apart. The spatial weight matrix, used in subsequent modeling, is constructed based on the inverse relationship between distance and the intensity of spatial dependence. This approach is particularly important for analyzing industrial clusters, such as the petrochemical sector, where geographic concentration substantially affects unit performance. In computing this matrix, we considered the spatial distances between the cities hosting the petrochemical companies.

Equation 7 presents the general form of a spatial regression model.

$$Y_i = \sigma\tau Y_i + \phi X_i + \tau X_i \psi + \varepsilon \tag{7}$$

In Equation 7, Y_i denotes the dependent variable vector, X_i represents the independent variable matrix, τ is the spatial weight matrix that defines the spatial neighborhood structure, σ represents the spatial autocorrelation coefficient of the dependent variable, ϕ is the vector of coefficients for the independent variables, ψ is the vector of coefficients for the spatial effects of the independent variables, and ε is the error term, assumed to follow a normal distribution.

Since this study is conducted in the stock market, where many shareholder decisions are influenced by past company performance, it is necessary to specify a dynamic form to capture how variables affect performance over time. The general form of the dynamic equations is given in Equation 8.

$$Y_{it} = \lambda_0 + \lambda_1 Y_{i\,t-1} + \lambda_2 X_{it} + \varepsilon_{it} \tag{8}$$

Where Y_{it} denotes the dependent variable, $Y_{i\,t-1}$ is the lagged dependent variable, and X_{it} represents the model control variables. Accordingly, to evaluate the impact of information asymmetry on the volatility of returns and the market structure of petrochemical companies in the presence of spatial effects, the generalized form of the Panzar-Rosse income equations can be applied dynamically, as supported by findings from previous empirical studies, as follows:

$$\pi_{it} = \mathrm{M} + \sigma\tau\pi_{it} + \varsigma\pi_{it-1} + \varsigma\tau\pi_{it-1} + \phi_1 FR_{it} + \phi_2 CP_{it} + \phi_3 Lev_{it} + \phi_4 Ainf_{it} + \tau X_i \psi + \varepsilon_{it} \tag{9}$$

$$R_{it} = \mathrm{M} + \sigma\tau R_{it} + \varsigma R_{it-1} + \varsigma\tau R_{it-1} + \phi_1 FR_{it} + \phi_2 CP_{it} + \phi_3 Lev_{it} + \phi_4 Ainf_{it} + \tau X_i \psi + \varepsilon_{it} \tag{10}$$

$$\Pi_{it} = \mathrm{M} + \sigma\tau\Pi_{it} + \varsigma\Pi_{it-1} + \varsigma\tau\Pi_{it-1} + \phi_1 FR_{it} + \phi_2 CP_{it} + \phi_3 Lev_{it} + \phi_4 Ainf_{it} + \tau X_i \psi + \varepsilon_{it} \tag{11}$$

Where π_{it} is the average rate of profit (loss) from stock price changes; ς represents the lagged response parameter of the dependent variable; FR_{it} denotes the average rate of financing; CP_{it} is the price of physical capital; Lev_{it} stands for the financial leverage of a given entity; $Ainf_{it}$ is information asymmetry index; R_{it} indicates the average rate of retained earnings of stocks; and Π_{it} is the average rate of total dividends (including appreciation, profits, and dividends per share). In Equations 9–11, the sum of the elasticities ($\sum_i \phi_i$) is represented by the H index.

One of the most widely used measures of information asymmetry among market participants proposed in recent financial literature is the probability of informed trading (PIN). Easley and O'Hara (1992) introduced a model of abnormal order flow in the market, which allows estimation of the probability of a random trade by an informed trader (PIN). Higher PIN values, ranging from 0 to 1, indicate the presence of greater confidential information or a higher level of information asymmetry. The probability of informed trading for a given stock *i* (PIN) is defined as the estimated entry rate of informed trades divided by the estimated entry rate of all trades on a given day. This probability is expressed in Equation 12:

$$Ainf_i = PIN_i = \frac{\kappa\upsilon}{\Lambda\Omega + 2\xi} \tag{12}$$

Assume that κ represents the probability of an information event, Ω represents the probability of a bad information event, and 1–Ω represents the probability of a good information event on a given day. In the absence of information events on a given day (with probability 1–κ), only uninformed (liquid) traders participate in market transactions. On such days, the entry rate of uninformed traders for both buying and selling follows an independent Poisson distribution with probability κ. It is important to note that informed traders will engage in trading only if an information event occurs, with probability υ. Consequently, the decision to buy depends on receiving favorable news (i.e., a "signal"), whereas the decision to sell is influenced by receiving unfavorable news. Therefore, under the assumption that a bad information event occurs on a given day (with probability Ωκ), the entry rate of buy orders (κ) will be lower than the entry rate of sell orders (ξ+υ) because traders are informed. Conversely, if a favorable information event occurs on a given day (with probability κ(1–Ω)), the entry rate of buy orders (ξ+υ) will exceed the entry rate of sell orders (ξ).

3.3. Research variables

The definitions of the research variables are presented in Table 1.

Table 1

The definition of the research variables

Variable	Definition
Average rate of profit (loss) from price changes	Shareholders earn a return from fluctuations in the company's stock price over a given period.
Average retained earnings rate	Retained earnings are the portion of a company's net profit that remains after the deduction of dividends and taxes and are used for future investments, business expansion, or debt reduction.
Average total profit rate	The total return on an investment in stocks is composed of two main components: capital gains and dividends per share.
Average financing rate	The cost of capital represents the average expense a company incurs when raising funds from various sources.
Cost of physical capital	The cost of physical capital reflects the financial expenditure associated with the use of physical assets, including equipment, machinery, and buildings, in the production process.
Financial leverage	The leverage ratio is a quantitative measure indicating the extent to which a company employs debt financing for its assets and operations.
Information asymmetry index	The probability of informed trading (PIN) index quantifies the likelihood of trading based on inside information and reflects the amount of confidential information present in stock trading.

The descriptive statistics for the research variables over the period 2013–2024 are presented in Table 2.

Table 2

Descriptive statistics of research variables

Variable	Average	Middle	Largest	Smallest	Standard deviation	Skewness
$\boldsymbol{\pi_{it}}$	0.171	0.174	0251	0.089	0.048	0.32
$\boldsymbol{R_{it}}$	0.082	0.083	0.103	0.045	0.019	–0.05

Variable	Average	Middle	Largest	Smallest	Standard deviation	Skewness
$\boldsymbol{\Pi_{it}}$	0.367	0.369	0.498	0.201	0.083	0.25
$\boldsymbol{FR_{it}}$	0.211	0.213	0.263	0.179	0.029	0.38
$\boldsymbol{CP_{it}}$	1.65	1.66	1.92	1.42	0.17	0.43
$\boldsymbol{Lev_{it}}$	2.03	2.05	2.45	1.68	0.26	0.40
$\boldsymbol{Ainf_{it}}$	0.40	0.43	0.60	0.27	0.09	0.49

A descriptive analysis of petrochemical companies listed on the Tehran Stock Exchange highlights the distinctive financial and performance characteristics of this industry. The total return on equity, with an average of 36.7% and a median of 36.9%, demonstrates the industry's strong performance in generating shareholder value, primarily driven by price returns, which average 17.1%. In contrast, the mean retained earnings of 8.2%, accompanied by a low standard deviation of 0.019, reflects the adoption of stable and conservative dividend policies by these corporations. From a financial structure perspective, the average financial leverage of 2.03 and a financing rate of 21.1% indicate the industry's reliance on debt financing. The price of physical capital, with an average of 1.65, and the information asymmetry index, averaging 0.40, fall within moderate ranges. However, the positive skewness of these indices, particularly in financial leverage and the price of capital, suggests the impact of critical periods and the presence of outliers. Despite its attractive returns, the petrochemical industry is characterized by high systematic risk due to elevated financial leverage and price volatility. Improving information transparency has the potential to reduce information asymmetry.

4. Empirical results and discussion

4.1. Prior to estimation

Given the panel structure of the research data, the Levin, Lin, and Chu (LLC) test was employed to assess stationarity, and the Variance Inflation Factor (VIF) was used to examine collinearity among the variables. The results of the LLC and VIF tests, presented in Table 3, indicate that all variables in the models are stationary and that no collinearity issues exist among the variables in this study.

Table 3

Results of the stationarity and collinearity test of research variables

Variable	$\boldsymbol{\pi_{it}}$	$\boldsymbol{R_{it}}$	$\boldsymbol{\Pi_{it}}$	$\boldsymbol{FR_{it}}$	$\boldsymbol{CP_{it}}$	$\boldsymbol{Lev_{it}}$	$\boldsymbol{Ainf_{it}}$
LLC	–5.23	–3.08	–4.72	–3.59	–2.71	–2.98	–5.57
p-value	0.000	0.001	0.000	0.000	0.004	0.002	0.000
Stationarity result	Stationary	Stationary	Stationary	Stationary	Stationary	Stationary	Stationary
VIF	1.768	2.412	2.604	3.530	3.352	3.290	4.364
Collinearity result	No	No	No	No	No	No	No

The results of the Hausman test in Table 4 indicate that estimating the spatial panel model using the random effects method is more efficient than using the fixed effects method.

Table 4

Hausman test results

Test	Statistics	df	p-value	Result
Hausman	8.45	5	0.133	Not reject H_0 (RE is appropriate)

Moran's test is a spatial statistic used to detect the presence of spatial autocorrelation in spatial data. The purpose of this test is to determine whether the values of a variable in neighboring geographic units (e.g., cities, provinces, or sampling points) are randomly distributed or display a specific pattern, such as clustering or dispersion. The results of Moran's test are presented in Table 5.

Table 5

Moran's test results

Variable	Moran's I	E[I]	z-score	p-value	Result
$\boldsymbol{\pi_{it}}$	0.42	–0.025	4.72	<0.001	Reject H_0
Residuals	0.18	–0.025	2.93	0.003	Reject H_0
$\boldsymbol{R_{it}}$	0.51	–0.028	5.34	<0.001	Reject H_0
Residuals	0.22	–0.028	3.12	0.002	Reject H_0
$\boldsymbol{\Pi_{it}}$	0.63	–0.020	6.87	<0.001	Reject H_0
Residuals	0.09	–0.020	3.21	0.001	Reject H_0

According to the findings presented in Table 5, there is compelling evidence of spatial autocorrelation in both the dependent variable and the residuals. The Moran's I values for the study's dependent variables are 0.42, 0.51, and 0.63, respectively, indicating strong spatial autocorrelation at the 1% significance level. Furthermore, after accounting for the independent variables, the residuals exhibit a positive and statistically significant Moran's I value, suggesting the presence of spatial dependence in the residuals. Consequently, the use of spatial models, such as SAR or SEM, is necessary to address this effect.

The selection of the most appropriate model among the spatial error models was based on the likelihood ratio (LR) and Wald tests. The results of these tests are presented in Table 6.

Table 6

LR and Wald tests results

Model	Log-Likelihood	Parameter	Value (SE)	Result
SAR	–190.2	Spatial lag	0.45 (0.08)	Significant neighborhood effect
SEM	–195.6	Spatial error	0.25 (0.10)	Weak error effect
Statistics	**Equation**	χ^2	p-value	**Result**
LR	$2 \times (LogL_{SAR} - LogL_{SEM})$	3.84	<0.001	Reject H_0: SAR is better than SEM
Wald	$(\frac{\hat{\rho}}{SE(\hat{\rho})})^2$	23.89	<0.001	Significant spatial lag coefficient (ρ)

Based on the χ^2 statistic and the significance levels of the tests, it can be concluded that the spatial autoregressive (SAR) model is more appropriate than the spatial error model (SEM).

4.2. Model estimation

The findings of the preceding empirical investigations indicate that the use of the SAR spatial autoregressive model is the most appropriate approach for estimating the spatial dynamic panel model in this study. The results of estimating the SAR model using R software for the research models are presented in Tables 7, 8, and 9.

Table 7

Estimation results of Model 1 (Equation 9: Average rate of profit from stock price change)

Variable	Coefficient	Standard deviation	T-Statistic	p-value
Dependent variable lag	0.323	0.058	5.56	<0.001
Dependent variable spatial lag	0.180	0.031	5.80	<0.001
Average financing rate	–0.006	0.001	–3.67	<0.001
Cost of physical capital	0.242	0.073	3.30	0.001
Financial leverage	–0.035	0.011	–3.39	0.001
Information asymmetry	–0.042	0.015	–2.80	0.005
H-index	0.159	Sargan test		0.36
R^2	0.732	Arellano-Bond test		0.20–0.17

The results presented in Table 7 indicate the presence of complex and significant relationships between financial variables and the rate of return derived from stock price fluctuations. The positive and significant coefficient of the lagged dependent variable (0.323) demonstrates the existence of temporal dynamics and the persistence of price return effects in future periods. Additionally, the positive coefficient of the spatial lag (0.180) indicates that the price performance of neighboring companies has a direct and significant impact on the price return of the focal company, confirming the presence of spatial spillover effects in this industry.

The findings show that the average financing rate exerts a negative and significant effect on price return, as evidenced by a coefficient of –0.006, suggesting that higher financing costs may negatively influence stock price performance. Conversely, the price of physical capital, with a positive and significant coefficient of 0.242, exerts the most substantial direct impact on price return, highlighting the critical role of physical investments in generating shareholder value. Financial leverage, measured by a coefficient of –0.035, and the information asymmetry index, measured by a coefficient of –0.042, also have significant negative effects on price returns, indicating that high debt levels and limited information transparency may reduce stock price performance.

All coefficients are significant at the 1% level, suggesting that the model possesses strong explanatory power. These findings emphasize the importance of considering both temporal and spatial effects when analyzing the price performance of petrochemical companies.

Table 8

Estimation results of Model 2 (Equation 10: Average retained earnings rate)

Variable	Coefficient	Standard deviation	T-Statistic	p-value
Dependent variable lag	0.410	0.072	5.69	<0.001
Dependent variable spatial lag	0.250	0.045	5.56	<0.001
Average financing rate	–0.038	0.018	–2.11	0.035
Cost of physical capital	0.104	0.018	5.55	<0.001
Financial leverage	–0.087	0.025	–2.68	0.007
Information asymmetry	0.005	0.002	2.66	0.008
H-index	–0.016	Sargan test	4.53	0.43
R^2	0.671	Arellano-Bond test	1.34–1.64	0.18–0.10

The results presented in Table 8 reveal a significant relationship between financial variables and retained earnings. The coefficient of the lagged dependent variable (0.410), significant at the 1% level, indicates the persistence and stability of dividend policies over time. Moreover, the positive and significant spatial lag coefficient (0.250) suggests that the retained earnings policies of neighboring companies significantly influence this variable in the focal company, confirming the presence of spatial spillover effects in the petrochemical industry.

The findings indicate that the average financing rate, with a negative coefficient of –0.038, and financial leverage, with a negative coefficient of –0.087, exert significant negative effects on retained earnings, implying that companies may reduce retained earnings in response to higher financing costs and elevated debt levels. Conversely, the price of physical capital has a direct positive effect on retained earnings, with a statistically significant coefficient of 0.104, suggesting that companies tend to retain profits for subsequent investment in physical assets. Although the numerical effect of the information asymmetry index (0.005) appears small, it is statistically significant, indicating that information factors may have a limited but measurable influence on retained earnings policies.

Overall, decisions regarding retained earnings in petrochemical companies are strongly affected by both temporal and spatial factors. The results further demonstrate that physical investment policies play a central role in determining retained earnings, while financial structure and financing costs exert a constraining influence on profit accumulation.

Table 9

Estimation results of Model 3 (Equation 11: Average total profit rate)

Variable	Coefficient	Standard deviation	T-Statistic	p-value
Dependent variable lag	0.352	0.048	7.33	<0.001
Dependent variable spatial lag	0.185	0.32	5.78	<0.001
Average financing rate	–0.022	0.006	–3.17	0.002
Cost of physical capital	0.203	0.041	4.95	<0.001
Financial leverage	–0.085	0.025	–3.40	0.001

Variable	Coefficient	Standard deviation	T-Statistic	p-value
Information asymmetry	–0.039	0.016	–2.44	0.015
H-index	0.057	Sargan test		0.58
R^2	0.712	Arellano-Bond test		0.21–0.13

As shown in Table 9, the positive and significant coefficient of the lagged dependent variable (0.352) indicates the stability and persistence of stock returns over time. This implies that a 1% increase in total return in the previous period is associated with a 0.352% increase in the current period. The spatial lag coefficient (0.185) further highlights the positive and significant spillover effects of neighboring companies' returns on the performance of the focal company, emphasizing the importance of spatial factors in this industry.

The results also indicate that the average financing rate, with a negative coefficient of –0.022, and financial leverage, with a negative coefficient of –0.085, exert significant negative effects on total stock returns, suggesting that higher financing costs and debt levels may adversely affect overall returns. Conversely, the price of physical capital, with a positive and significant coefficient of 0.203, has the most substantial direct effect on total returns, underscoring the critical role of physical investments in generating shareholder value. Additionally, the information asymmetry index exhibits a negative coefficient of –0.039, indicating that limited information transparency may lead to a decline in total stock returns.

It is noteworthy that all coefficients are significant at the 5% and 1% levels, indicating the high predictive power of the models. These findings highlight the importance of simultaneously considering temporal and spatial dimensions when analyzing the stock returns of petrochemical companies. This analysis can provide a foundation for informed investment decisions and financial policy formulation in the industry.

A key spatial parameter is the spatial lag variable in the models, which is estimated to be positive and significant. The model results indicate that the stock returns of a given petrochemical company contribute to increases in the returns of other companies in the industry. In other words, a portion of the changes in the stock prices of petrochemical companies can be attributed to the overall movement of the sector. Consequently, the spatial spillover effect of price changes is confirmed as a critical factor in evaluating fluctuations in the returns of companies within the petrochemical industry.

The H index, calculated as the sum of the elasticities ($\sum_i \phi_i$), presents different conditions across the various estimates. In both equations estimating the average rate of profit from stock price changes ($\pi_{it}: \sum_i \phi_i = 0.159$) and the average rate of total dividends ($\Pi_{it}: \sum_i \phi_i = 0.057$), the H index falls between zero and one. This result indicates that monopolistic competition best describes the level of competition among petrochemical companies listed on the Tehran Stock Exchange. The economic characteristics of the Tehran Stock Exchange (TSE) are a primary factor contributing to this competitive environment. The exchange's structure, marked by a substantial presence of economic agents operating within a monopolistically competitive pricing framework, plays a significant role in shaping its competitive dynamics.

In the equation for retained earnings ($R_{it}: \sum_i \phi_i = -0.016$), the H index is negative, indicating monopolistic behavior among companies regarding dividend distribution. This monopolistic behavior in the context of undistributed dividends can be attributed to the governance structures of petrochemical companies and the high degree of concentration in Iranian industries, making such behavior predictable.

In this study, the Sargan test was employed to assess the validity of the instrumental variables in the model. For the instruments to be considered valid, they must be uncorrelated with the error terms. The null hypothesis of this test asserts that the instruments are valid, meaning they are not correlated with the errors of the first-order differenced equation. Rejection of the null hypothesis would indicate the instruments are inappropriate. The results of the Sargan test suggest that the null hypothesis is not rejected, confirming the validity of the defined instrumental variables. Consequently, the model does not require the inclusion of additional instruments.

Furthermore, the Arellano-Bond test was applied to examine the presence of autocorrelation in the differenced residuals. The Arellano-Bond test statistic indicates that the null hypothesis of no autocorrelation in the differenced residuals is not rejected. Therefore, the Arellano-Bond method is appropriate for estimating the model parameters while effectively eliminating fixed effects.

5. Conclusions and policy recommendations

This study employs a dynamic spatial panel model to investigate the impact of information asymmetry and other key financial variables on the returns and market structure of petrochemical companies listed on the Tehran Stock Exchange. The findings indicate that information asymmetry has divergent effects across different dimensions of stock returns. While this index exhibits a positive but limited effect on retained earnings (0.005), it exerts a negative and substantial impact on price returns (–0.042) and total stock returns (–0.039). These results suggest that in environments characterized by informational opacity, investors adopt a more cautious stance, particularly regarding price returns, whereas companies may accumulate profits to mitigate this uncertainty. This finding is consistent with the studies of Alimoradi and Rajabdorry (2018), Alimoradi et al. (2020), and Zarei (2020).

The analysis further indicates that the financial structure of companies significantly influences returns. High financial leverage and financing costs negatively affect both price and total returns, whereas investment in physical assets positively and substantially impacts all three types of returns (price, retained, and total). These results underscore the importance of optimal capital structure management and the allocation of resources to productive investments in the petrochemical sector. Moreover, the identification of significant spatial and temporal effects in all models, as evidenced by positive time and spatial lag coefficients, suggests that financial decisions are influenced both by past performance and by the behavior of neighboring competitors. This emphasizes the necessity of adopting integrated and macro-level approaches in the analysis of the Iranian capital market.

The H index results further indicate the presence of a monopolistic competition structure in stock pricing, reflecting the nature of stock exchanges as markets composed of multiple economic agents. Despite competition among companies in stock pricing, they retain a degree of monopoly power. Conversely, monopolistic behavior in the distribution of retained earnings reflects the centralized structure of the Iranian petrochemical industry and its influence on corporate decision-making. This observation aligns with the findings of Bercovici (2015) and Tilsted and Bauer (2024).

Based on these findings, several policy recommendations are proposed to enhance the market performance of petrochemical companies. First, increasing information transparency through timely and accurate disclosure of financial and operational data, particularly regarding dividend policies and future investment plans, can mitigate the negative effects of information asymmetry. Second, reforming the financial structure to optimize the mix of financing sources and reduce reliance on costly debt is advised. Third, strengthening corporate governance is essential to reduce centralization and improve management accountability in profit distribution decisions. Fourth, establishing effective regulatory mechanisms to monitor spatial and network effects in the capital market is recommended to prevent the emergence of collective malpractices. Implementation of these policies may lead to higher market returns, improved stock performance, and enhanced competition within the petrochemical sector.

Finally, by integrating advanced spatial econometric methods with dynamic analysis, this study provides a novel framework for understanding the dynamics of the Iranian capital market. This framework can serve as a foundational basis for future research across various industries.

Nomenclature

$Ainf_i$	Information asymmetry
CP	Cost of physical capital
EX	Exogenous variable
FR	Average financing rate
Lev	Financial leverage
MC	Marginal cost
MR	Marginal revenue
P	Profit rate
PIN	Probability of informed trading
R	Average retained earnings rate
S	Firm output
TR	Total revenue
W	Production price
X_i	Independent variable matrix
Y_{t-1}	Dependent variable lag
Y_i	Dependent variable vector
π	Average rate of profit from price changes
Π	Average total profit rate

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