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PRICING WAVES: EXPLORING BOUNDED RATIONALITY IN PRICE SETTING

The paper aims at developing a theoretical framework designed to explain and empirically model the pricing behaviour of companies in competitive markets with differentiated products. The study addresses the limiting assumptions of classical rational choice models by incorporating the concept of bounded rationality, which is in this case reflected in price rigidity and hierarchical decision-making process regarding pricing by companies. In this regard, a concept of "pricing waves" is introduced, using the method of scientific analogy with physics to describe market dynamics. The research structures the pricing decisions into three pillars: strategic (setting the regular price, representing the wave direction), operational (determining the frequency and depth of discounts, corresponding to wavelength and amplitude), and tactical (short-term price adjustments due to market fluctuations, competitor activities, etc.). This structure illustrates how firms operate under internal constraints, balancing long-term positioning with immediate market objectives.

The theoretical framework was empirically tested using weekly retail distribution audit data from the premium whiskey category in Ukraine (2018–2021). The analysis supported the idea that pricing strategies of top brands exhibit distinct cyclical components. Moreover, it was estimated that market players typically maintain relatively stable operational pricing parameters for periods of 12–13 or 25 weeks, implying that firms review their pricing principles 2–4 times per year.

Furthermore, the study hypothesises that consumers, due to rational inattention, base their decisions on perceived pricing patterns (similar to the wave parameters) rather than solely on spot prices. The proposed approach potentially offers a toolkit for empirical modelling of demand and analysing market equilibrium, specifically taking into account the interference of competitors' pricing strategies (pricing waves).

Keywords: pricing strategies; price competition; pricing waves; bounded rationality; hierarchical decision-making; oligopoly; price rigidity.

Statement of the problem. In many modern markets, the issue of effective pricing has grown in importance recently due to numerous general economic and market-specific factors including higher inflation rates, intensified competition, evolution of consumer behaviour, etc. In markets with differentiated products, effective price setting calls for a particular attention to analysing and forecasting pricing behaviour and strategies of competitors due to their prominent impact on sales of a specific market player. At the same time, accurate inferences about competitor pricing behaviour and strategies require proper understanding of the underlying decision-making principles used by different market players especially in the presence of bounded rationality and at least partial price rigidity. Moreover, proper

approaches to modelling those phenomena should also be in place both for researchers and companies operating in real markets.

Analysis of recent publications. Pricing has been a hot research topic for decades involving scientists from different fields. The basic models of pricing are those originating from the classic economic theory. However, while laying fundamental grounds for further research, these approaches are often criticised for the set of limiting assumptions they impose including those related to market structures (typically, monopoly or duopoly) or limited number of companies, purely rational behaviour of market players, perfect information, static market environment and lack of intertemporal choice, etc. [1; 2].

Modern game-theoretic approaches to pricing research represent a powerful toolkit [3]. However, such approaches tend to be rather excessively complicated and computationally intensive especially when many players are involved. Moreover, the assumption of pure rationality is still an important part of many game-theoretic approaches, thus sometimes limiting their applicability to real-life cases [4;5].

Developments in behavioural economics have been often a response to the limiting assumptions of the classic theories [6]. Particular attention in behavioural economics is paid to dealing with the assumption of pure rationality via offering a concept of bounded rationality, assuming that economic agents are not fully rational in their decisions, moreover, such irrationality might in some cases represent the best strategy for such agents [7].

The phenomenon of bounded rationality by itself is not new in the research discourse. However, as the overview of recent developments in the area suggests, there is still a growing need in further development of the approaches to investigate the roots of this phenomenon depending on the market context, as well as to empirical modelling of the impact of bounded rationality on pricing decision-making [7].

Unresolved parts of the problem. As illustrated above, despite noticeable developments in the pricing research, further investigations are needed in the area. Primarily, this is due to the following identified gaps of the existing approaches: Analysis of actions of market players involved many simplifying assumptions, in some cases the modelling was too complicated, bounded rationality was not considered in many cases, intertemporal choice sometimes ignored, the presence of strategic and operational targets or limitations was not considered properly. In this article, we make an attempt to at least partially deal with these limitations via offering a methodological approach to enrich the existing body of the theoretical and empirical developments.

The article aims at developing a theoretical framework that can be further used to effectively explain and model pricing behaviour of companies in a competitive market with differentiated products in the presence of bounded rationality in decision making and resulting rigidity in price setting and competitor price response. Specifically, we would like to offer an approach allowing for empirical modelling of a multi-pillar structure of the pricing decision making process on the side of the market players.

Research methods. The study relies on an interdisciplinary approach that combines principles of classic economic theory, behavioural economics, and, to some extent, game theory. To achieve the research objective, we applied general scientific methods of analysis and synthesis to review existing pricing models and identify gaps in explaining price rigidity in the markets with differentiated products and presence of competition.

The methodological core of the paper is based on the method of scientific analogy, which allowed us to adapt the physical principles of wave theory (amplitude, frequency, interference, etc.) to model the pricing behaviour of different market players. Deduction was used to formulate the hypothesis of "pricing waves" as a reflection of bounded rationality in pricing decision-making.

To validate the proposed theoretical framework, empirical statistical analysis and simulations were conducted. The empirical part of the study is based on real market data – specifically, the retail audit of distribution of an alcoholic beverages category (premium whiskey category).

Results of the study. Our review of theoretical and practical developments in the field of pricing and price competition analyses showed the presence of several areas that need to be improved or further developed. Taking into account the identified gaps, we offer an analytical approach or framework that will allow one to analyse, identify specifics, and classify pricing strategies different agents use in the market, as well as potentially investigate interactions of pricing strategies of different players, assess their impact on the sales of the company itself, consumer behaviour, and the market as a whole.

The suggested approach is an attempt to analyse market pricing from the standpoint of not only tactical actions (for example, frequent adjustments to the current price in e-commerce), but also price strategies setting the logic and limiting the firm's behaviour for a longer time horizon. Therefore, we aim to describe the pricing behaviour of a firm that has longer-term goals and constraints in addition to the (fully rational) task of maximizing profits in each specific period, by combining pricing tactics and strategy analysis within a single approach. In addition to the fact that this principle of action is often found in real markets, it clearly illustrates the limited rationality regarding pricing in the behaviour of firms.

Key assumptions of the approach. The proposed approach is based on several important assumptions that determine the course of further analysis. These assumptions are rather not simplifying or restrictive but determine the range of application of the approach and its logic.

First, we state that our approach focuses on markets with a differentiated product and active price competition. Therefore, the market structure is assumed to be either an oligopoly (a limited number of large players dominating the market and several smaller players), or monopolistic competition (a sufficient number of players, none of which dominates the market, who sell a differentiated product), and therefore each player has a certain degree of market power. In any case, we are talking about market players receiving non-zero profits and, accordingly, participating in vigorous price competition for the sake of ensuring those profits.

Secondly, we assume bounded rationality of firms in the market (in the classical meaning of this term in economic theory [8]) and the presence of certain restrictions on their immediate pricing decisions in the form of predetermined longer-term pricing strategies. In the literature, different possible causes of bounded rationality behaviour are analysed, including lack of market information, insufficient analytical capabilities, inability to change prices frequently, inertia in the behaviour of pricing managers, specifics of internal organizational processes and decision-making procedures, etc [9;10].

Sources of bounded rationality. In our approach, we assume that bounded rationality in pricing often originates from the procedure how decisions are made by companies. As observations in real markets reveal, firms often have a certain hierarchy of decision-making regarding pricing, which collectively determines the final price set by them in a certain period. At each level of such a hierarchy, decisions are obviously made taking into account the behaviour of competitors and buyers in the market, as well as the peculiarities of the market positioning of the firm itself. Thus, we distinguish the following pricing levels (using terminology by analogy with the military or management sphere):

- Strategic: Determination of the regular price (strategic price benchmark) or the general price positioning of a product or service.
- Operational: General (or acceptable) parameters of price changes in the short or medium term, which include the intensity or frequency of temporary periodical price reductions (how often the firm plans to change the price) and the size of such price reductions (how deep the discounts to the regular price are/may be). An example of this level of decision-making is the practice of planning a "promo schedule" in advance, which is used by some firms.
- Tactical: Determination of the specific periods for carrying out price discounts and the exact depth of discounts in the specified periods.

Following this logic, in any period (in the short run), the company operates under the conditions of pricing restrictions. Such restrictions are imposed by a defined strategy (regular price without discounts), which usually changes gradually and evolutionarily (in the longer term). Decisions about such changes are most often made at the highest level of the company's management or at the headquarters level in the case of multinational companies. Examples in this case can be a strictly defined regular price or a price index to the market average price, which is set as a target for a certain period (for example, a year or two), or a recommended price set by a manufacturer of goods for a retail chain that sells the goods and ultimately determines the final price for the buyer.

Additional restrictions or pricing guidelines are operational decisions that are more often made in companies at the middle management level and consist of outlining the key parameters or "rules" for temporary price changes. Such decisions are made for a shorter period than the strategic period, however, still for a relatively long time (for example, half a year or a year). Such operational parameters, as described above, are the intensity (frequency) of temporary price reductions and the acceptable (recommended) range of such price reductions.

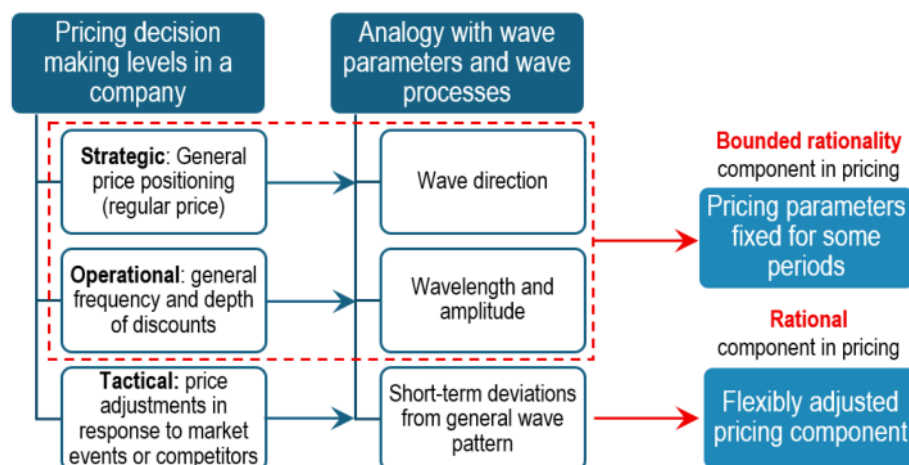
Finally, at the tactical level, adjustments of price setting take place in a specific period which, on the one hand, are aligned with the strategic and operational decisions, and on the other hand, are the reaction or adaptation of the firm to short-term changes or shocks in the market. The adjustments are made to promote sales or profits under existing constraints and given these changes or shocks. Tactical adaptations can be manifested, for example, in determining a specific period of temporary price reductions ("now, tomorrow or the day after tomorrow") or the exact size of a temporary reduction to the base price.

It is worth noting that, in our opinion, such assumptions about the logic of pricing are quite realistic if we talk about modern markets. From the point of view of our further analysis, such an approach allows, firstly, to take into account the described specifics of decision-making, and secondly, to assess separately the effects of the firm's strategic, operational and tactical decisions on the final pricing.

Wave theory as a tool to analyse and model bounded rationality. To incorporate the three-pillar decision making flow in the analysis and modelling, we suggest using an analogy with waves in physics (sound, light waves, etc.) as a convenient and useful tool for generalizing the pricing strategies of market players. Indeed, empirical analysis of data on many markets only confirms the fact that the dynamics of firms' prices in the market often resembles a wave movement. Therefore, we can talk about "pricing waves" (it is not just about price movements but about describing the conscious strategies of firms in a market). Figure 1 describes the logic how we apply the wave theory to the pricing decision making flow.

Figure 1.

Proposed approach to analysing pricing strategies under hierarchical decision making causing bounded rationality in firm behaviour



Source: Developed by the author.

Pricing waves can be considered as waves because in the longer term, price fluctuations for any product, when it comes to real prices adjusted for inflation, resemble the movement of waves, because no company can constantly reduce prices or raise them. Periods of price promotions (price reductions to improve the market outcome) are interspersed with periods of price increases.

Periodic price fluctuations can often be caused by the fact that firms try to simultaneously achieve both targets of their activities: maintaining or increasing sales in physical terms (or market share) and a certain level of profitability (less often incomes). Therefore, periods of price decline potentially allow a firm to achieve the first goal, while the second goal often requires the opposite price movements.

Such wave patterns have different reasons under conditions of different price sensitivity (elasticity) of demand for a particular product:

- In case of inelastic demand (the absolute value of price elasticity is less than one), price promotions (temporary price reductions) or longer downward price adjustments are usually used to stimulate product trial, expand product penetration, and increase sales in physical terms in the short run. However, the fact that with inelastic demand, a decrease in price leads to a drop in revenue and often gross profits, forces the seller to increase the price to the initial, or even (temporarily) to a higher level over time to compensate for the lost financial benefits. In turn, the seller is forced to reduce the price at least temporarily to increase the market share in physical terms due to the competitive environment, which is characteristic of dynamic markets.
- Under the condition of elastic demand (the absolute value of price elasticity is greater than one), price promotions are effectively used to increase sales, gross revenue, or grow product penetration. However, such positive effects are often observed only in the short run due to several reasons. Firstly, competitors begin to reduce prices in response, which neutralizes the short-term positive achievements of the company. Secondly, price promotions reduce an important operational margin indicator and often have a negative impact on the company's gross profit in the longer run. Therefore, after periods of price declines, companies are forced to raise them so that they eventually stabilize around or approach a long-term "desirable equilibrium price".

The proposed concept should not be confused with, for example, Edgeworth's price cycles [11] or Elliott's wave principle [12] dealing with general market dynamics and mass behaviour. Instead, by our concept, we rather talk about "pricing waves" as a tool describing the logic and principles of pricing strategies that are determined by the firm itself based on its understanding and perception of market specifics, and also according to the principle of hierarchy of price determination (see above), which can often be observed in reality. Therefore, pricing waves are rather a descriptor of the general strategic logic of the firm's pricing behaviour in a certain period, which it chooses and which it can modify over time. Such strategically determined logic is further superimposed by tactical adjustments, which consist of determining specific periods of price reduction and the exact amount of such reduction.

Continuing the analogy with physical waves and considering the hierarchical principle of decision-making on pricing on the side of firms, it can be assumed that the pricing behaviour of a firm in the market can also be described in terms of the usual physical parameters of waves, namely:

- The direction (vector) of the wave is a strategic price positioning of a firm or brand (the first level of the hierarchy),
- The amplitude and wavelength are quite reminiscent, respectively, of the target acceptable amount of price discounts and the frequency of regular price reductions over a certain period, which altogether describe the second level of pricing (operational decisions) of the firm,
- Ultimately, tactical price adjustments are nothing more than short-term fluctuations (deviations) of the actual market price from the main pricing wave, which describes the third (tactical) level of pricing decisions.

Another important measure in this approach is the period for which the pricing parameters of a company can be evaluated as relatively stable (can be a proxy for the planning horizon typical for the company). The length of this period might be assumed to depend on the market specifics, its developments, and the frequency with which the company reviews its pricing principles (strategic and tactical). The shorter this period is, the more flexible and adoptive the company is in terms of pricing, the more rational behaviour it exhibits. A longer period may indicate greater inertia in pricing or inefficiencies on the side of the company, which is probably a manifestation of bounded rationality in the price setting behaviour. The longer period also makes the pricing behaviour of the company more predictable, since it tends to use similar pricing logic and principles during a more extended time horizon.

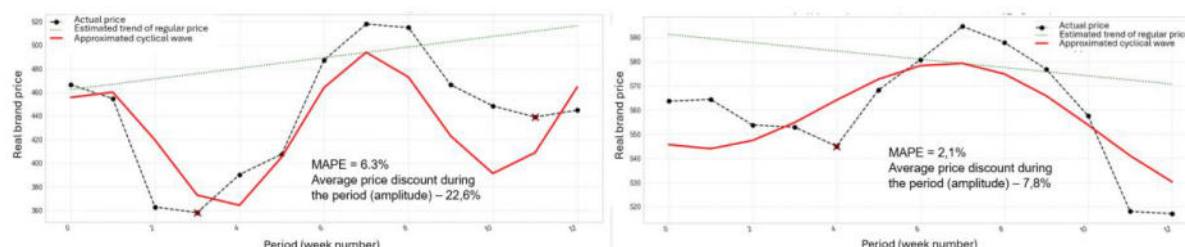
Empirical testing of the approach. In order to check the assumptions of the suggested approach, an empirical analysis was conducted based on the time-series data for the premium whiskey market in Ukraine for the period of 2018-2021. For the purpose of the analysis, we used weekly data for the prices of top ten brands in the market. The statistical analysis envisaged estimating the optimal parameters (minimising the mean absolute percentage error) including (1) the direction of the pricing wave (strategic price positioning), (2) wavelength and amplitude (frequency and depth of price discounts), and (3) the period during which the wave parameters can be considered as relatively stable. The estimated optimal parameters were expected to describe actual prices of the market players with a minimal error (MAPE).

Figure 2 presents some illustrative results of the analysis for two brands during different time slots. Generally, our analysis supports the assumption of the bounded rationality and specifics of price setting behaviour described above (presence of strategic and operational planning by the market players). Moreover, the wave approach can be effectively used to empirically model this bounded rationality – pricing of selected brands in the premium whiskey category indeed contains a cyclical component which largely explains their pricing behaviour during certain periods. One might also clearly observe the tactical components of pricing

(deviations of actual prices from the estimated waves) reflecting short-term price adjustments conducted by the brands most likely in response to some changes in the market environment.

Figure 2.

Examples of different estimated cyclical components (pricing waves) in the pricing strategies of two premium whiskey brands (left – more frequent and deeper discounts, right – less frequent and smaller discounts).



Source: Simulations and calculations by the author based on the data from the “Audit of retail distribution in the category of alcoholic beverages” conducted by “Kvadrans-M” LLC in 2018-2021.

The analysis also revealed noticeable differences in operational pricing parameters of different brands, as well as in the intensity of estimated tactical adjustments from the cyclical component. Identified differences in fact reflect peculiarities of the pricing strategies and tactics of different brands in the market under consideration.

Table 1.

Estimated wave parameters reflecting operational pricing principles of two selected premium whiskey brands

Operational wave parameter (in selected period)	Brand 1	Brand 2
Amplitude (average depth of discounts from regular price)	22.6%	7.8%
Wavelength (average number of weeks between discounts)	6 weeks	12 weeks
Estimated period of wave parameter stability (pricing review frequency)	12 weeks	12 weeks

Source: Simulations and calculations by the author.

We have also estimated that the length of the periods during which the pricing wave parameters can be considered stable differ across brands. However, the most typical time slots were 12-13 weeks (a quarter of a year) or 25 weeks (approximately half a year). Therefore, it was evaluated that most brands in the whiskey market typically review their pricing principles (operational parameters) 2-4 times per year.

Possible practical applications of the suggested approach. In our opinion, our approach of pricing waves allows one to describe the pricing logic of a particular firm in the market. In addition, it also reflects well the principle by which market participants (buyers or sellers)

perceive or summarize market information and form their general idea and expectations of the pricing of firms under conditions of bounded rationality. The fundamental assumption here is that bounded rational behaviour involves a generalization of information for a certain previous period by market agents, as well as a gradual refreshing of the market perceptions when new information becomes available.

Most likely, consumers or companies perceive and generalize their vision of the actions or strategies of brands or competitors in a way similar to how it is described by pricing waves. For example, buyers are unlikely to remember the specific dates of price discounts for a particular brand or the exact depth of such a discount. However, buyers rather remember (or have an idea of) the average frequency of discounts for this brand or the average discount on it – and this is actually all the same parameters of pricing waves that were mentioned above. In other words, buyers react both to the tactical actions of firms (short-term price fluctuations) and generalize their vision of the market as a whole and the behaviour of individual firms, observing the strategic and operational decisions of such players.

Therefore, in our opinion, the usage of pricing wave parameters, for example, in the demand equation, will make it possible to model the effect on demand from the "bounded rationality component" of the buyer's decision-making. In addition, it will allow one to decompose it into the effects of various parameters of pricing waves. Moreover, the ratio of the impact of the current price and the parameters of the pricing waves will make it possible to understand whether the behaviour of buyers is more rational or exhibits bounded rationality. A similar logic of analysis can also be applied to the pricing models of firms with partially rational behaviour, which develop their own strategies and tactics, among other things, taking into account the perception of competitors' pricing decisions.

Comparison of pricing strategies of market players with waves and their assessment through wave parameters has four main grounds and advantages:

- Firstly, it provides a convenient and unified tool for typologizing strategies of firms in a market, as well as describing the mechanism of price competition simultaneously at the tactical, operational and strategic levels,
- Secondly, it is consistent with our assumption of the hierarchy and bounded rationality of the firm's pricing decisions, and therefore helps to describe and model this bounded rationality,
- Thirdly, it is consistent with how buyers, not being fully rational in their decisions, probably tend to generalize the price behaviour of firms and make decisions based on such information (taking into account and modelling bounded rationality in buyers' actions),
- Fourthly, it allows one to analyse price competition, considering the interference of price waves of market players.

Given the above, we can suggest the following formal definition of "pricing waves": Pricing waves are a set of simultaneous and successive decisions of market players regarding pricing, which have, on the one hand, strategic logic, and on the other hand, tactical specifics

of implementation, interact with each other and affect the behaviour of buyers, cumulatively determining the outcome and equilibrium for the whole market and its individual players.

The proposed framework is expected to contribute to the pool of analytical approaches to studying pricing strategies, competition, market dynamics and interactions. Moreover, the parameters of the pricing waves describing a firm's pricing strategy and tactics can be directly included in and potentially enrich econometric models and other market simulation approaches when it comes to modelling:

- Price setting by firms and their pricing strategies,
- Demand for individual goods and consumer behaviour,
- Demand in a market overall.

Conclusions. The suggested "pricing waves" framework offers a structured approach to analysing and modelling company pricing behaviour in markets with imperfect competition and differentiated products. By applying the analogy of waves in physics, we mapped the hierarchical nature of pricing decision making, distinguishing among strategic positioning (wave direction), operational principles (amplitude and frequency of discounts), and short-term tactical adjustments. This three-pillar structure addresses the limitations of traditional models by incorporating the factor of bounded rationality, explaining why companies often adhere to pre-set pricing patterns rather than engaging in continuous instantaneous pricing optimization.

Empirical validation using data from the premium whiskey market confirms that pricing strategies often exhibit identifiable cyclical components. The analysis revealed that market players typically maintain relatively stable operational pricing parameters for periods ranging from 12-13 to 25 weeks, hence, reviewing their operational logic 2–4 times per year. These findings support the hypothesis that relative price rigidity results from deliberate operational constraints rather than mere market friction. Furthermore, the study hypothesises that consumers likely perceive price competitiveness also through these generalized wave parameters – such as the average frequency of discounts – rather than through isolated price points (the hypothesis needs further testing).

From a practical and theoretical standpoint, the proposed approach provides a unified tool for classifying market strategies and analysing price competition. Moreover, by quantifying the "interferences" of pricing waves, researchers and practitioners can potentially better assess the collective market dynamics and the potential for price wars. Ultimately, integrating these wave parameters into econometric demand models offers a promising approach for more accurate forecasting of both firm-level sales and broader market equilibrium in the presence of bounded rationality.

Potential directions for further development of the suggested pricing wave concept might include:

- Further testing of the concept on different markets;
- Analysing peculiarities and potential outcomes for specific market players and general market dynamics originating from the interference of pricing waves of different companies;

- Incorporating the concept of pricing waves into empirical models of demand and competitor price response;
- Developing approaches to clustering pricing strategies based on the parameters of pricing waves of different market players;
- Analysing differences in pricing strategies and decision-making principles by companies of different types (for example, small and large or those that offer premium and mass products, etc.);
- Using the pricing wave concept for the analysis of threats and leaks of possible price wars in the market.
- Deepening analysis of consumer behaviour taking into account its likely limited rationality and strategic behaviour.

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ХВИЛІ ЦІНОУТВОРЕННЯ: ДОСЛІДЖЕННЯ ОБМЕЖЕНОЇ РАЦІОНАЛЬНОСТІ У ВСТАНОВЛЕННІ ЦІН

Дане дослідження присвячено розробці комплексного теоретичного підходу до аналізу та моделювання цінової поведінки фірм на конкурентних ринках із диференційованим продуктом. Автор відходить від обмежуючих припущень класичних моделей, які передбачають раціональну поведінку економічних агентів, шляхом використання концепції обмеженої раціональності (bounded rationality), яка, серед іншого, виявляється у жорсткості цін та ієрархічному підході до прийняття рішень щодо ціноутворення фірмами.

Автором запропоновано концепцію «хвиль ціноутворення» (pricing waves), що базується на методі наукової аналогії з фізичними хвильовими процесами, для пояснення ринкової динаміки. Запропоновано та обґрунтовано ієрархічну структуру прийняття рішень щодо ціноутворення компаніями, яка включає три рівні: стратегічний (визначення цінового позиціонування або регулярної ціни – напрямок хвилі), операційний (визначення частоти та глибини знижок – довжина та амплітуда хвилі) і тактичний (короткострокові адаптації до змін на ринку або дій конкурентів). Така структура прийняття рішень ілюструє ймовірну наявність у компаній внутрішніх обмежень, які обумовлюють необхідність, балансувати між довгостроковими цілями або позиціонуванням та короткостроковими завданнями.

Запропонований підхід було перевірено емпірично на основі даних роздрібного аудиту дистрибуції ринку преміального віскі в Україні за 2018–2021 роки. Статистичний аналіз у цілому підтвердив наявність циклічних компонентів у ціноутворенні найбільших брендів. Виявлено, що операційні параметри цінових стратегій залишаються відносно стабільними протягом 12–13 або 25 тижнів, що свідчить про перегляд принципів ціноутворення компаніями 2–4 рази на рік.

У роботі також висловлено припущення, що споживачі через раціональну неуважність, ймовірно, так само сприймають цінову конкуренцію саме через узагальнені параметри хвиль (наприклад, середню частоту промо-акцій), а не лише через поточні цін. Запропонований підхід потенційно створює методологічне підґрунтя для доповнення економетричних моделей попиту та аналізу ринкової рівноваги, зокрема, й з урахуванням інтерференцій стратегій конкурентів.

Ключові слова: цінові стратегії; цінова конкуренція; хвилі ціноутворення; обмежена раціональність; ієрархічне прийняття рішень; олігополія; жорсткість цін.