THE SENSITIVITY OF COMMODITY MARKETS TO
EXCHANGE OPERATIONS SUCH AS SWING

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Abstract. A pricing model for the simplest commodity markets is considered. The model describes the behavior of the Order Book, consisting of orders from producers, consumers and speculators. The paper explores the external impact on this model in the form of large operations by new market participants, who at high speeds begin to push forward their orders, for example, first bids and then asks. Such strategies are called swings. This paper investigates a single cycle of one simple trading strategy of the swing type. Found a particular model case of pricing potentiality price relative to swing operation. An example is given, that shows that the simplest commodity markets with producers and consumers have the internal property that they are potentially vulnerable to external influences. The swinging of prices through large purchases and sales leads to systematic profits of the entrants at the expense of the traditional market participants.

1. Introduction. The article is devoted to the assessment of the impact of the actions of individual participants in exchange trading on pricing.

The classical approach to algorithmic trading always implied forecasting prices as some independent object with internal dynamics, that independent of other factors, like the movement of planets for astronomers observing it. In the literature, there are two main classes of classical methods of price forecasting: technical and fundamental analysis ([10], [11]). The first one studies the shape of the price chart, and based on the finding of some graphic patterns, draws conclusions about the further direction of the price change. The second appeals to the concepts of supply and demand, the internal profitability of an asset and other economic considerations, which should determine the so-called “fair” price, in the direction towards which it is required to make transactions in order to profit.

However, the forecasts obtained in the framework of these methods do not guarantee real profit on the account. If a certain zigzag on the price chart previously predicted an upward movement, this does not mean at all that in the next such case the price will not go down the other way. Any transaction on the exchange due to

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various transaction costs is a game with a common negative result. Therefore, if the number of bets in the direction of the forecast is more than half, then losses are inevitable. Because of this, it is believed that such forecasting methods do not reflect the laws of nature, and are not even a science. Meanwhile, for really trading traders, the use of both methods is an everyday norm and an urgent need.

This contradiction is resolved by the consideration that in fact the actions of each of the participants affect pricing. This is especially true when individual traders gather in large groups. This violates the key assumption that price dynamics is an independent entity in itself. In this case, the construction of a profitable trading strategy turns from the task of selecting adequate actions for external factors into a game-type task, where, among other things, the actions of other market participants must be taken into account.

Small traders in most cases really can not greatly affect the price, which determines the rationality and dominance of classical technical and fundamental analysis. But if the volume of transactions carried out according to the logic of one forecast becomes noticeable against the general background, then it becomes an independent factor. And not necessarily it will be the actions of the largest participant, although such tasks are also practically important and common. For example, similar effects are constantly observed even with relatively small volumes of exchange orders, but working in a short period of time, which leads to short-term, but high intensity cash flow in one direction. Which, in turn, determines the prevalence and commonality of such cases.

To account for and study such effects, this article created a mathematical model of exchange pricing, in the framework of which qualitative conclusions were formulated about the features of pricing depending on certain actions of a major participant. Thus, the problem was solved, the inverse of technical analysis, in which, on the contrary, they try to determine the intentions of traders by the form of the price chart.

The model used in the article is multi agent in type. Initially, in the world there were commodity markets where there were no speculators, i.e. such participants in trade transactions that do not set themselves the goal of obtaining or selling an asset (product), but exclusively to profit from transactions. Such simplest markets consist of only two members: solely of product manufacturers and consumers. Price movements in such markets occur only in the event of an imbalance of supply and demand, and usually lead to the return of the market to an equilibrium state ([3], [6], [13], [14]).

We complicate the model now by adding to it a third participant - the speculator. The paper explores the external impact on this model in the form of large operations by new market participants, who at high speeds begin to push forward their orders, for example, first bids and then asks. In exchange slang, such operations are often referred to as swings at short intervals of time [4], or on the horizon of several days or even months by corners. Sometimes you can find other slang names for such operations.

The importance of such operations is explained by the fact that such actions can lead to market manipulation, for example, to artificially inflate market capitalization on a global scale. So in a fairly recent work [9] a large number of examples of real world stock indices were cited, where a strong discrepancy between the daily and night price dynamics was revealed, i.e. swing between day and night.
This paper explores a single cycle of one simple trading strategy of the swing type. This example shows that the simplest commodity markets with producers and consumers have the internal property that they are potentially vulnerable to external influences. The swinging of prices through large purchases and sales leads to systematic profits of the entrants at the expense of the traditional market participants.

The paper continues research in the field of exchange pricing [1], [2], [7].

2. Two-agent model. A pricing model for the simplest two-agents commodity markets is considered. The model describes the behavior of the Order Book, consisting of orders from one producer (seller) and one consumer (buyer) only. In many cases, a single buyer can be understood as a group of all customers, since they are guided by similar motives, and therefore often act simultaneously. Similarly with sellers. Which extends the scope of the model.

Let consider the basic assumptions of the model. Buy orders (bid) and seller orders (ask) generalized buyer and generalized seller are divided with equal volumes and are set in equal parts \( v_{quote} \) and are located evenly on both sides of the current price. Order price each part \( p_i(t) \) are separated by a constant \( p_{\Delta} \).

\[
p_{ask,i}(t) - p_{ask,i-1}(t) = p_{\Delta}, p_{bid,i-1}(t) - p_{bid,i}(t) = p_{\Delta}
\]

This method of setting up a breakdown and placing orders is not a pure theory, since something similar is a popular practice in real trading. For example, in the framework of the so-called level trading, which is quite popular, for example, in grain markets [8], where grain stocks rarely change between crops, which leads to relative stability of “fair” price levels. In this situation, any deviation from fair prices is considered to be incorrect, which creates the prerequisites for profit. In such conditions, orders are placed at regular intervals on both sides of the ”fair” level, which allows you to collect any deviations on a systematic basis.

Dividing a single volume of planned operations into separate parts also allows you to better protect yourself from various accidents and uncertainties. Although real market producer and consumer as a rule, have additional information about the availability of goods, which is usually not available to most participants, i.e. insider, but they are forced to act largely in the face of a lack of information for decision-making too [5], [12]. Therefore, in conditions of incomplete information it is common for applications to purchase and sell to be submitted in parts. In this case, the wrong action will occur only with a small part of the operations, which allows you to take corrective measures in time. These applications can be submitted in the form of a regular Order Book. Thus, a pricing model for the simplest commodity markets describes the behavior of the Order Book, consisting of orders from producer and consumer only.

Each physical commodity market is usually characterized by planned or ordinary volumes of production and consumption. Similar effects can be found in financial markets. For example, when making large purchases or sales, traders often set planned transaction volumes during the day. Among the most recent examples are the actions of the US FED and other central banks during quantitative easing or squeezing. In such cases, in order to inform other market participants, special messages are issued stating that every month (week or other time interval) a certain volume of certain securities will be bought or sold.
Normally, in an equilibrium market, the volume of purchases and sales should be equal to each other so that there is no imbalance in supply and demand. Accordingly, in norm, this volume should also be sold and bought on the stock exchange so that there are no overstock or shortage processes. For this purpose producer and consumer, respectively, shift their orders as whole in the direction of the current price at some speeds, and thereby achieve the necessary number of transactions per unit of time. In the discrete case, this leads to some price shifts $h^{\text{bid}}(t)$, $h^{\text{ask}}(t)$ at certain points in time. The time step here is discrete and is determined directly by market participants, based on their personal trading preferences and market characteristics. For example, once an hour, once a day, or some other time intervals.

3. Dynamics of a discrete two-agent model. If the number of asks or bids is not enough in comparison with the volumes planned by the traders, then, there must be a compensatory mechanism to increase or vice versa reduce the volume of transactions. Such a mechanism within the framework of the model is the rule, that these shift speeds depend on the volumes the asset that sellers and buyers currently have. They must support the supply-demand balance.

The Order Book shifts by a certain amount $h^{\text{bid}}(t)$, $h^{\text{ask}}(t)$ per unit time (step), depending on current stock volumes:

\[
\begin{align*}
   h^{\text{bid}}(t) &= h^{\text{bid}}(0) - k^{\text{bid}} \left( V^{\text{bid}}(t) - V^{\text{bid}}(0) \right) \\
   h^{\text{ask}}(t) &= h^{\text{ask}}(0) - k^{\text{ask}} \left( V^{\text{ask}}(t) - V^{\text{ask}}(0) \right)
\end{align*}
\]

where volumes $V^{\text{bid}}(0)$ and $V^{\text{ask}}(0)$ denotes the stock that the buyer or seller prefers to maintain in an equilibrium situation. And current volumes $V^{\text{bid}}$ and $V^{\text{ask}}$ change as a result of transactions $\text{trade}(t)$ and production $q^{\text{ask}}(t)$ and consumption $q^{\text{bid}}(t)$ of goods:

\[
\begin{align*}
   V^{\text{bid}}(t) &= V^{\text{bid}}(t-1) - q^{\text{bid}}(t) + \text{trade}(t) \\
   V^{\text{ask}}(t) &= V^{\text{ask}}(t-1) + q^{\text{ask}}(t) - \text{trade}(t)
\end{align*}
\]

During one step the shift occurs continuously:

\[
\left\{ \begin{array}{ll}
   p^k(\tau) &= p^{\text{bid}}_k(t-1) + h^{\text{bid}}(t-1) \tau, \\
   p^k(\tau) &= p^{\text{ask}}_k(t-1) + h^{\text{ask}}(t-1) \tau, \\
   \tau &\in (0, 1], \quad k = 1, 2, \ldots, n.
\end{array} \right.
\]

As a result of such shifts, prices are shifted to opposite orders in the Order Book, and thus, transactions are formed from time to time. It is easy to prove the following statement.

**Lemma 3.1.** Suppose that in one step as a result of shifts of Order Book there was only one transaction. Then the time and price of the transaction are determined by the formulas

\[
\tau^0_k(t) = \frac{p^{\text{ask}}(t-1) - p^{\text{bid}}(t-1)}{h^{\text{bid}}(t-1) - h^{\text{ask}}(t-1)}
\]

\[
p^0_k(t) = \frac{p^{\text{ask}}(t-1)h^{\text{bid}}(t-1) - p^{\text{bid}}(t-1)h^{\text{ask}}(t-1)}{h^{\text{bid}}(t-1) - h^{\text{ask}}(t-1)}.
\]

At large shifts $h^{\text{bid}}(t)$, $h^{\text{ask}}(t)$ during one step several transactions can be triggered. Since there will also be several transactions of formulas in this case, because of the limited volume of the article, they are not given. Moreover, they will be determined from the same logic.
Thus as a result of the transactions, the stocks of sellers or buyers increase or decrease accordingly. On the other hand, the production and consumption of a commodity is constantly going on with intensities $q^{\text{bid}}$ and $q^{\text{ask}}$ per unit of time. Bidders seek to balance their volume of transactions per unit of time so that they would be equal to the volume of production of goods by sellers and the volume of consumption by buyers.

4. Continuous case. The dynamics of a discrete simulated system can also be described in a continuous form using the apparatus of differential equations. For this, it is required in the initial discrete model to carry out two limit transitions in price and in time.

We will increase the number of orders, with the distance between the parts of the order will tend to zero,

$$ p_\Delta = p_{\text{ask},i}(t) - p_{\text{ask},i-1}(t) \to 0 $$

while keeping the total volume of all orders unchanged. What leads to the concept of orders density $\rho$. Then the volume of one order in the discrete case is

$$ V(p) = \int_{p-h/2}^{p+h/2} \rho(p) \, dh $$

The time intervals between steps also tend to zero

$$ \Delta t = t_i - t_{i-1} \to 0 $$

while maintaining the total $v$ shift rate $h = v \Delta t$.

**Theorem 4.1.** The following formulas are true

$$ p' = \frac{\rho_{\text{bid}} v_{\text{bid}} - \rho_{\text{ask}} v_{\text{ask}}}{\rho_{\text{bid}} + \rho_{\text{ask}}} $$

$$ V'_{\text{trade}} = (v_{\text{bid}} - p') \rho_{\text{bid}} = (v_{\text{ask}} + p') \rho_{\text{ask}} $$

**Proof.** Let the price change from $p_0$ to over $p_1$ an infinitely short time $\tau$. Without loss of generality, suppose that prices have risen, i.e. there were more requests from buyers than from sellers. The converse is proved similarly.

Since the volumes of transactions for buyers and sellers always coincide, then the ratio

$$ V_{\text{bid}} = (v_{\text{bid}} \tau - \Delta p) \rho_{\text{bid}} = V_{\text{trade}} = (v_{\text{ask}} \tau + \Delta p) \rho_{\text{ask}} = V_{\text{ask}} $$

Dividing by $\tau$ and tend to the limit, we obtain the necessary formulas.

Note that although all formulas are correct from the point of view of the theory, for practical operations the continuous form system is worse applicable. In real exchange transactions, some parameters should fundamentally be discrete. One of the main problems in organizing any exchange trading is to ensure sufficient liquidity. And one of the main methods for solving these problems is the standardization of transactions. Therefore, orders are not allowed to be placed at an arbitrary price, but only in grid nodes that located apart at a certain constant interval, called a tick. This is directly determined by the specifications of exchange contracts. Also, to increase liquidity at the exchange trading, it is forbidden to specify an arbitrary volume of orders, but only a multiple of a certain minimum allowable volume, called a lot. These and other similar examples show the limited area of applicability of continuous form of system dynamics. Nevertheless, such a form of the system dynamics sometimes makes it easier to carry out theoretical calculations.
5. The case of pricing potentiality. Consider the simplest case, when the volumes of production and consumption of an asset do not depend on the price, and the volumes of individual orders from both sellers and buyers, as well as the speed of their shifts in the Order Book are constant. The key assumption here is the condition for independence of shifts from current inventory balances among producers and consumers.

\[ h_t = h_0 - k (V(t) - V(0)) = h_0 \]

Such a condition or close to it is usually fulfilled with small price deviations. For example, when trading intraday. Volumes of output and consumption rarely change every day.

In the case of stable supply and demand intensities, the current price change depends only on the size of the current imbalance between the volumes of purchases and sales. At the same time, the imbalance is covered by corresponding changes in the volume of reserves, so it is possible only as long as these volumes are non-zero. For a continuous form of recording a model, such conditions make it possible to obtain a very simple one.

Lemma 5.1. Let be \( v_{bid} = \text{const}, v_{ask} = \text{const}, \rho_{bid} = \text{const}, \rho_{ask} = \text{const} \). Then the price changes at a constant rate.

The proof is trivial from the formula for the derivative of price.

We now add to such a system another player, which we will call a speculator. We will assume that he first places buy orders uniform with density \( \rho_{sp,1} \), and during the time interval \( 0 \leq \tau \leq t_1 \) shifts them up as a unit with a constant speed \( 0 < v_{sp,1} \). Further during the time interval \( t_1 \leq \tau \leq t_2 \) on the contrary, he begins to sell in a similar way. He places his sell orders uniform with density \( \rho_{sp,2} \), and during the time interval \( t_1 \leq \tau \leq t_2 \) shifts them down at a constant speed \( v_{sp,2} < 0 \). Moreover, we will assume that the condition

\[ \rho_{sp,1} v_{sp,1} t_1 = -\rho_{sp,2} v_{sp,2} (t_2 - t_1), \]

the physical meaning of which is to zero the final position of the speculator after the end of the swing operation.

Definition 5.2. We call this sequence of actions a swing up.

Similarly, if the speculator first sells and then buys, then this sequence will be called a swing down. Further in the text, without loss of generality, we will assume that the operation "swing up" is always performed.

It is easy to see that from the point of view of exchange activity, the speculator is the same buyer and then seller, as are the participants in the original two-agent model. Moreover, depending on the combination of model parameters, three different system dynamics are possible. In the first, the speculator promotes his purchases with such high intensity \( \rho_{sp,1} v_{sp,1} \), that the final rate of price change is higher than the rate of shift of customers’ orders \( v_{bid} < p' \). In other words, all transactions take place between sellers and a speculator, and buyers only rearrange orders below in a Order Book without transactions. In this case, de facto again we get a two-agent model of exchange pricing, with the only difference being that a speculator acts instead of buyers. Correspondingly, the formulas

\[ p' = \frac{\rho_{sp} v_{sp} - \rho_{ask} v_{ask}}{\rho_{sp} + \rho_{ask}} \]

\[ V'_{trade} = (v_{sp} - p') \rho_{sp} = (v_{ask} + p') \rho_{ask} = V'_{sp} = V'_{ask} \]
In the second case, the final rate of price change is such that both the buyer and
the speculator manage to complete transactions simultaneously.

In this case, by analogy with the formulas of the two-component model, the
difference equations are true for an infinitely small time interval $\tau$.

\[
V_{\text{trade}} = V_{\text{ask}} = (v_{\text{ask}} \tau + \Delta p) \rho_{\text{ask}} =
= (v_{\text{bid}} \tau - \Delta p) \rho_{\text{bid}} + (v_{\text{sp}} \tau - \Delta p) \rho_{\text{sp}} = V_{\text{bid}} + V_{\text{sp}}
\]

Putting together the members with $\Delta p$ we get

\[
\Delta p (\rho_{\text{ask}} + \rho_{\text{bid}} + \rho_{\text{sp}}) \rho_{\text{ask}} = (v_{\text{bid}} \rho_{\text{bid}} + v_{\text{sp}} \rho_{\text{sp}} - v_{\text{ask}} \rho_{\text{ask}}) \tau
\]

\[
p' = \frac{\rho_{\text{bid}} \rho_{\text{bid}} + \rho_{\text{sp}} \rho_{\text{sp}} - \rho_{\text{ask}} \rho_{\text{ask}}}{\rho_{\text{bid}} + \rho_{\text{ask}} + \rho_{\text{sp}}}
\]

\[
V'_{\text{trade}} = V'_{\text{ask}} = (v_{\text{ask}} + p') \rho_{\text{ask}},
\]

\[
V'_{\text{bid}} = (v_{\text{bid}} - p') \rho_{\text{bid}};
\]

\[
V'_{\text{sp}} = (v_{\text{sp}} - p') \rho_{\text{sp}}
\]

Purely theoretical, a case is possible when the speculator’s speed of orders shift
is so small that he does not keep up with the buyer’s transactions. But in this case,
the dynamics of the system is completely identical to the dynamics of the initial
two-agent model between producers and consumers.

From the obtained formulas, the truth is easily verified.

**Lemma 5.3.** For any parameters combination of the three-agent model with con-
stant orders densities and shift speeds, the price changes in a linear way.

**The main theorem.**

Suppose that in the three-agent model production is equal to consumption, the
intensities of shift speeds and densities from producers and consumers are equal,
stationary and independent of warehouse volumes. Then the price does not change
from the speculator conducting the swing operation.

**Proof.** Let us first consider the case when all three participants complete transac-
tions on the entire interval of the swing time. Then

\[
p_2 - p_0 = \int_0^{t_2} p' \, dt = \int_0^{t_1} p' \, dt + \int_{t_1}^{t_2} p' \, dt =
\]

\[
= \int_0^{t_1} \frac{\rho_{\text{bid}} \rho_{\text{bid}} + \rho_{\text{sp}} \rho_{\text{sp}} - \rho_{\text{ask}} \rho_{\text{ask}}}{\rho_{\text{bid}} + \rho_{\text{ask}} + \rho_{\text{sp}}} \, dt + \int_{t_1}^{t_2} \frac{\rho_{\text{bid}} \rho_{\text{bid}} - \rho_{\text{sp}} \rho_{\text{sp}} - \rho_{\text{ask}} \rho_{\text{ask}}}{\rho_{\text{bid}} + \rho_{\text{ask}} + \rho_{\text{sp}}} \, dt
\]

Since the demand of producers and consumers is balanced, then

\[
= \int_0^{t_1} \frac{\rho_{\text{bid}} \rho_{\text{bid}} - \rho_{\text{ask}} v_{\text{ask}}}{\rho_{\text{bid}} + \rho_{\text{ask}} + \rho_{\text{sp}}} \, dt =
\]

\[
= \int_0^{t_1} \frac{\rho_{\text{bid}} \rho_{\text{bid}} - \rho_{\text{ask}} \rho_{\text{ask}}}{\rho_{\text{bid}} + \rho_{\text{ask}} + \rho_{\text{sp}}} \, dt + \int_0^{t_1} \frac{\rho_{\text{sp}} v_{\text{sp}}}{\rho_{\text{bid}} + \rho_{\text{ask}} + \rho_{\text{sp}}} \, dt =
\]

\[
= \int_0^{t_1} \frac{\rho_{\text{sp}} v_{\text{sp}}}{\rho_{\text{bid}} + \rho_{\text{ask}} + \rho_{\text{sp}}} \, dt = k \rho \rho_{\text{sp}} v_{\text{sp}} t_1.
\]
Here
\[ k_p = \frac{1}{\rho_{bid} + \rho_{ask} + \rho_{ask}}. \]

Similarly for the second integral over the time interval \([t_1, t_2]\)
\[
\int_{t_1}^{t_2} \frac{\rho_{bid} v_{bid} - \rho_{sp} v_{sp} - \rho_{ask} v_{ask}}{\rho_{bid} + \rho_{ask} + \rho_{ask}} \, dt =
\]
\[
= -\int_{t_1}^{t_2} \frac{\rho_{sp} v_{sp}}{\rho_{bid} + \rho_{ask} + \rho_{ask}} \, dt = -k_p \rho_{sp} v_{sp} (t_2 - t_2)
\]
But by definition a swing operation
\[
\rho_{sp} v_{sp} t_1 - \rho_{sp} v_{sp} (t_2 - t_2) = 0
\]
Cases when a participant does not participate in pricing are proved in the same way.

Consequence pricing under the conditions of the main theorem has the property of potentiality with respect to swing operations.
An example of a zero total effect on prices as a result of a swing type operation is shown in Figure 1.

Figure 1 illustrates this statement. Here, the up arrow means a buy order, the down arrow for sale, the black arrow is a deal, the number is the volume of the order. The price returned to the starting point after having bought 10 and then sold 10.

At first glance, it may seem that the property of price potentiality for purchases and sales with a total zero asset balance for the speculator at the end of the transaction is some exception, requiring the coincidence of many difficult to implement in practice conditions. However, as the experience of real exchange trading shows, if the markets observe lateral movements without a clearly defined trend, something seems to be observed very frequently, almost everywhere. From this point of view, the theorem, on the contrary, reflects only a small part of a more general result.

Discrete forms of the model are more complex for such conclusions, although in principle they coincide ideologically. Since the volume of applications is fixed, this leads to non-zero balances after the completion of transactions, which requires a significant complication of the wording of statements and evidence. Sometimes this can even lead to a formal failure to fulfill the potentiality property accurate to the
tailings of transactions. But from practice it is known that in most cases, if you buy some volume and then sell it, then in a calm equilibrium market this usually does not lead to a significant change in price.

6. Exchange operations such as swings. In this section, we will consider the opposite situation when the swing operation leads to a change in price. In the most general case, this always happens when the intensities of the shift speeds and densities of orders from producers and consumers begin to change depending on the buildup or depletion of inventories from manufacturers and consumers. I.e. relations of the type

\[ h_t = h_0 - k (V(t) - V(0)), \]

moreover, the coefficients \( k \) are significant in absolute value. Nonlinear dependency types are also possible.

Consider a situation where a certain large player begins to buy large amounts of an asset at a rate exceeding the speed of a group of buyers.

We will also assume that the third player’s rate of shift is such that all sellers requests are satisfied by a third player, while ordinary buyers do not have time to raise their bids to levels where their satisfaction may occur.

Since the intensity of purchases by a third player is higher than usual, sellers stocks decrease faster than usual. Therefore, they reduce both the speed of advancement of their applications, and their intensity. On the contrary, since buyers do not have time to make their usual purchases, they try to compensate for the lag and increase the shear rate and intensity of purchases.

The Figure 2 illustrate this situation. The price has risen, although general purchases of the third players are zero. The third player makes a profit.

![Figure 2](image)

**Figure 2.** Impact of the exchange operations such as swings.

Specific types of functions as well as the speeds and sizes of applications of buyers and sellers change are not so important here, since the profitability of a swing trading strategy will be maintained with very wide variations. So in the simplest case, you can consider the option when only the shear rates of applications change.

After the third player has purchased all of his planned volume, he begins to sell it, for example, also at a constant speed. Since at this moment buyers are buying more than usual, and sellers are selling less than usual, the third participant will have time to sell his entire position before the price has time to return to its original level. And so he sells at higher prices than he originally bought, which ensures him the profitability of such operations. Because of this, such groups of traders arise independently and exist in almost any market.
It is easy to see that such a strategy artificially creates a shortage or excess of goods, which is why the reflection of traditional participants begins to change.

7. Conclusions. If the intensities of purchases and sales are equal and stationary, the effect of price potentiality arises. Violation of the stationary for intensities creates prerequisites for price manipulation.

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