4
The Simulation Task

Stock market forecasting assessment through classical prediction error metrics does not capture the system impact in real market operations. Thus, in order to provide better evaluation metrics, our trading system uses the predictions to guide trader actions in effective market conditions, considering with full fidelity all stock market possibilities and constraints.

Our trading system is prepared to simulate the investor's decision making according to predicted values, by considering either buy and sell operations or Pairs Trading. It operates according to boundary values given as input, which refer either to stock prices or spreads.

The proposed trading system considers just the natural person investor and, as recommended by Chande [74], has three essential functions: to find propitious times when to enter and exit a trade, to control the trading risk and to provide efficient money management.

In the sections 4.1, 4.2 and 4.3, we explain how each of these three functions work in our trading system. And in section 4.4, we depict the stock market possibilities and constraints, as well as we present all the costs involved in the simulation.

Once the simulation is complete, two documents are created with all relevant information to investors. The first is a more detailed document called "Trades Report" where we describe in detail all trades carried out during the simulation. And the second is a more concise report called "Summary Report" containing several important and informative data about the simulation, including the evaluation metrics used here. Examples of these two types of report are presented in appendices A and B.

4.1
Trade Timing

The most important function of a trading system is to indicate propitious times when to enter and exit a trade. In the search of these good times to buy or

to sell the considered stocks, the trading system considers the difference between the current price or spread and its predicted boundary values.

If we consider buy and sell trades, we compare the current stock price and its minimum and maximum predicted values every minute. When the current price is close to its predicted minimum value by at most a difference α, the trading system interprets it as a good moment to buy the considered stock. Similarly, a good moment to sell that stock is evidenced when the current price is close to its predicted maximum value by at most a difference β.

If we focus on Pairs Trading, the system works in the same way, but compares the current spread between the considered stock pair and the minimum and maximum predicted spreads every minute. When the current spread is close to its predicted minimum value by at most a difference γ, the trading system indicates a favorable moment to simultaneously buy the first stock and sell the second. Analogously, a proximity of at most δ between the current spread and its predicted maximum value suggests a favorable moment to sell the first stock and buy the other one at the same time.

The purpose of these flexibility factors α, β, γ and δ is to ensure that the trade is held either near the real minimum value or the real maximum value, even when the predictions are not entirely correct. We calculate their values using the following formula:

$$\rho \left| cv_{max} - cv_{min} \right|, \tag{4.1}$$

where cv_{min} and cv_{max} are the minimum and maximum predicted values, respectively, and ρ is a constant set empirically in the range of -0.5 to 0.5 depending on both the investor's profile and the stock or pair considered.

The figure 4.1 ilustrates the reflections of a flexibility factor presenting a positive or negative value, by showing the boundary spreads of the Pair Trading USIM5 x GGBR4 predicted by PLSR predictor and the ranges achieved by γ and δ according to the signal of the parameter ρ.

If $\rho > 0$, the flexibility factors of a simulation present a positive signal and the values that must be reached to indicate when to buy and sell the considered stocks approach each other. Similarly, these values become more distant when $\rho < 0$ implies negative values to the flexibility factors. In practice, positive flexibility factors represent a greater chance that the trading system will indicate a trade, even if the predicted values do not present a good accuracy, resulting in simulations with a bigger number of trades. On the other hand, negative values represent conservative entry and exit points that makes the trading system indicate only trades where the odds of winning are more significant.
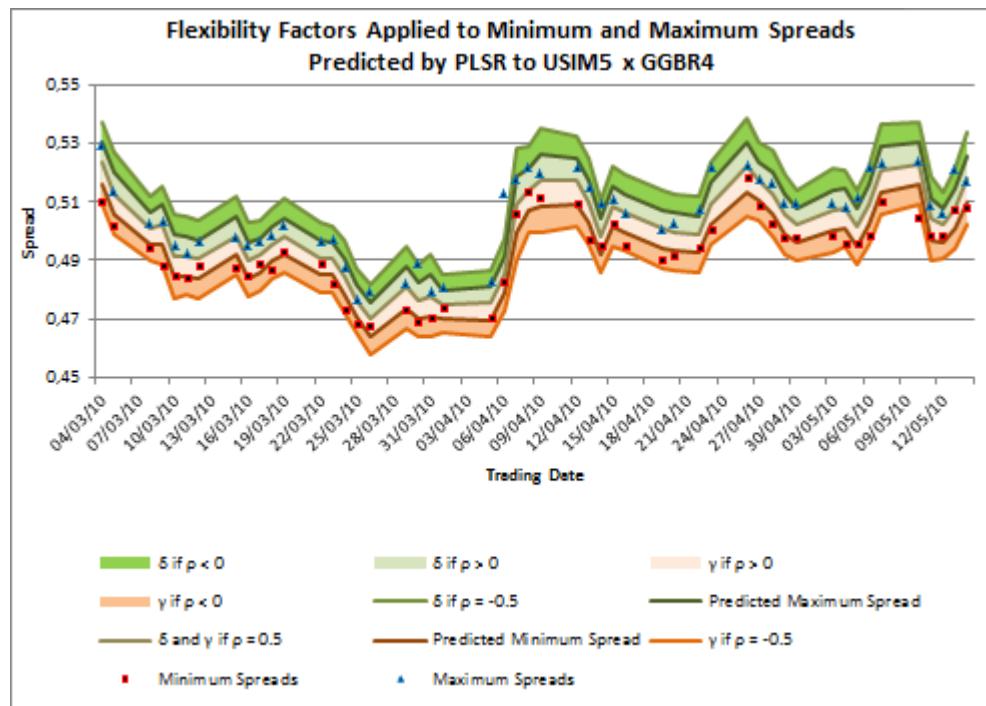
Figure 4.1: Flexibility Factors Signal Reflections

These flexibility factors must be set according to the investor's level of conservatism. If the investor has a more aggressive profile and intends to support a higher risk for the sake of a possibility of higher returns, he can use positive factors. Otherwise, if the investor has a more conservative profile and do not want to expose his assets, he must consider only negative factors.

As this work focuses only on day trading, any operation that has not yet completed at the market closing is dismantled by considering the stock prices at the last minute of the trading day.

It is important to note that more than one trade is allowed during the same day. However, we must ensure that for each buy there is a corresponding sell operation. Once we consider the stock market possibility of short selling, the order in which the buy and sell operations occur is irrelevant.

4.2
Risk Control

In order to control the trading risk, we use a well-known strategy: Stop Orders (SO). Aiming to protect the invested capital, this strategy defines safety margins, so that if the stock price reaches a certain value, the investor exits the trade.

The proposed trading system performs two kinds of SO: Stop Loss and Stop Gain. Stop Loss is used to limit losses. Thus, each trade has a preset allowable maximum loss and it is automatically dismantled if this value is achieved. Stop Gain, on the other hand, is used to avoid the loss of already achieved profits. Thus, if an operation reaches a preset gain, it is dismantled to ensure the already obtained profit.

The SO values are defined as percentage changes from the price negotiated in the entry trade. As the flexibility factors, they are also set empirically and depend on the considered stock or pair. These values vary from 0.005 to 0.1. In practice, a SO assuming the value 0.1 represents the non-use of the strategy, since in the performed experiments, a 10% variation was not seen neither in price nor in spread.

4.3
Money Management

Money management refers to how the available money is employed in the operations signalized by the trading system.

Our best results are obtained by applying all the available money in each operation. Hence, when the trading system suggests to buy or sell the considered stock, the trading volume is as close as possible to all money in cash. Similarly, when the trading system indicates a particular Pair Trading, we invest as much of the available money as possible to buy one of the two stocks and sell a quantity of the other one resulting at a value as close as possible to the purchase trading volume, taking advantage of the short selling opportunity.

Despite the fact that all the invested capital may be exposed in this type of money management, with the chosen risk control mechanism we ensure the operations safety by reducing their risks.

4.4
Stock Market Opportunities and Constraints

In order to perform a simulation as close as possible to effective market behaviour, we reproduce all real stock market features in our trading system. These features are shown below, including opportunities and constraints.

The most important possibility of the financial market exploited in our trading system is short selling. It is the name given to the practice of selling assets that the investor does not have in his portfolio. In this cases, he must exit the trade at the same trading day by buying the same assets, or must borrow from

a third party with the intention of buying identical assets back at a later date to return to the lender. As usual in Brazilian brokerages, since we perform only day trading and so all short sales will be dismantled by the end of the trading day, no additional cost is charged to perform short selling.

Since the odd lot market has different prices than those available in our dataset, the proposed trading system performs only operations over BM&FBovespa standard lots, composed by 100 stocks.

For all experiments, we consider a slippage factor for each operation. Slippage is the difference between the price indicated by the trading system and the price negotiated in the simulation. This variation occurs when at the time when the order is sent to the broker, there are already orders from other investors in the order book's queue for the same stock at that same price indicated by the trading system. In these cases, the orders sent earlier have priority, and the asset price can fluctuate in the extent that these orders are executed.

The slippage must be taken into account mainly at low trading volume asset operations and when the volume of the sent order is greater than the average trading volume of that asset, where the price variation is even more significant. Once all tests are performed, considering only high liquidity stocks, the slippage can assume low values. Thus, in our experiments, we set a pessimistic slippage factor of 0.1% for each operation. Therefore, every stock is bought 0.1% more expensive and is sold 0.1% cheaper than the price indicated by the trading system.

To simulate the Brazilian stock exchange with fidelity, we must consider three kinds of rates: brokerage house rates (brokerage commission and custody), stock exchange rates (trading and liquidation) and income tax rates (withholding income tax and income tax).

The following table summarizes all day trading rates applied to natural person investors by presenting the incidence or generating factor, the payment way and the value of each.

Rate	Incidence	Payment Way	Value
Brokerage Commission	Every trade	Every trade	R$15.77
Custody	Every month	1° business day of next month	R$6.90
Trading	Every trade	Every trade	0.0285% of trading volume
Liquidation	Every trade	Every trade	0.006% of trading volume
Withholding Income Tax	Every sell trade	Every trade	1.00% of profit
Income Tax	Every profitable month	5° business day of next month	20.00% of profit

Table 4.1: Rates Considered in Our Trading System

For each trade, we consider a brokerage commission rate equivalent to R$15.77. We chose this value because it is the value charged in XP Investimentos, the biggest independent brokerage house in Brazil [75]. In addition to the brokerage rate, the Brazilian brokerage houses also charge a monthly custody rate of R$6.90 to store the investor's assets.

In our trading system, we also consider the Brazilian stock exchange rates to day trading. Every trade, rates of liquidation and trading are charged with values of 0.0285% and 0.006% of trading volume, respectively.

Finally, we consider in the proposed trading system, the Brazilian day trading income tax. Due to this tax, each obtained gain is deducted by a value of 1.0% referring to the withholding income tax. And to each profitable month, an income tax of 20% is charged on the fifth business day of the next month. In these cases, any losses suffered in recent months can be discounted off the value from which the tax will be calculated.

It is important to note that the trading volume consideration is not significant for the tests performed here. This is true since in the experiments this value never exceeds R$300,000.00, whereas the daily trading volume of the tested stocks reaches hundreds of millions of dollars.