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The Use of Investment Portfolio Orthogonality to Secure Investment against Bank Interventions

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Abstract. Addressing risk from price fluctuations is usual for traders in finance markets, but interventions from banks are extreme and unpredictable. The principle of portfolio orthogonality was investigated as one way of securing investment in the face of interventions in financial markets. The research tested two forecasting tools: the adequate portfolio model and an ensemble of Evolino recurrent neural networks. The paper draws on different investment portfolios in global capital and foreign exchange markets to illustrate the potential of investment portfolio orthogonality. Banking interventions are relatively rare phenomena which have an impact on the security of investment. The investment portfolio orthogonality principle can be used as a tool to protect against unexpected losses.

Keywords: Orthogonality, bank intervention, portfolio management, financial markets, Evolino recurrent neural networks, ensemble, adequate portfolio.

1. Introduction

The uncertainty of financial markets is based on the dynamic environment of economic and policy. Economic uncertainty is inevitable and economic actors must adapt to this condition. Knüppel (2014) estimated forecast uncertainty in the absence of a panel of forecasters. He argues that most forecasting institutions base their assessments of forecast uncertainty solely on their own past forecast errors. Knight (2012) notes that the level of uncertainty can be reduced in several ways, including improving our knowledge through future research and compiling and testing the necessary data.

Central banks' interventions in foreign exchange markets have been widely researched and discussed. There is a general opinion that intervention may be warranted to stabilize the exchange rate and provide liquidity to the market. Exchange rate volatility can often have serious macroeconomic consequences in developing and emerging economies because they frequently lack hedging facilities that protect domestic enterprises from such volatility. The interventions that developing and emerging market countries undertake, together with other policies that they pursue to increase the effectiveness of those interventions, can limit the very financial development that they so badly need (Bordo et al, 2012).

Assessing intervention activities in developing and emerging market economies is not straightforward. Their financial markets are underdeveloped and often tightly regulated. They often impose restrictions on cross-border financial flows. Their interventions are not always sterilized and hence they are a product of monetary policy as much as exchange rate policy. Their motives for buying or selling foreign exchange vary widely – beyond what has previously been considered intervention. Nonetheless, because of their unique characteristics, these countries provide useful laboratories for understanding the behaviour of exchange rates and the effectiveness of intervention.

Canales-Kriljenko's (2004) study found that foreign exchange markets in countries with developing and emerging economies are underdeveloped, particularly at the interbank level. Central banks may play an important role in foreign exchange receipts to market. Central banks have their own propinquity with the market. They may also act as government administrators of the foreign exchange market. They can often decide who, in terms of market participants, may engage in foreign exchange trade. Central banks may also enforce macroeconomic controls on cross-border financial flows. Furthermore, Canales-Kriljenko (2003, 2004) found that most central banks in these countries participate in the market irrespective of the underlying exchange rate regime. They often intervene heavily in markets characterized as flexible or floating. Surprisingly, however, less foreign exchange intervention occurs under credible fixed exchange rate regimes. If an exchange rate peg is credible, foreign exchange intermediaries tend to act as stabilizing speculators, minimizing the need for official intervention (Canales-Kriljenko, 2003, pp. 6–7).

Exchange rate stability is the main reason for intervention in developing and emerging market economies, acquiring foreign exchange reserves and providing foreign exchange to market participants. Developing and emerging countries often buy foreign exchange to accumulate foreign currency reserves. Many countries view holding substantial portfolios of foreign exchange reserves as a means of building investor confidence by strengthening their debt repayment capabilities and maintaining external liquidity (Canales-Kriljenko et al, 2003). Moreover, buying and selling foreign exchange is necessary if the central bank is the main intermediary for foreign exchange in countries where the government is the chief foreign currency recipient.

Investors and speculators in the financial markets try to protect investments from extreme market changes generated by banking interventions, natural disasters and other unexpected events. The formation of a portfolio is very important in the investment process. Markowitz's (1952) pioneering work on modern portfolio theory developed profit–risk dimensions, this later being complemented by the efforts of Black (1974) and many others. Anderson and Francle (1980), Jorion (1986), De Santis and Gerard (1997) researched the problem of portfolio diversification, experimentally analysing how many financial tools must be in a portfolio to afford safe investment. More recently, Fuertes et al (2009) have researched the volatility of stock markets, examining whether the importance of using intraday data depends on market conditions and the use of daily GARCH forecasts. Amenc and Martellini (2011) assert that "… modern portfolio theory unambiguously identifies portfolio diversification as a particularly powerful source of added value in investment management because it allows for the design of much needed efficient performance benchmarks" (p. 2). Furthermore, Kiani (2011) finds that diversification lowers the portfolio risk and an additional reduction in portfolio risk is realized by international diversification. Meucci et al (2014) used the 'Effective Number of Minimum-Torsion Bets' to measure portfolio diversification and compared it to the equal weight approach to portfolio allocation. Some models, based on economic theory, have serious problems forecasting exchange rates. Based on a study using a panel of 33 exchange rates vis-à-vis the US dollar, Carriero et al (2009) propose forecasting exchange rates with a large Bayesian vector autoregression (VAR), which they argue is more robust than random walk models, providing better forecasts for most countries over any horizon.

One risk mitigation technique is to construct an orthogonal portfolio. Roll (1980) first introduced the term 'portfolio orthogonality'. Jobson and Korkie (1982) and Asgharian (2011) have proposed asset allocation models with latent factors based on the portfolio orthogonality principle. In our research, we use algorithms to predict the finance market and employ portfolio orthogonality for asset allocation. However, it should be noted that other authors, such as Yevseyeva et al (2014) and St-Pierre and Teytaud (2014), are opposed to the idea of using investment portfolio orthogonality for the selection of algorithms. Rutkauskas (2000) suggests the application of an adequate portfolio model for the construction of an investment portfolio, combining the profitability, risk and reliability. Thus, one allocates a portfolio which has the lowest risk for a given profitability with a certain probability, or the highest return for a given level of risk associated with a certain probability (Rutkauskas, 2006).

Addressing risk from price fluctuations is usual for traders in finance markets, but bank interventions are extreme and unpredictable. The aim of this paper is to investigate the application of the portfolio orthogonality principle as a means of saving investment from interventions in finance markets. Our paper examines how the intervention of the Swiss National Bank on 15 January 2015 affected the instruments of financial markets: exchange rates and indices. The currency before 15 Jnauary 2015 was tied to the euro, and on 15 Jnauary 2015 Swiss National Bank untied the currency against from the euro. This decision had a significant impact on both private and institutional investors. We tested two forecasting tools: one based on an adequate portfolio model and the other comprising an ensemble of Evolino recurrent neural networks (RNNs). We also tested trading in the stock market and exchange market.

2. Constructing an efficient portfolio

The search for portfolio assets consists of a number of steps (see Fig. 1):

1) Historical data monitoring and the accumulation of experience. Change in financial market prices is a chaotic process which has a memory: what happened in the past affects the future. The amount of data and the form of storage is determined by the chosen method of forecasting.

2) Future forecasting. There are many different methods of forecasting, based on different means: arithmetic, geometric, harmonic and its hybrids. Artificial intelligence systems, such as neural networks, genetic algorithms, fuzzy systems and expert systems, are also used for forecasting financial markets.

3) Asset allocation and assessment of reliability. The main aim of investors is to select portfolio elements from different financial and asset markets and divide the invested funds for all the elements to obtain an optimal result. The greatest gain is selected for a given level of risk, or the lowest risk is selected

for a given level of profit.

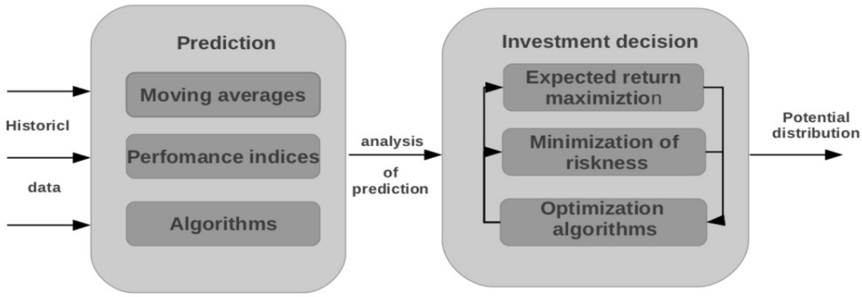

Fig.1. Constructing an efficient portfolio

The basic rule of portfolio optimization is to maximize the return, minimize the risk (Markowitz, 1952) and maximize reliability P (Rutkauskas, 2000):

$$\begin{cases} max\ ER_p \\ min\sigma^2 \\ max\ P \end{cases} \quad (1)$$

where for a portfolio consisting of p assets: W is part of many, investing in asset i; ERi denotes the planned profit from asset i; n is the number of assets in the portfolio, rij is the correlation between assets i and j; σ is the standard deviation. Thus, the portfolio optimizing equation is as follows:

$$\begin{cases} ER_p = \sum_{i=1}^{n} W_i ER_i \\ \sigma^2 = \sum_{i=1}^{n} W_i \sigma_i^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} W_i W_j r_{ij} \sigma_i \sigma_j; \\ P = \prod \frac{f}{N} \end{cases} \quad (2)$$

where fi is frequency of the distribution mode, N is the number of predictions and ∑Wi=1 .

Roll (1980) introduced the term 'portfolio orthogonality', given by:

$$\sum_{i=1}^{n} r_{ij} \sigma_i \sigma_j = 0 \quad (3)$$

We enter ε, which is the scale of proximity to portfolio orthogonality:

$$\sum_{i=1}^{n} r_{ij}\sigma_i\sigma_j = \varepsilon \quad (4)$$

The closer ε is to zero, the better the orthogonality. This principle of orthogonality should be checked experimentally in real time in foreign exchange and stock markets.

3. Selection of investment portfolio

Real investment is a way of assuring the soundness of applicable strategies. The portfolios in this study were formed from exchange rates and indices of the US (NYSE, NASDAQ), German (DAX), UK (FTSE) and French (CAC 40) markets. The methods of inquiry are based on: analysis of data from primary sources, the study of secondary data and scientific literature, the simulation of financial markets, the optimization of the utility function, application of adequate portfolio theory and an ensemble of Evolino RNNs. The prediction of both tools is based on stochastically informative distribution, reflecting the behaviour of the forecast finance market.

3.1 Selection of investment portfolio using adequate portfolio theory

The construction and management of a portfolio requires effective evaluation of various portfolio conditions on the efficiency curve, the description of their interaction and the analysis of other portfolio characteristics (Rutkauskas, 2000). Portfolio decisions should be made not by describing the profit possibilities of a portfolio as point estimated, but as their distribution of probability (Rutkauskas, 2000). Before examining the concept of the adequate portfolio, it should be noted that this relates to a common set of financial assets which determine the reliability of profitability. The idea of this portfolio was first proposed by Rutkauskas (2000) and in later works he examined the specific features of this theory (Rutkauskas, 2001, 2005a, 2005b; 2006; Rutkauskas & Kvietkauskienė, 2013; Rutkauskas et al, 2009). The essence of this theory is the assessment of investment portfolio risk, profitability and reliability. To allocate available resources effectively in the financial markets, it is important to identify the opportunities offered by the markets, their profitability and risk level. In this way markets are selected in which the investors, by taking the appropriate level of risk, will receive optimal utility and reliability (Rutkauskas et al, 2013).
In this case, to make successful investment decisions we draw on the survival function, which allows each market opportunity to be evaluated in terms of the size of the opportunity and the guarantee of its size. This approach enables a

quicker review of market opportunities than with any other model or methods. The choice of useful options for the entity is associated with the equivalent recovery of the utility function. As utility is associated with efficiency, reliability and risk, it is possible to employ the utility function as follows:

$$U = \frac{f_e \cdot f_p}{f_r} \tag{5}$$

where U is the utility function, f(e) denotes efficiency, f(p) denotes reliability and f(r) denotes level of risk. To select the most useful utility function, it is necessary to take into account the profitability and reliability. The utility function depends on the efficiency and reliability, the latter being associated with the level of risk; thus, the survival function is calculated and plotted from the available data. On the basis of the calculations, all selected capital markets can be ranked according to the utility for the investor.

The view of three-dimensional e□ective area especially useful for understanding the influence of distributions of individual investments forms on overall portfolio opportunities distribution form.

Together here is submitted the geometric view of three-dimensional model of the utility function. (Fig. 2)

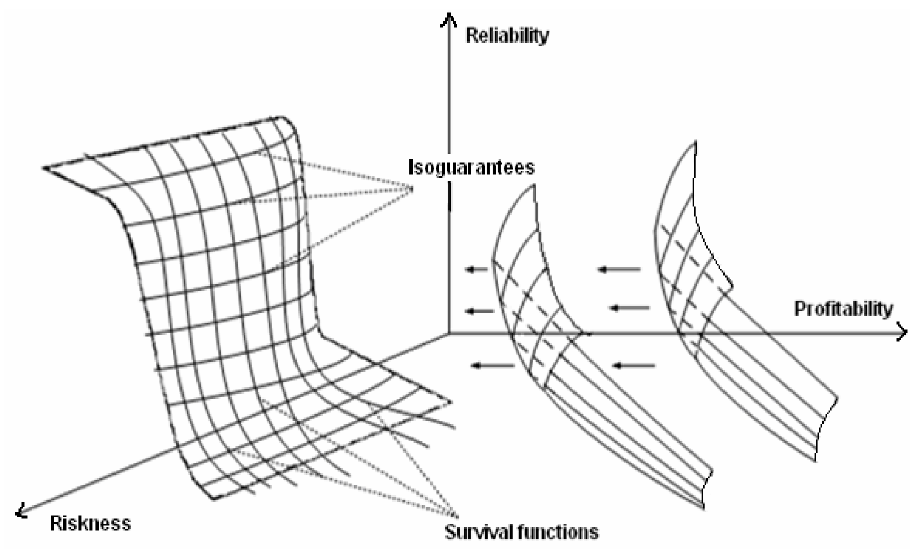

Fig. 2. The general view of three-dimensional e□cient surface and respective utility functions

(Source: Rutkauskas 2006)

Portfolio orthogonality was used to select indices for the investment portfolio. The values calculated and used to construct the portfolios are presented in Tables 1–3.

Table 1. Correlation coefficients of financial indices (Portfolio A1)

	NYSE	DAX	CAC 40	NASDAQ	FTSE
NYSE	1	0.945804	0.922233	0.9477666	**0.719116**
DAX	0.945804	1	0.954873	0.902154	0.686034
CAC 40	0.922233	0.954873	1	0.837259	0.692218
NASDAQ	0.947767	0.902154	**0.837259**	1	0.607837
FTSE	0.719116	0.686034	0.692218	0.607837	1
Σ	7.346959	7.871053	2.748654	4.7404925	2.278674
ε	22.94841				

(Source: created by authors)

Table 2. Correlation coefficients of financial indices (Portfolio B)

	NYSE	DAX	CAC 40	NASDAQ	FTSE
NYSE	1	0.945804	0.922233	0.9477666	0.719116
DAX	0.945804	1	0.954873	0.902154	0.686034
CAC 40	0.922233	0.954873	1	0.837259	0.692218
NASDAQ	0.947767	0.902154	0.837259	1	0.607837
FTSE	0.719116	**0.686034**	**0.692218**	**0.607837**	1
Σ	7.346959	7.871053	2.748654	4.7404925	2.278674
ε	23.20584				

(Source: created by authors)

Table 3. Correlation coefficients of financial indices (Portfolio A3)

	NYSE	DAX	CAC 40	NASDAQ	FTSE
NYSE	1	**0.945804**	**0.922233**	**0.947767**	0.719116
DAX	0.945804	1	0.954873	**0.902154**	0.686034
CAC 40	0.922233	0.954873	1	0.837259	0.692218
NASDAQ	0.947767	0.902154	0.837259	1	0.607837

FTSE	0.719116	0.686034	0.692218	0.607837	1
Σ	7.346959	7.871053	2.748654	4.7404925	2.278674
ε	139.9889				

(Source: created by authors)

In our investigation, we thus included three portfolios A1, A2, A3, consisting of financial indices that were ”not orthogonal” (ε = 139.99) (A3), ”orthogonal” (ε = 23.21) (A2) and ”more orthogonal” (ε = 22.95) (A1). As mentioned previously, these parameters are important for dividing investments found for selected indices. Investments were made for selected indices over a testing period from 4 December 2012 to 30 January 2015. The period of a week was chosen to reduce the cost of sale and buying and to use the active portfolio management model.

Using the adequate investment portfolio system in the DNB Trade demo version, we analysed the index portfolios for US (NYSE, NASDAQ), German (DAX), UK (FTSE) and French (CAC 40) markets. The DNB Trade platform was chosen because of its functionality and the similarity of the investor’s operating tools in global capital and currency markets. This provides ease in managing investments (buying and selling financial instruments), replicating the process with technical analysis indicators (graphs and modifications) and publishing the data required for the fundamental macro-level analysis and information flow. The process of making transactions and the order submission is fully automated.

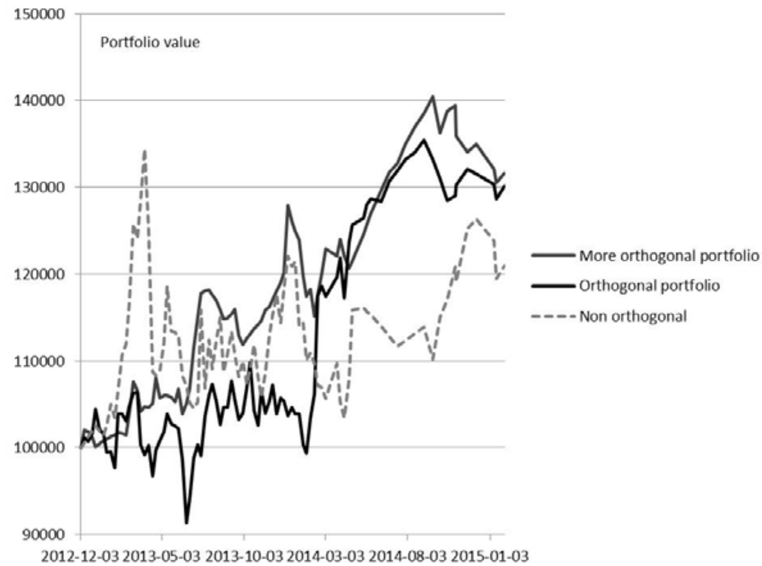

Fig. 3. Test for the three different portfolios using the DNB Trade platform in real time

(Source: created by authors)

The test using the DNB Trade platform in real time is shown in Fig. 3. Before the Swiss National Banks intervention on 15 January 2015, the profit of the three portfolios was 23.87% (not orthogonal (A3)), 30.34% (orthogonal (A2)) and 32.13% (more orthogonal (A1)). All three portfolios included US indices that experienced a decrease in price of about 5% on 15 January 2015. Our prediction tool (the adequate portfolio model) predicted the decrease in the NYSE index, but it did not predict the right direction of change in the NASDAQ index. The losses for the three portfolios were -2.9% (not orthogonal (A3)), -1.7% (orthogonal (A2)) and -1.6% (more orthogonal (A1)).

3.2 Selection of investment portfolio using an ensemble of Evolino RNNs

For the forecasting of expected values we used an ensemble of RNNs, based on the evolutionary system, Evolino RNN, proposed by Wierstra et al. (2005). It is known that an ensemble can provide more accurate predictions than single RNNs. We therefore constructed an Evolino RNN-based prediction model (Fig. 4) comprising an ensemble of 176 RNNs. (For a detailed description of the prediction model, see Maknickiene˙ and Maknickas (2013), Maknickien and Maknickas (2013).

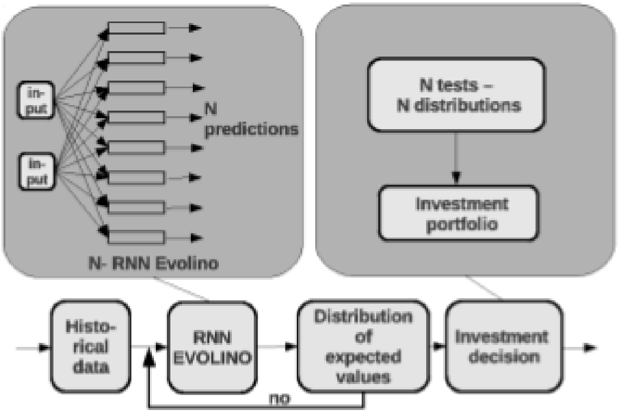

Fig. 4. Forecasting model using an ensemble of 176 Evolino RNNs.

(Source: created by authors)

To select the exchange rates for investment we used portfolio orthogonality based on eight currencies: pound sterling (GBP), Australian dollar (AUD), New Zealand dollar (NZD), Canadian dollar (CAD), euro (EUR), Japanese yen (JPY), US dollar (USD) and Swiss franc (CHF). Portfolio orthogonality (eq. 4) employs the correlation coe□cient rij and standard deviations σi and σj. The values calculated are presented in Tables 4–6.

Thus, we selected three portfolios:"not orthogonal" (B3) (ε = 0.17),"orthogonal" (B2) (ε = 0.09) and "more orthogonal" (B1) (ε = 0.078). These parameters are important for dividing the investments found for the selected exchange rates. Testing was undertaken in real time for the period from 1 July 2014 to 29 January 2015. The portfolios were constructed using two equations. To calculate ERp, σi, σj and Pp, we used the parameters of distribution and the last known values of the exchange rates.

Table 4. Correlation coefficients of exchange rates (Portfolio B1)

	GBP/AUD	NZD/CAD	EUR/JPY	USD/CHF
GBP/AUD		-0.35388	0.515709	0.459788
NZD/CAD			-0.18521	-0.72808
EUR/JPY				0.370028
USD/CHF				
Σ	0.036098	0.023079	3.254101	0.037039
ε	0.090964			

(Source: created by authors)

Table 5. Correlation coefficients of exchange rates (Portfolio B2)

	GBP/USD	EUR/AUD	USD/JPY	USD/CHF
GBP/USD		0.007377	-0.92744	-0.92
EUR/AUD			-0.09726	-0.2773
USD/JPY				0.84809
USD/CHF				
Σ	0.048536	0.040137	6.296869	0.037039
ε	0.171148			

(Source: created by authors)

Table 6. Correlation coefficients of exchange rates (Portfolio B3)

	GBP/USD	EUR/AUD	USD/JPY	USD/CHF
GBP/USD		0.007377	-0.92744	-0.92
EUR/AUD			-0.09726	-0.2773
USD/JPY				0.84809
USD/CHF				
Σ	0.048536	0.040137	6.296869	0.037039
ε	0.171148			

(Source: created by authors)

The test for the foreign exchange market in real time is shown in Fig. 5. Before the Swiss National Banks intervention on 15 January 2015, the profit of three portfolios was as follows: 0.7% (not orthogonal (B3)), 2.07% (orthogonal (B2)) and 4.07% (more orthogonal (B1)). All three portfolios experienced a severe problem with the USD/CHF exchange rate, which shifted by approximately 15% on 15 January 2015. Our prediction tools did not predict the change of exchange rates in the right direction and thus the losses for all three portfolios were significant: -2.2% (not orthogonal (B3)), -1.5% (orthogonal (B2)) and -1.4%

(more orthogonal (B1)).

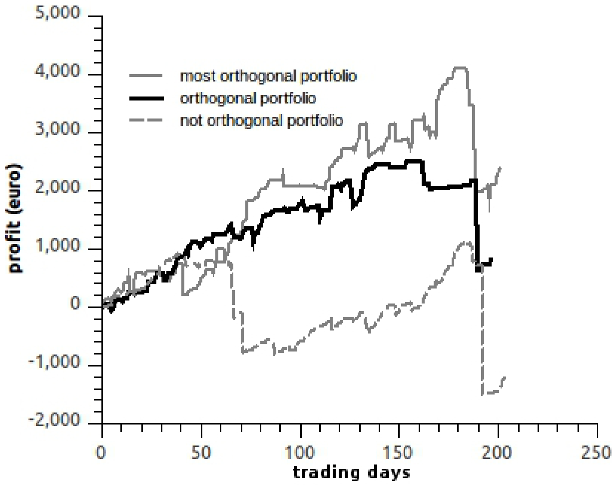

Fig. 5. Constructing an e□cient portfolio

(Source: created by authors)

3.3 The Comparison of portfolios with different orthogonality

The results of research is presented in Table 7. Comparison of Sharpe ratio before 15-01-2015 Switzerland National bank's intervention (sharpe 1) and after intervention (sharpe 2). Also there are presented comparison of two forecasting tools and di□erent orthogonality of investment portfolios. The most orthogonal portfolios (A1, B1) has the highest Sharpe ratio before intervention, so it means that this portfolios were less risky in the stock and exchange markets. Not orthogonal portfolios (A3, B3) are e□ective too but the losses after bank intervention are higher comparing with the most orthogonal and orthogonal portfolios.

Table 7. Comparison of orthogonal and less orthogonal portfolios

	Most orthogonal		Orthogonal		Not orthogonal	
	A1	B1	A2	B2	A3	B3
Sharpe1	2.01	1.42	1.68	1,16	1.13	1,06
Sharpe2	0.83	1.19	1.29	0,98	0.22	0,43

(Source: created by authors)

The investment portfolio taking into account the orthogonality condition allows productive investment in the foreign exchange market in all periods of testing. Losses incurred through bank intervention are lower when portfolio deversification takes account of portfolio orthogonality. Banking interventions are relatively rare and have an impact on the security of the investment. The investment portfolio orthogonality principle can be used as a tool to protect against unexpected losses. The comparison of Sharpe ratios before and after Switzerland National bank's intervention in the stock and foreign exchange markets showed that both markets are sensitive to banking interventions.

4. Conclusions

The exchange market has been analysed as a chaotic process. The result of forecasting models is determined as the stochastically informative distribution of expected values, reflecting the behaviour of the forecast stock prices and exchange rates in the future.

The use of equations for investment portfolio optimization and the application of the portfolio orthogonality principle show that investment decisions under conditions of uncertainty and risk are more e□cient whichever prediction tool is used. Losses due to bank interventions are greater in the exchange market than in the stock market, as the foreign exchange market is inherently more risky. However, in both cases the losses are lower when the principle of portfolio orthogonality is applied.

Testing the principle of portfolio orthogonality in the imitative market in real time provides further information concerning bank interventions and ways to secure investments.

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