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Violation of interest-rate parity: a Polish example

Jerzy Przystawa[a,*], Marek Wolf[a,b]

[a]Institute of Theoretical Physics, University of Wrocław, Pl. Maksa Borna 9, 50-204 Wrocław, Poland
[b]School of Management and Finance, ul. Pabianicka 2, 53-339 Wrocław, Poland

Abstract

The mechanism of the so-called "Bagsik Oscillator" is presented and discussed. In essence, it is a repeated exploitation of arbitrage opportunities that resulted from a marked departure from the interest-rate parity relationship between the local Polish currency and the western currencies.

Keywords: Interest-rate; Parity

1. Introduction: arbitrage and forward contracts

Two extremely important concepts in modern finance are the concepts of efficient market and no-arbitrage.

"A capital market is said to be efficient if it fully and correctly reflects all relevant information in determining security prices. Formally, the market is said to be efficient with respect to some information set, if security prices would be unaffected by revealing that information to all participants. Moreover, efficiency with respect to an information set implies that it is impossible to make economic profits by trading on the basis of [that information set]" [1].

The efficient market hypothesis is, basically, a statement that the prices of financial instruments behave randomly.

"A perfect market for a stock is one in which there are no profits to be made by people who have no special information about the company, and in which it is difficult even for people who do have special information to make profits, because the price adjusts so rapidly as the information becomes available" [2].

* Corresponding author.
E-mail addresses: przystaw@ift.uni.wroc.pl (J. Przystawa), mwolf@ift.uni.wroc.pl (M. Wolf).

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Since the prices of financial instruments behave randomly, each person who owns any particular instrument is exposed to the risk that as time goes by, that instrument may be worth less than it was when it was purchased. Oftentimes, especially in business, a company may know that at some future point in time, it is going to receive some foreign currency. Since much of the company's business may be carried out in some other currency and it may have some expected expenses in that currency, the company may not be comfortable not knowing what the exchange rate of the currency will be at the future point in time when it receives the foreign currency. Consequently, the company may desire to enter into an agreement with another company, a bank, for instance, to convert the currency at the future point in time at an agreed upon price. This is an example of the so-called forward contract, in this case a foreign-exchange forward contract, or forex forward.

Clearly, if the future behaviour of the prices of financial instruments were deterministic, i.e., were known today, there would be no need ever to conceive of such contract. If the exchange rate for a foreign currency were known today, the company would then know its cash flows exactly and, so, could plan with complete certainty. Instead, it is the efficiency of the market which causes risk and which can be lowered, or as it is termed, hedged, using a contingent claim, in this case, a forward contract.

However, given that only today's exchange rate is known, what is a reasonable price for the future exchange rate? In order to calculate this, a second important concept of modern finance must be introduced. The concept of arbitrage and the fact that no risk-free arbitrage opportunities exist in an efficient market. Arbitrage is the simultaneous purchase of similar securities to take advantage of different prices in different markets [3]. In other words, an arbitrage opportunity presents itself when a person can make money with no, or infinitesimal, risk to himself. An example of an arbitrage opportunity would be if the price of a share in IBM were trading at 90 USD in London but at 100 USD a share in New York. In that case, a person could buy a share in New York and immediately sell it in London and make a 10 USD per share profit. Clearly if such were the case, everybody who was able to do so, would buy shares of IBM in New York and sell them in London. As a result of this, the prices would very, very quickly come to some sort of common equilibrium.

Most generally, an arbitrage opportunity will arise whenever the efficiency of the markets is violated, i.e., whenever it is possible to predict the future behaviour of the price of a financial asset.

2. Interest-rate parity

Suppose we have some assets of value S_0 on which we want to take a loan at a foreign bank. Let the risk-free rate be r_f. If we are to obtain the secured loan at the time t_1 against which we use our assets S_0 as collateral and the loan will mature at the time T, then the bank may give us

$$F_1 = S_0 \exp[-r_f(T - t_1)] . \quad (1)$$

If we now convert F_1 to the local currency at the exchange rate $k(t_1)$, we obtain P_1,

$$P_1 = k(t_1)F_1 . \tag{2}$$

Let us deposit P_1 in a local bank that offers a rate r. Thus, at the time T we should get

$$D_1 = P_1 \exp[r(T - t_1)] = k(t_1)S_0 \exp[(r - r_f)(T - t_1)] . \tag{3}$$

Ultimately, we will have to repay the foreign bank at time T; however, there are two possible strategies that we can pursue, namely we could enter into a forward agreement for the foreign currency at present and secure an exchange rate (subject only to counterparty default risk) or we could simply wait until time T and convert the currency at the then spot price. This former amounts to hedging while the latter to pure speculation.

Let us consider the former case, namely of hedging [3]. We now enter into an agreement to guarantee us a spot rate $k(T)$ for the time T. What is a no-arbitrage price for the exchange rate? Well, if we convert D_1, at the exchange rate $k(T)$, we obtain

$$M_1 = \frac{D_1}{k(T)} . \tag{4}$$

In this case we would pay back S_0 to the bank and calculate the profit:

$$W_1 = M_1 - S_0 = S_0 \left(\frac{k(t_1)}{k(T)} \exp[(r - r_f)(T - t_1)] - 1 \right) . \tag{5}$$

To make no profit, i.e., no arbitrage, on such a simple scheme, we must require

$$W_1 = 0 . \tag{6}$$

This gives the well-known *interest-rate parity relationship* (IRP) in the field of international finance [4]:

$$k(T) = k(t_1) \exp[(r - r_f)(T - t_1)] . \tag{7}$$

It is worth drawing attention to the fact that this forward price is simply the arbitrage-free forward price that any rational trader should use in order to avoid losing money. There is no deterministic relationship between the forward price $k(T)$ and what the spot rate will be on T. If the markets are truly efficient this latter is unknowable *a priori*. If someone were to know what the exchange rate was going to be on a given date in the distant future, they could make enormous sums of money with this knowledge with a suitable combination of short or long positions in the currency. To see let us assume that $r_f < r$ and that a certain person knows that the spot price on a given day T will be $k(T)$, then there would be no need to enter into the forward agreement; rather this person would be able to obtain the risk-free profit of

$$RiskLessProfit = M_1 - S_0 = S_0 \left(\frac{k(t_1)}{k(T)} \exp[(r - r_f)(T - t_1)] - 1 \right) . \tag{8}$$

If this were negative, he would be able to get a profit by simply reversing the procedure. Either way, the knowledge of the exchange rate on a given day in the future is an arbitrage opportunity which can be exploited to make a riskless profit.

3. Financial pendulum

Of course, once one has certain knowledge about the future one can concoct a scheme to magnify almost arbitrarily the risk-free profits. Suppose, for example, that instead of collecting W_1 and going to another business we rather take a letter of credit from the local bank for the amount M_1, and, at the time t_2 we take another foreign loan

$$F_2 = M_1 \exp[-r_f(T - t_2)] . \tag{9}$$

This being immediately transferred to our country, changed, at the rate $k(t_2)$ to the local currency:

$$P_2 = k(t_2)F_2 \tag{10}$$

and deposited until T. We should then expect

$$D_2 = P_2 \exp[r(T - t_2)] = S_0 \frac{k(t_2)k(t_1)}{k(T)} \exp[(r - r_f)(2T - t_1 - t_2)] . \tag{11}$$

At the time T, one may collect D_2 and buy M_2 of foreign currency at the rate $k(T)$:

$$M_2 = D_2/k(T) . \tag{12}$$

In such a way, after having paid back the loans S_0 and M_1, one is securing the profit

$$\begin{aligned} W_2 &= M_1 + M_2 - M_1 - S_0 = M_2 - S_0 \\ &= S_0 \left(\frac{k(t_2)k(t_1)}{k^2(T)} \exp[(r - r_f)(2T - t_1 - t_2)] - 1 \right) . \end{aligned} \tag{13}$$

If one is in a position to repeat the above steps N times, the gain at the time T, should be

$$W_N = S_0 \left(\frac{\prod_{i=1}^N k(t_i)}{[k(T)]^N} \exp\left[(r - r_f) \left(NT - \sum_{i=1}^N t_i \right) \right] - 1 \right) . \tag{14}$$

4. The Bagsik oscillator

In 1990, in the midst of the complicated Polish economic situation, the Polish National Bank introduced a fixed price for one dollar unit, which was 1 USD to 10 000 Polish zloty. As it turned out, this rate was to be maintained for about 2 years. At the same time, presumably to curb inflation, the interest rates for deposits in Polish banks approximated 100% per annum. Such a situation created unheard of arbitrage opportunities.

To visualize this let us put in Eq. (3.6)

$$k(t_i) = k(T) , \quad \text{for every } t_i < T . \tag{15}$$

Table 1
Efficiency of the oscillator (4.4) for $T = 1$ year

N	Year 1990; $r_f = 0.8$, $r = 0.1$	Year 2000; $r_f = 0.14$, $r = 0.04$
1	1.0138	0.1052
2	1.8577	0.1618
3	3.0552	0.2214
4	4.7546	0.2840
5	7.1662	0.3499
6	11.807	0.4191
7	15.445	0.4918
8	22.336	0.5683
9	32.115	0.6487
10	45.993	0.7333
11	65.686	0.8221
12	93.020	0.9155

This way the formula for W_N simplifies to

$$W_N = S_0 \left(\exp \left[(r - r_f) \left(NT - \sum_{i=1}^{N} t_i \right) \right] - 1 \right) . \tag{16}$$

Let us assume, for simplicity, that the oscillator steps are taken at regular time intervals:

$$t_k = (k - 1)T/N . \tag{17}$$

This gives

$$\frac{W_N}{S_0} = \exp[(r - r_f)(N + 1)T/2] - 1 . \tag{18}$$

As we can see the actual exchange rate is totally irrelevant and the gains depend only on difference of the bank interest rates and the number N.

Table 1 provides examples of how this mechanism could be exploited. The second column gives values of W_N/S_0 corresponding to the financial realities in Poland in the year 1990, and the third column corresponds to the year 2000. The interest rates r_f and r are taken from the official announcements of the PKO Bank, at the beginning of 2000.

The results of such financial machinations are possible due to the knowledge of the spot price on a day in the future which then makes irrelevant the interest-rate parity relationship stated in Eq. (2.7). Fig. 1 presents relation (2.7) for the interest rates of the year 1990. If, at the beginning of 1990, the price for 1 USD was 10 000 zl, then, to observe (2.7), by the end of that year one dollar should have cost over 20 000 zl. A gigantic arbitrage opportunity emerged from the fact that this exchange rate was maintained constant throughout that year. Fig. 2 shows a similar curve for the year 2000. It is not yet known, however, how serious will the departure from the relation be (2.7).

Some examples of exploiting the arbitrage opportunities in the years 1990 and 1991 in Poland were presented and described in Ref. [5].

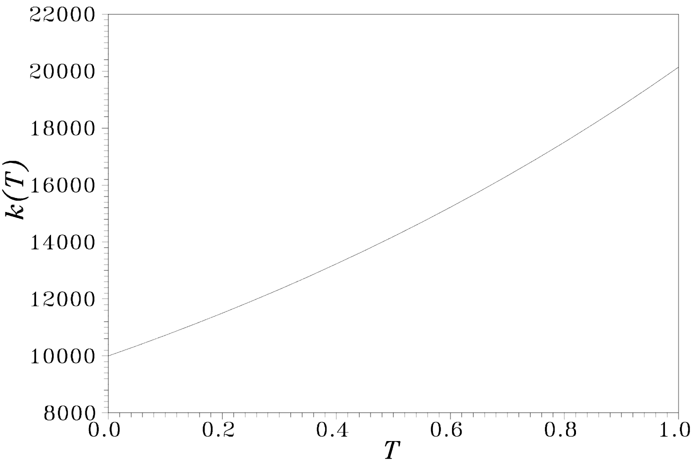

Fig. 1. The plot of the rate of exchange of Polish zloty to US dollar as predicted by (2.7) for the year 1990. Here we took $r = 0.8, r_f = 0.1$, the initial rate was 10 000 Polish zloty per dollar.

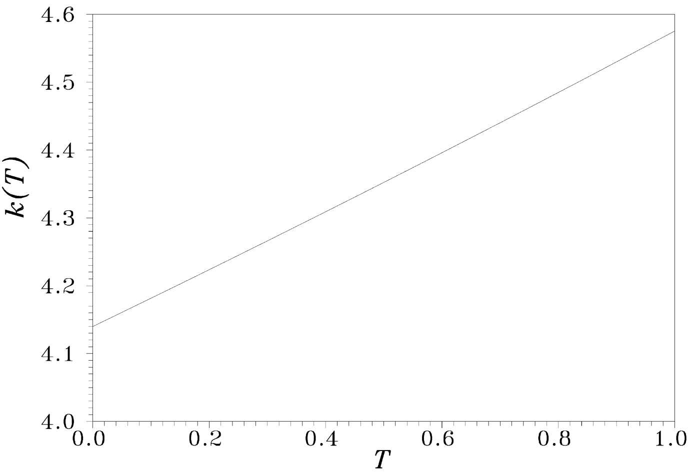

Fig. 2. The plot of the rate of exchange of Polish zloty to US dollar as predicted by (2.7) for the year 2000. Here we took $r_f = 0.14, r = 0.04$, the initial rate was 4.14 new Polish zloty (PNL) per dollar (the new Polish (PNL) was introduced in the year 1995: 1 PNL = 10 000 old Polish zloty).

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References

[1] B. Malkiel, Efficient market hypothesis, in: P.M. Newman, M. Milgate, J. Eatwell (Eds.), New Palgrave Dictionary of Money and Finance, Macmillan, London, 1992.
[2] F. Black, Towards a fully automated stock exchange, Financial Analysts J., Nov.-Dec. 1971, page 29.
[3] R.N. Mantegna, H.E. Stanley, An introduction to Econophysics: Correlations and Complexity in Finance, Cambridge University Press, Cambridge, 2000.
[4] M. Baxter, A. Rennie, Financial Calculus, Cambridge University Press, Cambridge, 1996.
[5] M. Dakowski, J. Przystawa, Via bank i FOZZ (in Polish), Antyk, Warszawa, 1992.