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THE RISK OF CREDIT INDEXED
WITH FOREIGN EXCHANGE

Summary: The purpose of the paper is to identify and measure the risk of hypothecary credit indexed to the Swiss franc rate. The study is based on real data showing the payment of credit obligations in the period November 2006 – October 2012. An assumption was made about the acceptable level of the PLN/CHF currency exchange rate, being an essence of the definition of risk of credit index in the foreign exchange. The conclusion supports the hypothesis of the paper that the analysed credit product does not show the basic property of a credit. Indexation in combination with the indexation currency rate growth translates into a growing balance of the credit obligation.

Keywords: hypothecary credit, credit indexation to Swiss franc, risk of hypothecary credit indexed with foreign exchange, risk measure.

JEL Classification: G21.

Introduction

The option where financial institutions co-finance the cost of solving the society's housing problems, is, due to the high cost of transaction, a subject of interest to those buying their first home, as well as those who decided to change the place they have lived so far. With the funds obtained from financial institutions, the demand for this type of a good can be met immediately, while the payment can be scheduled over a period of 20, 30 years or more. There is no doubt that this type of a credit product solves the basic expectations of human existence.

Since 2000, the hypothecary credit market in Poland[1] had been offering a particular product – a loan indexed to Swiss franc – CHF. It was granted and paid out in the domestic currency, but the lending bank recorded the credit in the currency of indexation, applying the rate of exchange as of the date of release.

The period between 2004 and 2014 saw the materialization of risks involved in the product, which had been expected to solve the housing problem of many people in Poland[2]. The consequences were caused by exchange rate fluctuations and the resultant changes in the credit cost. This distress should have been anticipated by all conscious borrowers, as any exchange rate can change extremely as compared with that of the loan release date, even within a short time. The credit cost variability in response to the exchange rate fluctuations is an obvious effect, but a significant defect of the product remained overlooked. Namely, although payments were made – in Polish zlotys – following indexation to Swiss franc, the loan balance was rising over time rather than decreasing, due to the foreign currency rate growth.

The present study analyses the hypothecary credit indexed to Swiss franc in terms of the banking product standards. The focus is on those of the product properties that determine the monthly payments of the principal and the resultant financial consequences.

Loan agreements include a provision, where the borrower declared his or her understanding of the currency risk. The wording of the statement is imprecise, since it does not define the currency risk concept and does not specify the currency risk consequences. Any change in the PLN/CHF exchange rate is reflected in the cost of the loan, but this is not the only effect of this change, hence the hypothesis of the study: The hypothecary credit indexed to Swiss franc is not consistent with the basic principle of lending, since the domestic currency debt balance variable (where the credit balance is a random variable, due to the indexation of principal payments) depends on the direction of the currency exchange rate changes.

1. Hypothecary credit in Poland in the years 2004-2008

At the beginning of the XXI century, the situation on the Polish financial market was governed by high interest rates[3]. For bank customers, this translated

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[1] Such products were also offered by banks in: France, Peru, Turkey, Australia, Austria, UK, Montenegro, Island, Norway, Denmark, Spain, Hungary, Croatia. Indexation was applied to USD and EUR as well.

[2] About 700 thousand such loans were allowed in Poland.

[3] The reference rate changed from 24% in February 1998 to 5% in June 2008. Appendix 1.

into high costs of their loan. This situation prevented businesses, but also individuals, from borrowing. As a result, the high interest rates slowed the pace of economic development down. Under the circumstances, investors would postpone their fundraising decisions, seek other, more advantageous sources of funding, or would be looking for financial products offered at an acceptable cost. At the same time, interest rates were very low in the euro area, in Switzerland and in the UK[4]. This correlation between the Narodowy Bank Polski (NBP) basic rate and the rates of EU states, USA and Switzerland created a banking product, which was very well received in Europe and across the world.

The new credit product was offered in Europe at the very beginning of the 2000s[5]. The idea was to reduce the financial cost of loans. This important attribute of the product was a result of the domestic currency loan indexation to a strong and stable currency. In addition, the term of these loans was very long, thereby giving banking institutions a guarantee of the expected rate or return, which was mostly determined by banks. This benefit was achieved owing to the annuity payment model. Loan payments were fixed and consisted of two components: an interest on the current debt balance and a principal share. The interest was defined as a total of the base rate which depended on changes in LIBOR 3M and the bank's margin specified in the loan agreement.

The indexation of payments made in PLN transferred the loan administration to the area of accounts recorded in the indexed currency. The procedure of indexation was based on a foundation consisting of a schedule of payments computed in the indexation currency, since the loan paid out in PLN was converted by the bank into the foreign currency by the buy rate. The schedule of payments specified the borrower's obligations in the indexation currency and each payment made in PLN was converted by the PLN/CHF rate as of the day of transaction. The borrower's current debt reversed the loan payment procedure. The outstanding balance of principal in CHF was converted by the bank to PLN by the sell rate[6]. The Financial Supervisory Commission's T-recommendation permitted loans to be repaid in the indexation currency, where the Bank determined the amount to be paid, but the payment receipt included both the amount paid in CHF and the same amount converted to PLN by the buy rate as of the day of the transaction.

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[4]   Appendix 2.
[5]   Banks in Peru, Turkey and Australia offered indexed loans in the 1990.
[6]   In 2010, the Financial Supervisory Commission issued Recommendation T, which permitted the repayment of borrowed principal and the payment of loan interest in the indexation currency.

1.1. Currency exchange rate

For national economies to function in many different currency systems and the international trade to work successfully, it is necessary to determine the price of one currency in terms of another. This price is the currency exchange rate. Currency rates are subject to the laws of the market, therefore they represent a market clearing price. More often referred to as the equilibrium exchange rate, it is believed to be the currency rate, which ensures the correct balance of payments. Another meaning of the equilibrium rate is related to the theory of the purchasing power parity theory, where the relation between two currencies should reflect the proportion of the purchasing power measured by the level of domestic prices. In the 1970s, the effective currency rate concept gained recognition. An effective currency rate is determined by estimating the share of trade in bilateral relations. Based on an analysis of inflation in the countries for which the currency rate was determined, a nominal rate was defined – in this case, the domestic currency depreciation is positively correlated with the rate of inflation. The overview of currency rate definitions would not be complete without mentioning the real exchange rate. It is the relative price of imports to exports [Hall, Taylor, 1997, s. 354].

Any economy is subject to diverse factors present in the economic, political, environmental, cultural, demographic and psychological environment. The main determinants include the supply of foreign currencies on the domestic market, the demand for foreign currencies, varying interest rates, differences in the domestic and foreign inflation rates, the level of domestic prices, any formal restrictions on the currency trading, the currency policy, the condition of the domestic economy, as well as that of foreign partners, the international situation, political tensions or expectations as regards the future standing of the economy. Speculative transactions that interfere with the currency market mechanisms are likewise important, while more unpredictable. They are combined with an artificially created demand and supply on the currency market[7].

The multiplicity of the currency rate definitions may be and is the cause of misunderstandings that result from differences in exchange rates in a situation, when the rules used for estimating the rate have not been agreed.

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[7] The attitude adopted by Goldman Sachs is an example of a situation like this. When recommending their strategic clients to sell the Polish currency, they went short with PLN at the same time, in order to benefit from the Polish currency drop. With the weak PLN, currency rates increased [*Oto bank, który grał na spadek złotego*, 2009].

2. Hypothecary credit indexed to Swiss franc

An indexed credit was extended and released in a domestic currency, but on the day of crediting the recipient's bank account with the funds, the principal was indexed by the currency rate specified in the loan agreement and effective as on the day of transferring the funds to the recipient's bank account. Based on the loan agreement provisions, the bank would prepared a schedule of payments in the indexation currency, where the monthly payment was specified and broken into the principal share and the interest share. These values were quoted in Swiss francs.

The lending bank would determine the conditions affecting the cost of the loan. The component which depended on LIBOR 3M would change, when the current value of the base rate differed from the previous one. The size and the scale of differences required changes in the base rate and these changes were specified in the loan contract [Komisja Nadzoru Finansowego, 2010].

Financial institutions marketed the new product dynamically. In 2002, the share of credits indexed to Swiss franc, euro or US dollar represented 60% of the banks' loan portfolio. In the next year 2003, this share increased to 70% of the total loan portfolio. After a significant decline in 2007, this proportion stopped in 2008 – the year of financial crash – at 60% of the total value of the Polish banks' loan portfolio. What was the borrowers' motivation behind the decision to choose namely this product? The answer to this question is clear. The cost of the loan was the borrowers' only criterion. This cost was acceptable in the situation of a stable, low currency exchange rate. The financial crisis, which began in the middle of 2008 in USA, in combination with the exchange rate growth, revealed another unperceived aspect of the indexed credit repayment, namely, that the outstanding principal can be growing despite regular payments. The debt balance converted from CHF to PLN was increasing, despite the payments made. This aspect of the exchange rate growth is disregarded, but it comes to light with all its strength when the credit is called in after a default. Despite several years of repaying the principal, the debt increased by ten, twenty or more percent of the original size of the loan [Hubbard, 2010].

3. Indexed credit risk

Regardless the credit type, be it a working capital loan, an investment loan, a short-term or a long-term one, the borrower may experience payment problems. Any shortage or lack of funds at the time when the payment is due may be

caused by some adverse changes in the surrounding. The payment of an indexed loan is jeopardized mainly by a long-lasting high exchange rate caused by unfavourable conditions that affect the valuation of the loan indexation currency supply/demand relation [Zemke, 2009a].

The credit risk, or more precisely, its consequences affect both parties to the loan agreement. A question is, whether the distribution is symmetric here? Borrowers benefit from any drop of the domestic currency to the indexation currency exchange rate, since the cost of the loan declines then. If the exchange rate increases, the lending bank is the beneficiary, its revenue from the sale of the loan indexation currency to borrowers growing. In any case, both parties to the contract take a risk measured by an unknown cost of credit for the borrower and an unknown revenue for the bank. Both the cost of the loan repayment incurred by the borrower and the bank's revenue are random variables. In addition, the revenue from indexation of the debt balance growth in response to the exchange rate growth should be taken into account.

Lending institutions, even if aware of the second aspect of risk involved in the hypothecary credit indexed to Swiss franc, are "reluctant" to mention it. They rather emphasise the aspect of the lower cost of borrowing, despite the currency rate growth, but this problem is solved by the currency risk statement integrated in the loan agreement signed by the borrower. The borrower might have not realised all consequences of indexation, but the lending bank should be aware that the product offered did not have the significant feature of a loan, namely that the loan balance should be decreasing as a result of payments made in PLN. The paradox here is that due to the loan repayment procedure, the value of payments in PLN is an equivalent of the value in CHF converted by the rate as of the day of payment, hence the exchange rate fluctuations occurring over the term of payment translate into changes in the borrower's debt balance. It is possible to prove that changes in the exchange rate showing a continuous growing tendency cause the debt balance converted to PLN to constantly grow in the annuity payment model, where fixed payments consist of a principal share and interest on the debt balance [Zemke, 2017, s. 55-73].

3.1. Empirical data

The loan being paid off is characterised by a decreasing debt balance. The loan is extended in the domestic currency – PLN, the debt will be paid off in the domestic currency too, hence this is a classic loan in Polish zlotys. It is an obvi-

ous thing, therefore, that the debt balances distribution will form a decreasing sequence.

The analysis covers the period between November 2006 and January 2012. Table 1 shows figures for a loan extended in the amount of PLN 527,973.93, which equalled CHF 223,056.16 following indexation as of the date of the agreement[8]. Payments were next made in the domestic currency (PLN) and converted by the bank by the indexation currency – CHF – sell rate as of the day of payment. The loan agreement signed by the parties specifies that the repayment is arranged in fixed principal and interest monthly payments.

Column 4 of Table 1 summarises the outcomes of a loan balance changes scenario which has never come true. The result obtained is based on an assumption that the debt is paid off following to the rule specified in the loan agreement, namely, that the payment is arranged into equal monthly payments. The figures presented in column 3 of Table 1 – monthly payments consisting of a principal component and an interest component – were estimated by the lending bank.

Table 1. Debt balance for a loan indexed to CHF as of the dates of payments, under changing interest rates

Interest rate change since	Loan interest rate (%)	Monthly principal payments as per the agreement (CHF)	Debt balance: fixed instalments, principal + interest over the whole (CHF)	Monthly principal payments inconsistent with the agreement (CHF)	Debt balance, variable instalments + interest (CHF)
01.11.2006	7.11	1 706.77	222 671.00	1 706.77	222 671.00
01.01.2007	7.39	1 706.77	221 945.68	1 744.90	221 907.56
01.04.2007	7.65	1 706.77	220 967.46	1 780.35	220 778.06
01.07.2007	7.91	1 706.77	220 115.19	1 815.85	219 664.41
01.09.2007	8.17	1 706.77	219 649.45	1 851.46	218 938.10
01.11.2008	7.43	1 706.77	216 422.68	1 749.48	212 958.60
01.12.2008	6.65	1 706.77	215 915.25	1 651.07	212 487.68
01.01.2009	5.40	1 706.77	215 180.10	1 499.92	211 943.95
01.02.2009	4.99	1 706.77	214 368.12	1 452.19	211 373.09
01.04.2009	4.88	1 706.77	212 714.44	1 439.63	210 217.48
01.10.2009	4.74	1 706.77	207 588.11	1 424.07	206 664.54
01.07.2010	4.58	1 706.77	199 452.94	1 407.02	201 097.76
01.01.2012	4.44	1 706.77	181 848.62	1 393.30	189 197.23

Source: author's analyses. Data sourced from the case study documents.

On 1 January 2007, following the first change of the loan interest rate, the lending bank altered the monthly payment value in a manner inconsistent with the loan agreement. Over the period 2007-2012, monthly payments were modi-

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[8] Real loan contract data; loan repayment arranged into 252 instalments.

fied always after loan interest rate changes and as a result, the debt balance changed accordingly – see column 5 in Table 1.

Column 6 of Table 1 specifies debt balances resulting from the repayment of the loan principal according to the rules adopted by the bank each time after a change in the loan interest rate. The comparison of figures from column 4 and column 6 of Table 1 shows how deviations from the contract provisions regarding equal payments affect the principal debt balance over the analysed period. The balance shows a significant difference of CHF 7.35 thousand to the borrower's disadvantage.

The loan balances presented in column 4 of Table 2. Were estimated based on data on the loan balances in CHF and the Swiss Franc sell rates as of the dates of payments. Column 6 in Table 2 shows balances estimated with an assumption that the bank extended a loan, the cost of which was estimated for the statutory interest of 11.50% of the loan contract date.

Within the period of over 5 years of payments, the debt to the bank increased from PLN 527,973.93 to PLN 675,320.59 (column 5 in Table 2).

The estimated changes in the loan balance presented in column 5 of Table 2. support the thesis formulated in the introduction to this paper. The graph of changes in the debt balance reflecting the distributions of the analysed period summarised in columns 5 and 6 of Table 2 shows clearly, that the procedure of payments imposed by the bank contradicts the fundamental assumption of any loan repayment, where payments of the loan principal should translate into a reduction of the debt balance.

Table 2. CHF, PLN loan balance as per the CHF/PLN exchange rate; loan payable in PLN

Date	Buying rate (CHF)	Selling rate (CHF)	Balance of credit changeable instalment (thous. CHF)	The balance of credit is wreathing, an instalment of capital stood (PLN)	The balance of credit will play, stood instalment capital + cost (without the indexation)
1	*2*	*3*	*4*	*5*	*6*
30.11.2006	2,3817	2,4299	222 671,00	541 068,26	527 389,53
31.01.2007	2,4039	2,4525	221 907,56	544 228,29	526 203,88
30.04.2007	2,2759	2,3219	220 778,06	512 624,58	524 382,44
31.07.2007	2,2864	2,3326	219 664,41	512 389,20	522 508,14
30.09.2007	2,2475	2,2929	218 938,10	502 003,17	521 228,48
30.11.2008	2,4149	2,4609	212 958,60	524 069,82	511 553,56
31.12.2008	2,7365	2,7962	212 487,68	594 158,05	510 811,80
31.01.2009	2,9547	2,9617	211 943,95	627 714,40	510 062,93
28.02.2009	3,1422	3,1843	211 373,09	673 075,33	509 306,88
30.04.2009	2,8994	3,0175	210 217,48	634 331,25	507 772,98
31.10.2009	2,7790	2,8372	206 664,54	586 348,63	502 991,76

Table 2 cont.

1	2	3	4	5	6
31.07.2010	2,9276	2,9620	201 097,76	595 651,57	495 286,78
31.01.2012	3,4988	3,5694	189 197,23	675 320,59	477 743,11

The changes in the loan balance estimated in column 5 represent a product of the loan balance indexed by the bank and the CHF sell rate as of the day of payment.

Source: author's analyses.

As a result of changes in the debt payment conditions measured by the balance of outstanding loan converted into the loan currency (PLN), the hypothecary credit indexed to Swiss franc does not the fundamental characteristic of a loan, since the loan debt balances do not form a decreasing sequence. In the analysed case, such an undesirable and unpredictable distribution of the loan debt balanced was caused directly by changes in PLN/CHF exchange rates in combination with the debt indexation. The indexation procedure is a filter which works with its own logic, processing the payment balance information by an unpredictable exchange rate. This mechanism of converting payments made in the domestic currency (PLN) by the indexation currency sell rate does not transfer the properties of the CHF loan balance distribution onto the corresponding distribution of balances in PLN. Figure 1 shows clearly tendencies in debt balance changes for the three analysed case studies. A constant decreasing tendency is observed in debt balances of a loan paid off in CHF and in PLN, without indexation applied. This tendency is not observed for the sequence of debt balances of a loan repaid in PLN and indexed to CHF.
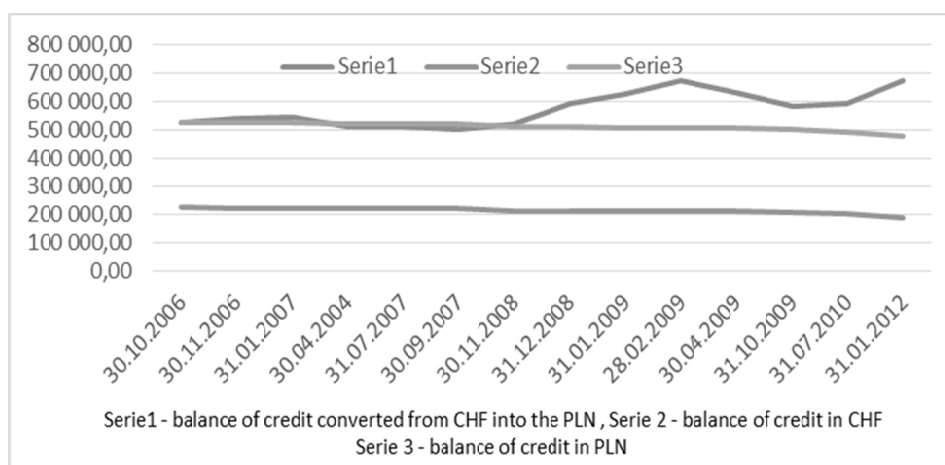

Figure 1. Loan balance changes: a loan in CHF, converted from CHF to PLN
and a loan in PLN over the period 30.11.2006-31.01.2012

Source: author's own analyses based on data from Table 2.

Table 3. Changes in the exchange rate, balances of a loan indexed to CHF by the CHF/PLN rate, balances of a loan paid off in PLN, as of the day of payment

Balance data	Debt balance converted from (CHF) to (PLN), fixed instalments (principal + interest)	Change in the balance of a loan converted from (CHF) to (PLN) K(t)-K(t-1)	Debt balance, fixed instalments (principal + interest) (PLN)	Change in the balance of a loan extended and paid off in (PLN) K(t)-K(t-1)
30.11.2006	541 068 .26		527 389 .53	
31.01.2007	544 228 .29	3 160 .03	526 203 .88	−1 185 .65
30.04.2007	512 624 .58	−31 603 .71	524 382 .44	−1 821 .44
31.07.2007	512 389 .20	−235 .37	522 508 .14	−1 874 .30
30.09.2007	502 003 .17	−10 386 .03	521 228 .48	−1 279 .66
30.11.2008	524 069 .82	22 066 .65	511 553 .56	−9 674 .92
31.12.2008	594 158 .05	70 088 .23	510 811 .80	−741 .76
31.01.2009	627 714 .40	33 556 .35	510 062 .93	−748 .87
28.02.2009	673 075 .33	45 360 .93	509 306 .88	−756 .05
30.04.2009	634 331 .25	−38 744 .08	507 772 .98	−1 533 .90
31.10.2009	586 348 .63	−47 982 .61	502 991 .76	−4 781 .22
31.07.2010	595 651 .57	9 302 .94	495 286 .78	−7 704 .98
31.01.2012	675 320 .59	79 669 .02	477 743 .11	−17 543 .67

Source: author's own analyses based on data from Table 3.

Table 3 contains increments of: CHF sell rate in column 3, loan balances converted from CHF to PLN in column 5, hypothetic forecast of changes in the balance of a loan paid off in PLN – column 7. Figures in column 5, presenting the direction of changes in the balances of loans, support the research hypothesis of the paper.

The significant strength of the relation between the currency rate change and the change in the loan balance converted from CHF to PLN is confirmed by the Pearson's correlation value equalling 0.9666[9]. The Pearson's correlation between the currency rate variation and the changes in the balances of the loan paid off in PLN is negative and equals 0.5957. This outcome supports the expectations regarding changes in the effect of both variables. The growing tendency in currency rates corresponds with the decreasing sequence of balance of the loan paid off and recorded in PLN.

The analysis reveals the insignificance of the relation between the balance of a debt converted from CHF to PLN and debt balances estimated for the loan extended and paid off in PLN. The negative value of this relation, which equals –0.3803, proves that the growing sequence of balances of the loan converted from CHF to PLN occurring under currency rate changes corresponds with

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[9] For significance level α = 0,10 and n – 2 = 11 degrees of freedom, $t_a = 1,796$, hence $r^* = 0,6441$. Hypothesis $H_o: r_{ij} = 0$ *dla* $i \neq j$, there are no grounds for rejecting hypothesis H_0, correlation coefficient r_{ij} is statistically non-zero [Aczel, 1993].

a decreasing sequence of balances of the loan paid off and recorded in PLN. This outcome supports the research expectations.

3.2. Risk identification, model and measurement

Applying for a mortgage loan indexed to Swiss franc is a decision, which involves significant risk for the borrower. This risk needs to be identified and measured. Of the two parties to the loan agreement, the bank is definitely better equipped with risk identification and measuring instruments, while the borrower's knowledge or tools that might be used to prepare the loan application are rather limited.

One might assume that by signing the loan agreement, the borrower approved the PLN to CHF exchange rate level. This approval in this case, in the borrower's opinion, means that the repayment of the loan is not at risk. The currency rate risk acceptance is based on intuition only and cannot be regarded as a rational argument for signing the loan agreement. The problem is, however, that neither the bank, nor the borrower, has defined the currency risk concept, which may mean that it is used instrumentally. Both the bank and the borrower, being aware of the risk, are minimizing it in an attempt to achieve their goals. How should the bank's and borrower's risk be disambiguated?

Definition. The risk involved in the domestic currency – PLN – exchange to Swiss franc – CHF – is a state which accompanies the process of loan repayment in a situation, where the moment of monthly payment coincides with an increase in the exchange rate exceeding the value acceptable to the borrower as of the day of signing the loan contract.

The process of monitoring the risk level is confined to following the currency rate fluctuations between the previous monthly payment and the next payment due date. The exchange rate data are the control variable of the process. Monitoring the exchange rate on a regular basis enables one to estimate the direction of changes and the minimum of funds needed to meet the obligation towards the lending bank within the nearest payment perspective.

While accepting the currency risk consequences, the borrower accepts also the risk involved in the direction and pace of changes in the debt level. After each change in the loan interest rate, the lending bank prepares a payment schedule, with the monthly payments and the debt balance quoted in the loan indexation currency. This presentation of the schedule distorts the picture of the debt status, showing that the loan balance decreases when measured in the in-

dexation currency – CHF, but failing to quote its value in the domestic currency. How to define the risk of a situation, where the borrower may be forced to pay back more than the original loan amount extended by the bank?

Definition. The risk that the loan debt will grow, despite regular payments made as scheduled, is a state, which accompanies the payment of a loan in a situation where payments are indexed to a currency other than the one in which the loan was extended.

The risk of the credit debt growth is caused by the growth of the domestic currency to Swiss franc exchange rate. Exchange rates are random variables by definition, but the balance of the principal being paid off should not be subject to such variability, while this is the case here. Hence, how should one measure the risk of changes in the credit debt level [Zemke, 2009a]?

Assuming that the indexation currency exchange rate fluctuations /growth/ are the control variable of risk, the risk model is a random vector with a single component: the exchange rate. The risk model design identifies the following risk measurement instruments: the probability of events that the currency rate takes values from a certain interval of variability, the exchange rate expected value and the exchange rate variance. Let random variable $X = [x]$ stand for the currency rate, then:

1. The probability of an event that the credit currency – PLN – rate of exchange to the indexation currency – CHF – takes a value from a certain interval [a, b], assuming that the probability density function of the risk vector is f(x), equals: $P\{a \leq x \leq b\} = \int f(x)\ dx$ – an integral on interval [a, b] .

2. The expected value of random variable – currency exchange rate: $E(X) = \int x\,f(x)\ dx$ an integral defined on interval $[-\infty, +\infty]$.

3. The variance of random variable – currency exchange rate: $Var(X) = \int [x - E(X)]^2 f(x)\ dx$ an integral defined on interval $[-\infty, +\infty]$.

Assumptions for the measurement of risk:

1. The distribution of the variable X probability distribution density follows normal distribution:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}\ e^{\frac{(x-\mu)^2}{2\sigma^2}}$$, with distribution parameters μ and σ – with this

assumption, statistical measures of risk can be defined:

- The probability that random variable X takes value from interval [a, b]:

$$P (a \leq x \leq b) = \frac{1}{\sigma \sqrt{2\pi}} \int_a^b e^{\frac{(x-\mu)^2}{2\sigma^2}} dx$$

- The expected value of random variable X:

$$E (X) = \frac{1}{\sigma \sqrt{2\pi}} \int_{\infty}^{+\infty} x e^{\frac{(x-\mu)^2}{2\sigma^2}} dx$$

- The variance of random variable X:

$$Var (X) = \frac{1}{\sigma \sqrt{2\pi}} \int_{\infty}^{+\infty} (x-\mu)^2 e^{\frac{(x-\mu)^2}{2\sigma^2}} dx$$

2. The analysis covered a period from November 2006 to January 2012.
3. The CHF sell rate as of the date of the loan contract – PLN/CHF 2.4636 was used as the reference point for measuring the currency rate variations.
4. Risk was estimated based on an assumption that the acceptable risk level is associated with a 15% exchange rate growth against the contract date rate, i.e. 2.8331 PLN/CHF.
5. Risk was estimated based on currency rates quoted as of the date of the loan agreement and the first payment due date after a change in the loan interest rate [Zemke, 2010].

Based on the risk measurement assumptions defined in point 3 and 4, measures:

$$\langle P(X), E(X), \sqrt{Var(X)} \rangle = \langle 0.3828; 2.6484; 0.3695 \rangle$$

were estimated. They were taken as an acceptable level of the exchange rate risk. Risk measures of the analysed period were estimated based on the Swiss franc – CHF – selling rate and point 5 of the risk measurement assumptions.

Table 4. Statistical measures of currency risk (PLN/CHF)

It.	Sell rate (PLN/CHF)	$P (a \leq x \leq b)$	E(X)	Var (X)	Standard deviation	Due date
1	2	3	4	5	6	7
1	2 .4299	0 .5085	2 .4468	0 .0006	0 .0238	30.11.2006
2	2 .4525	0 .2183	2 .4487	0 .0003	0 .0172	31.01.2007
3	2 .3219	0 .6928	2 .4170	0 .0042	0 .0649	30.04.2007
4	2 .3326	0 .6656	2 .4001	0 .0046	0 .0677	31.07.2007
5	2 .2929	0 .7453	2 .3822	0 .0056	0 .0747	30.09.2007
6	2 .4609	0 .0095	2 .3935	0 .0055	0 .0744	30.11.2008
7	2 .7962	0 .4373	2 .4438	0 .0250	0 .1582	31.12.2008
8	2 .9617	0 .5446	2 .5014	0 .0517	0 .2274	31.01.2009
9	3 .1843	0 .6146	2 .5697	0 .0926	0 .3043	28.02.2009

Table 4 cont.

1	2	3	4	5	6	7
10	3 .0175	0 .5767	2 .6104	0 .1016	0 .3187	30.04.2009
11	2 .8372	0 .4513	2 .6293	0 .0966	0 .3108	31.10.2009
12	2 .9620	0 .5682	2 .6549	0 .0971	0 .3116	31.07.2010
13	3 .5694	0 .7326	2 .7202	0 .1494	0 .3865	31.01.2012

Source: author's analyses based on PLN/CHF exchange rate data published on the Narodowy Bank Polski website [www 1].

The currency risk measures estimated for the period from November 2006 to January 2012 have a significant informative value as regards the role of exchange rate risk in the financial liquidity management in respect of the credit payment. The estimated measures constitute a set of information, based on which the currency rate risk can be estimated on a short-term (monthly) basis using the uncomplicated rolling forecasting methods [Zemke, 2013, s. 30-39].

The currency rate representing the price of one currency against another one, is estimated based on diverse inputs. Consequently, diverse assumptions will be used for the prediction[10]. Currency rate as a currency market category requires prediction of changes in the relation between the indexation currency demand and supply on the domestic market. If currency rate is considered to be an equilibrium rate which ensures the payment balance equilibrium, this state has to be monitored for any changes and, as a consequence, tendencies and dynamics of changes have to be estimated. Identifying currency rate with the purchasing power parity involves the need to monitor the domestic market prices. If currency rate is regarded to be the result of differences in dynamics of inflation in the countries, for which the so-called nominal rate is estimated, tendencies in inflation fluctuations need to be estimated. Should currency rate be identified with the relative price of imported goods to the relative price of exported goods /real rate/, another methodology has to be used for estimating exchange rate variations. In this case, changes over time will be the control variable for the currency risk variations.

The probability that the currency rate grows shows a growing tendency over the analysed period and this currency risk measure deviates adversely from the acceptable level of probability. This level was defined in points 3 and 4 of the assumptions accepted for the risk measurement procedure in this study.

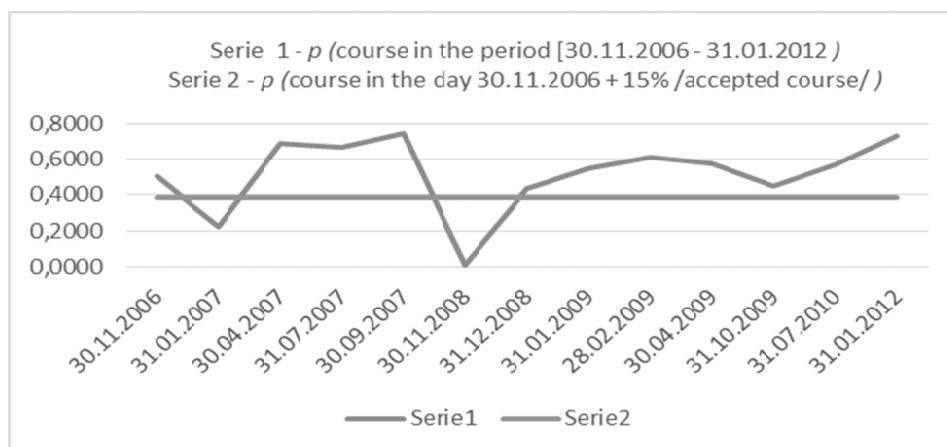[10] See section 1.1. of this paper, currency rate definitions.

Figure 2. The probability of events that the PLN/CHF exchange rate will take values
from the interval determined by the PLN/CHF selling rate as of the day of the
credit release against the PLN/CHF rate as of the loan instalment payment,
in relation to the probability of events that the PLN/CHF

Source: author's own analyses based on data from Table 4.

The PLN to CHF rate "entered the path of growth" in QIV 2008 and ex-
ceeded the acceptable level in January 2009. This tendency has been observed
for more than five years now. Over this period, the probability of events result-
ing in the currency rate to "take" a position above the acceptable level, which
was set at PLN 2.8331 for one Swiss franc, increased significantly. Similar
tendencies were observed for other risk measures, the expected value and the
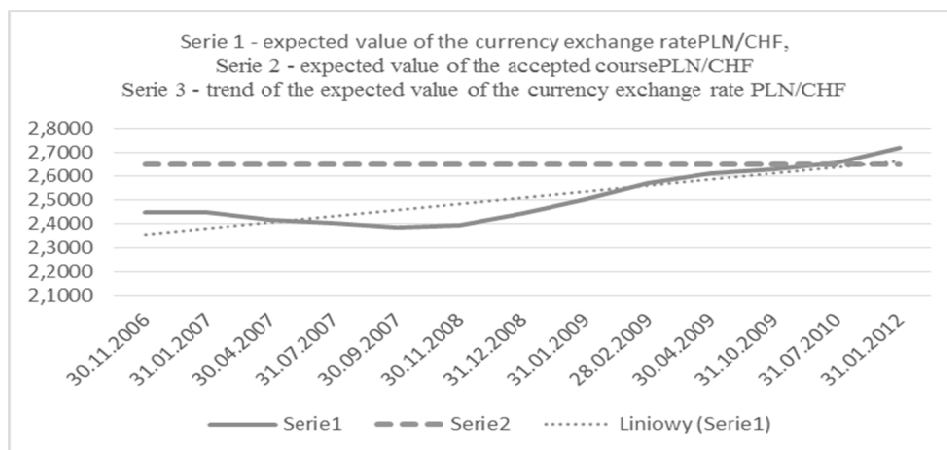currency risk variance.

Figure 3. Changes in the currency rate expected value

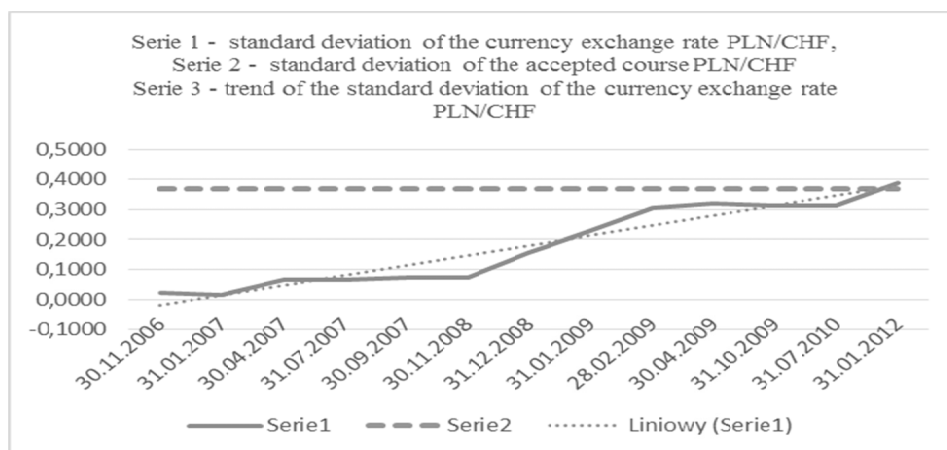Source: author's own analyses based on data from Table 4.

Figure 4. Changes in the currency rate standard deviation

Source: author's own analyses based on data from Table 4.

The analysed period is characterised by a significant growth of the currency rate average value. The standard deviation, representing the measure of the PLN to CHF rate deviations from the estimated mean values of the rate, is showing exactly the same tendency. Both exchange rate risk measures are characterized by the same moment of the estimated measures "transition" over the level defined as acceptable.

4. Recapitulation

Even with the uncomplicated tools that have been used, the analysis of loan payment taking place under the circumstances determined by the banking product such as hypothecary credit indexed to Swiss franc, permits an evaluation of the product offered by banks. From the borrower's point of view, the banking product analysed in the paper does not show an important feature, namely, the repayment of the loan principal does not result in a lower debt balance expressed in the loan currency – PLN – if the exchange rate grows, which is in conflict with the principle "I am paying back as much as I borrowed".

The research hypothesis of the study has been positively verified. The indexation of a loan extended in the domestic currency (PLN) has been proved to lead to an unacceptable situation: the debt grows as a result of the currency rate increase, even though principal payments were made. The debt balance change is a random variable, the principal balance being unpredictable in case of the currency rate variations. It is impossible to say how much the debtor will have to

pay back in PLN in total after the last payment scheduled in the loan contract is made.

Conclusions

There are two typical arrangements for the repayment of a loan: a fixed principal share plus interest on the outstanding principal – the total of principal instalments and interest decreases after each payment made or fixed instalments where the principal share and the interest total is always the same (annuity payments). In the first arrangement, the principal share is a fixed one, therefore the debt balance variable decreases regardless interest rate changes and is clearly specified at any point of the loan term, providing that the loan is paid off in the currency of the loan. In the annuity arrangement, the debt is a decreasing, deterministic variable only for a fixed interest rate for the whole term of the loan, providing that payments are made in the loan currency. With a variable interest and fixed payments, the proportion between the principal share and interest varies too. Here, the debt balance is a random variable despite regular payments and depends on rather unpredictable base interest rate fluctuations, but debt balances form a decreasing sequence anyway.

The pattern of debt balance changes becomes unpredictable in arrangements, where the loan has been extended in a domestic currency and indexed to a foreign currency. Any growth of the currency rate is followed by a higher cost of the loan and namely debt servicing is the main, although not the only area, where the currency risk effects show up. The empirical part of the paper proves, that notwithstanding the payment arrangement, the currency rate growth affects the loan balance in PLN, making it grow too. The strong correlation between these two variables was an important argument in the proof of the research hypothesis here – the balance of a loan extended and paid out in PLN, indexed to Swiss franc, is a random variable showing no stable tendencies, despite regular monthly repayment of the loan principal.

The paper defines a risk model for the hypothecary credit extended in PLN and indexted to Swiss franc (CHF). The model is a random vector, whose only component is the PLN/CHF exchange rate. The risk model has been used as a basis for defining statistical measures of risk. Monitoring on a current basis the consequences of risk involved in the payment of loan obligations entails the measurement of risk, thereby allowing the evaluation of tendencies and dynamics of risk. This evaluation is an important element of the loan payment man-

agement, which is fundamental to the selection of instruments protecting against the consequences of risk.

The payment of a loan under currency risk entails the need to protect the financial assets against currency rate fluctuations, but such instruments are mainly available to institutional entities, not to individual borrowers. The risk, that the debt balance may grow despite regular payments, is not pointed up by financial advisers. Monitoring the currency risk and, consequently, its effects, is merely a substitute of risk management instruments that are available to individual clients and does not solve the problem of providing a systemic protection against the potential growth of the loan principal balance resulting from the currency rate growth.

Appendices:

Appendix 1. Basic interest rates of the NBP in the years 1998-2013
Appendix 2. LIBOR Swiss franc 3M from 2000-01-04 to 2014-06-30
Appendix 3. DBF index and interest rate change
Appendix 4. PLN to CHF exchange rate as of the date of payment

Appendix 1

Basic interest rates of the NBP in the years 1998-2013

Applicable since	Reference rate	Lombard rate	Deposit rate	Rediscount rate	Discount rate
1	2	3	4	5	6
1998					
1998-02-26	24.00	27.00	*	24.50	*
1998-04-23	23.00	27.00	*	24.50	*
1998-05-21	21.50	26.00	*	23.50	*
1998-07-17	19.00	24.00	*	21.50	*
1998-09-10	18.00	24.00	*	21.50	*
1998-10-29	17.00	22.00	*	20.00	*
1998-12-10	15.50	20.00	*	18.25	*
1999					
1999-01-21	13.00	17.00	*	15.50	*
1999-09-23	14.00	17.00	*	15.50	*
1999-11-18	16.50	20.50	*	19.00	*
2000					
2000-02-24	17.50	21.50	*	20.00	*
2000-08-31	19.00	23.00	*	21.50	*

1	2	3	4	5	6
2001					
2001-03-01	18.00	22.00	*	20.50	*
2001-03-29	17.00	21.00	*	19.50	*
2001-06-28	15.50	19.50	*	18.00	*
2001-08-23	14.50	18.50	*	17.00	*
2001-10-26	13.00	17.00	*	15.50	*
2001-11-29	11.50	15.50	*	14.00	*
2001-12-01	11.50	15.50	7.50	14.00	*
2002					
2002-01-31	10.00	13.50	6.50	12.00	*
2002-04-26	9.50	12.50	6.50	11.00	*
2002-05-30	9.00	12.00	6.00	10.50	*
2002-06-27	8.50	11.50	5.50	10.00	*
2002-08-29	8.00	10.50	5.50	9.00	*
2002-09-26	7.50	10.00	5.00	8.50	*
2002-10-24	7.00	9.00	5.00	7.75	*
2002-11-28	6.75	8.75	4.75	7.50	*
2003					
2003-01-30	6.50	8.50	4.50	7.25	*
2003-02-27	6.25	8.00	4.50	6.75	*
2003-03-27	6.00	7.75	4.25	6.50	*
2003-04-25	5.75	7.25	4.25	6.25	*
2003-05-29	5.50	7.00	4.00	6.00	*
2003-06-26	5.25	6.75	3.75	5.75	*
2004					
2004-07-01	5.75	7.25	4.25	6.25	*
2004-07-29	6.00	7.50	4.50	6.50	*
2004-08-26	6.50	8.00	5.00	7.00	*
2005					
2005-03-31	6.00	7.50	4.50	6.50	*
2005-04-28	5.50	7.00	4.00	6.00	*
2005-06-30	5.00	6.50	3.50	5.50	*
2005-07-28	4.75	6.25	3.25	5.25	*
2005-09-01	4.50	6.00	3.00	4.75	*
2006					
2006-02-01	4.25	5.75	2.75	4.50	*
2006-03-01	4.00	5.50	2.50	4.25	*
2007					
2007-04-26	4.25	5.75	2.75	4.50	*
2007-06-28	4.50	6.00	3.00	4.75	*
2007-08-30	4.75	6.25	3.25	5.00	*
2007-11-29	5.00	6.50	3.50	5.25	*
2008					
2008-01-31	5.25	6.75	3.75	5.50	*
2008-02-28	5.50	7.00	4.00	5.75	*
2008-03-27	5.75	7.25	4.25	6.00	*
2008-06-26	6.00	7.50	4.50	6.25	*
2008-11-27	5.75	7.25	4.25	6.00	*
2008-12-24	5.00	6.50	3.50	5.25	*

1	*2*	*3*	*4*	*5*	*6*
2009					
2009-01-28	4.25	5.75	2.75	4.50	*
2009-02-26	4.00	5.50	2.50	4.25	*
2009-03-26	3.75	5.25	2.25	4.00	*
2009-06-25	3.50	5.00	2.00	3.75	*
2010					
2010-01-01	3.50	5.00	2.00	3.75	4,00
2011					
2011-01-20	3.75	5.25	2.25	4.00	*
2011-04-06	4.00	5.50	2.50	4.25	*
2011-05-12	4.25	5.75	2.75	4.50	*
2011-06-09	4.50	6.00	3.00	4.75	*
2012					
2012-05-10	4.75	6.25	3.25	5.00	*
2012-11-08	4.50	6.00	3.00	4.75	*
2012-12-06	4.25	5.75	2.75	4.50	*
2013					
2013-01-10	4.00	5.50	2.50	4.25	*
2013-02-07	3.75	5.25	2.25	4.00	*
2013-03-07	3.25	4.75	1.75	3.50	*
2013-05-09	3.00	4.50	1.50	3.25	*
2013-06-06	2.75	4.25	1.25	3.00	*
2013-07-04	2.50	4.00	1.00	2.75	*

Source: [www 2].

Appendix 2

LIBOR Swiss franc 3M from 2000-01-04 to 2014-06-30

Date	LIBOR 3 M CHF	Change to previous quotation (%)
2000-01-04	1.8100	
2000-06-30	3.3967	87.66%
2002-01-02	1.8267	–46.22%
2002-06-28	1.2433	–31.94%
2004-01-02	0.2600	–79.09%
2004-06-30	0.4983	91.65%
2006-01-03	1.0100	102.69%
2006-06-30	1.5200	50.50%
2008-01-02	2.7600	81.58%
2008-06-30	2.7900	1.09%
2010-06-30	0.1117	–96.00%
2012-01-03	0.0517	–53.72%
2012-06-28	0.0890	72.15%
2014-01-02	0.0230	–74.16%
2014-06-30	0.0080	–65.22%

Source: [www 3].

Appendix 3

DBF index and interest rate changes

1. The loan carries a floating interest rate, which shall be modified on the first day of the nearest month following the last change of the DBF index.

2. The DBF index is computed for each calendar quarter, as an arithmetic mean of 3m rates (for three month interbank deposits), applicable on working days in the period from the 26th day of the month closing the quarter which preceded the last calendar quarter until the 25th day of the calendar month ending the previous quarter.

3. The DBF index is computed for each month as an arithmetic mean of LIBOR 3m applicable on working days in the period from the 26th day of the month which preceded the last month, until the 25th day of the month preceding the modification.

4. If the 26th day of the month is a non-working day, the mean of LIBOR 3m is computed for a period from the next working day following that day. If the 25th day of the month is a non-working day, the mean of LIBOR 3m is computed for a period until the next working day preceding that day.

5. The DBF index is computed with a two decimal places accuracy.

6. The DBF index shall be modified subject to the following principles:

   a) The DBF index shall be modified in quarterly periods, in the event if the current value of the Index differs from the previous one by 0.1 percent points at least and shall be effective from the 1st day of the calendar quarter.

   b) The DBF index shall be modified in monthly periods and shall be effective from the first day of the month, if the value of the Index differs from the currently applicable DBF Index by 0.25 percent points at least and shall apply from the first day of the calendar month.

   c) In the events specified in a) and b) above, the DBF Index shall take the value computed as an arithmetic mean of LIBOR 3ra rates for the a.m. periods,

   d) In the quarters, when the DBF Index was modified in periods shorter than a quarter, the Index is checked for the need of modification at the end of the calendar quarter through the comparison of arithmetic means of LIBOR 3m applicable on the working days in the period from the 26th day of the month preceding the last modification, until the 25th day of the month ending the calendar quarter.

7. In the event of LIBOR elimination, the Bank shall specify, within 14 days of the elimination, a new factor which shall be the basis for determining the interest on the loan, but this shall not increase the Bank's risk margin. The

new index shall be applicable from the 1st day of the quarter following the quarter in which LIBOR was eliminated.

8. Upon the interest rate modification, the Bank shall notify the Borrower, the Guarantor and the property owners of the current interest rate and its effective date, by sending a new schedule of payments delivered by registered mail. The notification on the interest rate modification shall become an integral part of the loan contract, with no amendment required.

Appendix 4

Exchange rate as of	Buy	Sell	Mean
1. 30.11.2006	2.3817	2.4299	2.4058
2. 31.01.2007	2.4039	2.4525	2.4282
3. 30.04.2007	2.2759	2.3219	2.2989
4. 31.07.2007	2.2864	2.3326	2.3095
5. (01.10.2007)*	2.2475	2.2929	2.2702
6. (01.12.2008)*	2.2475	2.4609	2.4379
7. 31.12.2008	2.7365	2.7962	2.7664
8. (02.02.2009)*	2.9547	2.9617	2.9582
9. (02.03.2009)*	3.1422	3.1843	3.1633
10. 30.04.2009	2.8994	3.0175	2.9585
11. (02.11.2009)*	2.7790	2.8372	2.8081
12. (02.08.2010)*	2.9276	2.9620	2.9448
13. 31.01.2012	3.4988	3.5694	3.5341

* The first day of rate quotation on the first non-working day.

Source: author's analyses based on [www 4].

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[www 3] www.money.pl/pieniadze/depozyty/walutowe/LIBORCHF3M,depozyty,html (access: 30.05.2015).

[www 4] www.money.pl (access: 30.05.2015).

RYZYKO KREDYTU INDEKSOWANEGO WALUTĄ OBCĄ

Streszczenie: Celem pracy jest identyfikacja i pomiar ryzyka kredytu hipotecznego indeksowanego walutą obcą – CHF. Przeprowadzono badanie na rzeczywistych danych kredytu indeksowanego walutą CHF w okresie listopad 2006 – październik 2012. Zdefiniowano ryzyko produktu jako wzrost kursu PLN/CHF powyżej poziomu, który powodował utratę płynności finansowej. Zdefiniowano model ryzyka jako wektor losowy o jednej składowej, kurs PLN/CHF. Wartością dodaną pracy jest pewnik, że analizowany produkt nie wykazuje podstawowej właściwości kredytu, mianowicie indeksacja w połączeniu ze wzrostem kursu walutowego PLN/CHF powoduje wzrost salda zadłużenia kredytowego pomimo spłat kapitału.

Słowa kluczowe: kredyt kipoteczny, kredyt indeksowany frankiem szwajcarskim, ryzyko kredytu hipotecznego indeksowanego waluta obcą, pomiar ryzyka.