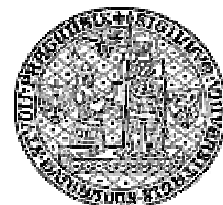


Institute of Economic Studies, Faculty of Social Sciences
Charles University in Prague

Credit Risk in the Czech Economy

Petr Jakubík

IES Working Paper: 11/2007



Institute of Economic Studies,
Faculty of Social Sciences,
Charles University in Prague

[UK FSV – IES]

Opletalova 26
CZ-110 00, Prague
E-mail : ies@fsv.cuni.cz
<http://ies.fsv.cuni.cz>

Institut ekonomických studií
Fakulta sociálních věd
Univerzita Karlova v Praze

Opletalova 26
110 00 Praha 1

E-mail : ies@fsv.cuni.cz
<http://ies.fsv.cuni.cz>

Disclaimer: The IES Working Papers is an online paper series for works by the faculty and students of the Institute of Economic Studies, Faculty of Social Sciences, Charles University in Prague, Czech Republic. The papers are peer reviewed, but they are *not* edited or formatted by the editors. The views expressed in documents served by this site do not reflect the views of the IES or any other Charles University Department. They are the sole property of the respective authors. Additional info at: ies@fsv.cuni.cz

Copyright Notice: Although all documents published by the IES are provided without charge, they are licensed for personal, academic or educational use. All rights are reserved by the authors.

Citations: All references to documents served by this site must be appropriately cited.

Bibliographic information:

Jakubík, P. (2007). “ Credit Risk in the Czech Economy. ” IES Working Paper 11/2007. IES FSV. Charles University.

This paper can be downloaded at: <http://ies.fsv.cuni.cz>

Credit Risk in the Czech Economy

Petr Jakubík[#]

[#] Czech National Bank and IES, Charles University Prague
Email: Petr.Jakubik@cnb.cz

March 2007

Abstract:

This paper deals with credit risk in the Czech aggregate economy. It follows structural Merton's approach. A latent factor model is employed within this framework. Estimation of this model can help to understand relation between credit risk and macroeconomic indicators. The credit risk model of the Czech aggregate economy was estimated in this manner for purpose of stress testing. The results of this study can be used for stress testing of banking sector.

Keywords: banking, credit risk, latent factor model, default rate, stress test

JEL: G21, G28, G33

Acknowledgements:

The findings, interpretations and conclusions expressed in this paper are entirely those of the author and do not represent the view of any of the above institutions. The study was supported by research grant GACR 402/05/2123.

1 Introduction

Our recent experience with effects of economic downturn on banks' loan portfolios in the Czech economy in the late 1990s provides an opportunity to investigate the link between macroeconomic development and credit portfolio quality.

This study follows paper of Jakubík (2006). We considered the same methodology which was applied for the Finnish data in order to estimate aggregate credit risk model.

This paper is structured as follows. Section 2 presents selected approach to credit risk modeling. A nonlinear one-factor model, which is derived from idea of return assets modeling by systematic factor and idiosyncratic shocks, is described. Section 3 introduces estimated one-factor macro credit risk model for the Czech economy. This model is used for the financial stability purpose in the Czech National Bank. Last section concludes and discusses possible further research issues.

2 Credit Risk Models

Two basic group of models are usually used for credit risk modeling. The first group of models try to estimate the individual risk of debtors. These are involved in credit risk assessment of the commercial banks and are called individual credit risk models. Nevertheless, banks can also incorporate some macroeconomic indicators into a model in an effort to avoid the problem of credit risk assessment procyclicality.¹ The outputs of the individual credit risk models can provide inputs for capital adequacy ratio calculation as well – Internal Ratings-Based Approach (IRB) – New

¹That is, the problem where the credit risk of a single entity is assessed in positive terms during a period of economic growth and in negative terms during a period of economic slowdown. Credit risk models which fail to address the issue of procyclicality might result in a further strengthening of the economic downturn.

Basel Capital Accord (Gordy 2003), (Finger 2001).² The estimated model in this paper belongs to the group of macroeconomic credit risk models. This group of models try to estimate aggregate credit risk and therefore correspond to financial stability purposes. Macroeconomic credit risk models are usually related to individual risk models, which are possible to express with the following general equation.

$$p_t = f(X_t), \quad (1)$$

where p_{t_1} is individual default probability at time t and X_t are some indicators of client quality related to the financial statement in the case of the traditional model, firm's value and leverage in the case of structural models or the bond price in the case of the reduced model. Macroeconomic indicators can be part of this inputs for all types of these models. Originally macroeconomic factors were not considered, but in recent years a lot of papers research the influence of the macroeconomic environment on the credit risk model.

The structural model was chosen for the stress testing of the Czech banking sector.³ The aim of the model is prediction of the possible future development of non-performing loans as a function of the negative changes in the macroeconomic environment. The selected approach follows the one-factor model which will be introduced later in this paper.

2.1 Credit Risk Models in Central Banks

Most central banks employ some form of sensitivity analysis or stress testing, but only a few of them use a macroeconomic credit model. Where central banks do use such macroeconomic credit models, they are mostly empirical-type models, as, for example, in the case of the United Kingdom, Germany, Belgium and Finland. The Bank of England uses an empirical model which estimates the bankruptcy rate of non-financial corporations and the default rate in mortgage and credit card portfolios (Bunn, Cunningham, Drehmann 2004). The data collected in this manner are then entered into credit loss estimation models as explanatory variables. The default rates are estimated from real GDP, the real interest rate, unemployment, the corporate debt ratio and other aggregate indicators. Finland uses a macroeconomic model based on logistic regression which explains the default rate relationship for individual sectors of the economy using macroeconomic indicators (Virolainen 2004). This model regards real GDP, nominal interest rates and the debt ratios of the individual sectors investigated as the explanatory variables. The default rate is modelled using the bankruptcy rate of companies in the total number of companies

²A One-factor model was used to calibrate risk weights for the purposes of Basel II framework (default probability, assets correlation of borrowers within risk classes).

³Review of literature may be found in (Jakubík 2006)

for the given sector of the economy. The Hungarian central bank is also preparing a credit model which uses the number of bankruptcies of companies for individual sectors of the economy, based on the approach employed by the Finnish central bank. Germany used a regression model estimated on a panel of German banks (Deutsche Bundesbank 2005). The explanatory variable here is a logistic transformation of the proportion of provisions in the credit portfolio. This model works with the change in the risk-free interest rate, GDP growth and loan portfolio growth as the macroeconomic indicators in the role of explanatory variables. The Belgian central bank uses a model based on logistic regression estimating the aggregate default rate of the corporate sector (National Bank of Belgium 2005). The output gap, nominal long-term interest rates and the lagged rate of aggregate corporate default are used as the explanatory variables. Generally speaking, the development of macroeconomic credit risk models has become an important area of interest of central banks as institutions pursuing financial stability. However, the topic associated with these models is undergoing very rapid development and there is no overall consensus on which model is the best.

2.2 One-factor Model

The one-factor model is one of the variants of the latent factor model which belongs to the class of the Merton structural model. The following model appears in many papers, for example in (Rösch 2003), (Rösch 2005), (Céspedes, Martín 2002), (Cipollini, Missaglia 2005), (Lucas, Klaassen 2003), (Hamerle, Liebig, Scheule 2004) or (Jakubík 2006).

The model assumes a homogenous portfolio of firms in the economy. A random process with a standard normal distribution is assumed for the standardized logarithmic return on assets of a firm. The discrete normal logarithmic return satisfies the following equation for each firm in the economy.

$$R_{it} = \sqrt{\rho}F_t + \sqrt{1 - \rho}U_{it} \quad (2)$$

R denotes normal logarithmic return on assets for each firm i at time t . F corresponds to the logarithmic return in the economy independent of firm i at time t , which is assumed to be a random variable with a standard normal distribution. This variable represents the part of the return which is not specific to the firm and can thus satisfy the general conditions for profitability of firms in the economy. U denotes the return specific to the firm i at time t , which is again assumed to be random with a standard normal distribution. The two random variables F and U are also assumed to be serially independent. Given these assumptions, the logarithmic return on assets of each firm i at time t also has a standard normal distribution.

The model is based on the Merton approach, according to which a default event occurs if the return on a firm's assets falls below a certain threshold. Formally,

$$P(Y_{it} = 1) = P(R_{it} < T), \quad (3)$$

where Y denotes a random variable with the two potential state (1/0 - borrower i defaults/non-defaults at time t). Different macroeconomic indicators can be considered if the applied variant of the model assumes that the value of this threshold changes depending on changes in the macroeconomic environment. This value can be modeled as a linear combination of macroeconomic variables. The final version of the model is described by equation (4) in the case when macroeconomic indicators are included.

$$p_{it} = P(Y_{it} = 1) = P(\sqrt{\rho}F_t + \sqrt{1 - \rho}U_{it} < \beta_0 + \sum_{j=1}^N \beta_j x_{jt}) = \Psi(\beta_0 + \sum_{j=1}^N \beta_j x_{jt}), \quad (4)$$

The conditional probability of default on realization f_t of random unobservable factor at time t corresponding to the default probability (4) is given by formula (5).

$$p_i(f_t) = P(U_{it} < \frac{\beta_0 + \sum_{j=1}^N \beta_j x_{jt} - \sqrt{\rho}f_t}{\sqrt{1 - \rho}}) = \Psi(\frac{\beta_0 + \sum_{j=1}^N \beta_j x_{jt} - \sqrt{\rho}f_t}{\sqrt{1 - \rho}}) \quad (5)$$

If a very high number of borrowers in the portfolio is assumed, all counterparties have the same individual probability p_i and all default events are independent, then according to the "law of large numbers" the default rate of the portfolio can be estimated as individual default probability. The random factor is assumed to be independent between borrowers. The number of defaults $D_t(f_t)$ at time t have binomial distribution with conditional default probability $p(f_t)$ and the given number of companies N_t .

$$D(f_t) \sim \text{Bi}(N_t, p(f_t)) \quad (6)$$

Unconditional probability can be obtained as a integral over the random factor.

$$P(D_t = d_t) = \int_{-\infty}^{+\infty} \binom{n_t}{d_t} p(f_t)^{d_t} (1 - p(f_t))^{n_t - d_t} \psi(f_t) df_t \quad (7)$$

The Parameters of the one-factor model can be estimated with the log-likelihood function. The number of defaults D_t is a conditional binomial distributed random variable with the number of borrowers N_t and the conditional probability $p(f_t)$ according to equation (6). Realization d_t and n_t of random variables D_t and N_t are

known. The unconditional number of defaults can be computed by an integral over the random effect. The log-likelihood function depends only on parameters β and ρ .

3 Macroeconomic Credit Risk Model of the Czech Economy

This paper focuses on the macroeconomic default rate model in the Czech economy (Jakubík 2006). The aim is to produce a model allowing us to estimate the expected proportion of bad loans in the total loan portfolio of banks in response to the evolution of key macroeconomic indicators. The proportion of bad loans is one of the inputs to the stress testing model developed by the Czech National Bank (CNB).⁴ It has hitherto been regarded as a constant parameter estimated from extreme historical events. The new approach enables modeling of the impacts of various macroeconomic shocks on loan portfolio quality and subsequently, in combination with the stress-testing system, on the capital of the entire banking system. Such shocks may be set either expertly on the basis of historical experience or constructed in the form of alternative scenarios linked to the CNB's main macroeconomic forecasting model.

3.1 Data Used

Quarterly data for the Czech economy have been used for all calculations. The model is based on time series of the inflow of total aggregate bad loans in the economy and selected macroeconomic indicators.

3.1.1 Bad loans

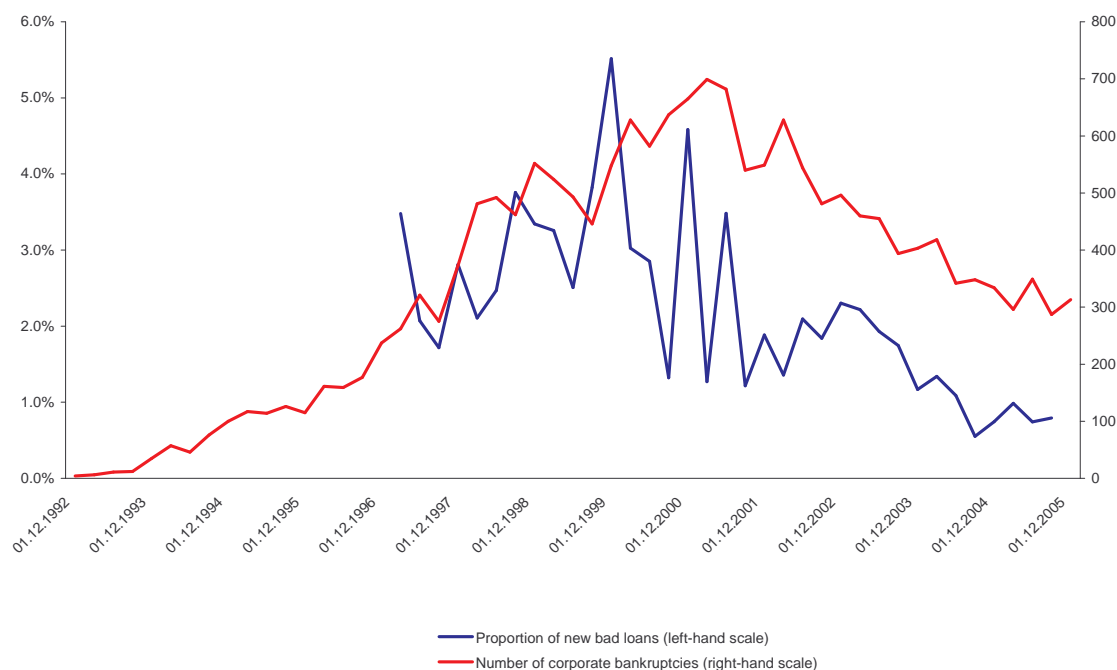
The (dependent) credit risk variable or default variable estimated in the model can be defined in several ways. A default event is commonly defined as a breach of payment discipline. A 12-month default probability is usually employed in credit risk assessments. This is defined for a given moment as the probability of a default event occurring in a 12-month period following that given moment, provided that the given person did not default in the period immediately preceding the given moment. This definition thus corresponds to new default events in the economy.

In our model, the default rate was modelled by the proportion of new bad loans in the total volume of loans in the economy.⁵ Quarterly time series of new bad

⁴The stress testing methodology is described in detail by Čihák, Heřmánek (2005).

⁵That is, loans which became "bad" in the given quarter. The moment of default means the time when the loan was classified as substandard or worse for the first time. Shifts within the "bad"

loans were available from Q1 1997 to Q3 2005.⁶ They were, however, affected by one-off measures entailing reclassification of outstanding mortgage-backed loans in 1999-2001.⁷ This period saw significant deviations in the calculated proportion of newly classified loans in the banking portfolio. However, this reclassification did not in fact change the true quality of these portfolios and can be seen as a way of making the indicator of the stock of classified loans more realistic.



Source: CNB, Ministry of Justice of the Czech Republic

Figure 1: Corporate default rates in the Czech economy (quarterly data)

The special (dummy) variable used took a value of 1 for quarters when the monitored indicator saw significant deviations from the observed trend. The quarters include Q3 1999, Q4 1999, Q4 2000 and Q2 2002. In other cases, this variable takes

loans category (for example, a further downgrading of the loan from doubtful to loss) will not affect the default rate according to this definition. This variable does not correspond to the proportion of total non-performing loans, which are not an optimum measure of credit risk as they may include loans which were first classified a very long time ago and which remain in the loan portfolio, for example, for accounting purposes and are not related to the current economic situation. The new bad loans mean inflow into the pool of bad loans.

⁶The new loan loss provisions as a proxy for credit risk can be used. However the new bad loans reflect more precisely the real credit risk in the economy.

⁷CNB Provision of 17 September 1997 stipulating the principles for classifying loan receivables and for provisioning for these receivables, as amended.

the value of 0. The dummy variable so defined corresponds to the effect of changes in the approach to loan classification.

An alternative approach to approximating the default rate in the economy is to use time series of the number of adjudicated bankruptcies or compositions. This approach has been used, for example, to estimate the macroeconomic credit risk model of the Finnish economy.⁸ For the Czech Republic, such data have been available since the start of the transformation. However, they have probably had a higher information content only since the late 1990s.⁹ The quarterly development of the number of adjudicated bankruptcies in the Czech Republic is demonstrated in Figure 1. In practice there seems to be a lag between the filing of a petition for bankruptcy and the actual adjudication, and the default event in the loan portfolio usually precedes the adjudication of bankruptcy. The application of such time series for the Czech economy may also be limited by the frequent amendments made to the relevant legislation. Given these facts, the time series of bankruptcies in the end was not used to estimate the macroeconomic credit model for the Czech economy. Nevertheless, Chart 1 confirms the similar development of this time series and the share of growth in classified loans in the loan portfolio.

3.1.2 Considered Macroeconomic Indicators

Various macroeconomic indicators are used as explanatory variables relating to the indicator of the default rate in the economy. Interest rates and gross domestic product are most commonly considered in this context in the literature.¹⁰ Gross domestic product (GDP) is a basic indicator of the cyclical position of the economy. A decline or low growth in GDP affects credit risk, for example via a negative effect on corporate earnings, wage growth, unemployment or prices of assets (such as real estate), which, in turn, leads to a deterioration in loan portfolio quality. A rise in interest rates affects the loan portfolio in a similar way, increasing the costs of corporate and household financing, decreasing the market value of assets, etc.

In the case of GDP, annual real GDP growth was applied. One-month and one-year PRIBOR¹¹ interbank rates were considered as nominal interest rates. Real interest rates were deflated ex post by the consumer price index.

The real effective exchange rate and the nominal koruna-euro and koruna-dollar

⁸Macroeconomic models of the credit risk of the Finnish economy using the number of corporate bankruptcies can be found in (Virolainen 2004), (Jakubík 2006).

⁹The time series of bankruptcies shows that the number of bankruptcies at the start of the 1990s was very low, probably as a result of inadequate legislation.

¹⁰For a discussion of the issue of explanatory macroeconomic indicators, see, for example, Virolainen (2004), Deutsche Bundesbank (2005), Rösch (2003) and Jakubík (2006).

¹¹Prague Interbank Offered Interest Rate

rates¹² were also considered among the explanatory variables. They are important for credit risk given the nature of the Czech economy as a small open economy where the financial condition of the corporate sector in particular strongly depends on the exchange rate. The last indicator used was the level of indebtedness of the economy, measured by the ratio of client loans to GDP, which approximates the exposure of the financial sector to the rest of the private sector.

In selecting the set of macroeconomic indicators, the issue of the interpretability of the results obtained was also taken into account. Emphasis was put on determining the relationship between credit risk, represented by growth in bad loans in the banking portfolio, and the macroeconomic indicators which are already entered in the stress testing scenarios.¹³ Another partial limitation on the selection of the variables was the effort to link this credit risk model to the results of the CNB's macroeconomic forecast. Although many macroeconomic indicators were considered, finally only GDP, the interest rate and inflation were included in the model.¹⁴

3.2 Model Estimation

We employed the concept of the one-factor model. However, the total number of firms and the number of firms in default in the economy were not available for individual periods for the model estimation (formula (6)). Aggregate data on growth in banks' bad loans were employed in the estimation of the model for individual quarters in place of bankruptcy data. To this end, we made the following additional assumptions. Each koruna of a loan was considered an individual loan of a single client. In such case, therefore, the random variable D corresponds to the number of new bad koruna loans, or the growth in the volume of bad loans, while N stands for the total volume of loans granted. A default event is represented here by non-repayment of a loan of CZK 1. Under these assumptions, the volume of bad loans can be modeled by means of the relation (6).¹⁵ The model was estimated by

¹²An internal CNB calculation based on CPIs and continuous weights corresponding to the average previous annual trade turnover was used to calculate the real exchange rate.

¹³These indicators thus affect the resulting capital adequacy in the stress testing through two channels. The first acts directly via their effect on banks' balance sheets, while the other operates indirectly via the estimate of credit risk.

¹⁴Other macroeconomic indicators such as the indebtedness of the non-financial sector (corporate and households), the unemployment rate, nominal and real exchange rate, money aggregate, etc. were considered. However none one of them increased performance of the model and the relevant estimated coefficients were not significant.

¹⁵The assumption regarding koruna loans is somewhat simplified, as koruna loans are not in fact independent. The ideal solution would be to use the real default rates of clients in default divided by the total number of clients. However these data are not available. Nevertheless all tests of the model shows that the model is robust enough and the utilized assumption mentioned above does not destroy the result of the regression.

maximization a likelihood function containing a random latent factor, which was assumed to have a standard normal distribution.

Taking into account the criteria for the selection of variables relating to the stress testing scenarios and the outputs of the CNB's macroeconomic forecast, we selected the statistically best model containing GDP, the nominal interest rate, inflation and the dummy variable for the purposes of a change in methodology with a subsequent one-off impact on reclassification of the loan portfolio.¹⁶ The selected model is in line with macroeconomic stress test scenarios and outputs of the macroeconomic prediction model of the Czech National Bank.

In the case of GDP, non-lagged annual real GDP growth was used. The statistically most significant interest rate was the nominal 1Y PRIBOR lagged by four quarters. In the case of inflation, the annual rate of growth of the average quarterly CPI lagged by two quarters was the most significant. The model was also tested without the dummy variable.¹⁷ This gave very similar results, although it slightly overestimated the default rate at the end of the period under review, showing that the chosen model has some degree of robustness.

Table 1 demonstrates the results of the estimated model of the aggregate default rate in the Czech economy. All the coefficients were significant at the 5% confidence level. The default rate in the economy is negatively related to gross domestic product, hence higher GDP growth leads to lower credit risk. By contrast, the level of credit risk is positively related to interest rates, which is also consistent with economic intuition. Including inflation in the model reduces the effect of nominal interest rates lagged by four quarters by real inflation lagged by two quarters. For this reason, the estimate of the coefficient representing inflation in the model is negative. The combination of nominal interest rates and inflation demonstrates that the credit default rate in the Czech economy depends on real interest rates rather than nominal rates, although the estimated coefficients are not exactly the same and have different lags. The statistical significance of the effect of the unobservable component shows that this factor is still necessary for explaining the dependent variable, despite the inclusion of macroeconomic indicators.¹⁸ This result implies that the default rate in the economy is also affected by factors other than the macroeconomic indicators considered.

The following equation (8) of the one-factor model (4) expresses the estimated rela-

¹⁶ We tried to use the real interest rate instead of lagged nominal interest rate and inflation. However the performance of such estimated model decreased.

¹⁷ Number of lags in the case of explanatory variables were chose according the significancy of the coefficients and performance of the model. However the standard methodology can not be used for the selection of the lags number due to the nonlinearity of the model. The economic theory can help for the specification.

¹⁸ The latent factor expressed the unobservable part of the macroeconomic risk in the model, which cannot be explained by macroeconomic indicators.

Description of variable corresponding to estimated coefficient		Denoted by	Estimate	Standard error	Pr> t
Constant	(β_0)	c	-2.0731	0.1019	<0.0001
Gross domestic product	(β_1)	gdp	-4.9947	1.9613	0.0162
Nominal interest rate	(β_2)	R_{t-4}	2.7839	0.9076	0.0045
Inflation	(β_3)	π_{t-2}	-2.4364	1.0994	0.0344
Dummy	(β_4)	dum	0.3296	0.06629	<0.0001
Effect of latent factor	(ρ)	ρ	0.01211	0.003243	0.0008

Table 1: Macroeconomic credit risk model (4) of the Czech Economy

tion for the aggregate default rate in the Czech economy.¹⁹

$$df_t = \psi(-2.0731 - 4.9947gdp_t + 2.7839R_{t-4} - 2.4364\pi_{t-2} + 0.3296dum_t) \quad (8)$$

The dummy variable will continue to take the value of zero for the credit risk prediction. This implies that relationship (8) can be simply rewritten in the form of (9) for the purposes of the quarterly default rate prediction.

$$df_t = \psi(-2.0731 - 4.9947gdp_t + 2.7839R_{t-4} - 2.4364\pi_{t-2}) \quad (9)$$

The coefficients from equations (8) and (9) cannot be simply interpreted as the commonly used elasticities of impacts of the relevant macroeconomic factors on credit risk, as they are further recalculated using the cumulative distribution function of a normal distribution, hence their impact is not linear. A simple sensitivity analysis of the impacts of changes in macroeconomic variables is given in subsection 3.3.

The ability to explain the quarterly default rate by means of the estimated model (8) is shown in Figure 2. The estimated model is a version of the binary choice model,²⁰ to which the standard approaches to measuring the statistical significance of an estimate cannot be applied. However, there are numerous less common indicators which can be applied and which suggest that the model has good performance.

One of the tests of model quality is a test of the hypothesis that all the coefficients β_j except the constant member are zero ($H_0: \beta_1 = \beta_2 = \dots = \beta_K = 0$).

¹⁹ ψ denotes the standard normal distribution function, df denotes the quarterly default rate, index t denotes the relevant time.

²⁰Binary models generally consider situations with two possible realisations of a dependent variable (0,1).

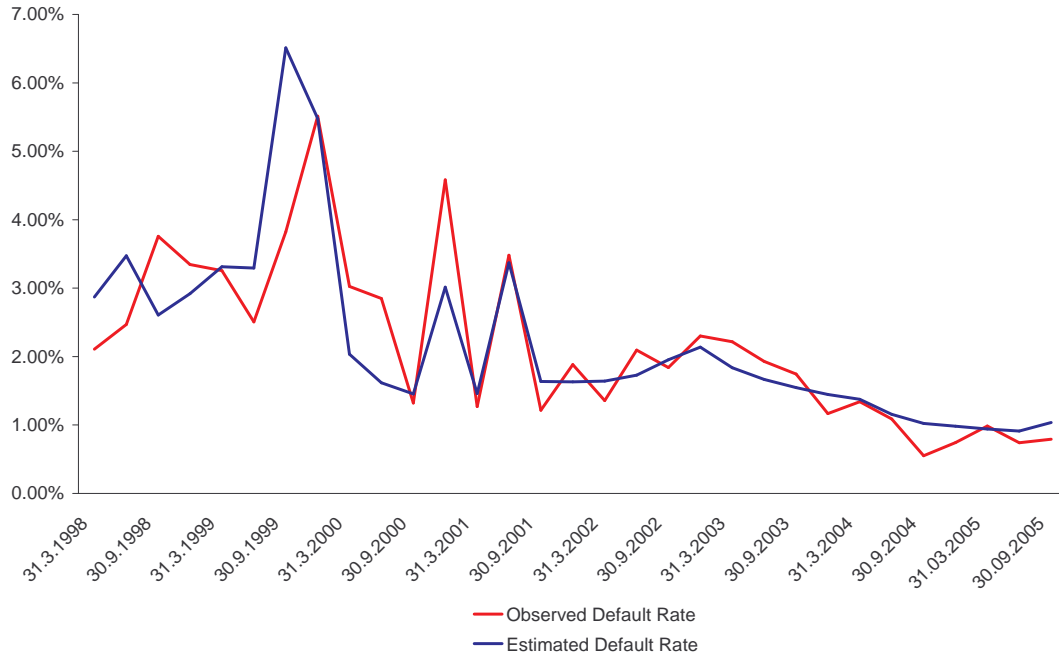


Figure 2: Performance of the one-factor model for the Czech economy

This hypothesis can be tested by likelihood ratio $\lambda = \frac{L_C}{L_U}$, where L_C denotes the likelihood function of the constrained model and L_U the likelihood function of the unconstrained model. The known result says that $-2\ln\lambda$ is an asymptotic chi-squared distributed variable with K degrees of freedom.²¹ The result of the test rejected the hypothesis at a significance level of less than 1%.

The observed criteria of pseudo-coefficients of determination based on the likelihood function also bear out the high quality of the model. These coefficients should be in the interval $[0,1]$, with results close to 1 attesting to the very high quality of the model.

$$R_E^2 = 1 - \frac{\ln L_U}{\ln L_C} \stackrel{-2 \ln L_C}{=} = 0.97 \quad \text{Estrella (1988) (10)}$$

$$R_{CU1}^2 = 1 - \left(\frac{L_C}{L_U}\right)^{\frac{2}{n}} = 0.95 \quad \text{Cragg-Uhler (1970) (11)}$$

²¹The known result of the distribution is mentioned, for example, by Rao (1973).

$$R_{CU2}^2 = \frac{1 - \left(\frac{L_C}{L_U}\right)^{\frac{2}{n}}}{1 - L_C^{\frac{2}{n}}} = 0.95 \quad \text{Cragg-Uhler (1970) (12)}$$

$$R_{VZ}^2 = \frac{\ln L_U - \ln L_C}{2(\ln L_U - \ln L_C) + n} \frac{2 \ln L_C - n}{2 \ln L_C} = 0.80 \quad \text{Veall-Zimmermann (1992) (13)}$$

Despite the good performance of the aggregate model, sectoral models would be desirable. The impact of the macroeconomic indicators on household and corporate sector credit risk should be different. Although sectoral analysis could help to distinguish these effects, only aggregate time series of the new bad loans were available. The Central Register of Credits which is operated by the Czech National Bank was introduced in October 2002. This register contains data of firms and entrepreneur. However time series obtained from this register are too short for the credit risk modeling of corporate sector.

3.3 Use of the model in stress testing

Using the estimated model, the impacts of macroeconomic shocks on the default rate of the banking portfolio can be tested at the level of the aggregate economy. The estimated model is based on quarterly time series, so the estimated default rate is also a quarterly figure, which needs to be annualised for the purposes of stress testing. Two approaches are possible for solving this problem. First, the quarterly default rate is multiplied by four, which is the upper estimate of the annual default rate. Second, the calculation of the four quarterly default rates and their sum under the assumption that the observed portfolio does not change are calculated. In order to forecast the default rate, we have to set the inputs to the macroeconomic credit risk model, which will also be used as the stress testing parameters. These include the non-lagged annual real GDP growth rate, nominal annual interest rates lagged by four quarters and annual inflation lagged by two quarters relative to the forecast horizon. These values can be set either expertly or as a percentage deviation from the macroeconomic forecasts drawn up by the CNB or as outputs from the CNB's macroeconomic model under an assumption of significant, improbable, but not entirely impossible, negative macroeconomic shocks.

The following Table 2 gives the results of the macroeconomic credit risk model for different combinations of values for GDP growth rate, the nominal interest rate and inflation rate.²² These are merely illustrative examples of the sensitivity of the

²²The sensitivity analysis uses non-lagged GDP growth, CPI inflation lagged by two quarters and nominal interest rates lagged by four quarters.

credit risk indicator for different combinations of the explanatory variables, and are not the actual values entering the stress testing.²³ Quarterly change in bad loans means inflow into the pool of bad loans.

CPI	GDP Growth Rate								
	R	-1%	0%	1%	2%	3%	4%	5%	6%
1%	2%	2.3%	2.1%	1.8%	1.6%	1.4%	1.2%	1.1%	1.0%
	3%	2.5%	2.2%	2.0%	1.7%	1.5%	1.3%	1.2%	1.0%
	4%	2.6%	2.4%	2.1%	1.8%	1.6%	1.4%	1.3%	1.1%
	5%	2.8%	2.5%	2.2%	2.0%	1.8%	1.5%	1.4%	1.2%
2%	8%	3.4%	3.0%	2.7%	2.4%	2.2%	1.9%	1.7%	1.5%
	3%	2.3%	2.1%	1.8%	1.6%	1.4%	1.3%	1.1%	1.0%
	4%	2.5%	2.2%	2.0%	1.7%	1.5%	1.4%	1.2%	1.0%
	5%	2.7%	2.4%	2.1%	1.9%	1.6%	1.5%	1.3%	1.1%
3%	8%	3.2%	2.9%	2.6%	2.3%	2.0%	1.8%	1.6%	1.4%
	4%	2.4%	2.1%	1.9%	1.6%	1.4%	1.3%	1.1%	1.0%
	5%	2.5%	2.2%	2.0%	1.8%	1.6%	1.4%	1.2%	1.1%
4%	8%	3.1%	2.7%	2.4%	2.2%	1.9%	1.7%	1.5%	1.3%
	5%	2.4%	2.1%	1.9%	1.7%	1.5%	1.3%	1.1%	1.0%
	8%	2.9%	2.6%	2.3%	2.0%	1.8%	1.6%	1.4%	1.2%

Table 2: Sensitivity analysis of the model (quarterly change in bad loans in response to the value of exogenous variables)

Table 2 shows that the sensitivity of credit risk to, for example, a change in GDP growth of 1 percentage point differs *ceteris paribus* depending on the rate of such growth. For higher GDP growth rates, the impacts of a decline in growth of 1 percentage point are lower than for lower growth rates. The underlying reason for this is that the chosen variant of the model or estimation of the model (9) uses a calculation based on the standard normal distribution function. A similar conclusion applies to the other variables in the model.

The results of the macroeconomic credit model are used in the current version of stress testing for estimating the proportion of bad loans in the portfolio, which is then entered in the stress testing as an input parameter. The credit risk model allows us to generate bad loans in the banking portfolio as a result of a shock in the form of a change in real GDP growth, nominal interest rates or inflation.

²³According to the estimated model, there is some minimal level of default rate in the economy even in the good time.

4 Conclusion

We have investigated macroeconomic models of default rate estimation. The concept of a latent factor model which is based on the Merton idea was followed. These models were originally employed in individual credit risk modeling. Unobservable factors are an integral part of the models. The standard normal distribution of the unobservable factor is usually assumed. A static version of this model was considered for all of the estimations in this paper. Coefficients can be estimated using the likelihood function. The solution of a maximization problem leads to the integral over the random effects.

In order to develop a macroeconomic credit model for the Czech economy, we used a one-factor Merton-type model estimated for the aggregate economy. The model confirmed a very strong link between bank portfolio quality and the macroeconomic environment. The estimated macroeconomic credit risk model was incorporated into the existing version of stress testing.

Despite the good performance of the aggregate model, sectoral models would be desirable. The impact of the macroeconomic indicators on household and corporate sector credit risk should be different. Sectoral analysis could help to distinguish these effects. The others difficulties of the model are related to the incorporation into stress testing. The current framework assumes the worst possible scenario for a variable referred to as "loss given default", i.e. a 100% loss. The modeling of the impact of macroeconomic shocks on the volume of bad loans in the portfolio could be made more precise by estimating a model of loss given default. A further possible improvement to the default rate modeling of the Czech economy would be to make the model dynamic. This approach is able to capture non-constant assets volatility. Nevertheless numerical solution of such models is fairly complicated.

References

- Babouček I, Jančar M.: *Effects of Macroeconomic Shocks to the Quality of the Aggregate Loan Portfolio*, CNB Working Paper Series, Czech National Bank, 1/2005
- Basel Committee on Banking Supervision: *International Convergence of Capital Measurement and Capital Standards*, Revised Framework, Bank for International Settlements, June, 2004
- Bunn P., Cunningham A., Drehmann M.: *Stress Testing as a Tool for Assessing Systemic Risks*, Financial Stability Review, Bank of England, June 2005

- Céspedes J., Martín D.: *The Two-Factor Model for Credit Risk: A comparison with the BIS II one-factor model*, January 2002
- Cipollini A., Missaglia G.: *Business cycle effects on portfolio Credit Risk: scenario generation through Dynamic Factor analysis*, February, 2005
- Čihák M., *A Review of key Concepts*, Research and Policy Notes 2004/02, Czech National Bank, 2004
- Čihák M., *Designing Stress tests for the Czech Banking System*, Research and Policy Notes 2004/03, Czech National Bank, 2004
- Čihák M., Heřmánek J.: *Stress testing the Czech Banking System: Where Are We? Where Are We Going?*, Research and Policy Notes 2005/02, Czech National Bank, 2005
- Deutsche Bundesbank: *Financial Stability Review*, November 2005
- Estrella A.: *A New Measure of Fit for Equations with Dichotomous Dependent Variables*, Journal of Business and Economic Statistics, 1998, vol. 16, no. 2, pp. 198-205, April 1998
- Finger Ch.: *The One-Factor CreditMetrics Model In The New Basel Capital Accord*, RiskMetrics Journal, Volume 2(1), 2001
- Gordy M.: *A risk-factor model foundation for ratings-based bank capital rules*, Journal of Financial Intermediation 12, p. 199-232, 2003
- Hamerle A., Liebig T., Scheule H.: *Forecasting Credit Portfolio Risk*, Discussion Paper Series 2: Banking and Financial Supervision, No 01, Deutsche Bundesbank, 2004
- Jakubík P.: *Does Credit Risk Vary with Economic Cycles? The Case of Finland*, IES Working Paper, 11/2006
- Jakubík P.: *Macroeconomic Credit Risk Model*, Financial Stability Report 2005, Czech National Bank, 2006
- Koopman S., Lucas A.: *Business and Default Cycles for Credit Risk*, Journal of Applied Econometrics 20: 311-323, 2005
- Lucas A., Klaassen P.: *Discrete versus Continuous State Switching Models for Portfolio Credit Risk*, Tinbergen Institute Discussion Paper 075/2, Universiteit Amsterdam, and Tinbergen Institute, 2003

- Merton R.C.: *On the pricing of corporate debt: The risk structure of interest rates*, Journal of Finance, vol. 29, 1974
- National Bank of Belgium: *Financial Stability Review*, 2005
- Pesaran M., Schuermann T.: *Credit Risk and Macroeconomic Dynamics*, March, 2003
- Pesola J.: *The role of macroeconomic shocks in banking crises*, Bank of Finland Discussion Papers 6, 2001
- Rösch D.: *Correlations and Business Cycles of Credit Risk: Evidence from Bankruptcies in Germany*, Financial markets and Portfolio Management 17, No. 3, 2003, 309-331
- Rösch D.: *An empirical comparison of default risk forecast from alternative credit rating philosophies*, International Journal of Forecasting 21, 2005, 37-51
- Tudela M., Young G.: *A Merton-model approach to assessing the default risk of UK public companies*, Working Paper no. 194, Bank of England, June 2003
- Vlieghe G.: *Indicators of fragility in the UK corporate sector*, Working Paper no.146, Bank of England, December 2001
- Virolainen K.: *Macro stress testing with macroeconomic credit risk model for Finland*, Bank of Finland Discussion Papers 18, 2004

IES Working Paper Series

2006

1. Martin Gregor: *Globální, americké, panevropské a národní rankiny ekonomických pracovišť*
2. Ondřej Schneider: *Pension Reform in the Czech Republic: Not a Lost Case?*
3. Ondřej Knot and Ondřej Vychodil: *Czech Bankruptcy Procedures: Ex-Post Efficiency View*
4. Adam Geršl: *Development of formal and informal institutions in the Czech Republic and other new EU Member States before the EU entry: did the EU pressure have impact?*
5. Jan Zápál: *Relation between Cyclically Adjusted Budget Balance and Growth Accounting Method of Deriving 'Net fiscal Effort'*
6. Roman Horváth: *Mezinárodní migrace obyvatelstva v České republice: Role likviditních omezení*
7. Michal Skořepa: *Zpochybnění deskriptivnosti teorie očekávaného užítku*
8. Adam Geršl: *Political Pressure on Central Banks: The Case of the Czech National Bank*
9. Luděk Rychetník: *Čtyři mechanismy příjmové diferenciacie*
10. Jan Kodera, Karel Sladký, Miloslav Vošvrda: *Neo-Keynesian and Neo-Classical Macroeconomic Models: Stability and Lyapunov Exponents*
11. Petr Jakubík: *Does Credit Risk Vary with Economic Cycles? The Case of Finland*
12. Julie Chytilová, Natálie Reichlová: *Systémy s mnoha rozhodujícími se jedinci v teoriích F. A. Hayeka a H. A. Simona*
13. Jan Zápál, Ondřej Schneider: *What Are Their Words Worth? Political Plans And Economic Pains Of Fiscal Consolidations In New Eu Member States*
14. Jiří Hlaváček, Michal Hlaváček: *Poptávková funkce na trhu s pojištěním: porovnání maximalizace paretovske pravděpodobnosti přežití s teorií EUT von-Neumanna a Morgensterna a s prospektovou teorií Kahnemana a Tverského*
15. Karel Janda, Martin Čajka: *Státní podpora českého zemědělského úvěru v období před vstupem do Evropské unie*
16. Nauro F. Campos, Roman Horváth: *Reform Redux: Measurement, Determinants and Reversals*
17. Michal Skořepa: *Three heuristics of search for a low price when initial information about the market is obsolete*
18. Michal Bauer, Julie Chytilová: *Opomíjená heterogenita lidí aneb Proč afrika dlouhodobě neroste*
19. Vít Bubák, Filip Žikeš: *The Price of Stock Trades: Evidence from the Prague Stock Exchange*
20. Vladimír Benáček, Jiří Podpiera a Ladislav Prokop: *Command Economy after the Shocks of Opening up: The Factors of Adjustment and Specialisation in the Czech Trade*
21. Lukáš Vácha, Miloslav Vošvrda: *Wavelet Applications to Heterogeneous Agents Model*
22. Lukáš Vácha, Miloslav Vošvrda: *"Morální hazard" a „nepříznivý výběr“ při maximalizaci pravděpodobnosti ekonomického přežití*
23. Michal Bauer, Julie Chytilová, Pavel Streblov: *Effects of Education on Determinants of High Desired Fertility Evidence from Ugandan Villages*
24. Karel Janda: *Lender and Borrower as Principal and Agent*
25. Karel Janda: *Optimal Deterministic Debt Contracts*

26. Jiří Hlaváček: *Pojištění vkladů: současný stav, srovnání a perspektiva v kontextu EU*
27. Pavel Körner: *The determinants of corporate debt maturity structure: evidence from Czech firms*
28. Jarko Fidrmuc, Roman Horváth: *Credibility of Exchange Rate Policies in Selected EU New Members: Evidence from High Frequency Data*
29. Natálie Reichlová, Petr Švarc: *Strategic Referring in Labor Market Social Networks*
30. František Turnovec: *Publication Portfolio of the Czech Economists and Problems of Rankings*
31. Petr Kadeřábek : *Correcting Predictive Models of Chaotic Reality*
32. Wadim Strielkowski : *People of the road: the role of ethnic origin in migration decisions. A study of Slovak Roma asylum-seekers in the Czech Republic in 1998-2006*

2007

1. Roman Horváth : *Estimating Time-Varying Policy Neutral Rate in Real Time*
2. Filip Žikeš : *Dependence Structure and Portfolio Diversification on Central European Stock Markets*
3. Martin Gregor : *The Pros and Cons of Banking Socialism*
4. František Turnovec : *Dochází k reálné diferenciaci ekonomických vysokoškolských vzdělávacích institucí na výzkumně zaměřené a výukově zaměřené?*
5. Jan Ámos Víšek : *The Instrumental Weighted Variables. Part I. Consistency*
6. Jan Ámos Víšek : *The Instrumental Weighted Variables. Part II. \sqrt{n} - consistency*
7. Jan Ámos Víšek : *The Instrumental Weighted Variables. Part III. Asymptotic Representation*
8. Adam Geršl : *Foreign Banks, Foreign Lending and Cross-Border Contagion: Evidence from the BIS Data*
9. Miloslav Vošvrda, Jan Kodera : *Goodwin's Predator-Prey Model with Endogenous Technological Progress*
10. Michal Bauer, Julie Chytilová : *Does Education Matter in Patience Formation? Evidence from Ugandan Villages*

All papers can be downloaded at: <http://ies.fsv.cuni.cz>

