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MODELLING COUNTRY EQUITY RISK PREMIUM IN CZECH REPUBLIC USING TIME-VARYING CAPM

With the fall of communism, since beginning of the 1990s, the world economy has been characterized by its globalization. As a consequence, the structure and size of the international capital flows has been changed rapidly. The rapid change toward a globalized environment has already highlighted the importance of global risk factors for the management of firms and organizations, as well as for the sustainable socio-economic development of countries. Country risk analysis has evolved as a major research topic within the fields of economics and finance during the past three decades, focusing on the investigation of the economic and financial. According to Erb et al. 2 the major significance of country risk analysis is clearly understood by the plethora of existing risk agencies that provide assessments of country risk.

A generally accepted definition on country risk offered Panras Nagy in Euromoney. According Nagy 9 country risk is the exposure to a loss in cross-border lending caused by events in a particular country which are, at least to some extent, under the control of the government but definitely not under the control of a private enterprise or individual. Cosset et al. defined country risk as the probability that a country will fail to generate enough foreign exchange in order to pay its obligation toward the foreign creditors. Other researchers have emphasized the necessity of defining country risk in a broader context that better represents the multidimensional character of country risk. Indeed three types of event can cause country risk, namely political events, economic factors, and social factors. Country risk therefore means the exposure to a loss in cross-border lending (of different types) due to events more or less under the control of the government.

As Bouchet, Clark and Groslambert 1 discuss there is not a consensus about a comprehensive definition of “country risk”. In the literature dealing with the risk of international investment, the two terms most frequently encountered are “country risk” and “political risk”. Also references to “cross-border risk” or “sovereign risk” can be found.

In the early 1970s was introduced a series of scientific papers on the capital asset pricing model (CAPM). This standard form of the general equilibrium relationship for asset returns, also known as the Sharpe-Lintner-Mossin mean-variance equilibrium model, builds on the theoretical works of Harry Max Markowitz

67 and James Tobin 11 on diversification and modern portfolio theory, which was independently introduced in the works of Jack Treynor 12, William Sharpe 10, John Lintner 5, and Jan Mossin 8. The model takes into account the sensitivity of capital assets to non-diversifiable component of risk (systematic risk), represented by the relative measure of risk in the form of beta (ß) coefficient, as well as the expected return and expected return n on the market theoretically defined risk-free asset, and that, based on defined assumptions.

The pioneer work by Harvey 4established the methodology most frequently used to assess country risk level applying time-varying capital asset pricing model originally proposed by Sharpe and Lintner. Harvey and Zhou in their study use monthly data on MSCI equity indices for 16 OECD countries and Hong Kong in order to confirm the efficiency of using the international asset pricing formula in examining risk at the country level. Erb et al. 2 assert that country risk can be captured by country credit ratings, which are dependent on a combination of financial, political, and economic variables. Erb et al. 2 impose the correlation between different types of risk, such as political risk, financial risk, economic risk and a composite risk as well as the country credit ratings.

To find appropriate model for country risk of the Czech Republic we use a multistep model-building strategy espoused so well by Box and Jenkins, well described in Želinský et al. 14. There are three main steps in the process, which may be used iteratively:

- model specification or identification,
- model fitting,
- model diagnostics.

The selected data set contains observations on 12 variables (see the global and local variables' description summarized in Table 1) for a single entity - the Czech Republic for 89 time periods, months. The observations in this data set begin in the February of 2014, which is denoted Feb-14, and end in the half of 2019 (denoted as Jun-2019). The number of observations (that is, time periods) in a time series data set is denoted by n. Because there are 89 months from Feb-2014 to Jun-2019, this data contains n = 89 observations. Descriptive statistics of the observations in this data set are listed in Appendix 1 and described in Table 1.

Standard form of the general equilibrium relationship for asset returns was derived in several forms involving different degrees of rigor and mathematical complexity. As mentioned in Elton et al. (2007) the equilibrium CAPM model can be written in the form

$$R_i = R_f + \left(R_m - R_f\right)\beta_i \qquad (1)$$

The basic model (1) can be rearranged to the time series model where the excess return of asset $\left(R_{i,t} - R_{f,t}\right)$ is explained through the excess return of market portfolio $\left(R_{m,t} - R_{f,t}\right)$

$$\left(R_{i,t} - R_{f,t}\right) = \alpha_i + \beta_{it}\left(R_{m,t} - R_{f,t}\right) + e_{i,t} \qquad (2)$$

Table 1

Global and local risk factors. Sources: Eurostat, US Energy Information Administration

Variable	Description
Global risk factors	
M	Monthly rate of returns calculated from average monthly values of Euronext global index – share price index (rebased). Also used as a proxy for stock market index (Eurostat)
Brent	Average monthly oil prices - Europe Brent Spot Price FOB per Barrel (US Energy Information Administration)
USDEUR	Average monthly USD/Euro exchange rates (Eurostat)
HICP EU	Harmonised consumer price index of Euro Area (Eurostat)
IR 12M	Average monthly data of Euro yield curves with 12 months maturity (Eurostat)
IR 3M	Money market interest rates - monthly data with 3 months maturity (Eurostat)
Local risk factors	
I CR	Monthly rate of returns calculated from average monthly values of Prague Stock Exchange 50 Index – share price index (rebased). Also used as a proxy for stock market index (Eurostat)
M1	Monetary aggregate M1 - Banks' balance sheet assets and liabilities - monthly data (Eurostat)
HICP CR	Harmonised consumer price index of Czech Republic (Eurostat)
ProductVol	Volume index of production - Industry production index - monthly data - (2014 = 100) acc. to NACE Rev.2 (Eurostat)
IR 1M	Average monthly data of Money market interest rate in Czech Republic with 1 month maturity (Eurostat)
CZKEUR	Average monthly CZK/Euro exchange rates (Eurostat)

According to Gangemi et al. 3 in an efficient financial market, we would only expect stock market reaction to the unanticipated component of the macroeconomic variables. We find the unanticipated components as the residuals from ARIMA models fitted to the macroeconomic data. These models were identified from ACF and PACF functions of the data.

Based on our aforementioned equations and discussion we propose a time-varying model of country systematic risk as follows

$$\beta_{i,t} = b_{0,i} + \sum_{j=1}^{n} b_{j,i}\gamma_{j,it} + u_{i,t} \qquad (3)$$

where all variables are defined as their unanticipated components. Due to the fact that one is unable to directly observes beta $\beta_{i,t}$ in equation (3), we cannot estimate the model directly. However, we could postulate a general beta market model from equation (2). Within this framework we can now substitute equation (3) for $\beta_{i,t}$ into equation (2). Thus the specific time-varying beta market model of Czech Republic's country risk to be estimated is

$$\left(R_{i,t} - R_{f,t}\right) = \alpha_i + b_{0,i} + \sum_{j=1}^{n} b_{j,i}\gamma_{j,it} + \vartheta_{i,t} \qquad (4)$$

Now we can indirectly determine the values for the parameters in equation (3) by estimation of equation (4).

According to the description in the model specification we should fit appropriate ARIMA models to estimate expect stock market reaction to the unanticipated component of the local and global variables. We find the unanticipated components as the residuals from ARIMA models fitted in Table 2. These models were identified from ACF and PACF functions of the data.

Table 2

Fitting the appropriate ARIMA models for the particular local and global variables

Variable	Brent	USDEUR	HICP EU	IR 12M	IR 3M	M1	HICP CR	Product Vol	IR 1M	CZKEUR
ARIMA(p,i,q) model	(1,1,0)	(0,1,1)	(0,1,0)	(1,1,0)	(1,1,0)	(0,1,1)	(0,1,0)	(1,1,2)	(1,1,0)	(0,1,1)

Applying the formula (4) the appropriate and validated time series model could be estimated (using the excess return of investment and the excess return of market portfolio) in equation (5) as follows

$$R_{CZR,t} - R_{ft} = b_{0,\mathrm{CZR}}\left(R_{m,t} - R_{f,t}\right) + b_{1,\mathrm{CZR}}\left(R_{m,t} - R_{f,t}\right) f_{1,t} + b_{2,\mathrm{CZR}}\left(R_{m,t} - R_{f,t}\right) f_{2,t} + b_{4,\mathrm{CZR}}\left(R_{m,t} - R_{f,t}\right) f_{4,t} + b_{10,\mathrm{CZR}}\left(R_{m,t} - R_{f,t}\right) f_{10,t} + \vartheta_{i,t} \quad , \tag{5}$$

where:

$\mathrm{R_{CZR,t} - R_{ft}}$ = the monthly excess return of Prague Stock Exchange 50 Index;

$\mathrm{R_{m,t} - R_{f,t}}$ = the monthly excess return of Euronext global price index;

$\mathrm{f_{1,t}}$ = the time series of residuals from the fitted ARIMA model for Brent;

$\mathrm{f_{2,t}}$ = the time series of residuals from the fitted ARIMA model for USD/EUR exchange rate;

$\mathrm{f_{4,t}}$ = the time series of residuals from the fitted ARIMA model for interest rates in Euro-area with 12M maturity;

$\mathrm{f_{10,t}}$ = the time series of residuals from the fitted ARIMA model for CZK/EUR exchange rate;

$\vartheta_{\mathrm{i,t}}$ = random error or a unique effect on asset's excess return;

$\mathrm{b_{0,CZR}, b_{1,CZR}, b_{2,CZR}, b_{4,CZR}, b_{10,CZR}}$ = the pricing relationship between the market risk premium multiplied by residuals fitted from particular ARIMA models and the asset's excess return.

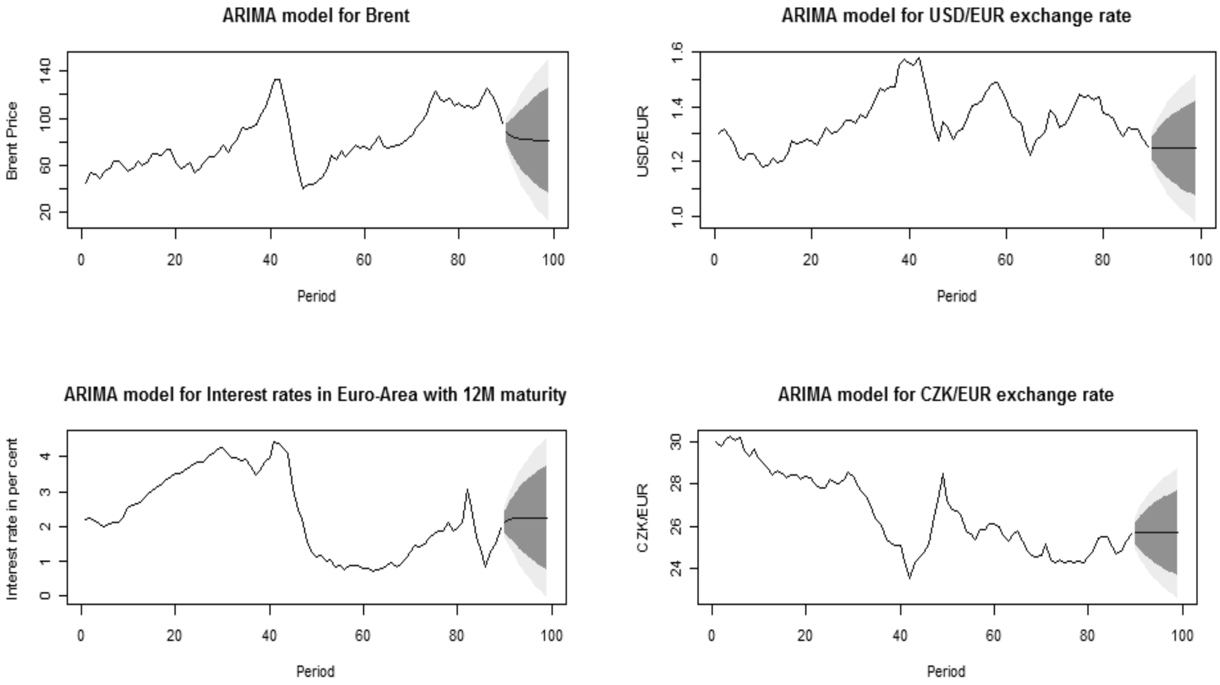

Figure 1: Fitted ARIMA models for the particular significant variable with short-term forecast

The standard goodness-of-fit test for a multiple regression is summarized in Table 3. The regression R-squared 0.8183 indicates very good fit for the model of average monthly excess return of Prague Stock Exchange 50 Index. The goodness of fit test statistic is determined by F-statistic equals to 75.64. The upper 5% critical value of the $F_{5,84}$ distribution is 2.3231. The upper 1% critical value is 3.2433, so we can conclude a very good fit for the model at 1%. Also p-value confirms signification of the model. Almost all coefficients of the multiple regressions exceed the 0.01 critical values, so we can proof that explanatory variables are significant enough to be included in the regression.

Table 3

Summary of regression equation statistics of estimated model. Source: own calculation

```
       Estimate Std. Error t value Pr(>|t|)
er_m  1.23957    0.07453  16.631  < 2e-16 ***
f1    0.05519    0.01334   4.138 8.28e-05 ***
f2   -5.26049    2.28858  -2.299   0.0240 *
f4   -0.47786    0.24652  -1.938   0.0559 .
f10   0.70539    0.17113   4.122 8.78e-05 ***
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.0287 on 84 degrees of freedom
Multiple R-squared: 0.8183,     Adjusted R-squared: 0.8074
F-statistic: 75.64 on 5 and 84 DF,  p-value: < 2.2e-16
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To diagnostic the model as the whole we test if the estimated model in Table 3 pass all tests: test of normality in residuals, test of autocorrelation in residuals, multicollinearity test, heteroscedasticity test and Regression specification error test.

For testing the normality Jarque-Bera test have been applied to estimate if there is *normality in random errors (residuals)*. We can formulate null and alternative hypothesis at 0.05 significance level as follows

H_0: Residuals are normal distributed.

H_1: Residual are not normal distributed.

According to the corresponding asymptotical p-value of 0.843 we cannot reject the null hypothesis. We could assume normality in residuals.

Durbin – Watson (DW) test was applied to *test the autocorrelation* in the residuals in our regression model. Small values of DW indicate positive autocorrelation and large values indicate negative autocorrelation. DW for large samples is approximately equal to $2 \cdot (1 - r)$, where r is the estimate of the first order autocorrelation in the residuals. DW has an expected value of approximately 2 under the null hypothesis of zero autocorrelation. Upper and lower limits D_U and D_L for the significance levels of DW from Durbin-Watson tables excluding the intercept, for almost 100 observations and 5 variables, are $D_U = 1.78$ and $D_L = 1.57$ for the 0.05 significance level and $D_U = 1.65$ and $D_L = 1.44$ for 0.01 significance level. If the null hypothesis for the test is that there is no autocorrelation in the residuals, against the alternative hypothesis of positive autocorrelation the decision rule is

if $DW < D_L$ then we can reject the null hypothesis;

if $DW > D_U$ then we cannot reject the null hypothesis; and

if $D_L < DW < D_U$ then the test is inconclusive.

According to the rule we cannot reject the null hypothesis and we can assume there is no autocorrelation in residuals (DW for our model is 1.9651 what is very close to 2 and $DW > D_U$). In addition p-value is also greater than 0.05 significance level. So we cannot reject the null hypothesis as well.

A potential problem with multiple linear regressions is that a collection of random variables is heteroscedastic, if there are sub-populations that have different variabilities from other. With other words the *heteroscedasticity* is the absence of homoscedasticity. The possible existence of heteroscedasticity is a major concern because the presence of it can invalidate statistical tests of significance that assume that the modelling errors are uncorrelated and normally distributed and that their variances do not vary with the effects being modelled. The Breusch-Pagan test is often used to test for heteroscedasticity in a linear regression model. We apply the test at 0.05 significance level with following hypothesis

H_0: Variabilities of residuals are constant (there is a presence of homoscedasticity) $\sigma_1 = \sigma_2 = \cdots = \sigma_n$.

H_1: Variabilities of residuals are not constant (presence of heteroscedasticity) $\sigma_i \neq \sigma_j$.

According to the corresponding p-value of 0.5121 that is greater than significance level, we cannot reject the null hypothesis and so we can assume the presence of homoscedasticity.

Other potential problem with multiple linear regressions is that explanatory variables may have a high degree of correlation between themselves. In this case it may not be possible to determine their individual effects. The perfect *multicollinearity* only occurs when we make a mistake in the model specification – some linear transform of one or more of the explanatory variables is included as another explanatory variable. The real problem arises when there is a high degree of multicollinearity. The regression model has been noted in the equation (5) and we use Variance Inflation Factor (VIF) to quantify the severity of multicollinearity in our ordinary least squares regression analysis. VIF provides an index that measures how much the variance of an estimated regression coefficient is increased because of collinearity. A common rule of thumb is that if VIF is higher than 5 then multicollinearity is high. The square root of the variance inflation factor tells you how much larger the standard error is, compared with what it would be if that variable were uncorrelated with the other predictor variables in the model. From the VIF of the particular coefficients is visible that we can assume low degree of correlation between them, so there is not a high degree of multicollinearity.

At the end of model diagnostic phase the *correctness of the selected model* have been tested. The model specification error has been tested with Ramsey's RESET test, which is a popular diagnostic for correctness of functional form. If the null hypothesis for the test is that there is a good specification in the model form, against the alternative hypothesis of inefficient specification of the model. Due to fact that the corresponding p-value is greater than 0.05 significance level, so we cannot reject the null hypothesis as well. So we can assume a good model specification.

Based on the estimated coefficient in Table 3, we plot the time-varying country beta of the Czech Republic in Figure 2.

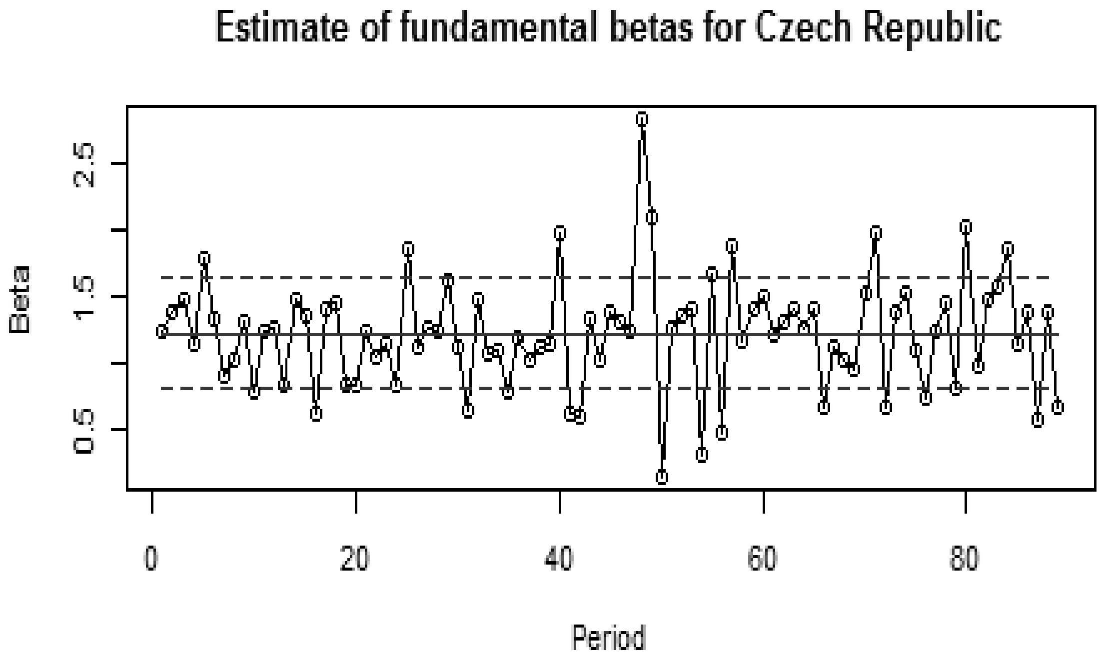

Figure 2: Time-varying country beta coefficient

A summary of descriptive statistics for Czech Republic in Table 4 shows relative low variability in estimated beta coefficient, especially if we compare our results to results of Verbenik et al. 13, who have used a different type of time series models for estimation of unanticipated changes in the particular variables.

Table 4

Descriptive statistics for Czech Republic's beta. Source: own.

Characterisitc	Values
Mean	1.226604
Median	1.251088
Max	2.823421
Min	0.160314
Standard deviation	0.416519
Skewness	0.437645
Kurtosis	1.598207
Count	89

The country equity risk helps us determinate the equity risk premium or using other words what an investor expect to earn on equities in a specific country over and above the risk free rate. The equity risk premium of a country is applicable in general to all stocks within the country. According to common understanding one can apply the CAPM model to determinate country equity systematic risk and so on the country equity risk premium is multiplied by a global equity index risk premium and the relevant country equity systematic risk in form of beta coefficient. There are many disadvantages of static form of simple or multiple linear regression models as well.

To avoid these problems we have used time-varying beta model in this paper and a viable econometric model has been specified and fitted. This model describes systematic equity risk of the Czech Republic and hereby enables us to understand how the systematic risk varies over time. Equity risk premiums come into play at every step in investing. At the asset allocation stage, where we determine how much of our portfolio we will be allocating to different asset classes and to different geographical areas. Naturally we have to make judgements of which markets we are getting the best risk to return trade off and allocate more money to those markets. In all these issues we will need use equity risk premium and therefore equity systematic risk.

Over the last decades one of the central issues in financial economics has been the estimation of the equity risk premium in valuing different investment opportunities in capital markets. In our study we tackle a problem whether and which local and global risk factors have varying degrees of influence on country risk in Czech Republic. Under country risk we understand country equity systematic risk or so called country beta. We have extended portfolio theory in an international framework by applying the works of Markowitz and his followers who derived the Capital Asset Pricing Model in an international context. We address this issue de facto by investigating the return properties and potential diversification benefits from investing abroad and their effect on expected returns. To demonstrate the applicability of our model we use financial econometrics involving three plain key steps – model selection, estimation and diagnostics. We suggest a variety of local and global factors (eleven variables) that potentially could influence country systematic risk of the Czech Republic. We focus on unanticipated component of the fundamental variables, thus we focus on the unanticipated or unexpected components, which we find as the residuals from ARIMA models. We have fitted an appropriate model expresses in analytical part of the paper. The most significant coefficient or explanatory variables which indirectly affect systematic risk of Czech Republic are selected using model estimation and model diagnostics. We have applied relevant residuals of ARIMA models for Brent Oil Price Index, USD/EUR exchange rate, interest rates of Euro-Area with 12 months maturity and CZK/EUR exchange rate. Tests are indicating an absence of autocorrelation and heteroscedasticity in the model. The applied model can be used to determination of systematic risk of the Czech Republic or so called time-varying country beta of the Czech Republic. It also helps investors to estimate and determinate equity risk premium for capital market invest within the Czech Republic.

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ФІСКАЛЬНА БЕЗПЕКА УКРАЇНИ В СИСТЕМІ ЕКОНОМІЧНОЇ БЕЗПЕКОЛОГІЇ

В умовах поглиблення геофінансових викликів посилюється роль і значення подальшого розвитку знань про безпеку в широкому розумінні [1; 2]. З накопиченням знань безпекознавство, як й кожний науковий напрям перетворюється на науку – безпекологію, в якій нині формується комплекс поглядів, що спрямовані на тлумачення і пояснення явищ безпеки.

Як будь-яка наука, безпекологія потребує чітких теоретико-методологічних (наукових) підходів, а саме конкретизації об’єкта і предмету дослідження, структури та чіткішого визначення понятійно-категоріального апарату, пріоритетності забезпечення тощо. За побудовою безпекологія є наукою, цілісною системою знань, у якій всі її елементи взаємозалежні, становлять сукупність тверджень, категорій, понять, що визначені за певними методологічними принципами.

Безпекологія, на нашу думку, це наука, яка вивчає закономірності ефективного забезпечення безпеки у соціальних, біологічних, технічних та інших системах, котрі реалізуються за допомогою відповідних відносин у сфері безпеки. В залежності від сфери безпеки, безпекологія як наука має теж свої види (різновиди). Мова йде про безпекологію в політичній, військовій, екологічній, інформаційній, економічній та інших сферах.

Економічна безпекологія – це наука, яка вивчає закономірності ефективного забезпечення безпеки економічних систем, своєчасного виявлення,