The Value of the Firm in Dependence on Technological Shocks – the Czech Republic Case

Hodnota firmy v závislosti na technologických šocích – zkušenosti z České republiky

PETR MAKOVSKÝ

Abstract

The article presents an innovative interpretation of the relationship between firm value and technological shocks. The motivation comes from the theory of technological shocks and their effects on the economy. We tried to confirm the hypothesis of neoclassical technology of the firm regarding the relationship between firm value and investment amount (interconnected with the interest rate). The relationship was empirically tested using a sample of data for the last 16 years (quarterly data). The Solow residuals represent the technological shocks and the PX index is an approximation of the firms´ value. The model explaining the rate of growth of the PX index in dependence on the Solow residuals is confirmed, but the linear coefficient is negative. However, it is close to zero value, which means that there is no dependence between the observed variables. The falsification of the neoclassical firm approach is argued using the Czech economy as an open small economy with high interdependence on the financial sector. Due to the presented solution, we secondly tried to explain the evolution in the firms´ value using autoregressive methods. We ran GARCH tests in order to gain a proper model of the PX index's rate of growth behaviour. The most appropriate model was the GARCH (2,1) model. Moreover, we made a forecast of the volatility of the PX index. The theoretical values of the forecast fit the empirical data we observed. Furthermore, we discuss the features of the model on two levels: the whole time horizon of observations (quarterly horizon 1999-2015, 85 observations) and the post-crisis horizon (quarterly 2010-2015, 25 observations).

Keywords

technological shocks, GARCH, firm value, volatility, time series analysis, variance

JEL Codes

E22, G17

Abstrakt

Článek přibližuje inovativní interpretaci vztahu mezi hodnotou firmy a technologickými šoky. Prvotní motivaci jsme získali na základě závěrů teorie technologických šoků a jejich dopadu na ekonomiku. Primární testovaná hypotéza je sestavena na závěrech neoklasické teorie firmy a vypovídá o vztahu mezi hodnotou firmy a investicí do fyzického kapitálu (i na základě vývoje úrokové míry). Samotný vztah byl v příspěvku testován na vzorku dat české ekonomiky za posledních 16 let (kvartální data). Jako aproximaci technologického šoku uvažujeme vývoj Solowových reziduí, aproximací hodnoty firem v ČR je vývoj indexu PX. Model, který vysvětluje tempo růstu indexu PX za pomoci vývoje Solowových reziduí je možno sestavit. Nicméně lineární koeficient regrese je negativní. Hodnota koeficientu je velmi blízko nule, což značí spíše nezávislost hodnoty firem v ČR na technologickém pokroku. Falzifikace primární hypotézy je argumentována českou ekonomikou jako malou otevřenou ekonomikou s významnou mírou propojenosti vzhledem k zahraničnímu i vnitřnímu finančnímu sektoru. Na základě představených závěrů jsme nabídli alternativní hypotézu, která vysvětluje hodnotu firmy na vzorku dat české ekonomiky autoregresním přístupem GARCH. Provedli jsme několik testů typu GARCH, abychom získali uspokojivý model vývoje indexu PX (hodnoty firem). Nejvhodněji se jeví GARCH (2,1). Tento model uspokojivěji vysvětluje vývoj hodnoty firem v ČR než technologické šoky. Navíc jsme představeným modelem provedli předpověď volatility indexu PX a nyní můžeme konstatovat, že teoretické předpovědi modelu odpovídají empirickým pozorováním v současnosti. Dále jsme diskutovali vlastnosti modelu ve dvou rovinách. Zaprvé v kontextu celého vzorku dat (kvartálně od roku 1999 do roku 2015, 85 pozorování), zadruhé na vzorku dat po krizi v roce 2008 (kvartálně od 2010 do roku 2015, 25 pozorování).

Klíčová slova
technologické šoky, GARCH, hodnota firmy, volatilita, analýza časových řad, rozptyl

Introduction

Pastor and Veronesi (2005) have provided conclusions on the explanation of technological shocks. Technological shocks influence parts of the economy in different ways. There is a lag in the "old economy"'s absorption of technological shocks in comparison with that of the "new economy". This is why we observe technological bubbles. According to previous theory, the technological shock explanation is consistent with the goal to maximise firm value. We are interested in the dependence of firm value on technological shocks. More particularly, this means the technological progress. In this article we assume there to be little difference between technological shock and technological progress (or regression).

The main purpose of this article is to evaluate the verification of the neoclassical theory of investment using a data sample for the Czech Republic economy, and if this relationship is falsified, to find an alternative.

In the following analysis we assume the firms´ value in the Czech Republic to be approximately the same as the value of the PX index (the index of the Prague stock exchange market). On the other side, the technological shocks are measured in the form of Solow residuals. The primary hypothesis is that an increase in technological progress causes an increase in firms´ value in the economy. If this is falsified, we expect the alternative hypothesis to hold about the value of firms being dependent on the previous values of the firms.

Further connected literature has been interested in the interdependency between the financial sector and real economy processes (Wickens 2012) or in modelling of volatility of financial variables (Cipra 2008). The contemporary state of research of primary hypotheses and alternatives more or less consists of two methodological areas. The first is the meaning and explanation of pure economic theory, and the second is the time series analysis approach, which concentrates on variable modelling and forecasting (sometimes on the equilibrium state between confirmation of variables).

The presented relationships of both approaches have been empirically tested using data samples for various financial time series across various economies, for instance analysis of the Czech Republic case of the FOREX market (Pošta 2012a, 2012b). The theoretical solutions have been argued on the basis of the C-CAPM model (consumption-based) and these arguments were discussed in Cochrane (2009). It is important to state that for small open economies, according to these empirical results, the risk premium dependency is weakened. There is a space for other explanatory variables, for example technological progress.

1 Methodology – economic theory analysis

In this study we used the theoretical conclusions of pure macroeconomic theory and time series analysis. First we found a suitable approximation for firm value: the rate of growth of the PX index. Technological progress is most appropriately simulated with the evolution of the so-called Solow residuals. These are calculated from the production function of the economy, assuming standard features.

Here we prefer the real business cycle theory (Lucas 1975), which is why we assume the potential product growth is the same as the real GDP growth. So here we see the basis of our analysis. We need to calculate the real GDP and subtract the influence of the input factors (labour, physical capital). Then we achieve the residuals, which represent technological progress. This is standard usage of the growth accounting equation (Solow 1988). Although the approach is said to be obsolete, in many way it is much more useful than the variety of innovation indices, in which we observe subjective biases. Solow residuals are gained from nominal GDP rates, gross fixed capital formation, evolution of labour amount and the deal of valued physical to GDP. The Solow residuals are achieved from Equation 1.

$$y_t = \psi_t + w * l_t + (1-w)k_t \tag{1}$$

where y_t is the rate of growth of real GDP, ψ_t is the Solow residuum in a particular year, w is the deal of labour force (financial value) to the nominal GDP, the growth rate of the labour force and, k_t is the growth rate of physical capital (gross fixed capital). Then *(1-w)* is the deal of capital to nominal GDP. Although modern mainstream theory does not reject the growth accounting equation (Equation 1) alternatives have appeared for technology progress measurement, for instance Mihola and Wawrosz (2014).

The dependency between firm value (rate of growth of the PX index) and technological shocks (relative change in the Solow residuals) is theoretically based on the pure theory of the firm. The value of the firm is the sum of future discounted economic profits. The value of the firm (Pindyck 1986) is calculated according to Equation 2:

$$VoF_t = \sum_{j=0}^{\infty} E_t \beta^j \pi_{t+j} \tag{2}$$

where *VoF* is the value of the firm, E_t is the expectation in time, β_j is the discount factor in time from *t,* and π_{t+j} is the future economic profits. As there is an increase in physical investment, this is interconnected with lower interest rates. This low general interest rate forms the discount factor in an inverse way. This is why we expect that higher technological progress leads to lower interest rates and this also leads to higher value of the firm according to Equation 2.

2 Methodology – time series analysis

The second part of our analysis concerns time series analysis. The alternative method for modelling the value of the firm for our purposes is autoregressive conditional heteroscedasticity (ARCH). There are many ARCH-based approaches (Bollerslev, Engle & Nelson 1994). These methods provide both the regression equation for the mean value and the variance regression equation. The ARCH approach uses the lagged value of the "white noise" stochastic process to explain the value of contemporary variance. Thus the ARCH method belongs to the autoregressive time series analysis methods (Box-Jenkins methodology). The generalised ARCH (GARCH) further expands the analysis on the lagged value of conditional variance.

ARCH (q) is the stochastic process following Equation 3:

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \tag{3}$$

where $\alpha_i > 0$, $\omega \geq 0$ for all $i > 0$.

The stationary condition is that all of the roots of the polynomial equation are inside the unit circle. Unconditional variance of the stochastic process ε_t does not differ through time, moreover it provides unconditional homoscedasticity. The prediction ARCH(q) in horizon *h* is calculated according to Equation 4.

$$\sigma_{t+h/t}^2 = \hat{\omega} + \sum_{i=1}^{q} \hat{\alpha}_i \varepsilon_{t+h-i/t}^2 \tag{4}$$

Here the $\varepsilon^2_{t+i/t} = \sigma^2_{t+i/t}$ for all $i > 0$, but when $\varepsilon^2_{t+i/t} = \varepsilon^2_{t+i}$ for all $i \leq 0$.

In contrast with the ARCH procedure, the GARCH approach is a modification of the previous model with delayed conditional variance (Nelson, 1990). It is useful to calculate GARCH when there are many parameters α in ARCH (for high q). The ARCH has its useful features using higher *q*. With knowledge of this we prefer the GARCH (1,1) approach to ARCH.

It is necessary to state that the presented time series methods provide a useful statistical confirmation, but the meaning is more technical than empirical. In other words, conclusions based on the explicit explanation of autoregressive-based methods are more difficult to draw, but this has been explained in the further literature (Makovský 2014). There is an advantage for the economic meaning of problem-solving.

3 Data

In order to provide the empirical analysis we used a data sample of the variables from 1997 to 2015 in the Czech Republic economy. We modified the data into quarterly data which are each the moving averages of 60 observations. This time series was transformed into differences of logarithm. For small changes, this is an appropriate approximation for the relative change of the variable – the rate of growth of the PX index or the percentage evolution of the Solow residuals. Moreover, the logarithmic transformation provides better features for the linear regression model which we wanted to use (mainly stationary). The data sample for the PX index was gained from the database of the Prague Stock Exchange. Other variables were gained from the Czech Statistical Office. Finally, for all the variables we removed the seasonality from the time series using the Hodrick–Prescott filter (Hodrick & Prescott, 1997). The dataset is structured according to Table 1. Readers may be surprised that for many quarters we see negative technological shocks (negative contribution). As far as we are aware, our calculation has no mistakes, but there might be differences from the official statistics, in which there are many adjustments. Moreover, we used the gross physical capital formation not the physical capital evolution. We used quarterly data and avoided seasonality in order to be able to find the relationship to the financial data of the PX index. Nevertheless the main purpose of this article is to verify whether there is any relationship between the rates of growth. This means that a small increase (connected with an official adjustments) in all the values in the data series does not matter. The complete dataset can be found in Annex 1.

Table 1: Data for analysis

	T (quarter)	nGDP (bn CZK)	wages + salaries (bn CZK)	L (amount of labor)	W	K (amount of capital)	rate of growth nGDP	rate of inflation (%)	rate of growth rGDP	rate of growth L	rate of growth K	Technologic progress (%)	PX index	rate of growth PX
1997	Q1	439.6	177.9	nGDP	0,40	136098	0,076	7,162	0,482	-2,463	-0,901	-2,360	579,3	-0,011
	Q2	484.6	204.6	2374345	0,42	149910	0,075	6,596	0,944	0,336	1,811	-3,141	569,5	-0,040
	Q3	502.3	196.8	2335886	0,39	154169	0,076	9,860	-2,291	0,045	-2,810	-3,652	510,9	-0,041
	Q4	526.8	218	2438651	0,41	185612	0,083	10,100	-1,849	0,382	7,018	-3,866	532,8	-0,023
1998	Q1	484	191.9	2265713	0,40	155940	0,101	13,299	-3,195	-2,249	14,579	-3,043	501,4	-0,034
	Q2	541.2	210.2	2428820	0,39	158020	0,117	12,690	-0,994	2,294	5,410	-0,916	479,0	-0,024
	Q3	554.5	204.9	2266195	0,37	161173	0,104	9,511	0,875	-2,983	4,543	0,096	467,5	-0,015
	Q4	562.8	230.2	2440186	0,41	177652	0,068	7,478	-0,643	0,063	-4,289	0,449	426,8	-0,009
2015	Q1	1 035.4	427.4	2298923	0,41	247738	0,053	0,126	5,172	-0,094	4,876	-0,473	966,9	0,001
	Q2	1 121.4	443.5	2383449	0,40	279688	0,052	0,654	4,512	2,438	10,114	-1,136	1002,8	0,003
	Q3	1 141.6	440.9	2198483	0,39	298686	0,045	0,391	4,139	1,769	8,828	-0,725	1018,6	-0,005
	Q4	1 173.9	475.1	2332938	0,40	327069	0,049	0,126	4,769	3,285	8,737	-0,353	1008,9	-0,009

Source: own calculations in MS EXCEL

Notice: All input data are gained from the CZSO database. We found the real GDP growth rate on the basis of the quarterly nominal value of GDP by the expenditure method and the quarterly average of the inflation rate (year-on-year moving average). The growth rate of capital was obtained on the basis of the evolution of gross fixed capital formation and the rate of change in the workforce, based on the number of recalculated employees by hours worked. The labor force share on the GDP in individual quarters was based on the nominal GDP structure based on the income method. The share of capital on the product is a complement to one of the labor force share on the product.

4 Economic analysis

Table 2 presents the descriptive statistics. There are two variables in the relative changes, rate of growth of the PX index (vPX) and relative change in the Solow residuum (vS). We see that the mean value is stable (non-zero). The PX index increases in a stable way, but the relative change in the Solow residuals decreases. Both movements are less than a 0.2% change. The standard deviation is greater in the vPX variable than in the vS.

Table 2: Descriptive statistics

	Mean	Median	Maximum	Minimum	Std. dev.	Skewness	Kurtosis	Jarque-Bera	P-value
vPX	0.015009	0.001120	0.129519	-0.069180	0.049490	0.741026	2.749616	7.812967	0.020111
vS	-0.139416	-0.308511	4.127763	-3.866459	1.889717	0.208883	2.683534	0.869815	0.647324

Source: own calculations in Eviews

When the best prediction of stochastic variable is its present value, then the stochastic process is called martingale. The random walk stochastic process is less restrictive than the martingale process. In the case of martingale, we assume independence of the iid (identically independent distribution) residuals from the AR process, but the conditional variance is not iid. We are able to predict the future conditional variance from the previous variance. This assumption is broken for the random walk stochastic process (Cuthberson & Nitzsche 2005).

Here we observe a well-known fact from the financial markets. We are able to reject the null hypothesis of normality for the vS (represents the real sector). But the same hypothesis cannot be rejected normality for vPX (this does not mean that the vPX follows normal distribution).

An unsatisfactorily high level of autocorrelation appears in the relative changes of the analysed variables. Better input data features are gained through transformation into logarithms: then we can use the logarithmic differences. These are approximately the same as the relative changes. The primary transformation of the PX index is clear. The problem appeared in the case of the Solow residuals. These are sometimes negative. We had to sum to all values of variable its minimum. This drift is avoided through following differentiation. Table 3 shows more from the analysis of the process (PX is the PX index, firm value; S is the Solow residuum, technological process).

Table 3: Series statistics

	$lnPX_t - lnPX_{t-1}$ (vPX)	$lnS_t - lnS_{t-1}$ (vS)
Correlogram	No autocorrelation for first and second lagged values	No autocorrelation
Augmented Dickey-Fuller test	Does not have a unit root	Does not have a unit root
Jarque-Bera test	55.828 (p-value: 0.000)	334.2148 (p-value: 0.000)

Source: own calculations in Eviews

Both analysed time series are stationary. We were able to run the regression analysis in order to analyse the interdependence between the rate of growth of the PX index and the percentage change in the Solow residuals. Neither of these time series have a unit root and they are not auto correlated. We provide the regression analysis maximally to the second lagged values (two quarters).

Table 4: Regression analysis

	vPX=c(1)+c(2)*vS	**vPX=c(1)+c(2)*vS(-6)**	**vS =c(1)+c(2)* vPX**
C(1)	*0.0722 (p-value:0.5744)*	*0.0093(p-value:0.468)*	*0.0149(p-value:0.73)*
C(2)	*-0.042 (p-value:0.2199)*	*-0.075 (p-value:0.0286)*	*-0.479(p-value:0.22)*
DW statistics	*1.483033*	*1.641415*	*1.226960*
Prob. (F-statistics)	*0.219892*	*0.028606*	*0.219892*

Source: own calculation in Eviews

We do not present the solution for the first value lagged relationship. It provides more or less similar results to the second lagged relationship. Now we provide a few comments on the solutions presented in Table 4. Here we can see that the inverse relationship is not confirmed. According to the statistics, technological progress is not a function of firm value. We are further able to generalise the presented statement for the lagged values modification.

To sum up the analysis, we see that a non-delayed relationship between firm value and technological progress is, in the data sample for the Czech economy, falsified. We are not able to reject the null hypothesis for the constant to be zero. The same result appears for the linear regression coefficient. Firm value is not a function of the present technological progress.

But there are different solutions for the analysis of lagged variables. We are not able to reject the null hypothesis for the constant to be zero again. But we do reject the null hypothesis for the linear regression coefficient at a statistical significance of 5%. The value of this linear coefficient is -0.075 (the value for the first lagged situation is close at -0.07). Firm value is a function of the lagged technological progress (for a half year). The regression formula is described in Equation 5. The Durbin–Watson statistics achieve a suitable value. This speaks for the non-auto-correlated regression residuals. Furthermore, the F-statistics bring conclusions on the suitability of the regression model at all. The interconnection between Equations 2 and 5 is that an increase in technological progress leads to an increase in investment in physical capital, which causes an increase in future economic profits and in the value of the firm. The data observation fits the following empirically tested Equation 5:

$$VoF(\%) = -0{,}07 * Tech.progress\ (\%) \tag{5}$$

Using the data sample for the Czech Republic, we have drawn a conclusion about the negative influence of technology shocks on firm value. According to our analysis, a percentage increase in technology leads to a 0.07% decrease in firms' value in the Czech Republic. Our primary hypothesis on the positive dependence of firm value on technology shocks is rejected. The primary hypothesis is built on the idea that a positive shock in technology leads to an increase in firms' investment in physical capital. These investments are essentially interconnected with the lowering of the general interest rate. Finally, this lower interest rate increases the present value of the total discounted sum of economic profits. We must repeat the conclusion that there is a negative dependence between the variables. More generally, according to the almost null value of the coefficient, there is no relationship between the analysed variables.

We need to further discuss the primary assumptions of the linear regression. These are the a) metric valued endogenous variable, b) metric valued exogenous variables, c) absence of multicollinearity, d) elimination of observed outliers in the data, e) linear relationship between the variables, f) normal distribution for all the variables, g) homogeneity in variance (homoscedasticity). In the presented analysis, some of these assumptions are confirmed (linearity through decadic logarithm linearisation), but some do not fit completely (for instance the normality assumption). These problems are connected with the inappropriate usage of linear regression in economic dynamics studies.

5 Time series analysis

In order to provide a more useful solution to our problems, we used autoregressive methods. As was presented in the theoretical section, we used the method of autoregressive conditional heteroscedasticity (ARCH) or generalised autoregressive conditional heteroscedasticity. In other words, we have tried to explain the evolution of the PX index (rate of growth in the PX index) using the (G) ARCH methodology. The starting point in this following analysis is the Box-Jenkins methodology, which assumes that the evolution of a time series is explained through the stochastic process with the random part.

For the volatility modelling we used the autoregressive conditional heteroscedasticity (ARCH), which is useful in the evolution of financial risk and uncertainty in a time series. A more simple explanation is the linear regression of conditional variance. The conditional variance is a function of the delayed squares of the residuals of the stationary autoregressive process. The delayed conditional variance is added in generalised ARCH (GARCH).

The persistence of variance is explained with the additional assumption of the autocorrelation function being hyperbolic (long memory process). The shock influences the variance in the long term. The conditional variance relies on the input conditions, no matter how far the prognosis is.

Non-linear models are able to foresee the asymmetric effect. This means that the impacts of positive and negative shocks on the variance are different. Let us explain this using implicit contracts. These assume firms to be risk neutral, while consumers are risk averse (Mankiw 2014). In this section we try to create a model of the volatility of the PX index. This is built in consequence to the discovery of the falsification of the previous hypothesis on firms' dependency on the technological progress.

First we calculated the autocorrelation function and PACF function of the logarithmic difference of the PX index (dlPX), which is approximately the rate of return of the PX index. This was done in order to gain the appropriate level of lag. The Eviews output gives information about autocorrelation through a graphical solution and the so-called Q-statistics (p-value 0.058). For the dlPX evolution, we are not able to falsify the hypothesis of no autocorrelation for the lags up to two.

The second-level lag in the autocorrelation results in the volatility model GARCH (1,1). Moreover, this specification does not contradict the practical experience. A smart money trader predicts volatility based on the information of volatility in the previous period and further on newly gained innovative information. If the yield is abnormal in both directions, the trader takes a new volatility estimation for the following period. GARCH (1,1) is also useful in explaining volatility clustering. This means that higher changes in volatility last for a longer time and the probabilistic distribution is leptokurtic (Cont 2007).

Here, we wish to make a few comments about the result of testing the GARCH (1,1) on the empirically observed data. The mean value is not confirmed at the value of 0.01544% at a 5% level of statistical significance as presented in Figure 1. The mean value is the null value as we have seen from the previous analysis.

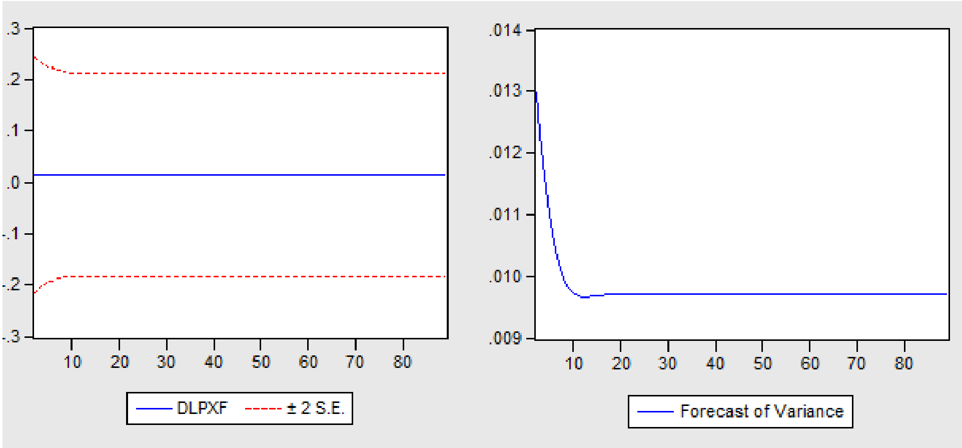
The variance equation falsifies the constant and GARCH term at a 5% statistical significance. Moreover, the ARCH term is verified. Now, according to our previous analysis from the autocorrelation analysis we ran the test up to the second lag. The results are presented in Table 2 (Annex 2).

The lagged analysis provides a better solution. Once again we falsified the non-zero mean value. But the ARCH terms are verified and the GARCH term up to the first lag is also verified at a suitable level of statistical significance. The second lag GARCH term is falsified.

In contrary with the conclusions from the previous "economic" analysis, we have been able to create a model explaining the evolution of the rate of growth in the PX index (firms´ value in the Czech economy in the last 15 years). The previous statement is an alternative which is confirmed in the data sample for the Czech Republic's economy upon the rejection of the primary hypothesis.

Volatility is dependent on the volatility in the previous period (previous quarter) and on the random part of stochastic processes. The whole analysis is made in a range from 1999 to 2015 (quarterly data, 85 observations). Here in Figure 1 we tried to use the model for forecasting future evolutions in volatility. We made a prognosis for one year (4 observations). At the time of creating this contribution, we were able to gain the data for half of 2016 and compare. The forecast for the four periods of 2016 predicted stable volatility. For those who might argue with the wide spread between the four times' standard deviations, we need to highlight that there is a percentage analysis. The spread is then much smaller and appropriate.

Figure 1: Forecast of PX volatility based on the GARCH (2,2) model for 2016

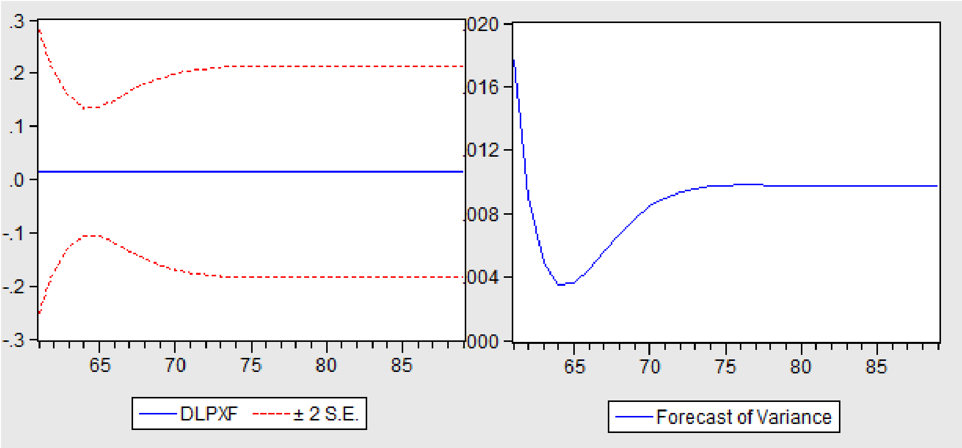


Source: own calculations in Eviews

In Figure 2 we present the forecast of PX volatility of the GARCH (2,2) model, which considers the just post-crisis period (2010 to 2015, 25 observations). The model is based on the whole period analysed. It is not confirmed in the post-crisis period data (insufficient amount of observation).

The output for the post-crisis data predicted a decrease in volatility in the first post-crisis year (2009) and an increase in the second post-crisis year (2011). For the rest of period the forecast predicts stable volatility at 0.8%.

Figure 2: Forecast of PX volatility based on the GARCH (2,2) model for 2016 – post-crisis period



Source: own calculations in Eviews

The alternative hypothesis is confirmed. We have found a useful explanation of firm value. Remember that the pure economic theory of capital was falsified in the data sample for the Czech Republic economy. In contrast with the previous falsification of the primary hypothesis, we verified the alternative explanation of firm value by its previous values and random factor (white noise). This GARCH methodology provided a useful solution and we made a prediction for the whole year 2016 (four quarters). The main purpose of this article has been achieved. According to the results of our research, we prefer the time series analysis, mainly GARCH (2,2), to the neoclassical theory of capital for the future prediction of the value of firms in the Czech Republic economy. This idea is based even on the evolution during the economic crisis in 2008.

Conclusions

The main purpose of this article was to evaluate the verification of the neoclassical theory of investment using a data sample for the Czech Republic economy, and if this relationship was falsified, to find an alternative. We were particularly interested in the effects of technological shocks on firm value. In order to achieve this goal, we tested the primary hypothesis that an increase in technological shock causes an increase in firms´ value in the economy. According to pure economic theory, firm value is dependent on technological progress. We calculated the Solow residuals from the nominal GDP evolution and tried to explain the evolution in the rate of growth of the PX index (approximation for firm value). Based on this empirical data sample from 1999 to 2015, we were able to gain the regression model (no spurious regression). The problem is the negative value of the linear coefficient where we expected a positive value. The primary hypothesis of this article is thus rejected. It is necessary to mention that the coefficient is about small percentage values. We have falsified the original hypothesis on the dependence of firm value on technological progress. But we are able to make the statement that there is no relationship between technological progress and firm value. This statement is arguably due to the Czech Republic being a small open economy in which there are other factors than just real factors.

The main goal of this article is achieved in the statement of the falsification of the relationship. A useful evaluation should contain alternatives. An alternative for the firms´ value explanation is its dependence on the previous values of firms. This alternative hypothesis was tested using the GARCH methodology (models explaining the volatility of a time series). The presented conclusions are connected with the evolution of the international financial sector. In order to provide an alternative research method for the presented problem, we ran GARCH tests, meaning that we were interested in the time series analysis of the evolution of the PX index.

The autoregressive methodology GARCH provides a useful solution for the PX index (approximation for the firms´ value). We confirmed the GARCH (2,1) model. The volatility of the rate of growth of the PX index is explainable with its previous volatility (the GARCH term) and with not up to three lagged values of the stochastic process "white noise".

Furthermore, we ran forecasts for 2016 (4 quarters observations) using the presented model on first the whole dataset and secondly on the dataset involving the post-crisis period (2010 to 2016). In the first half of 2016 we are able to confirm the theoretical values of the GARCH volatility forecast using the actual values of the volatility.

Finally, although we rejected the primary hypothesis, the alternative relationship was confirmed. The firms´ value volatility (PX index rate of growth) is explained with the previous values of volatility and the stochastic process called white noise. The presented model built on the data sample of 1999q1 to 2015q4 predicts the stable volatility for 2016q1 to 2016q2, which fits the observed volatility. We observed martingale behaviour of the PX rate of growth.

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Contact address

Ing. Petr Makovský, Ph.D.
Czech Technical University in Prague, School of Business and Interdisciplinary Studies, Department of Economic Studies
University of Economics in Prague, Faculty of Business Administration, Department of Microeconomics
(petr.makovsky@vse.cz)

Appendix 1

T	T (quarter)	nGDP (mld CZK)	wages +salaries (mld. CZK)	L (amount of la	W (%)	K (amount of Capital)	rate of nGDP (%)	rate of inflation (%)	rate of rGDP (%)	rate of L (%)	rate of K (%)	Technologic progress (%)	PX index	Rate of growth PX (%)
2005	Q1	748169	301131	2244128	0,402	202255	0,077395079	1,631	6,109	3,087	5,286	-0,265	970,651	0,112
	Q2	816100	319755	2357820	0,392	232846	0,082296149	1,553	6,677	2,496	7,876	-0,919	1144,876	0,082
	Q3	823330	323815	2110089	0,393	230170	0,060457939	1,853	4,193	2,142	7,288	-1,373	1158,516	0,052
	Q4	870373	354496	2232445	0,407	256548	0,045116475	2,394	2,117	0,078	7,590	-1,316	1327,391	0,056
2006	Q1	797802	323376	2298728	0,405	219956	0,06633929	2,833	3,801	2,433	8,752	-1,100	1403,704	0,029
	Q2	870410	342995	2294343	0,394	236785	0,066548217	2,897	3,758	-2,692	1,692	-0,959	1532,591	0,019
	Q3	896437	345783	2110322	0,386	239984	0,088794287	2,895	5,984	0,011	4,264	-2,167	1401,840	-0,001
	Q4	942482	381880	2271696	0,405	286226	0,082848388	1,491	6,794	1,758	11,568	-3,128	1423,911	0,017
2007	Q1	882421	353927	2321185	0,401	264926	0,106065164	1,547	9,059	0,977	20,445	-3,477	1558,773	0,014
	Q2	949243	371302	2339194	0,391	272323	0,090569961	2,466	6,591	1,955	15,009	-3,236	1667,011	-0,008
	Q3	976901	374791	2126216	0,384	274900	0,089759793	2,491	6,485	0,753	14,549	-2,964	1826,965	-0,027
	Q4	1023254	413234	2301001	0,404	320243	0,085701371	4,762	3,808	1,290	11,885	-2,710	1782,596	-0,053
2008	Q1	926672	390484	2338911	0,421	287716	0,050147265	7,364	-2,349	0,764	8,602	-2,218	1831,455	-0,056
	Q2	1014549	401015	2411508	0,395	288023	0,068797979	6,767	0,113	3,091	5,765	-0,647	1529,384	-0,069
	Q3	1039324	397976	2235738	0,383	287439	0,063899003	6,665	-0,275	5,151	4,561	0,393	1608,038	-0,041
	Q4	1034801	427374	2327473	0,413	302154	0,011284588	4,564	-3,435	1,150	-5,649	1,407	1393,169	-0,056
2009	Q1	929368	383943	2317023	0,413	254033	0,002909336	2,163	-1,872	-0,936	-11,707	1,696	855,647	-0,032
	Q2	980926	387882	2367413	0,395	256036	-0,033140834	1,411	-4,725	-1,829	-11,106	0,722	723,556	0,052
	Q3	987262	379975	2151086	0,385	262793	-0,050092175	0,245	-5,254	-3,786	-8,574	0,181	901,689	0,093
	Q4	1024271	416761	2254060	0,407	290610	-0,01017587	0,433	-1,451	-3,154	-3,821	-0,191	1106,720	0,048
2010	Q1	914538	377961	2341325	0,413	234033	-0,015957081	0,665	-2,261	1,049	-7,873	-0,730	1136,475	0,002
	Q2	1000113	390410	2393712	0,390	254611	0,019560089	1,166	0,790	1,111	-0,557	-1,308	1169,467	-0,005
	Q3	1004700	394692	2127038	0,393	275386	0,017662991	1,933	-0,166	-1,118	4,792	-1,634	1191,555	-0,013
	Q4	1034300	425989	2239016	0,412	301975	0,009791354	2,095	-1,116	-0,667	3,911	-1,223	1161,760	-0,020
2011	Q1	933307	388179	2371954	0,416	239686	0,020522931	1,733	0,320	1,308	2,415	-0,652	1164,304	-0,018
	Q2	1012128	402675	2393930	0,398	258857	0,012013642	1,793	-0,591	0,009	1,668	-0,336	1238,631	-0,021
	Q3	1017894	402461	2093999	0,395	268779	0,013132278	1,733	-0,419	-1,553	-2,399	0,008	1239,275	-0,038
	Q4	1059182	432428	2246635	0,408	301670	0,02405685	2,399	0,007	0,340	-0,101	-0,337	1035,605	-0,043
2012	Q1	954584	401352	2357115	0,420	243732	0,022797429	3,665	-1,385	-0,626	1,688	-0,327	894,920	-0,011
	Q2	1016849	410327	2329392	0,404	258154	0,00466443	3,397	-2,931	-2,696	-0,272	0,164	986,102	0,019
	Q3	1016439	408397	2037982	0,402	262999	-0,001429422	3,264	-3,407	-2,675	-2,150	0,606	895,724	-0,002
	Q4	1053738	443392	2270927	0,421	287225	-0,005139815	2,803	-3,317	1,081	-4,788	0,927	932,275	0,019
2013	Q1	941608	401285	2260677	0,426	230138	-0,013593356	1,764	-3,124	-4,091	-5,577	1,294	989,709	0,012
	Q2	1015585	415031	2326379	0,409	242963	-0,001243056	1,523	-1,648	-0,129	-5,884	1,051	1008,580	0,000
	Q3	1034183	415610	2111926	0,402	260252	0,017457024	1,221	0,525	3,628	-1,044	0,745	950,239	-0,005
	Q4	1085733	442601	2258534	0,408	291438	0,030363335	1,115	1,921	-0,546	1,467	0,923	947,803	0,008
2014	Q1	983311	411234	2301089	0,418	236220	0,044289131	0,200	4,229	1,788	2,643	0,777	997,105	0,009
	Q2	1066281	424121	2326713	0,398	253998	0,049918028	0,200	4,792	0,014	4,542	0,319	1006,351	-0,002
	Q3	1092149	422891	2160266	0,387	274458	0,056050041	0,594	5,011	2,289	5,459	-0,177	1011,273	-0,004
	Q4	1119145	454084	2258734	0,406	300788	0,03077368	0,648	2,429	0,009	3,208	-0,323	975,612	-0,006
2015	Q1	1035402	427392	2298923	0,413	247738	0,052975101	0,126	5,172	-0,094	4,876	-0,473	966,939	0,001
	Q2	1121364	443450	2383449	0,395	279688	0,05165899	0,654	4,512	2,438	10,114	-1,136	1002,798	0,003
	Q3	1141631	440940	2198483	0,386	298686	0,045307005	0,391	4,139	1,769	8,828	-0,725	1018,619	-0,005
	Q4	1173927	475102	2332938	0,405	327069	0,048949868	0,126	4,769	3,285	8,737	-0,353	1008,949	-0,009

Appendix 2

Table 1: Output from GARCH (1,1) analysis in Eviews

Dependent Variable: DLPX
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 06/20/16 Time: 12:18
Sample (adjusted): 2 85
Included observations: 84 after adjustments
Convergence achieved after 16 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.015444	0.011886	1.299386	0.1938
Variance Equation				
C	0.003919	0.003032	1.292371	0.1962
RESID(-1)^2	0.369381	0.141168	2.616616	0.0089
GARCH(-1)	0.354039	0.336038	1.053568	0.2921

R-squared	-0.004407	Mean dependent var	0.008122
Adjusted R-squared	-0.042072	S.D. dependent var	0.110961
S.E. of regression	0.113272	Akaike info criterion	-1.569513
Sum squared resid	1.026435	Schwarz criterion	-1.453760
Log likelihood	69.91956	Hannan-Quinn criter.	-1.522982
Durbin-Watson stat	1.460381		

Source: own tests in the Eviews

Table 2: Output from GARCH (2,2) analysis in Eviews

Dependent Variable: DLPX
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 06/20/16 Time: 12:35
Sample (adjusted): 2 85
Included observations: 84 after adjustments
Convergence achieved after 7 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)
+ C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.014190	0.008135	1.744157	0.0811
Variance Equation				
C	0.001295	0.000697	1.857444	0.0632
RESID(-1)^2	0.466113	0.104477	4.461406	0.0000
RESID(-2)^2	-0.375880	0.101240	-3.712773	0.0002
GARCH(-1)	0.898373	0.149538	6.007642	0.0000
GARCH(-2)	-0.121822	0.096043	-1.268406	0.2047

R-squared	-0.003026	Mean dependent var	0.008122
Adjusted R-squared	-0.067323	S.D. dependent var	0.110961
S.E. of regression	0.114636	Akaike info criterion	-1.537226
Sum squared resid	1.025024	Schwarz criterion	-1.363597
Log likelihood	70.56351	Hannan-Quinn criter.	-1.467429
Durbin-Watson stat	1.462391		

Source: own tests in the Eviews