

Computer Simulation of Stock Exchange Behavior in Maple

Zuzana Chvatalova, Jiri Hrebicek, Martin Zigardy

Abstract—This paper describes computer simulation of behavior Prague Stock Exchange (PSE) with use of application software (Maple) with special user-friendly interface (Maplet). It is very useful tool for the company management operating in the capital market. Firstly, we briefly mention the specifics of the PSE in the Czech Republic. Then we introduce some the proposed algorithms for modeling continuous development of shares with application the methods of mathematics and statistics. Computation and simulations of Stock Exchange behavior are made by Maplet with both numeric and symbolic computations. The developed Maplet is designed for easy user friendly control. The example of the master thesis of the Faculty of Business and Management, Brno University of Technology (shortly FBM BUT) of one of co-authors of the paper is presented. It demonstrates the close link of the educational process and practice at FBM BUT.

Keywords—application software, computer simulation, Maple system, form Maplet, regression, modeling, Stock Exchange.

I. INTRODUCTION

The turn of 20th and 21st century in post-communist economies means many new problems of market economy – there is a need to solve these problems efficiently. Significant support for financial managers and decision-makers in business is computer simulation and modeling of economic variables and the application of mathematical and statistical methods [13]. It is necessary to respect the socio-economic trends (use of communication networks, information systems, computer simulation and modeling technologies) [14]. Particularly the economic universities focus on the direct link of theory and research with practice. Therefore these aspects are important:

- addressing the technical, technological, economical, business and financial problems in companies in the processing of bachelor and master thesis,
- the future employment of students in business companies,
- collaboration between schools and business companies and their involvement in joint studies, research and projects,
- exchange of experience and knowledge through workshops, conferences, internet networks, websites, etc.

Identifying talented students (their creativity and knowledge potential) is important especially in post-communist economies. Therefore study programs and curricular of the

Faculty of Business and Management of the Brno University of Technology in Czech Republic (shortly FBM BUT) should be targeted on the use of theoretical knowledge in practice. Subjects such as mathematics and statistics must have the modern character of both the content and form to a clear understanding for the application [16]. This method of teaching is utilized also at the FBM BUT in the framework of projects supported by the Ministry of Education and Youth of the Czech Republic.

A summary of the facts mentioned above is realized in successful master thesis [7] of the third co-author of the paper (graduated at FBM BUT). This thesis also received FBM BUT dean's award. The practical result of this thesis is applied software (program) for the processing of financial data by using regression modeling in the Maple system (<http://www.maplesoft.com>). It is ready to be implemented as the module of any information system of a business company. Currently the master thesis is available in the online database at the website of FBM BUT (<http://www.fbm.vutbr.cz/>). The results of this thesis will be provided for modifications and extensions for other practical purposes.

This developed application software (Maple program) is used for analysis based on modeling the dependency and trends from observed data (values). The issue relates to the capital market environment. The output of the program is an interactive form (Maplet) with transparent user friendly interface. It is possible to directly import the large amount of data from office applications to Maple program – thanks to this important feature of Maple it is widely usable.

The input is a set of empirical data from the Prague Stock Exchange (<http://www.pse.cz/?language=english>). Maplet functionality is based on a multi-level algorithm design and implementation of information criteria for the appropriate choice of regression model. Modeling and calculations are carried out with the help of symbolic / numerical statistical techniques directly from the Maple system [15].

II. MOTIVATION FOR PROGRAM DEVELOPMENT

Author of thesis [7] during his studies at the FBM BUT worked in the company which is on the list of the PSE members (<http://www.pse.cz/Clenove-Burzy/>). He had the opportunity to understand the specifics of the current capital market in the Czech Republic and the company operations in market conditions. This is highly sought-after combination of:

- professional knowledge gained university education

(especially the application of mathematics, statistics and programming in economic sciences);

- experience gained in practice (company, trading in the stock exchange);
- skills, creativity and diligence.

This motivated the author to choose this topic for his thesis. The designed program is considered as an important corporate asset.

A. What was the specific objective?

The main idea was to create special program which makes mathematical models of dependencies between the dependent variable PX index (Czech Stock Index) on independent variables (other stock titles) using statistical methods. The program was created so that it could be used by its users for computer simulation of the behavior of stock titles thanks to the simple user friendly interface. The program architecture allows easy import of data from the external application software, for example MS Excel which is widely used in the Czech Republic. Early identification of PX index development depending on other stock titles is a fundamental tool for further analysis and prognosis. In doing so, we must remember that the input of the program is an extensive collection of rapidly changing financial data. To design the program and its output forms we chose the Maple system.

It should be noted that there are many commercial software products related to capital market. However for small and medium-sized enterprises in the Czech Republic these software products are too expensive – especially right now because of the global financial crisis.

B. Why did we choose Maple?

Maple is universal mathematical software - it is not just for the capital markets. It can be also used for solving other problems in business companies. It offers a friendly user interface and users can work with this software easily. But it also provides solutions for very complex problems even for experienced users and scientists. It includes many predefined procedures, methods and tools. Maple programming language is similar to Pascal. Maple software is available for all main computer platforms. It also provides special packages targeted at professional disciplines (including Maple Financial Modeling Toolbox). Maple is very affordable - it can be used by small business companies with limited budgets for research. Therefore it is very advantage to create the programs in Maple which solving concrete problem, so-called bespoke.

Reference [10] and the fact that there is a fourth edition and has been translated into several languages indicating the increasing popularity of Maple in the world for symbolic and numerical computing, the modeling, visualization, animation and simulation of phenomena. Canadian company Maplesoft, Inc. (developing Maple system) leads Application Center where the Maple users present and evaluate their Maple applications in many disciplines (<http://www.maplesoft.com/applications/>). Maple is used in education, research, commerce and government. Many world

companies such as NASA, TOYOTA, MITSUBISHI, and others use Maple software. Maplesoft, Inc. supports other activities of their users (more information at <http://www.maplesoft.com>). It has been used at Czech universities since 1992 and the Czech Maple User Group (CzMUG) was founded by (<http://www.maplesoft.cz>) in 1993.

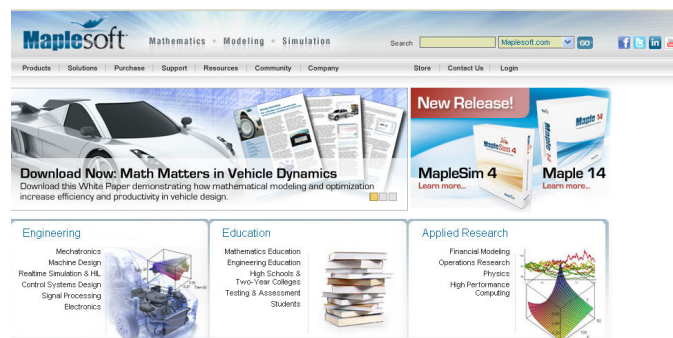


Fig. 1 Homepage of Maplesoft Inc. - Maple 14
Source: Available at [www < http://www.maplesoft.com/>](http://www.maplesoft.com/)

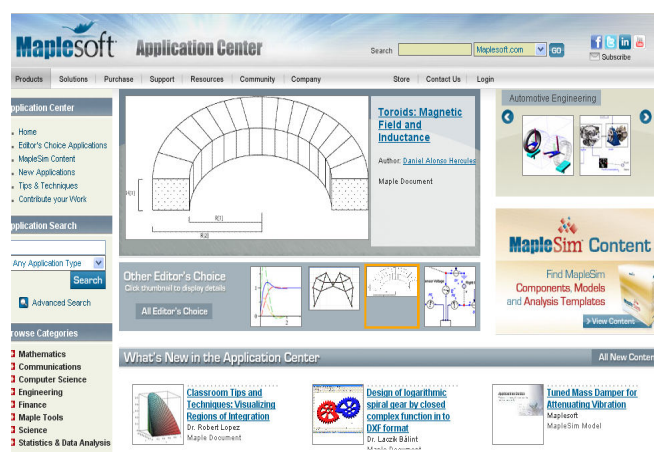


Fig. 2 Maplesoft Application Center
Source: Available at [www < http://www.maplesoft.com/applications/>](http://www.maplesoft.com/applications/)

III. DEFINING TERMS OF STOCK MARKET ENVIRONMENT IN CZECH REPUBLIC

The capital market of the Czech Republic consists of the Prague Stock Exchange (shortly PSE) (<http://www.pse.cz/>) and RM SYSTEM (<http://www.rmssystem.cz/>).

Note: In the Czech Republic, there are only two organizers of the securities market, The Prague Stock Exchange (with two exchange indices PX index and PX-GLOB index) and RM-SYSTEM. We will only deal with the PSE and PX stock index in SPAD (System for Support of the Share and Bond Markets) segment, especially with shares.

The PSE is the biggest organizer of the securities market in the Czech Republic located in Prague. By law it is a joint stock company. It is based on the membership principle meaning that only licensed securities dealers who are members of the

Exchange have access to the Exchange's system and are entitled to make trades. [Amended and upgraded according to [8]] The PSE currency is Czech crown (CZK - in Czech: Koruna česká (Kč) which has been the currency of the Czech Republic since 1993).

Trading at the PSE

- is based on automated processing of instructions to buy and sell investment instruments meaning that the PSE is a so-called electronic exchange;
- is allowed only through its members.

Individual investment instruments admitted for trading on Exchange markets are further divided into business groups that designate (the method of trading, the determination of the price).

A. SPAD - System for Support of the Share and Bond Markets

We will simulate trading in the SPAD (<http://www.pse.cz/Trading/SPAD.aspx>) of the PSE. The SPAD system does not qualify for price-fixing. This segment of Exchange is reserved for the most liquid securities assigned to Trading Group 3.

Opening price for issues assigned to the SPAD segment is equal to the arithmetic midpoint of the allowable spread valid at the moment when the open phase starts in the SPAD (at 09:15 a. m.). Continuous price for issues assigned to the SPAD segment is determined as the arithmetic midpoint of the allowable spread valid at the moment. The allowable spread is defined as a limited best quotation expanded by 0.5 % in both directions (up or down).

SPAD trading is based on the activities of market makers who are responsible for providing enough liquidity on the market. A market maker is an Exchange member who has concluded a contract with the Exchange to act as the market maker for selected issues of share titles. The number of market makers per issues nor the number of issues per market makers are unlimited. SPAD trading is carried out in two phases: *open, closed*.

We will consider shares. A share is an investment instrument – a security issued by a joint stock company in order to acquire capital for its establishment or further development. The share expresses an equity share in the company that issued the security, while the holding of a share represents different rights (for instance the right to participate in the profits of the company in the form of a dividend, the right to participate in and vote at a General Meeting of the shareholders or to participate in the liquidation balance of the company in case of its liquidation). [amended and upgraded according to [8]].

IV. DESIGNING MAPLE PROGRAM AND MAPLET

Primary reason for the creation of the Maple program was to verify following hypothesis: Is there any relation between continual developments of stocks which are traded at the PSE (in the SPAD system). If such relation exists, we are going to create its mathematical model through regression analysis in

Maple.

Final goal is to create an interactive Maplet form (with user friendly interface) for analyzing and economical interpretation of above mentioned relations for broad practical application.

A. Acquire the daily values of selected indexes

To make drafted program rational and practically serviceable we need to analyze inputs through objective confrontation of general information from common practice. These facts were defined to input procedures in via Maple.

B. Data acquisition

Inputs are large data files. In most cases data is available in MS Excel files. Data import is made via copy-paste method to Maple.

Commands in the Maple system [amended and upgraded according to [7]]:

```
> march('open', "C:\\Program Files\\Maple\\2007.lib");
> with(plots) : with(plottools) :
> with(stats) : with(Statistics) :
> vectors := proc()
> global dol, dow, dax, eur, pxi, ...
> start := ["xx.yy.zz", "xx.yy.zz"] :
> final := ["xx.yy.zz", "xx.yy.zz"] :
> ....., nazev[pxi] := ....., "Index PX",.....
> ....., color[pxi] := ....., "Index PX",.....
> date := [ ....., "30.06.07",.....]
> pxi := [ ....., 24.587,.....]
> end proc;
```

C. Creating the lists with input data

Input data is the time series of actuals of shares which are traded on the PSE. In our analysis we are converting this data to quotient of daily values and starting value of studied time period, i.e. converted data means the relative values: i -th actuals to first one in the reference time period (for example

$\frac{x_i}{x_1}$, respectively $\frac{y_i}{y_1}$). They are converted like that because of

the possibility of differences in values of selected indexes.

Specially, the designed procedure in Maple will create the list of these converted inputs. This conversion makes output models transparently comparable.

D. Definition of suitable time period

Because large amount of data is not entirely suitable for regression analysis we tested many variously long time periods. After these test we selected the time period of six months as the most suitable to output information was objective as well as the application of mathematical and statistical methods were correct.

Procedure Date retrieves the start and the final date of the time period according to the flowchart (Fig. 3).

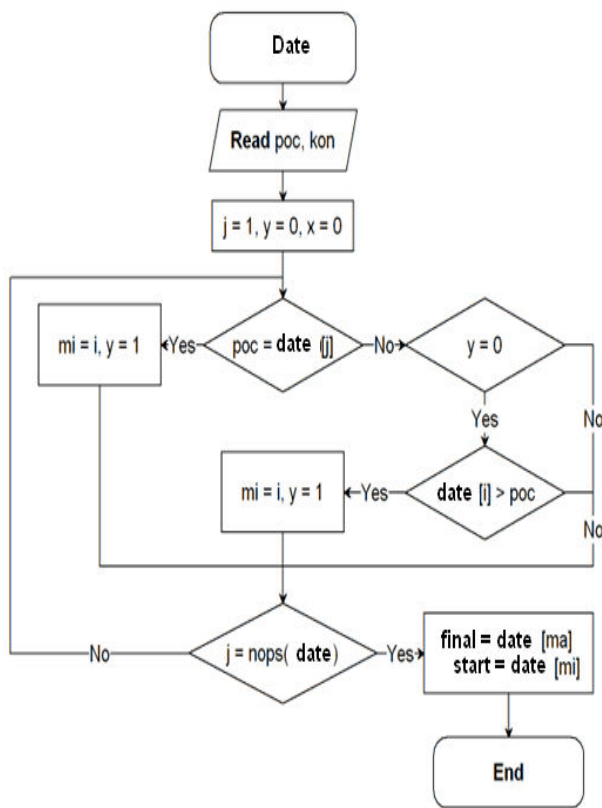


Fig. 3 Algorithm – Procedure Date
Source: [7]

V. USED MATHEMATICAL AND STATISTICAL METHODS AND ALGORITHMS OF MAPLE

The Statistics package in Maple system provides various commands and statements for fitting linear and nonlinear models to data points and performing regression analysis. The fitting algorithms are based on least-squares methods, which minimize the sum of the residuals squared. Available Commands includes Linear Fitting and Nonlinear Fitting. Most of the regression commands use methods implemented in a built-in library provided by the Numerical Algorithms Group (NAG).

A number of statements are available for fitting a model function that is linear in the model parameters to given data.

The LinearFit statement of Maple is available for multiple general linear regression. For certain classes of model functions involving only one independent variable, the PolynomialFit, LogarithmicFit, PowerFit, and ExponentialFit statements of Maple are available. The PowerFit and ExponentialFit statements of Maple use a transformed model function that is linear in the parameters. [e-book build-in Maple system [17]]

We have to define vectors *VectorY* and *VectorX* containing values of a dependent variable *y* and an independent variable *x* in the regression model. *VectorY* includes the converted data – the actuals of shares of PX index. *VectorX* includes the converted data - the actuals of shares of otherwise which is

traded on the PSE. Note: *vectorX* and *vectorY* contain thousands of values.

Commands in the Maple system [amended and upgraded according to [7]]:

```

> with(Statistics) :
> X := Vector([ ..... ]) :
> Y := Vector([ ..... ]) :
  
```

We chose to fit a polynomial of degree *n* through this data. Choosing the appropriate number of parameters for regression (and hence the degree *n* of regression polynomial) is not trivial. Further information about criteria (1), (3), (4), (5) can be found in literature, for example [3], [4], [7]: Andel's, Schwarz-Rissanen's (respectively Bayes's) a Hannan-Quinn's, Akaike's Information Criterion. The aim was to choose the polynomial degree which is recommended by most of them. In the most cases Akaike's Information Criterion was unstable because its results were not suitable for this case.

The Andel's Information Criterion is:

$$A_k = \frac{RSS}{n} \cdot (1 + k \cdot w_n), \tag{1}$$

where A_k is Andel's Information Criterion, *RSS* is the residual sum of squares, *n* is the number of measurements, *k* is the number of parameters, w_n is the penalty function.

The author of this criterion recommends that instead of giving the w_n value $\frac{1}{n^4}$. However, the criterion was unstable in the large number of input values.

Its results were also unstable. The exponent -1/4 can be changed depending on the number of parameters. Because the higher the count of measurements the lower influence should the penalization function should have.

The most suitable results were achieved with the exponent equal to -11/20. [7] Then the Andel's Information Criterion is:

$$A_k = \frac{RSS}{n} \cdot (1 + \frac{k}{\sqrt[20]{n^{11}}}). \tag{2}$$

With this constant the output values were the same like in Schwarz-Rissanen's and Hannan-Quinn's Information Criteria in the most cases:

$$BIC = n \cdot \ln(\frac{RSS}{n}) + k \cdot \ln n, \tag{3}$$

where *BIC* is Schwarz-Rissanen's Information Criterion, *RSS* is the residual sum of squares, *n* is the number of measurements, *k* is the number of parameters, *RSS/n* is residual dispersion.

$$HQ = n \cdot \ln(\frac{RSS}{n}) + 2 \cdot k \cdot c \cdot \ln n, \tag{4}$$

where *HQ* is Hannan-Quinn's Information Criterion,

RSS is the residual sum of squares,
 n is the number of measurements,
 k is the number of parameters,
 c is the added constant (professor Anedel recommends that instead of giving the k value 2),
 RSS/n is residual dispersion.

Akaike's Information Criterion is:

$$AIC = n \cdot \ln\left(\frac{RSS}{n}\right) + 2 \cdot k, \quad (5)$$

where AIC is Akaike's Information Criterion,
 RSS is the residual sum of squares,
 n is the number of measurements,
 k is the number of parameters,
 RSS/n is residual dispersion.

Aitken's Information Criterion was shown very different results from other criteria. Because the calculation is not possible to modify these results were not accepted.

We fit a polynomial of degree $k = 9$ through this financial data as maximum degree of polynomial. Information criterions automatically select the most appropriate degree of polynomial. We use the output option to see the residual sum of squares and the standard errors.

Commands in the Maple system [amended and upgraded according to [7]]:

```
>PolynomialFit(k, X, Y, x)
>PolynomialFit( k, X, Y, x, output = residualsumofsquares )
```

Note: Maple also provides complete statistical diagnostics and tests (for example: parameter values, parameter vector, residual sum of squares, residuals, degrees of freedom, residual mean square, residual standard deviation - in the nonlinear case; standard errors, confidence intervals, leverages, variance covariance matrix, internally standardized residuals, externally standardized residuals, Cook D-statistic, Atkinson T-statistic - in the linear case; the OneWayANOVA command generates a matrix that represents the standard analysis-of-variance (ANOVA) table for a one-way classification. Suppose one performs experiments varying only one factor. Each value of the factor results in one group of observations. The ANOVA table generated by analyzing all the observations can help in determining whether changing the factor has any significant influence. [e-book build-in Maple system[17]]

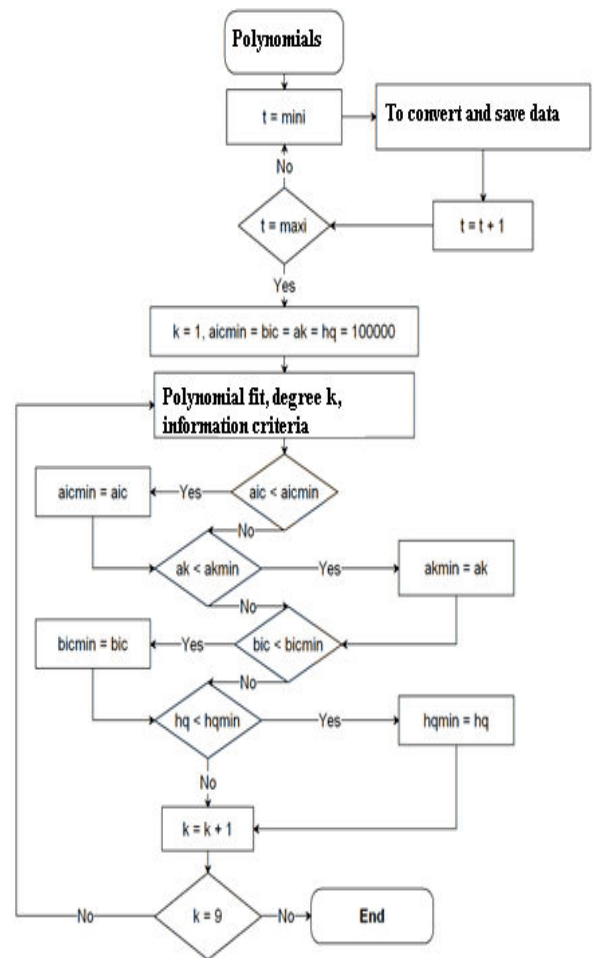


Fig. 4 Algorithm – Procedure Polynomials
 Source: [7]

VI. INTERACTIVE MAPLET

Firstly, we have created packages of the lists of internal and external values. Furthermore, we have created packages with procedures Date, Polynomials (appropriate choice of the regression model), Graphs (for plotting dependence of shares), Graphs1 (to capture the development of shares over time), Form (for creating Maplet) with next procedures: *Analyze, Plotting, Detail, Prognosis, Export*. [7]

Example: We present two from flowcharts (Fig. 3 and Fig. 4) for procedure Date (Fig. 3) and procedure Polynomials (Fig. 4). The names of these procedures are:

```
>Polynomials := proc(vector1, vector2, mini, maxi, z)
Vector1 and vector2 are lists with input data (independent and dependent variables), mini and maxi are the indices of first and end value of data. Parameter k indicates the maximum number of parameters in the regression polynomial. In this procedure will be performed alone polynomial regression analysis of first to ninth grade. Then there are calculated information criteria for each level.
```


\triangleright *Date := proc(start, final)*.

Variables *start* and *final* mean the first and the last day of the reference time period.

Note: Due to the extent of the contribution we do not consider other more appropriate specifications of the flowcharts as well as other procedures and packages.

The interactive Maplet contains five sections (Fig. 5 and Fig. 6); three on the left hand side and two on the right hand side.

Left upper section of the Maplet is designed to specify the time period - start and end date have format: xx.yy.zz. We can download internal data from previously developed data package there. External data we can download from known file (for example MS Excel) into middle left section of Maplet.

Lower section of Maplet consists of control variable for the activation of statements:

Analyze – the button activation starts the define regression model (including the application of information criteria), visualization, analytical formula and the residual sum of squares appear on the right;

Detail – the button activation makes the restriction of time interval for further observation;

Prognosis – the button activation predicts the development of dependence for certain time period;

Export – the button activation saves the graphs to an external file.

Right upper section of Maplet is designed to the visualization of discrete graphs: point graph, where vertical axis is for dependent variable (the convert actuals of shares of PX index, no unit) and horizontal axis is for independent variable (the convert actuals of shares of other indexes, no unit).

Example: Fig. 5, Fig. 6 and Fig. 7 present chosen dependence the index PX on the enterprise CEZ index (CEZ, Inc. is the dominant producer of electricity in the Czech Republic). Each point corresponds to a single date in time period. The regression model of dependence of development both indexes is blue curve. This section is activated using the buttons on the left of Maplet: *Analyze*. Currently analytical formula for the regression model and the residual sum of squares automatically appear in the windows: Regression function: $v = -3120.74173312105495 + 15831.5631969001662*v - 32026.6343814784959*v^2 + 32302.6851734133561*v^3 - 16243.7899729530327*v^4 + 3257.99990254010072*v^5$ and The residual sum of squares equals $0.392312381512755562e-1$.

Fig. 5 – after activation *Analyze* (for the time period from January 1, 2007 to June 30, 2007); Fig. 6 – after activation *Prognosis* (for the time period from July 1, 2007 to August 30, 2007); Fig. 7 – after activation *Detail* (for the time period from January 1, 2007 to January 20, 2007, next *Export*. [amended and upgraded according to [7]].

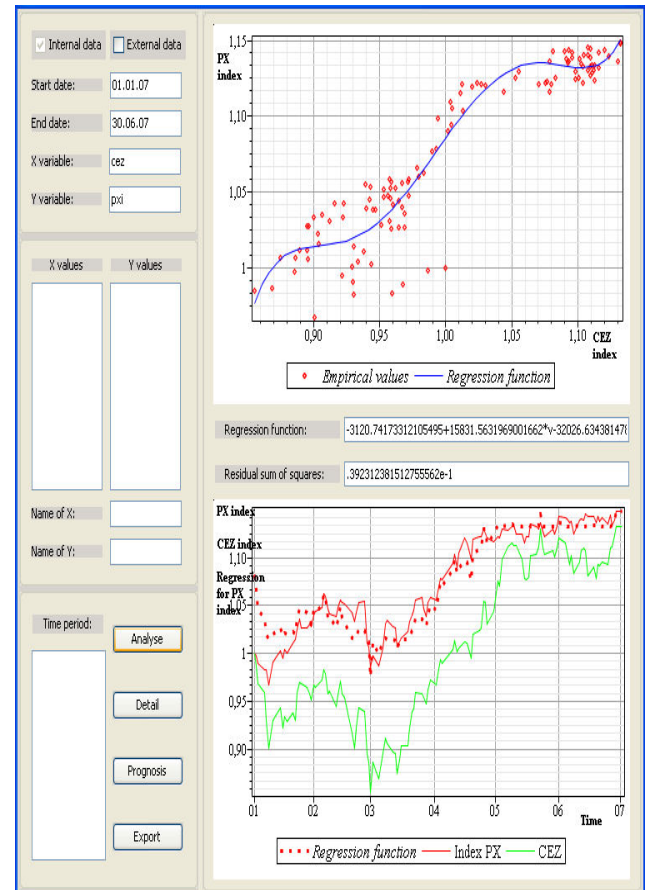


Fig. 5 Maplet – Analyze, January 1, 2007 – June 30, 2007 (index PX and index CEZ)

Source: [amended and upgraded according to [7]]

VII. CONCLUSION

Nowadays, a detailed analysis of market economic data is an integral part of management of any enterprise that seeks to be successful and wants to make a sustainable profit. The developed application program has opened new possibilities for example, to improve some results of prognoses of market development.

The developed program was applied for example for analysis of continuous dependence on the development of the PX PSE on five major stock titles, which are traded on the Prague Stock Exchange, Inc. (CEZ, Telefónica O2 C.R., Unipetrol, Erste Group Bank, and Komerční banka, as in the pervasive crisis in the Czech capital market (2006-2007). The economic interpretation of the results proved interesting facts (not the subject of this article).

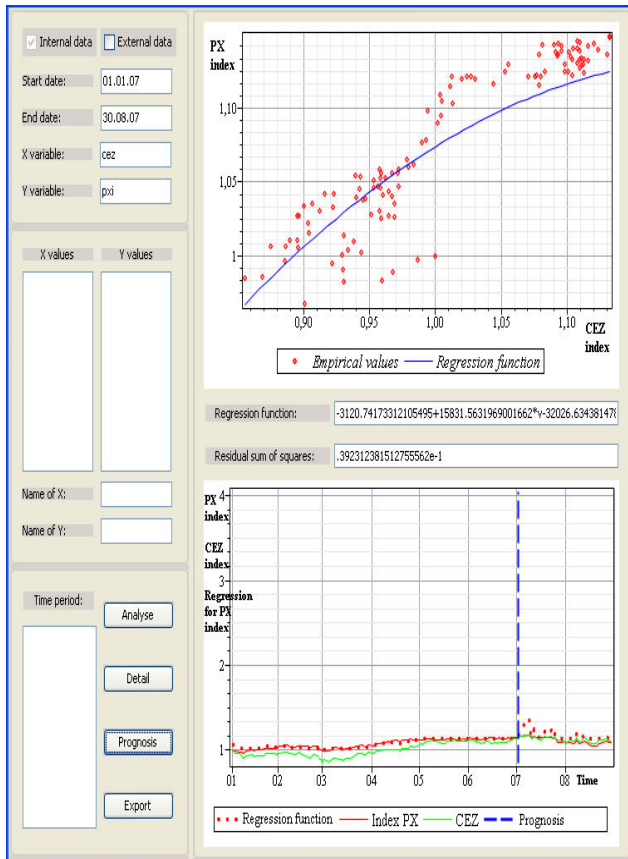


Fig. 6 Maplet – Prognosis for July 1, 2007 – August 30, 2007 (index PX and index CEZ)
Source: [amended and upgraded according to [7]]

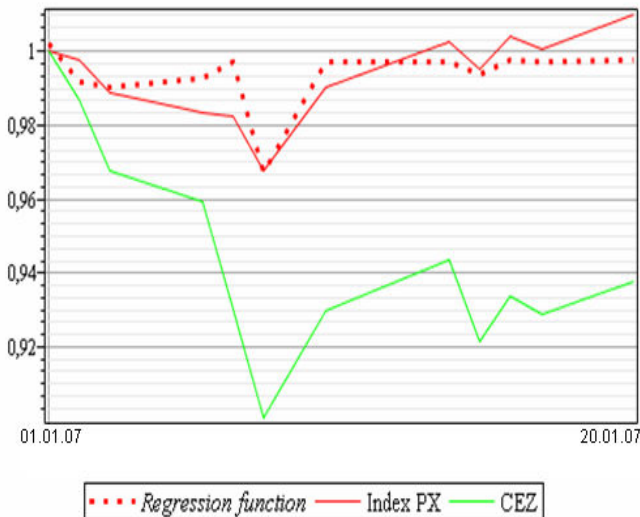


Fig. 7 Exported Detail from Maplet for January 1, 2007 – January 20, 2007 (index PX and index CEZ)
Source: [amended and upgraded according to [7]]

TABLE I
VARIABLE - UNIT

VARIABLE	Unit
PX index – convert form	-
CEZ index – convert form	-
Regression for PX index - convert form	-
Time	month

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