METEOR SHOWER VERSUS HEAT WAVE: UKRAINE AND EUROPEAN UNION

by

Iryna Moroz

A thesis submitted in partial fulfillment of
the requirements for the degree of

Master of Arts in Economics

National University "Kyiv-Mohyla Academy"
Economics Education and Research Consortium
Master's Program in Economics

2005

Approved by ___________________________________
Ms.Svitlana Budagovska (Head of the State Examination Committee)

____

____

____

Program Authorized
to Offer Degree Master's Program in Economics, NaUKMA

Date ___________________________________

National University "Kyiv-Mohyla Academy"

Abstract

METEOR SHOWER VERSUS
HEAT WAVE: UKRAINE AND
EUROPEAN UNION.

by Iryna Moroz

Head of the State Examination Committee: Ms.Svitlana Budagovska,
Economist, World Bank of Ukraine

This paper considers Ukrainian exchange rate volatility with help of GARCH modeling. The focus is on two theories of volatility determining. In accordance to Heat Wave hypothesis UAH/USD volatility is determined only by own previous fluctuations in the exchange rate. Under Meteor Shower hypothesis Ukrainian volatility is determined not only by own previous changes in exchange rate but is also influenced by European Union's exchange rate changes. The investigated dataset consists of daily interbank exchange rates of Ukrainian hryvna, Euro and Polish zloty all expressed in US dollar during period from 01.01.2000 to 31.12.2004. Based on the results of estimation, it was found that both Heat Wave and Meteor Shower effects are statistically significant. Ukrainian exchange rate volatility is determined not only by own previous volatility but is also influenced by EU exchange rate changes. Heat Wave effect is substantially more powerful comparing to Meteor Shower. Meteor Shower effect is economically insignificant in determining of Ukrainian exchange rate volatility since volatility remains almost the same despite different values of EU shocks.

TABLE OF CONTENTS

LIST OF GRAPHS AND TABLES

ACKNOWLEDGMENTS

I would like to express the appreciation and sincere gratitude to my adviser, Professor Tom Coupe, for his everyday assistance, critical comments and valuable advises.

I am also very appreciated to Tatiana Zabotina and Volodymyr Bilotkach for their ideas and helpful advises.

I express special thanks to my parents for their everyday support and to my friends for their help.

Chapter 1

INTRODUCTION

In the context of nowadays world integration of financial markets significant attention is paid to the behavior of different asset-pricing data, including the behavior of exchange rates. The changes in exchange rates tend not to be independent but exhibit volatility clustering and seem to depend on different economic determinants coming from abroad. Volatility is definitely an important economic phenomenon that needs to be considered. Such questions as which currencies are more volatile, do the exchange rates follow the same volatility patterns, does the volatility of one currency correlate with volatility of other currency, does the volatility reflect the impact of economic fundamentals, etc., need to be answered.

For people and other economic entities who deal with exchange rates it is important to answer the question about volatility and its sources in order to have the opportunity to forecast future fluctuations of currencies' exchange rate. Precise measurement and prediction of volatility are helpful for trading, choosing financial strategy and hedging. In the case we find that there is an external impact on volatility of exchange rate it will be useful for traders to take into account these results in order to be more efficient in their work.

Accurate estimation of volatility in financial markets is very important. Price fluctuations are connected with appearance of information flow even at an intraday level. During recent years financial markets are characterized by increasing international integration so that information from one market can "spillover" to other markets. In this work we consider the relationship between exchange markets in Ukraine and European Union because of it importance for the strategic partnership in the future. The goal is to investigate the influence of EU changes in daily euro/dollar exchange rate on Ukrainian exchange market. We consider the Exchange rates for currencies on Interbank Currency Exchanges in each region.

This work deals with volatility spillover or volatility contagion between international trading exchange markets. In the paper on the subject Engle, Ito and Lin (1990) demonstrated the interregional volatility persistence. It is suggested that there is common trend in cross-country volatility of exchange rates. It means that there exist autocorrelation across regions connected with the fact that information received at one point in time is followed with a lag by a stochastic response. These cross-market changes are connected due to influence of private and public information from one region on others. Such kind of comovement is known as meteor shower effect.

From the other point of view it can be the case of absence of correlation in cross-country volatility. It means that fluctuations of exchange rate are influenced only by domestic factors, including previous fluctuations of exchange rate to some extent. Today's change in exchange rate is correlated with yesterdays within the market. One reason for such volatility is that the market absorbs the available internal information flow. The theory about correlation of volatility only within one market is known as the heat wave hypothesis.

Euro and dollar are the most important currencies that are traded in the world and in Ukraine and their trading volume increases that is why I use hryvna/dollar and euro/dollar exchange rate for investigation in my thesis. My choice to investigate EU influence on Ukrainian exchange market was made because of strategic role of EU for Ukraine. Since we are aiming to become a member of EU in the future we are interested whether there exists any impact of our potential partner on Ukrainian Exchange market. Additional reason for this appears because of existing the number of entities with part or 100% foreign capital that act on Ukrainian Interbank Currency Exchange and are owned by the members of EU. There are 19 registered banks with foreign capital in Ukraine and among 7 banks with 100% foreign capital such as Raiffeisenbank Ukraine, HVB Ukraine, Bank Credit Suisse First Boston, Bank Lynnais Ukraine and ING Bank Ukraine are owned be countries of EU.

On the EU-Ukraine Cooperation Council Eighth Meeting on February 21, 2005, the EU acknowledged Ukraine's European ambitions and made clear that a new commitment to democracy and reforms opened new prospects for EU-Ukraine relations. In order to further strengthen and enrich the Action Plan, a number of measures have been agreed in support of a democratic and reform-oriented Ukraine. Among them were to deepen trade and economic relations between EU and Ukraine, to grant "Market Economy Status" to our country. This will make Ukrainian and EU economies closer. Hence, these facts also represent the justification of EU future influence on Ukraine in the field of exchange rate volatility.

To describe the issue I shall use the theory of time dependent heteroskedasticity that is revealed in exchange rate data. I shall apply AR, *autoregressive conditional heteroscedastic* (ARCH) and *generalized autoregressive conditional heteroscedastic* (GARCH) model of Engle (1982) and Bollerslev (1986). I shall formulate the ARCH model for Ukrainian changes in exchange market that depends upon previous information from this market and previous information from exchange markets of EU. A lot of studies were devoted to cross-country volatility of exchange rates. Outstanding economists investigated volatility using GARHC models. Great attention was devoted to the biggest world markets: Engle, Takatoshi, Lin (1990), Baillie, Bollerslev (1991), Black, McMillan (2004). My contribution to this issue is to consider applicability of such modeling to Ukraine as the country with the emerging economy. My goal is not only to use the class of GARCH models for investigation of Ukrainian hryvna's volatility but also to use extension of GARCH models to examine the cross-region impact of EU on Ukraine in the field of exchange rates volatility.

There is no previous research that was done in this field for Ukraine. This work provides empirical investigation of relationship between domestic Ukrainian volatility of exchange rates and foreign external factor that can influence it.

To summarize, this thesis considers and tests two hypotheses:

-exchange rate volatility in Ukraine is fully determined by domestic influence that is consistent with heat wave hypothesis;

-exchange rate volatility in Ukraine is also influenced by foreign factors such as fluctuations of EU exchange rates that is consistent with meteor shower hypothesis.

Our main findings are:

- meteor shower and heat wave effects are both statistically significant;

- heat wave effect is more powerful in determining Ukrainian volatility;

- meteor shower effect is economically insignificant in determining of Ukrainian volatility.

Chapter 2

LITERATURE REVIEW

In this chapter we describe and consider such items:

-the importance of exchange rates volatility in the context of emerging financial markets;

-fundamental notions that were used in the literature concerning the subject;

- econometric methods used for investigation;

-the main findings in this area and inferences that were made using these results.

The volatility is often used as a measure of the total risk of financial assets and is measured through the standard deviation or variance of the return. As will be shown later the volatility of exchange rates can not be modeled with help of linear models so we use nonlinear econometric models.

As Brooks (2000) noted in his book a lot of linear structural models are unable to explain some important properties that are common to variety of financial data. For example:

1) Volatility clustering- that is the tendency for fluctuations of financial time series to appear in bubbles, when large returns even of either

sign follow large return and small returns even of either sign follow small returns.

2) Leptokurtosis. It means the tendency of financial asset return to exhibit distribution with fat tails and excess peakedness at the mean.

3) Leverage effects. It means that volatility rises more due to large price decrease than due to price increase of the same magnitude.

The model that is widely used in finance and can take into account these three features is known as ARCH model. The model was first introduced by Engle (1982) and is known as *autoregressive conditional heteroscedastic* process. As Enders (1995) describes in his book in the typical linear structural model the residuals are assumed to be normally distributed with zero mean and constant variance, however, this assumption of homoscedasticity would be most likely violated for high frequency financial data. The class of ARCH models is especially useful because it allows the variance of the errors not to be constant. This assumption is known as heteroscedasticity. If the residuals are heteroscedastic, but assumed homoscedastic, an inference would be that standard error estimates are wrong. It is unlikely for financial data that the variance of residuals is constant over time, so it is useful to investigate the model with nonconstant variance and to describe the behavior of this variance.

The property of many financial data series that provides a motivation for the ARCH class models is volatility clustering. Volatility clustering shows that the current level of volatility tends to be positively correlated with the level during the immediately preceding periods. So it could be stated that the "volatility is autocorrelated". Under the ARCH models, the "autocorrelation of volatility" is modeled by allowing the conditional variance of error term to depend on the immediately previous value of the squared error.

One more attractive feature of the ARCH models is that the conditional mean equation that describes how the endogenous variable varies with time could take almost any form that the investigator wishes. This issue will be considered in more details in the next chapters.

As Franses and van Dijk (2000) noted in their book while ARCH provides the frame for the analysis of financial time series models of volatility it at the same time exhibits some shortcomings:

1) The equation for conditional variance is modeled through the number of lags, q, of the squared residual in the model. The problem is in how the value of q is decided. One solution is to use likelihood ratio test, but there is no the best answer to this puzzle. The number of q can appears very large in order to absorb all of the dependence in the conditional variance. This leads to huge conditional variance model which is not parsimonious.

2) Since we model the conditional variance, its value must be strictly positive because the negative variance at any point of time is senseless. But the constraint of nonnegativity can be violated. With increase in the number of parameters in the conditional variance equation the probability that one ore more of them will have negative estimated value rises.

To solve these problems the natural extension of ARCH(q) model known as *generalized* ARCH (GARCH) process, was introduced by Bollerslev (1986). Since even in this process shortcomings appear a lot other extensions were proposed, such as *Integrated* GARCH (IGARCH) by Engle and Bollerslev (1986), *Exponential* GARCH (EGARCH) by Nelson

(1991), *Fractionally Integrated* GARCH (FIGARCH) by Baillie, Bollerslev and Mikkelsen (1996).The model presented by Glosten, Jagannathan and Runkle (1993) offered the alternative way to permit for asymmetric effect of positive and negative shocks on volatility.

The class of GARCH models was used for modeling of exchange rate volatility in each work discussed here. But for our analysis the most useful is the GARCH model that allows modeling of cross-regional conditional volatility of exchange rates. It will be described later.

A huge amount of research was done for different regional currencies such as European, Asian and American currencies separately, but greater part of investigation was made in mixed form. This mixed form is represented by works devoted to cross-regional exchange rates volatility, for example European currency's exchange rate volatility against American one.

A lot of studies used the fundamental class of GARCH models for modeling and forecasting the volatility of the certain country's currency. Three following works were done for countries with the transition economies.

The aim of paper by Aysoy *et al.* (1996) was to present empirical evidence for daily volatility by estimating seasonal anomalies in the foreign exchange market of Turkey that was a high-inflationary developing country during the period of investigation. It was found that volatility of the Turkish daily foreign exchange rates is low. This can be explained by the behavior of economic agents who can anticipate the tendency of exchange rates during stable periods. The Central Bank intervention into the foreign exchange market is expected as usually when fluctuations are high. Hence, this decreases the volatility in the market. The empirical results also showed that seasonal effects, namely day of the week effects, exist in the foreign exchange returns in Turkey. It was established that volatility of the currency returns is time varying, ARCH effects are present.

Kocenda (1998) analyzed the role of exchange rate and the exchange arte regime in Czech Republic from the beginning of the economic transformations. Central and Eastern European countries were involved in the unique transformation and that is why their exchange rate arrangements differ from those in the developed countries. New emerging markets that appear in Central and Easter Europe have expanded the interest in exploring the behavior of the exchange rates of this region. Investigations were made for exchange rate under different regimes. In particular, the behavior of volatility was estimated when Czech koruna was pegged to the currency basket. The test that discovers similar properties between a pegged exchange rate and the behavior of free floating exchange rate was presented in the work and supported the application of ARCH model under the both regimes.

Fernandes (2002) examined the volatility of exchange rate in Chilean economy under dirty floating regime. From the mid-1980's to September 1999 the exchange rate regime in Chile consisted of a floating band with a reference exchange rate (*dolar acuerdo*). The floating band was eliminated finally in September 1999 and a free float was established. The investigations supported the applicability of GARCH models to dirty floating regime. By resorting to stochastic volatility models (asymmetric GARCH, Exponential Smooth Transition GARCH, EGARCH) it was found that volatility of exchange rate increase, but only slightly during the free floating regime.

The following works were done for currencies of different regions in the world, mostly for developed countries. These studies used not simple class of GARCH models but the extension of it to model the cross-region volatility of exchange rates. Categories as meteor shower and heat wave which appear in these works can be explained in such way. Using meteorological analogies, as was done by Engle, Ito and Lin (1990), it is supposed that news follow a process similar to heat wave so that one cold day in Kyiv is likely to be followed by another cold day in Kyiv but not typically by cold day in Moscow. The meteor shower rains on earth while it turns. A meteor shower in Kyiv almost surely is followed by one in Moscow. Hence, when we say about heat wave effect we mean that volatility inside country depends only on previous domestic volatility. And under meteor shower effect we mean that exchange rate depends on both domestic and foreign fluctuations of exchange rate.

The contribution of paper by Baillie and Bollerslev (1991) to discussing topic was to "consider the detailed relationship between the volatility of return of four major floating foreign exchange rates vis-à-vis the U.S. dollar on an hourly basis as they are quoted on the different currency market around the world". They specified the model for hourly movement of major European currencies and Japanese yen to USA dollar exchange rates, tested it and obtained the results that supported the evidence of volatility spillover. The estimation of the model showed that the volatility for each exchange rate is highly serially correlated. It means that the hypothesis called meteor shower was not rejected. Under the meteor shower effect news are transmitted in time and across different regions. Since the model was specified as seasonal GARCH (it includes hourly dummy variables) the significance of seasonal ARCH term of course suggested the presence of heat wave effect. Under this hypothesis the volatility absorbs only market-specific news.

The topic of volatility clustering and volatility spillover was successfully examined by Melvin and Melvin (2000). The volatility transmission of the DM/$ and ¥/$ exchange rates across regional markets of Asia, Europe and America was estimated. The distinguished feature of the work is based on the fact that the framework for model of volatility transmission was provided by nonsynchronous market segments. Authors divided the global world currency market into five regions that have different time of opening and closing. The persistence of volatility in foreign exchange markets was explained through speculative bubbles, bandwagon effects and serial correlation in appearing public information. The hypothesis of heat-wave was based on assumption that expected volatility would follow the same intraday pattern with only regionally specific autocorrelation in fluctuations. But this skeleton does not give the explanation why volatility transmits across differently located markets. The explanation of autocorrelated across regions volatility was based on meteor shower effect, that is, the public information appeared at one point of time is followed with some lag from one place to other. The results of estimation and testing indicated that own-regional volatility spillovers or heat-wave effect is significant for both DM/$ and ¥/$ exchange rates. The testing for meteor shower effect also exhibits the strong evidence in all regions.

As was shown by Black and McMillan (2004) volatility of exchange rate which is represented by the conditional variance can be separated into two components. It was decomposed by authors into permanent and transitory component.

The examination of movements in permanent and transitory components of ARCH specification exhibits quite different results. A common movement of long-run components was reported for the European currencies, particularly for the Deutsch mark and French franc. Such results suggested the common trend in volatility of European currencies but on other side they reported separate volatility trend for the Canadian dollar. Such findings support the suggestion that the long-term trend in daily exchange rates is stronger for currencies of Europe and Japan than for total G7 currencies.

The examination of temporary component shows that cross-country correlation of volatility for all currencies in European countries is weaker than for the permanent component.

The additional examination by Black and McMillan which is the most closely related to the topic of this thesis is testing for volatility spillover's mean and variance. As was noted by Baillie et al. (1993), efficient market must incorporate changes resulting from news into mean prices. The results of Black and McMillan (2004) confirmed the assumption of market efficiency since had shown the limited evidence of mean prices volatility spillover between countries. But variance volatility that is usually used in investigations indicated significant financial integration between exchange rate series in European countries. This integration is represented by monetary policy co-ordination.

So, this work expanded the investigated field considering the volatility as short-run and long-run components with their distinguished impacts.

The paper by Habib (2002) and work by Speight and McMillan (2001) were made for transition countries. Habib considered the volatility of only European currencies' exchange rates while Speight and McMillan devoted their work to exchange rate volatility of both European and American currencies.

Speight and McMillan (2001) considered the issue of volatility transmission in the context of black markets. This topic is closely related to Ukrainian circumstances since Ukraine was the member of Soviet Union and after independence was established our country received negative heritage in form of black markets for different goods. Black markets appear when there are some restrictions on good provision or the price of some good is set below equilibrium level. The currency exchange market was brought into such condition under which market transactions are characterized by imperfect information. Following Engle at al. (1990) authors suggest that the volatility of exchange rate can keep only location-specific autocorrelation or spillovers from market to market. In other words they examined the appearance of heat wave or meteor shower effects. The investigation of the time series features of the monthly black market dollar exchange rates for the currencies of six formerly socialist East European countries showed the following result. The GARCH estimation supported the heat wave effect through exhibition of significant positive and persistent correlation with past innovations and previous volatility on current fluctuations for all currencies except Hungarian forint. Testing for meteor shower disclosed the evidence of causality in variance from the Soviet ruble to the Bulgarian lev, from the lev to the Polish zloty, and greater evidence of such dependence of the Hungarian forint from the Romanian lei.

An investigation of only European currencies was done by Habib (2002). The effect of the external factors' volatility on volatility of interest rates and exchange rates in three Central and Eastern European countries

(CEECs) was considered: Czech Republic, Hungary and Poland. External factors that were investigated include German interest rates and emerging financial markets. The proxy for the emerging markets was represented by the J.P. Morgan EMBI+ bond index. This is the composite emerging-market band index that tracks total returns for traded external debt instruments in the emerging markets. The goal of analysis was to find if there exist any correlation between the volatility of determinants from other country and volatility of domestic variables. In the preliminary analysis it was found that in different situations external shocks may have a significant impact and different level of persistence on interest rates and exchange rates in Czech Republic, Hungary and Poland. The high level of persistence of shocks depends on the distinguished statistical features of interest rates and exchange rates. In the case when the investigated variable is stationary, the shock will exhibit temporary impact and will decay, but if the variable is instead nonstationary, shock will persist through time.

The volatility of domestic interest rates and exchange rate returns is not correlated with the volatility of German interest rates and there is no evidence of spillover from this source. While the volatility of returns on the EMBI+ emerging-market bond index is positively correlated with the volatility of exchange rate returns in the three CEECs. For such currencies as Czech koruna and the Polish zloty, this correlation is significantly higher during the period of emerging-market financial instability. The GARCH analysis confirms that indicators of emerging-market volatility can help in explaining the conditional variance of exchange rate returns in the two countries during the financial distortions of emerging markets. Such results provide mixed support for the theoretical trade-off between exchange rate reaction to external shocks and the volatility contagion under alternative exchange rate regimes. The role of the exchange rate as the shock absorber is partly supported for Polish zloty through fluctuating in a relatively wide band. Since there were observed relatively big changes in exchange rate of Polish zloty due to volatility of returns on the EMBI+ emerging-market bond index it was made the conclusion that the emerging-market financial turbulence was absorbed by the Polish zloty.

One of the most interesting findings was that results of testing provide substantial evidence of transmission of emerging-market volatility on foreign exchange markets in all three CEECs. The results confirmed that the Czech koruna and the Polish zloty were subject to volatility spillover caused by the financial turbulence in the emerging markets during the period 1997-1999. The Hungarian forint was also significantly influenced by emerging market volatility. In Poland the exchange rate absorbed the volatility coming from abroad, while in Czech Republic the exchange rate did not fully absorb the external volatility. It means that there is no strong evidence that exchange rate in Czech Republic depends on volatility from abroad as in Poland.

In discussed papers it was found the presence of both meteor shower and heat wave effects despite the fact that for some economies the meteor shower was significantly smaller than for others. It is explained through the fact that authors considered open economies. If the investigator wants to examine volatility in relatively closed economy he can expect that there will not be observed Meteor Shower effect. But in this case we also can suspect that exchange rate volatility can not be specified through class of ARCH and GARCH models.

Hence, there is no evidence that one particular effect has greater power in all discussed situations and in most cases they appear together. So, the aim of my work is to disclose the presence of one or both effects for Ukrainian exchange market.

Chapter 3

DATA AND METHODOLOGY DESCRIPTION

The data which is analyzed in my work relate to historical daily averages of exchange rates on Interbank Currency Exchange markets of two main regions: Ukraine and European Union. Additional data set of Polish zloty to US dollar exchange rate was used to make the comparison of estimated results. The currencies examined are Ukrainian hryvna, Euro and Polish zloty all expressed in US dollars, for period from 01.01.2000 to 31.12.2004. I introduce the notation UAH/USD for amount of US dollars for one Ukrainian hryvna, notation EUR/USD for amount of US dollars for one Euro and notation PLN/USD for amount of US dollars for one Polish zloty. US dollar was chosen to express the value of Ukrainian hryvna, Euro and Polish zloty because of two reasons:

1. US dollar is one of the most often traded currencies in the world.

2. Ukrainian economy is characterized by the high level of dollarization. It means that there exist a significant part of dollar deposits in total money supply.

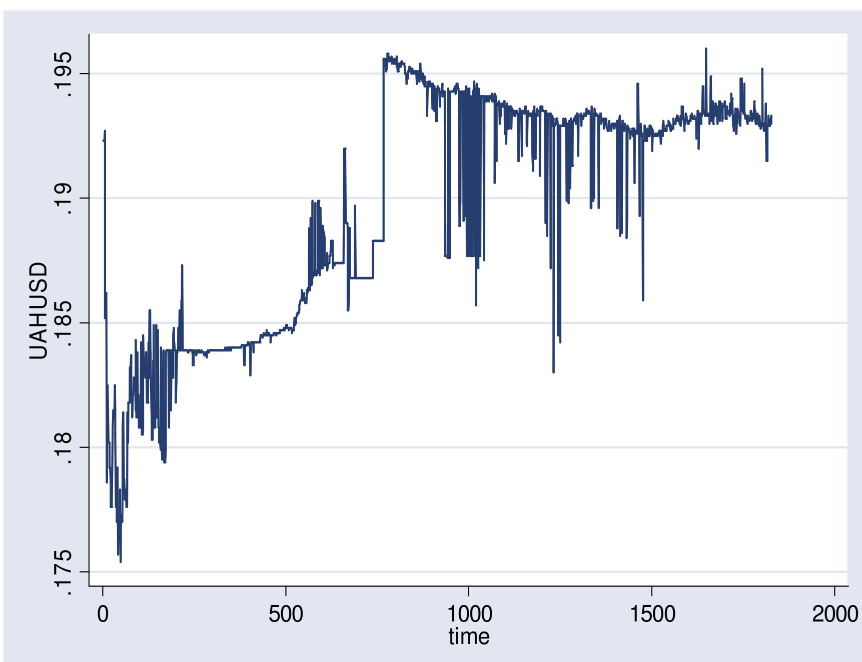
The period since 01.01.2000 till 31.12.2004 was chosen because of absence of fixed rate and strong narrow currency corridor of hryvna to dollar during this time. Since January 2000 the National Bank of Ukraine runs the floating exchange rate regime. It can not be defined as free floating because during this period the currency interventions of the National Bank of Ukraine were observed. But the currency policy is characterized by substantial liberalization. It means that the value corridor was not as narrow and restrictive as before 2000.

The total number of observations is 1827 daily average exchange rates for each currency. Each daily rate is the average ask price for the day. Short descriptive statistics of observed data set is presented in tables:

Table 1. Summary statistics of time series

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
UAH/USD	1827	.1895342	.0048043	.1754	.196
EUR/USD	1827	1.028728	.1431942	.8285	1.3644
PLN/USD	1827	.2540505	.0188369	.212044	.336089

Graph 1. UAH/USD exchange rate.

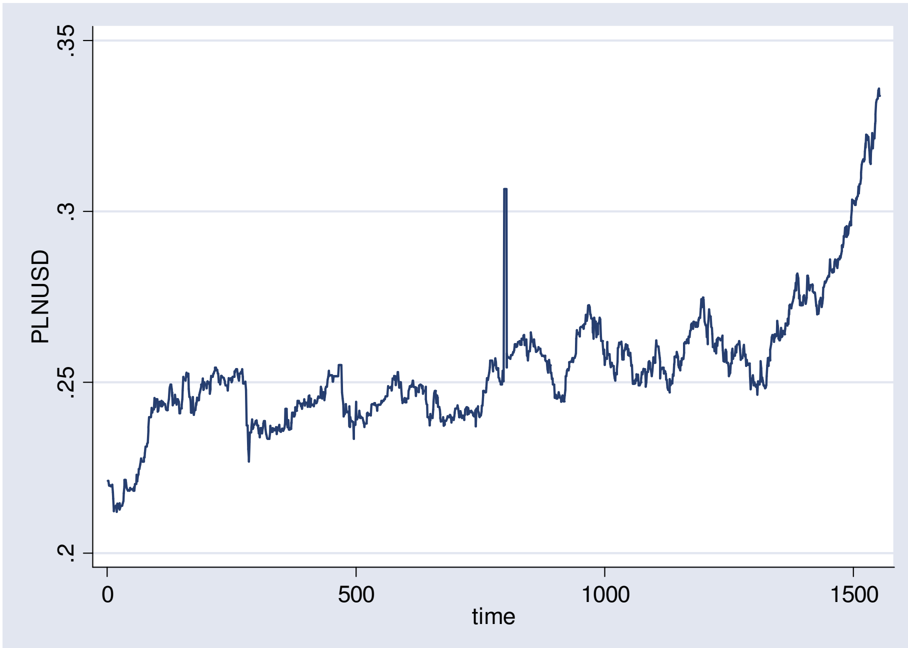


Ukrainian hryvna depreciated against US dollar during 2001-February 2002. After that period it slightly has appreciated till 2004. The starting exchange rate was USD 0.1930 for UAH 1. The last one in the period of investigation was USD 0.19230 for UAH 1. The fluctuations of Ukrainian hryvna value in dollars are sharper in comparison to Euro.

Graph 2. EUR/USD exchange rate.

Euro has the period of devaluation against US dollar (2000-2001) but after that this currency exhibits the stable trend of strengthening during the investigated period. The first exchange rate was observed on the level USD 1.008 for EUR 1. The last one was USD 1.3644 for EUR 1.

Graph 3. PLN/USD exchange rate.



Polish exchange rate exhibits more moderate fluctuations comparing to those of Ukrainian except the sudden jump during 07.12.2002-11.12.2002. Such behavior of PLN/USD is explained by more liberal exchange rate regime in Poland. Since Poland runs free floating exchange rate regime during the investigated period I construct and estimate GARCH model of exchange rate volatility for Polish zloty in order to compare the results with those for Ukrainian exchange market.

The data was given from web site www.oanda.com.

The basic model that is used in this thesis was written by Engle at al (1990). They made estimations using intra daily data. Such kind of data is absent for Ukrainian hryvna that is why I use daily data and modify some variables from the original model.

Engle at al (1990) used hourly data in research and included in their model today influence of foreign fluctuations on today volatility in contrast to model of my thesis. I exclude today impact of foreign volatility on today Ukrainian exchange rate volatility and do not use hourly intraday UAH/USD data due to its absence. Hence, there exists a suspicion that results of estimation with daily data could be inaccurate. But daily exchange rates are also used for research by McKenzie and Mitchell (2002) for modeling volatility. Black and McMillan (2004) considered daily data to examine the cross-country correlation in temporary and permanent components of the exchange rates for six currencies. In paper by Habib (2002) the data set contains only daily observations that were used for investigations of cross-country volatility contagion.

From the first look it seems reasonable that investigation of volatility can be made only for exchange rates under free floating regimes as in work by Engle, Ito and Lin (1990). We can suggest that managed exchange rate regimes could limit the fluctuations of exchange rates in response to the market demand and supply conditions. Hence, in these circumstances the volatility of exchange rate becomes strongly limited and we can not use such data stream for investigations. But, as we can observe from related literature, such topic can be examined for currencies under managed floating regime (Czech Republic) and even more rigid regimes (Hungary and Poland) as was done by Habib (2002). Habib analyzed the reaction of exchange rates to external shocks. He also examined the volatility of exchange rate testing for a possible cross-country volatility contagion. It was investigated whether the degree of exchange rate flexibility did matter in CEECs, checking if a managed floating exchange rate regime is able to insulate the domestic monetary policy by absorbing external shocks. It was verified whether relatively more rigid exchange rate systems were associated with cross-regional spillovers of shocks.

The application of conditional heteroskedasticity for analyzing semi-fixed exchange rate regimes proved to be an efficient tool by Kocenda (1998). He suggested that this approach could be used to examine other transition economies that choose to impose the strict discipline and peg their currencies using a fixed exchange rate arrangement.

Since exchange rates as high frequency financial data exhibit volatility clustering, to model the dynamic process of daily volatility I use GARCH method which is the most popular tool that allows to take into account time-varying nature of variance. This model was introduced by Engle(1982) and developed by Bollerslev(1986). Following Engle at al(1990) I assume that there are two foreign exchange markets: Ukrainian one and the market of European Union. I treat the volatility originating from EU market as predetermined variables. The economic power of EU and its geographical size are more significant than economic development and the size of Ukraine. That is the reason I assume the impact of change in EU exchange rate can be considered as unilateral process. I mean that EU influence Ukrainian volatility but not vise versa. So the information set for Ukrainian Exchange market contains news from EU market as well as own past information.

Let $\varepsilon_{i,t}$ be the change in exchange rate of current day from the previous day in market *i* on date *t*. So $\varepsilon_{i,t}$ can be constructed as difference between current and previous day exchange rate for UAH/USD and EUR/USD

(1) $\varepsilon_{i,t} \mid I_{i,t-1} \sim N(0, h_{i,t})$ for $i = 1, 3$.

$$h_{i,t} = \omega_i + \beta_{ii} h_{i,t-1} + \sum_{1}^{n} \alpha_{ii} \varepsilon_{i,t-1}^2 + \alpha_{ij} \varepsilon_{j,t-1}^2 \text{ for } i = 1, 3,\ j = 2$$

Where $\varepsilon_{i,t}$ denotes exchange rate change in country at time t; conditional distribution of which, given the information set I_{t-1}, assumed to be normally distributed with zero mean and time-varying conditional variance $h_{i,t}$. I_{t-1} is the information set for market *i* on date *t*, which includes the own previous information on date *t*-1 and past information from market *j*. Notation *n* means the number of lags included in the AR specification of change in exchange rate. Let denote Ukrainian exchange market by market 1, EU market by market 2 and Polish exchange market by 3. Coefficient β_{ii} means the influence of own previous market volatility on today's volatility and is consistent with heat wave effect. Coefficient α_{ij} denotes the impact of foreign market *j* change in exchange rate on domestic market *i* volatility. So it is possible to specify the equation of volatility for Ukrainian hryvna that depends on own previous changes and past changes of Euro.

$$h_{1,t} = \omega_1 + \beta_{11} h_{1,t-1} + \alpha_{11} \varepsilon_{1,t-1}^2 + \alpha_{12} \varepsilon_{2,t-1}^2$$

The estimation of the model is made with Stata. This program represents the results of estimation for GARCH specification including EU squared change of exchange rate in the following form:

$$h_{1,t} = \exp\{\omega_2 + \alpha_{12} \varepsilon_{2,t-1}^2\} + \beta_{11} h_{1,t-1} + \sum_{1}^{n} \alpha_{11} \varepsilon_{1,t-1}^2$$

Hence, Stata represents slightly different specification of the model. GARCH term of foreign exchange market and the slope appear in the equation as a power of exponent.

The null hypothesis that $\alpha_{12} = 0$ is consistent with the Heat Wave effect. It means that change in EUR/USD exchange rate does not influence UAH/USD exchange rate volatility. The significance of β_{11} while α_{12} is insignificant means that pure Heat Wave effect is observed. In case when both coefficients are significant we can conclude that both Heat Wave and Meteor Shower effects are present. It means that volatility of UAH/USD exchange rate is defined by own past volatility and influenced by the past changes of EUR/USD exchange rate changes.

Since there is no big time gap between Ukraine and EU and due to the absence of hourly data on UAH/USD exchange rate for Ukrainian market I am not investigated the influence of exchange rate changes within one or some hours. I include in regression of Ukrainian market only previous day's shocks from EU market. So the current date foreign shocks were excluded from regression as was done in the specification of Habib (2002) and in contrast to Engle, Ito and Lin (1990).

For Polish exchange market I specify the model that includes euro to dollar change in exchange rate as an exogenous variable in the same way as was done for Ukraine. I am not primarily interested in the result of estimation for Poland but I need them to compare it with those for Ukrainian market, in particular the value of the coefficient of exogenous variable EUR/USD. The model for Polish volatility of exchange rate can be written in the following form:

$$h_{3,t} = \omega_3 + \sum_{1}^{n} \alpha_{33} \varepsilon_{3,t-1}^2 + \alpha_{32} \varepsilon_{2,t-1}^2$$

Stata represents the ARCH specification of the PLN/USD volatility in such way:

$$h_{3,t} = \omega_3 + \exp\{\omega_2 + \alpha_{32}\varepsilon^2_{2,t-1}\} + \sum_1^n \alpha_{33}\varepsilon^2_{3,t-1}$$

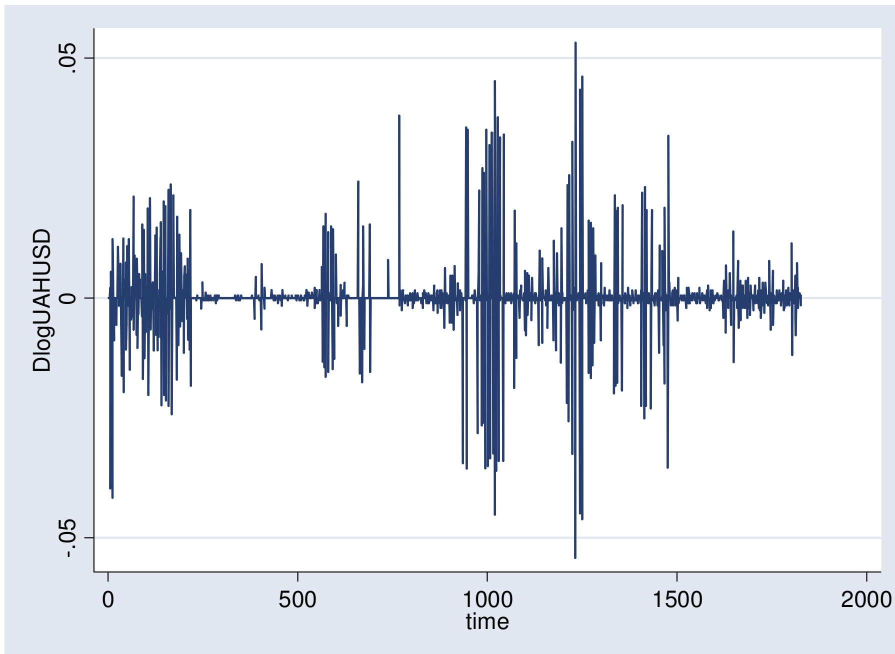
Chapter 4

EMPIRICAL ESTIMATION AND RESULTS

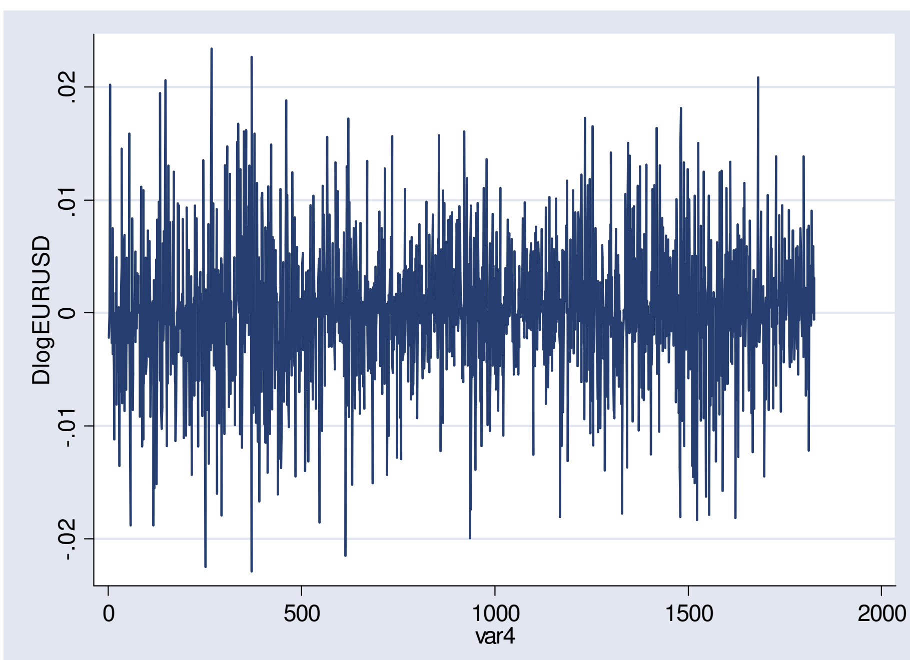
The first step in estimation of the specified model is to investigate how time series must be modified to be used in modeling. I work with the natural logarithm of exchange rate since I am interested in the percentage changes of variables. In order to use the exchange rate for modeling the time series should be examined for stationarity. For this purpose the Dickey-Fuller test for unit root is used. As one could expect, UAH/USD, EUR/USD and PLN/USD exchange rates were found to be not stationary and integrated of order one. Hence, only the first differences of natural logarithms of UAH/USD, EUR/USD and PLN/USD exchange rates are stationary.

For convenience the first differences graphs of all exchange rates natural logarithms were plotted. Visual inspection of graphs supports the evidence of presence of ARCH GARCH effects.

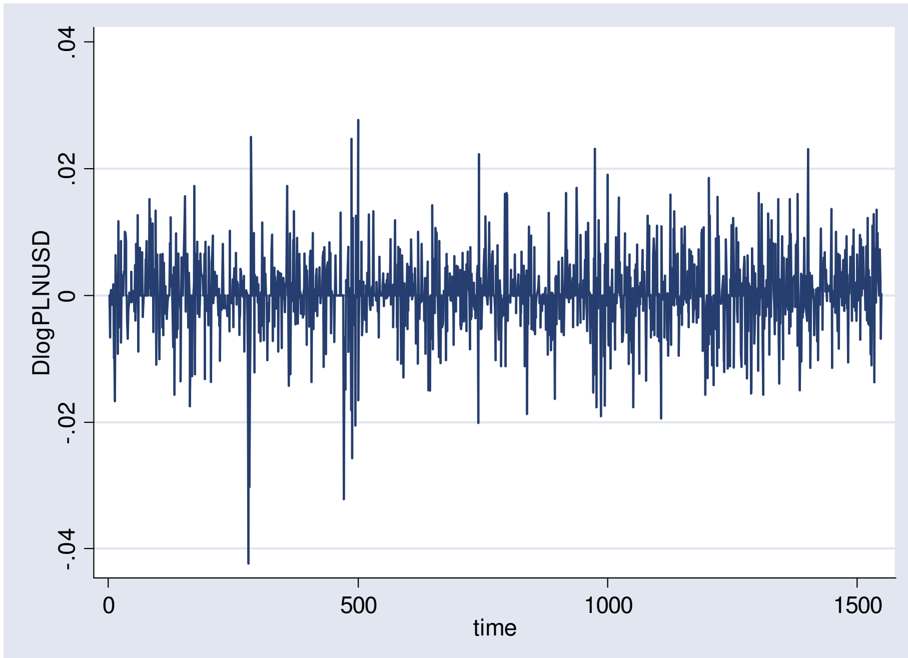
Graph 4. First difference of logUAH/USD exchange rate.



Graph 5. First difference of logEUR/USD exchange rate.



Graph 6. First difference of log PLN/USD exchange rate.



Since PLN/USD time series includes five outliers we exclude them from the sample to obtain appropriate results of estimation. In the case of using PLN/USD exchange rate with full list of daily observations the estimation can not be found since Stata does not converge. The graph of natural logarithm of PLN/USD exchange rate is plotted without these five outliers.

The next step is to figure out how many lags should be included in AR specification of logUAH/USD and logPLN/USD exchange rates first difference model. It either how Ukrainian and Polish change in exchange rate depends on its own past changes. The Durbin-Watson test showed that serial correlation in Ukrainian exchange market model is absent when the number of included lags is extented to 5. The same procedure was applied to the Polish exchange rate and it was found that serial correlation is absent when the number of lags in AR specification of change in PLN/USD is equal to 2.

Now I specify the basic GARCH model for only Ukrainian currency. After testing several models I choose GARCH (1, 1) for Ukrainian volatility since coefficients of higher lags are not significant when ARCH or GARCH terms are bigger than one. Hence, equation for change of Ukrainian exchange rate in one day ε_{1t} and volatility equation h_{1t} appear in the following form:

$$\varepsilon_{1t} = \gamma_0 + \gamma_1 \varepsilon_{1,t-1} + \ldots + \gamma_5 \varepsilon_{1,t-5}$$

$$h_{1,t} = \omega_1 + \beta_{11} h_{1,t-1} + \sum_{1}^{n} \alpha_{11} \varepsilon_{1,t-1}^2 + \alpha_{12} \varepsilon_{2,t-1}^2$$

Coefficients in GARCH specification must satisfy the requirements that $\omega_1 > 0$, $\alpha_i > 0$, $\beta_i \geq 0$ and the sum of all α_i and β_i must be less than one.

Estimation of Ukrainian change in exchange rate is presented by the equation:

$$\underset{}{\varepsilon_{1t}} = \underset{(0.0229)}{-0.4543\varepsilon_{1,t-1}} \underset{(0.0245)}{- 0.3113\varepsilon_{1,t-2}} \underset{(0.0249)}{- 0.2604\varepsilon_{1,t-3}} \underset{(0.0245)}{- 0.2558\varepsilon_{1,t-4}} \underset{(0.0229)}{- 0.1454\varepsilon_{1,t-5}}$$

Hence, today change in Ukrainian exchange rate depends on five previous lags. As one could expect the higher is the lag the smaller impact it has on the change of Ukrainian exchange rate. All coefficients in the model are statistically and economically significant.

Estimation of first difference of logUAH/USD volatility gives following result for simple GARCH (1,1) specification:

$$h_{1,t} = (6.16E - 07) + 0.0879\varepsilon^2_{1,t-1} + 0.8955h_{1,t-1}$$

. (2.44E-08) (0.0046) (0.0035)

All coefficients are significant and the sum of ARCH and GARCH terms are less than one. The requirement of GARCH modeling is satisfied. So, Ukrainian volatility of UAH/USD h_{1t} positively depends on own previous period volatility $h_{1,t-1}$ and past changes in exchange rate $\varepsilon^2_{1,t-1}$. The volatility is explained in higher extent through own previous volatility then through the sugared change in exchange rate since GARCH term has higher coefficient than ARCH term.

When exogenous squared change of first difference of logEUR/USD exchange rate is included in the equation of Ukrainian volatility the results of estimation are as follows:

$$h_{1,t} = \exp\{-13.87 - 36044.37\varepsilon^2_{2,t-1}\} + 0.0883\varepsilon^2_{1,t-1} + 0.8949h_{1,t-1} \quad .$$

. (0.0809) (11895.95) (0.0046) (0.0035)

In accordance with estimation all coefficients in the model of Ukrainian exchange market that is influenced by EU changes in exchange rate are significant. Hence, it means that both Meteor Shower and Heat Wave effects are present. The volatility of UAH/USD exchange rate h_{1t} is determined by own past volatility $h_{1,t-1}$ and also by changes in EUR/USD exchange rate ε^2_{2t-1}. The most powerful determinant of Ukrainian volatility is own previous volatility $h_{1,t-1}$. Own previous changes in UAH/USD exchange rate $\varepsilon^2_{1,t-1}$ have significantly smaller influence on UAH/USD volatility and the least impact is exhibited by the change in EUR/USD exchange rate $\varepsilon_{2,t-1}^2$. High value of coefficient near squared change of first difference of logEUR/USD $\varepsilon_{2,t-1}^2$ indicates that the impact of EU on Ukrainian exchange rate's volatility is very low. It can be seen more clearly if the equation will be rewritten in such way:

$$h_{1,t} = 1/\exp\{13.87\} * 1/\exp\{36044.37\varepsilon_{2,t-1}^2\} + 0.0959\varepsilon_{1,t-1}^2 + 0.8949h_{1,t-1}$$

So, the higher is the coefficient near the EU term $\varepsilon_{2,t-1}^2$ the lower is the influence of EUR/USD change in exchange rate on UAH/USD volatility. Estimated result confirms the suggestion that EU can have limited influence on Ukrainian exchange market due to regulated exchange rate regime. Despite the fact that NBU officially runs free floating exchange rate regime with minimal currency intervention the exchange rate is strongly restricted.

To disclose the evidence of limited EU impact on Ukrainian volatility I use following calculations:

Assume zero influence of EU exchange market on Ukrainian volatility and plug $\varepsilon_{2,t-1}^2 = 0$ into the model. Ukrainian exchange rate volatility will be:

$$h_{1,t} = \exp\{-13.87 - 36044.37 * 0\} + 0.0959\varepsilon_{1,t-1}^2 + 0.8949h_{1,t-1} =$$
$$= [9.46969E - 07] + 0.0959\varepsilon_{1,t-1}^2 + 0.8949h_{1,t-1} \approx$$
$$\approx 0 + 0.0959\varepsilon_{1,t-1}^2 + 0.8949h_{1,t-1}$$

When we plug into equation one standard deviation of squared change of first difference of logEUR/USD $\varepsilon^2_{2,t-1} = 0.000064$ and compute the volatility we obtain:

$$h_{1,t} = \exp\{-13.87 - 36044.37 * 0.000064\} + 0.0959\varepsilon^2_{1,t-1} + 0.8949h_{1,t-1} =$$
$$= [8.93518E - 08] + 0.0959\varepsilon^2_{1,t-1} + 0.8949h_{1,t-1} \approx$$
$$\approx 0 + 0.0959\varepsilon^2_{1,t-1} + 0.8949h_{1,t-1}$$

The mean of Ukrainian volatility h_{1t} is equal to 0.0000389. UAH/USD volatility does not differ a lot from the mean when we plug instead of $\varepsilon^2_{2,t-1}$ values of zero or one standard deviation of this variable. It implies that when there is foreign shock equal to 0.000064 or there is no this shock UAH/USD volatility stays almost the same. The change in the mean of Ukrainian volatility due to EU term is very small comparing to the value of mean, the change is so small that even does not influence the mean. Hence, we can conclude that EU influence on Ukrainian volatility is economically insignificant. Meteor shower effect is statistically significant but not economically.

In order to compare coefficients similar estimation for Poland was made. For Polish exchange rate volatility Stata shows such specification:

$$h_{3,t} = 0.0002851 + \exp\{-10.7480 + 8313.701\varepsilon^2_{2,t-1}\} + 0.08716\varepsilon^2_{3,t-1}$$

. (0.0001372) (0.02315) (577.4219) (0.01709)

The estimation result shows ARCH specification for Polish volatility. There is no GARCH term in the equation in contrast to Ukrainian volatility model. All coefficients in the model are statistically significant. Such specification implies that Polish volatility is explained only by previous change in own exchange rate but not by own previous volatility in contrast to Ukrainian volatility. The coefficient near EU term $\varepsilon_{2,t-1}^2$ in the case of Poland has positive sign. The influence of EU change in exchange rate on Polish volatility is positive in contrast to Ukraine where it exist a negative influence of EU shock. Such results are reasonable since Poland have more liberal exchange rate regime than Ukraine and we suggest that Polish volatility is influenced by foreign factors such as change in EUR/USD exchange rate to higher extent.

The mean of predicted Polish exchange rate volatility is equal to 0.000396. If we compute Polish volatility with the value of EU shock, $\varepsilon_{2,t-1}^2$, equal to zero and then to one standard deviation we will obtain following results:

$$h_{3,t} = 0.0002851 + 0.00002149 + 0.08716\varepsilon_{3,t-1}^2$$

$$h_{3,t} = 0.0002851 + 0.00003565 + 0.08716\varepsilon_{3,t-1}^2$$

Different shocks give us different results for mean of Polish volatility. The change in mean of PLN/USD volatility is substantial comparing to the value of mean. As we expected, the influence of EU change in exchange rate on Polish volatility is statistically and economically significant. Hence, meteor shower effect for PLN/USD volatility is statistically and economically significant in contrast to Ukrainian results.

Chapter 5

CONCLUSION

The goal of this work was to consider Ukrainian exchange rate volatility with help of GARCH modeling and check out two theories of volatility determining. One theory is called heat wave effect. In accordance to this hypothesis UAH/USD volatility is determined only by own previous fluctuations in the exchange rate. The other theory is called meteor shower effect under which Ukrainian volatility is determined not only by own previous changes in exchange rate but is also influenced by European Union's exchange rate changes.

We have showed that GARCH modeling is applicable to Ukrainian exchange market. There was a suspicion that GARCH can not be used for modeling under strongly regulated exchange rate, but our estimation supports the possibility of GARCH application.

Based on the results of our estimation, we can not reject meteor shower effect, so that Ukrainian volatility of exchange rate is influenced by European Union changes in exchange rate. Our main findings are:

1) Meteor shower and heat wave effects are both statistically significant. Ukrainian exchange rate volatility is determined not only by own previous volatility but is also influenced by EU exchange rate.

2) Heat wave effect is substantially more powerful comparing with meteor shower effect in determining of Ukrainian

volatility. Thus, hryvna to dollar exchange rate volatility is explained through domestic previous changes to higher extent than through foreign fluctuations.

3) Meteor shower effect is economically insignificant in determining of Ukrainian volatility since volatility remains almost the same despite different values of EU shocks or changes in euro to dollar exchange rate.

The situation may change drastically when limiting restrictions of NBU exchange regulation will be relaxed. Under such conditions the relationship between Ukrainian volatility and EU changes in exchange rate will surely differ from one we have now. It is supported by the results of Poland that currently has more liberal exchange rate regime. Polish volatility of exchange rate is positively influenced by EU changes and this influence is statistically and economically significant in contrast to Ukrainian relationship. So, based on our present findings we suggest the following implications:

- on micro level, traders and other financial intermediaries currently should not take into account changes of euro to dollar exchange rate in the process of predicting hryvna to dollar exchange rate volatility. But in the nearest future the situation could change.

- on macro level, the National Bank of Ukraine should take into account that in case of relaxing exchange restrictions it could observe different influence of EU exchange market on Ukrainian exchange market. The fact that relationship may change is supported by Polish results of estimation.

BIBLIOGRAPHY

Aysoy, Balaban, Kogar, Ozcan (1996) *"Daily Volatility in the Turkish Foreign Exchange Market"* Central Bank's of the Republic of Turkey Discussion Paper #9625

Baillie, Bollerslev (1991*):"Intra-Daily and Inter-Market Volatility in Foreign Exchange Rates,"* The Review of Economic Studies, 3, 565-585

Black, McMillan (2004): *"Long Run Trends and Volatility Spillovers in Daily Exchange Rates,"* Applied Financial Economics, 14, 895-907.

Bollerslev, T.P. (1986): *"Generalized Autoregressive Conditional Heteroskedasticity,"* Journal of Econometrics, 31, 309-328

Brooks, C.(2001): *"A Double-Threshold GARCH Model for French Franc/Deutschmark Exchange Rate,"* Journal of Forecasting, 20, 135-143

Council of the European Union, *EU-Ukraine Cooperation Council Eighth Meeting, EU Press Release*, 2005

Enders, Walter. (1995) *Applied Econometrics Time Series.* 1ST ed., John Wiley & Sons, Inc

Engle, Takatoshi, Lin (1990): *"Meteor Shower or Heat Waves? Heteroskedastic Intra-Daily Volatility in Foreign Exchange Market,"* Econometrica, 3, 525-542

Fernandez (2000): *"How Sensitive is the Volatility to Exchange Rate Regimes?,"* Department of Industrial Engineering at University of Chile (DII)

Fernandez-Izquierdo, A., Lafuente, J. (2004): *"International Transmission of Stock Exchange Volatility: Empirical Evidence from the Asian Crisis,"* Global Finance Journal, 15, 125-137

Franses P.H., van Dijk, D. (2000) *Non-linear Time Series Models in Empirical Finance.* Cambridge University Press

Johnston, K., Scott, E. (2000): *"GARCH Models and the Stochastic Process Underlying Exchange Rate Price Changes,"* Journal of Financial and Strategic Decisions, 13/2, 13-24

Habib, M. (2002): *"Financial Contagion, Interest Rates and the Role of Exchange Rate as Shock Absorber in Central and Eastern Europe,"* BOFIT Discussion Papers, 7

Institute for Economic Research and Policy Consulting, 2005, *Monthly Economic Monitoring of Ukraine* #3

Malik, A. (2004): *"European Exchange Rate Volatility Dynamics; an Empirical Investigation,"* Journal of Empirical Finance, 12, 29-46

Melvin, B., Melvin, M. (2003): *"The Global Transmission of Volatility in the Foreign Exchange Market,"* The Review of Economics and Statistics, 5, 35-45

Mills, T. (1999) *The Econometric Modeling of Financial Time Series.* 2nd ed., Cambridge University Press

Speight, A., McMillan, D. (2001) *"Volatility spillovers in East European Black-Market Exchange Rates,"* Journal of International Money and Finance, 20, 367-378

APPENDIX A

AR specification for Ukrainian change in exchange rate.

```
reg DlogUAHUSD l1.DlogUAHUSD l2.DlogUAHUSD l3.DlogUAHUSD l4.DlogUAHUSD
l5.DlogUAHUSD

      Source |       SS       df       MS              Number of obs =    1821
-------------+------------------------------           F(  5,  1815) =   90.46
       Model |  .017419021     5  .003483804           Prob > F      =  0.0000
    Residual |  .069896867  1815  .000038511           R-squared     =  0.1995
-------------+------------------------------           Adj R-squared =  0.1973
       Total |  .087315889  1820  .000047976           Root MSE      =  .00621

------------------------------------------------------------------------------
DlogUAHUSD   |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DlogUAHUSD   |
          L1 |  -.4543285   .0229766   -19.77   0.000    -.4993918   -.4092652
          L2 |  -.3113017   .0245847   -12.66   0.000     -.359519   -.2630844
          L3 |   -.260464   .0249031   -10.46   0.000    -.3093058   -.2116222
          L4 |  -.2558151   .0245851   -10.41   0.000    -.3040331   -.2075971
          L5 |  -.1454956   .0229763    -6.33   0.000    -.1905584   -.1004328
_cons        |   .0000255   .0001454     0.18   0.861    -.0002597    .0003107
------------------------------------------------------------------------------
```

Durbin-Watson test for absence of serial correlation in
AR specification for Ukrainian change in exchange rate.

```
durbina

Durbin's alternative test for autocorrelation
---------------------------------------------------------------------------
    lags(p)  |          chi2               df                 Prob > chi2
-------------+-------------------------------------------------------------
       1     |          3.632               1                   0.0567
---------------------------------------------------------------------------

                        H0: no serial correlation
```

Ukrainian volatility without EU influence.

```
arch  DlogUAHUSD, ar(1/5) arch(1) garch(1)

Iteration 47:  log likelihood =  7315.4355

ARCH family regression -- AR disturbances

Sample:  2 to 1827                               Number of obs      =      1826
                                                 Wald chi2(5)       =    387.01
Log likelihood =  7315.436                       Prob > chi2        =    0.0000

------------------------------------------------------------------------------
             |                 OPG
DlogUAHUSD   |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DlogUAHUSD   |
_cons        |   3.25e-07   .0000376     0.01   0.993    -.0000733    .0000739
-------------+----------------------------------------------------------------
ARMA         |
ar           |
          L1 |  -.4400961   .0254993   -17.26   0.000    -.4900737   -.3901184
          L2 |  -.3302305   .0363026    -9.10   0.000    -.4013822   -.2590787
          L3 |  -.2773207    .036974    -7.50   0.000    -.3497884    -.204853
          L4 |  -.1991184   .0338917    -5.88   0.000    -.2655448   -.1326919
          L5 |  -.1198864   .0273337    -4.39   0.000    -.1734595   -.0663134
-------------+----------------------------------------------------------------
ARCH         |
arch         |
          L1 |   .0879014   .0046286    18.99   0.000     .0788295    .0969734
garch        |
          L1 |   .8955274   .0034767   257.58   0.000     .8887132    .9023415
_cons        |   6.16e-07   2.44e-08    25.25   0.000     5.69e-07    6.64e-07
```

Ukrainian volatility with EU influence.

```
arch  DlogUAHUSD, ar(1/5) arch(1) garch(1)het(sqDlogEURUSD)

Iteration 138: log likelihood =  7336.2095  (backed up)

ARCH family regression -- ARMA disturbances and mult. heteroskedasticity

Sample:  2 to 1827                               Number of obs      =      1826
                                                 Wald chi2(5)       =    394.46
Log likelihood =   7336.21                       Prob > chi2        =    0.0000

------------------------------------------------------------------------------
             |                 OPG
DlogUAHUSD   |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DlogUAHUSD   |
_cons        |   3.52e-06   .0000402     0.09   0.930    -.0000752    .0000823
-------------+----------------------------------------------------------------
ARMA         |
ar           |
          L1 |  -.4410349   .0253706   -17.38   0.000    -.4907604   -.3913095
          L2 |  -.3318431   .0362212    -9.16   0.000    -.4028352   -.2608509
          L3 |   -.280289   .0370154    -7.57   0.000    -.3528378   -.2077401
```

```
          L4 |   -.199703   .0338454    -5.90   0.000    -.2660387   -.1333672
          L5 |  -.1218581   .0270398    -4.51   0.000    -.1748552    -.068861
-------------+----------------------------------------------------------------
HET          |
sqDlogEURUSD |  -36044.37   11895.95    -3.03   0.002       -59360   -12728.74
_cons        |  -13.87245   .0809779  -171.31   0.000    -14.03117   -13.71374
-------------+----------------------------------------------------------------
ARCH         |
arch         |
          L1 |   .0883224   .0045889    19.25   0.000     .0793283    .0973165
garch        |
          L1 |   .8949157   .0035077   255.13   0.000     .8880408    .9017907
------------------------------------------------------------------------------
```

Summary statistics for predicted conditional Ukrainian volatility.

sum condvar

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
     condvar |      1826    .0000389     .000059   3.66e-06   .0004095
```

Summary statistics for squared change in EU exchange rate.

sum sqDlogEURUSD

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
sqDlogEURUSD |      1826    .0000332     .000064          0   .0005462
```

APPENDIX B

AR specification for Polish change in exchange rate.

```
reg DlogPLNUSD l1.DlogPLNUSD l2.DlogEURUSD

      Source |       SS       df       MS              Number of obs =    1545
-------------+------------------------------           F(  2,  1542) =    8.86
       Model |  .000621605     2  .000310803           Prob > F      =  0.0001
    Residual |  .054066004  1542  .000035062           R-squared     =  0.0114
-------------+------------------------------           Adj R-squared =  0.0101
       Total |  .054687609  1544  .000035419           Root MSE      =  .00592

------------------------------------------------------------------------------
DlogPLNUSD   |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DlogPLNUSD   |
          L1 |  -.0594338   .0253171    -2.35   0.019    -.1090934   -.0097743
DlogEURUSD   |
          L2 |   .0947268   .0266766     3.55   0.000     .0424005     .147053
_cons        |   .0002597    .000151     1.72   0.086    -.0000364    .0005559
------------------------------------------------------------------------------
```

Durbin-Watson test for absence of serial correlation in
AR specification for Polish change in exchange rate.

```
durbina

Durbin's alternative test for autocorrelation
---------------------------------------------------------------------------
    lags(p)  |          chi2               df                 Prob > chi2
-------------+-------------------------------------------------------------
       1     |          1.438               1                   0.2305
---------------------------------------------------------------------------
                        H0: no serial correlation
```

Polish volatility without EU influence.

```
arch   DlogPLNUSD, ar(1,2) arch(1)

(setting optimization to BHHH)
Iteration 6:   log likelihood =  5762.3293

ARCH family regression -- AR disturbances

Sample:  2 to 1548                              Number of obs      =      1547
                                                Wald chi2(2)       =      4.69
Log likelihood =  5762.329                      Prob > chi2        =    0.0958

------------------------------------------------------------------------------
             |                 OPG
DlogPLNUSD   |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DlogPLNUSD   |
_cons        |   .0002979   .0001466     2.03   0.042     .0000106    .0005852
-------------+----------------------------------------------------------------
ARMA         |
ar           |
          L1 |  -.0491842   .0317246    -1.55   0.121    -.1113633     .012995
          L2 |    .040164   .0245833     1.63   0.102    -.0080185    .0883464
-------------+----------------------------------------------------------------
ARCH         |
arch         |
          L1 |   .1627367   .0212183     7.67   0.000     .1211495    .2043239
_cons        |   .0000297   7.57e-07    39.21   0.000     .0000282    .0000312
------------------------------------------------------------------------------
```

Polish volatility with EU influence.

```
arch   DlogPLNUSD, ar(1,2) arch(1)het( sqDlogEURUSD)

Iteration 72:  log likelihood =  5843.0899  (backed up)

ARCH family regression -- ARMA disturbances and mult. heteroskedasticity

Sample:  2 to 1548                              Number of obs      =      1547
                                                Wald chi2(2)       =      4.44
Log likelihood =   5843.09                      Prob > chi2        =    0.1084

------------------------------------------------------------------------------
             |                 OPG
DlogPLNUSD   |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DlogPLNUSD   |
_cons        |   .0002851   .0001372     2.08   0.038     .0000162    .0005541
-------------+----------------------------------------------------------------
ARMA         |
ar           |
          L1 |  -.0481422   .0287707    -1.67   0.094    -.1045317    .0082473
          L2 |   .0343752   .0251299     1.37   0.171    -.0148786    .0836289
-------------+----------------------------------------------------------------
HET          |
sqDlogEURUSD |   8313.701   577.4219    14.40   0.000     7181.975    9445.427
_cons        |  -10.74804    .023151  -464.26   0.000    -10.79341   -10.70266
```

```
-------------+----------------------------------------------------------------
ARCH         |
arch         |
          L1 |   .0876118   .0170973     5.12   0.000     .0541017    .1211218
------------------------------------------------------------------------------
```

Summary statistics for predicted conditional Polish volatility

sum condvar

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
     condvar |      1547    .0000396    .0000753   .0000215   .0016799
```