Central European Journal of Economic Modelling and Econometrics

Switching Volatility in Emerging Stock Markets and Financial Liberalization: Evidence from the new EU Member Countries

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Submitted: 7.08.2012, Accepted: 19.12.2012

Abstract

In this paper, we use weekly stock market data to examine whether the volatility of stock returns of ten emerging capital markets of the new EU member countries has changed since the opening of their capital markets. In particular we are interested in understanding whether there are high and low periods of stock returns volatility and what the degree of correlation across these markets is. We estimate a Markov-Switching ARCH (SWARCH) model proposed by Hamilton and Susmel (1994) and we allow for the possibility that two or three volatility regimes may exist for stock returns volatility. The main finding of the present study is that the high volatility of stock returns of all new EU emerging stock markets is associated mainly with the 1997-1998 Asian and Russian financial crises as well as over the 2007-2009 financial turmoil, while there is a transition to the low volatility regime as they approach the accession to the EU in 2004. It is also shown that the capital flows liberalization process has resulted in an increase in volatility of stock returns in most cases.

Keywords: emerging European stock markets, stock return volatility, Markov-switching, financial crises

JEL Classification: C22, G15

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1 Introduction

In the early 1990s a number of Central and Eastern European (CEE) countries established capital markets as part of their transition process towards adopting the mechanisms of a market economy. One of the main objectives of the reforms in the post-communist countries was the creation of private ownership via privatization of state-owned enterprises. As a result, a number of stock markets were established in the region. The first stock exchange that reopened in the area was the Ljubljana Stock Exchange (LJSE), on March 29, 1990, followed by the Budapest Stock Exchange (BSE), on June 21, 1990, and the Warsaw Stock Exchange (WSE) on April 16, 1991. In the aftermath of the establishment of the new stock markets in Central and Eastern Europe, the governments, in order to attract foreign capital, implemented several measures, such as the improvement of disclosure practices of firms, order execution, ownership rights, and the abolishment of restrictions on capital movements. The accession of these countries to the European Union on May 1, 2004, as well as the accession of Romania and Bulgaria on January 1, 2007, gave a big boost to these markets and attracted the interest of many investors worldwide, who had previously refrained from investing in legally open markets because of real or perceived political, liquidity and corporate governance risks. From January to December of 2004, the CEE stock exchange index recorded a return of significantly high value. The Romanian stock exchange recorded a return of 103.5%, the Slovakian 83.9%, the Hungarian 57.2%, the Estonian 57.1%, the Czech 50.9%, the Polish 27.9% and the Slovenian 24.7%

Financial liberalization is an important issue for a country that aims to attract substantial foreign direct investment in order to support its economic growth as well as to allow foreigners to invest in equity in the domestic stock market. The abolishment of capital controls is the key element to this procedure since it is argued by many researchers that the opening of the financial markets in emerging economies through this channel will have substantial positive effects on the domestic economy. Several studies on the pros and cons of financial liberalization process have further stressed the importance of increased capital flows on the dynamic effects that the development of stock markets will have on the long-run economic growth of the host country (Bekaert and Harvey (1997, 2000, 2002); Bekaert *et al.* (2002a, 2002b); Bekaert *et al.* (2006); De Santis and Imrohoroglu (1997); Edwards and Susmel (2001); Edwards et al. (2003); Henry (2000); Huang and Yang (1999); Kaminsky and Schumkler (2003) and Kim and Singal (2000) are among the numerous studies that have studied the effects of financial liberalization on emerging economies). The main argument in favor of the abolishment of capital controls is the reduction of the aggregate cost of equity capital which is expected to occur. A further positive effect of the liberalization of stock markets is the expected increase in physical investment which will come from the decline in the cost of equity capital. The call for increased transparency and accountability by the firm's management is a third positive effect since it will result in the improvement of resource allocation, reduction of the risk of holding stocks and

in further reduction of the cost of capital, (Henry, 2000; Kim and Singal, 2000).
However, the financial liberalization process is likely to induce negative effects in return. A major concern raised by the governments of emerging economies as well as by policy practitioners, is that the abolition of capital controls will increase uncertainty due to the high interest elasticity of international capital flows. Additionally, capital flows are subject to influences from the expectations about future economic growth as well as from the expected returns from holding domestic stocks. In light of such effects we could expect that even a small change in the factors that determine capital flows may lead to negative effects in the domestic economy. Furthermore, it is argued that the prices and therefore returns of domestic stocks will become more volatile because the abolition of capital controls will increase the exposure of the domestic capital market through its interdependence with the global financial markets. Finally, there are concerns that financial liberalization will have negative effects on the real economy of a country through its impact on the foreign exchange market. A substantial capital inflow will result to in appreciation of the domestic economy, causing a reduction in exports to those countries that are export-oriented, and in rising inflation in the economies whose incoming capital inflow is not matched by corresponding investment plans.
Over the last two decades the operation of the emerging European stock markets has been characterized by several events that may have affected the volatility of those markets. Such events were the massive privatization programs that took place in the early 1990s, the frequent exchange rate regime changes, the financial and currency crises (i.e. the 1997-1998 Asian and Russian crisis as well as recent financial turmoil of 2007-2009) and the European Union (EU) accession process. Understanding the channels the stock markets' volatility changes over time is important since the degree of risk of an asset is a crucial determinant of its price. A great number of studies have examined the link between financial liberalization and the volatility of stock returns for a number of emerging markets. The evidence from these works is rather mixed since some of them argue that the abolishment of capital controls has led to increased volatility of stock returns whereas another group of papers has not found that the process of opening up the capital markets has a positive effect on the volatility of stock returns (See Bekaert and Harvey (2000); Henry (2000); and Bekaert et al. (2000a,b). Furthermore, Bekaert and Harvey (1995, 1997), De Santis and Imrohoroglu (1997), Huang and Yang (1999), Aggarwal *et al.* (1999), Kaminsky and Schmukler (2003), Edwards and Susmel (2003), Bekaert *et al.* (2006), Cunado *et al.* (2006), Chiang *et al.* (2007), Moore and Wang (2007) and Diamandis (2008) are examples of studies that have examined the issue of increased volatility in emerging markets following financial liberalization).
In this paper we examine the effects of financial liberalization which ten Central and Eastern European countries have implemented since the early 1990s as part of the transition process to becoming market economies. Given that these economies have gone through different states since the beginning of this transition process, it is

expected that nonlinearities and regime switching behaviour in their stock markets are likely to be present. Although there exists a large number of applications of the switching regimes models to the study of the volatility of stock returns for several mature markets, there is a limited number of studies of empirical application of this type of models for modelling returns of Central and Eastern European stock market indices. Linne (2002), Bialkowski (2004) and Moore and Wang (2007) are the only works that examine this issue within the regime-switching setting which provides some evidence of regime switching behaviour in the volatility of stock returns for a subset of the CEE emerging markets. Our analysis extends previous research by including all ten CEE stock markets and pays particular attention to the effects of financial liberalization.

This paper contributes to the literature since it examines the volatility patterns of stock returns of the Central and Eastern European emerging capital markets by utilizing the Markov-switching ARCH (SWARCH) model proposed by Hamilton and Susmel (1994). This model allows the volatility of the stock returns of these emerging European markets to switch across different states, during the period of reconstruction of the underlying transition economies in the post communist era. Moreover, we investigate whether periods of increased stock market volatility identified by the SWARCH models coincide across countries and if they match the historical events (i.e. political and financial crises events) as well as whether they can be linked with the financial liberalization process that these economies are still implementing.

The main findings that emerge from our analysis are summarized as follows. First, using the SWARCH specification we were able to identify two - or in some cases three-state regimes for the ten Central and Eastern European countries. Second, with the exemption of Bulgaria, a 'low' and a 'high' volatility regime has been shown to be statistically significant. Third, based on the estimated transition probabilities we show that the estimated regimes are highly persistent. Fourth, the estimation of the three-state SWARCH specification also leads to the conclusion that, apart from Slovenia, all other stock markets have experienced very high volatility during the major financial crises of the period 1997-2001 as well as over the 2007-2009 financial turmoil. Fifth, we argue that the European Union accession process has acted as a stabilizer for the smoothing of volatility of these emerging capital markets. Finally, we provide evidence that stock returns volatility increased as a result of the abolition of capital controls in most cases. Our findings lead to several important policy implications for policy makers, practitioners, investors and portfolio managers, since changes in volatility that may be the results of financial crises, restructuring of an economy, frequent exchange rate regimes changes, and abolition of capital controls must be taken into consideration when policy or investment decisions are made. This is especially true in periods of financial instability when transmission of negative effects takes place across countries.

The rest of the paper is organized as follows. In section 2 we discuss the financial liberalization process and market characteristics of the CEE economies. Section 3

presents the econometric methodology. In section 4 we discuss the data and the empirical results and section 5 provides our conclusions.

2 Market characteristics and financial liberalization

Since the early 1990s, the governments of the CEE countries have implemented various programmes of financial liberalization. Initially, the capital account of the CEE countries was closed with limited capital flows in and out of their territories. In order to move from transition to market economies and become an integral part of the world economy, it was necessary for financial liberalization and capital account openness to be achieved. However, this adjustment was not uniform and it depended on the initial status of each CEE country as well as the macroeconomic environment. For most of the countries, current account convertibility was achieved between 1994 and 1996 as part of IMF membership obligations. For the Czech Republic, Hungary, Poland, and the Slovak Republic, the application to become members of OECD in 1993-1994 was an important step in achieving capital account openness. Certainly the major framework for these countries to implement a financial liberalization was set by the prospect of EU membership and the accession negotiations, given that under the EC Treaty, EU accession required full capital account liberalization. As a result a round of negotiations between each candidate CEE country and the European Commission began in order to provide the necessary framework for a complete abolishment of capital controls. A candidate country was allowed to deviate from the specific requirements only if they could destabilize the monetary and exchange rate policies operation. In principle no provision was made for capital restrictions to exist after the accession to the EU, unless it was linked with property rights regarding the acquisition of agricultural and forestry land and real estate in politically sensitive areas.

The speed of adjustment to the requirements of financial liberalization was not uniform. First were the Baltic countries and the Czech Republic, which had abolished most restrictions on capital transactions by 1995. In contrast, Hungary, Poland, the Slovak Republic, and Slovenia opened their capital accounts more gradually, achieving full liberalization in 2001-2004, whereas Bulgaria and Romania achieved full financial liberalization in late 2006 as they only became members in 2007. For a comprehensive analysis of the financial liberalization process in the CEE countries see Von Hagen and Siedschlag (2008).

Table 1A provides an overview of important characteristics of the examined stock markets in Central and Eastern Europe. It is shows that at the end of 2005 the larger stock markets in the CEE region, in terms of market capitalization, are those of Poland, the Czech Republic and Hungary, with market capitalization of 93.60, 54.12 and 32.57 billion dollars respectively. Moreover, the smaller markets in the region are those of Estonia and Latvia with market capitalization of only 3.52 and 2.59 billion dollars respectively. As a result of the different approaches to privatization pursued by the CEE countries, the examined stock markets had substantially different patterns

of growth, in terms of the listed firms. For instance, the number of firms listed on the Czech and Slovakian stock exchanges was initially large, following the first of several mass waves of privatization. Romania also followed a mass privatization program, but all of the newly privatized companies listed on an over-the-counter market, the RASDAQ. In December of 1998, 5946 companies were listed on the RASDAQ market. Moreover, Bulgaria and Lithuania followed the same privatization strategy, a fact that is revealed by the initial large number of listed firms (see Table 1B). Since then, the majority of those firms have been delisted, because of lack of liquidity and overly strict listing requirements. At most CEE exchanges only a minority of the companies are listed at the official and regulated markets, where the listing requirements are much higher than other developed exchanges. On the contrary, there is a large concentration of listings in the free market (unregulated) segments, since these listings impose no costs on the companies. However, in other exchanges, like the Polish one, the number of listed firms has grown slowly, as a result of a steady approach to the implementation of the privatization scheme.

Furthermore, Table 1B provides alternative signals of liberalization which include the Official Liberalization date and the dates of introduction of the First American Depository Receipt (ADR) as well as reporting various indicators of direct and indirect barriers for institutional investors which are used to assess the extent of financial liberalization in these economies. Bekaert and Harvey (1995) proposed an indicator for characterizing the situation in which the emerging markets were opened to foreign investors by considering a multitude of elements including: the official date of the capital market liberalization, the date of the ADR (American Depository Receipts) appearance on the market and the date of the first country fund. Based on this information we argue that most of these restrictions were lifted between 1996 and 1999, depending on the specific country. The Czech market was the first that made some steps towards official capital market liberalization, while the Lithuanian market was the last. However, it is important to point out that the legal restrictions on foreign participation were gradually lifted. The International Finance Corporation has a complete data set with all opening dates and legal arrangements since 1974 (IFC, various issues). Financial liberalization can take different forms: relaxation of foreign exchange restrictions, reduction of foreign ownership restriction and allowing of capital and dividends to be repatriated. In addition, in several emerging economies there have been indirect means of liberalization such as the creation of Country Funds and ADRs which allow foreigners to participate in local markets. These different approaches make the choice of liberalization date difficult in some cases but overall there is a broad agreement on this matter. For a comprehensive and detailed analysis of the liberalization dates and various indicators of direct and indirect barriers for international investors in various emerging economies, see DeSantis and Imrohoroglu (1997, table A1), Kim and Singal (2000, Appendix) and Henry (2000, Tables I and III).

Table 1A: Market Characteristics for CEE stock exchange markets

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Number of listed firms																
Bulgaria	15	9	0	998	861	524	402	356	338	332	331	340	369	399	390	390	393
Czech Rep.	1716	1670	320	304	195	151	102	79	65	55	39	32	32	29	25	27	26
Estonia	—	11	25	22	23	20	17	14	14	13	19	17	18	18	16	15	15
Hungary	42	45	48	54	66	59	58	49	50	47	44	41	41	43	46	52	54
Latvia	17	34	50	68	67	63	63	63	62	40	46	11	42	36	35	34	32
Lithuania	304	410	558	60	52	53	45	45	45	43	43	44	41	41	41	40	36
Poland	65	83	143	198	221	225	230	216	203	230	241	265	375	458	486	584	777
Romania	9	17	76	126	122	109	60	60	57	55	59	53	54	64	69	74	79
Slovak Rep.	850	970	918	833	830	866	888	510	452	389	306	187	160	193	107	90	81
Slovenia	17	45	78	90	130	149	151	135	134	140	116	100	87	84	76	72	66
	Market Capitalization (billions of US dollars)																
Bulgaria	0.058	0.0056	0	0.145	0.112	0.134	0.508	0.722	1.762	2.806	5.138	10.312	21.817	8.865	8.687	7.349	8.229
Czech Rep.	24.5	19.3	14.4	13.9	13.3	11.7	9.4	15.8	24.8	43.67	54.12	45.687	70.646	41.222	45.048	42.652	37.782
Estonia	–	0.694	1.111	0.519	1.178	1.812	1.734	2.427	3.79	6.203	3.525	5.955	6.044	1.953	2.665	2.251	1.606
Hungary	2.399	5.186	14.7	13.79	16.1	11.9	10.36	13.01	18.86	28.63	32.57	41.314	46.342	18.524	29.835	27.673	18.93
Latvia	0.009	0.152	0.337	0.385	0.39	0.563	0.697	0.71	1.14	1.655	2.594	2.164	3.089	1.623	1.897	1.258	1.068
Lithuania	0.157	0.9	1.705	1.074	1.138	1.587	1.196	1.523	3.51	6.462	8.125	10.178	10.145	3.629	4.638	5.638	4.062
Poland	4.564	8.413	12.13	20.46	29.57	31.42	26.15	28.84	37.4	71.54	93.6	148.597	212.453	94.51	151.493	189.634	139.068
Romania	0.1	0.06	0.626	0.356	0.313	0.415	1.228	2.717	3.71	11.93	18.18	24.839	31.68	9.004	12.101	13.068	14
Slovak Rep.	5.354	5.771	5.291	4.116	3.628	3.268	3.467	2.649	3.368	4.933	4.741	5.545	6.698	5.442	5.201	4.516	5.409
Slovenia	0.311	0.89	1.875	2.984	2.854	3.099	3.461	5.577	7.134	9.676	7.898	15.159	29	11.788	12.187	9.34	6.301
	Stock Index Return (%)																
		96/95	97/96	98/97	99/98	00/99	01/00	02/01	03/02	04/03	05/04	06/05	07/06	08/07	09/08	10/09	11/10
Bulgaria	BSE	-25.6	–	-36.6	-17.2	-22.8	11.1	54.3	148.2	37.6	32.3	48.7	44.4	-79.7	19.1	-15.2	-11.1
Czech Rep.	PX	26.7	-8.2	-29.4	24.2	-2.3	-13.6	17	41.6	50.9	46.9	6.9	14.2	-52.7	30.2	9.6	-25.6
Estonia	TALSE	–	61.9	54.86	39.3	19.1	4.7	46.8	34.4	57.1	50.7	28.9	-13.3	-56.5	35.7	72.6	-23.9
Hungary	BUX	1.764	93.5	-21.1	39.8	-11	-9.2	9.4	20.3	57.2	41	19.5	5.6	-53.3	73.4	0.5	-20.4
Latvia	RICI	–	39.6	-75	-7.7	1.9	-6.6	27.4	133.3	-30.3	68.9	-3.1	-14.1	-51	16.2	41	-5.6
Lithuania	LITIN	–	16.3	-41.6	9	-3.9	-18.3	6.6	98.2	68.2	52.9	9.8	4.2	-60	36.8	56.4	-27
Poland	WIG	89.1	2.3	-12.8	41.3	5	-26.7	3.2	44.9	27.9	33.7	23.7	5.2	-48.2	33.5	14.9	-21.9
Romania	BET	–	-24.2	-50.9	-2.6	9.1	-4.8	126.9	26	103.5	38.2	18	16.2	-70	61.7	12.3	-17.7
Slovak Rep.	SAX	15.8	2.5	-49.5	-19	19.2	31.4	15.9	26.9	83.9	26.5	0.6	7.2	-19.4	-25.7	-13.7	-6.5
Slovenia	SBI	-18.3	18.7	21.4	5.9	0.1	19	55.2	17.7	24.7	-5.6	56.6	71	-66.1	15	-13.5	-30.7
	Foreign Investors (%)																
Bulgaria	—	—	—	—	—	—	—	—	—	—	—	—	20	—	—	—	—
Czech Rep.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Estonia	—	—	—	—	—	—	—	81	65	83	61	47	48	—	—	—	—
Hungary	—	—	68	71	79	71	72	72	73	78	78	78	72	—	—	—	—
Latvia	—	—	—	—	39	49	44	46	42	43	41	39	40	—	—	—	—
Lithuania	—	34.1	49	49	44	55	46	52	52	55	39	38	35	—	—	—	—
Poland	—	—	—	—	36	56	54	60	55	44	39	35	42	—	—	—	—
Romania	—	—	—	—	—	—	—	—	—	—	—			—	—	—	—
Slovak Rep.	—	—	—	—	—	—	—	39	43	54	61	63	74	—	—	—	—
Slovenia	—	—	—	5.2	3	4.7	9.9	13	8	12	13	15	14	—	—	—	—

Sources: WFOE (World Federation Of Exchanges), FESE (Federation of European Securities Exchanges), National stock exchanges.

Given that exchange rate regimes played an important role in the transition process of these economies, in Table 2 we provide a full account of the exchange rate regimes that the CEE countries adopted over the sample under examination. We observe that almost all types of exchange rate regimes have been put in force, ranging from currency board to flexible exchange rates. Furthermore, we note that Slovenia became a member of the Eurozone on January 1, 2007, Slovakia joined on January 1, 2009 whereas Estonia adopted the European common currency on January 1, 2011. In addition Latvia and Lithuania have their currencies in the ERM II which is a requirement for the satisfaction of the exchange rate criterion of the Maastricht Treaty.

Excess volatility induced by foreign investors has often been used as an argument against the financial liberalization process. Substantial research has focused on liberalization of capital flows and stock market volatility with mixed empirical evidence. The focus of this literature has been mainly the workings of financial liberalization initially for the Latin America economies, and more recently for the Southeast Asian countries. For example, Bekaert and Harvey (1995, 1997), DeSantis and Imrohoroglu (1997), Cunado et al. (2006) and Diamandis (2008) found evidence that stock market volatility was reduced following the financial liberalization process in several Latin American markets and other emerging markets. Other studies like Huang and Yang (1999) have confirmed this reduction in volatility for Argentina and Chile but they also argue that stock return volatility has increased for a number of other emerging markets. The evidence for the reduction of stock return volatility in Latin American markets following the financial liberalization was further confirmed by Edwards and Susmel (2001) who also argue that in Asian countries volatility of stock returns has increased in Asian countries but not in Latin America. Aggarwal et al. (1999) have examined the reasons for the different reactions of the stock markets to the financial liberalization process and they argue that changes in volatility depend on country specific characteristics as well as on the order of events. They also argue that they found no evidence that the liberalization process has induced any change in variance. The present study is the first to our knowledge that examines the effect of financial liberalization on stock return volatility for the CEE countries.

3 The SWARCH model

Early approaches to modeling volatility of stock returns are the autoregressive conditional heteroskedasticity (ARCH) specification proposed by Engle (1982) and the generalized autoregressive conditional heteroskedasticity (GARCH) specification introduced by Bollerslev (1986). However, there are some shortcomings in the use of such models for the study of the volatility in stock return data. A number of researchers (i.e. Diebold, 1986; Lamoureux and Lastrapes, 1990) have shown that both ARCH and GARCH models would encounter high persistence in volatility and lower accuracy in the predicting performance due to low probability events (i.e.

Table 1B: Market Characteristics for CEE stock exchange markets

Country	Stock market established	Origins of stock markets	Restrictions lifted	1st ADR	US equity ownership (mil. dollars)[17]	Pace & sequencing of capital account liberalization	Current account convertibility
Bulgaria	October 1997	Mass privatization	1998[9]	January 1998	0	Gradual	September 24 1994
Czech Republic	June 1992	Mass privatization	September 1994[1]	January 1994	763	Fast	October 1 1995[10]
Estonia	May 1996	Initial public offerings	1996[5]	April 1998	17	Fast	August 15 1994[11]
Hungary	July 1990	Initial public offerings	1996[2]	December 1992	3483	Gradual	January 1 1996[12]
Latvia	January 1996	Initial public offerings	1996[7]	December 1997	4	Fast	June 10 1994[13]
Lithuania	January 1996	Mass privatization	June 1999[6]	January 1996	14	Fast	May 3 1994[13]
Poland	January 1991	Initial public offerings	February 1997	December 1992	1618	Gradual	June 1 1995[14]
Romania	April 1995	Mass privatization	March 1998[8]	January 1998	4	Gradual	March 25 1998
Slovak Republic	January 1994	Mass privatization	April 1998[4]	January 1996	87	Gradual	October 1 1995[15]
Slovenia	December 1989	Initial public offerings	1999[3]	January 1996	56	Gradual	September 1 1995[16]

Sources: Bekaert and Harvey (2005); Dvorak and Podpiera (2006); Hagen and Siedschlag (2008) and IMF's Approach to capital account liberalization (2005).
[1] More restrictions lifted in 1999
[2] More restrictions lifted in 1998
[3] Until 1999 foreign sales within 7 years taxed 12%. 25% foreign ownership limit.
[4] More restrictions lifted in 2000;
[5] More liberalization in 2000. Restrictions on certain industries.
[6] Some restrictions have been lifted since 1991, when the new FDI law (No. 35/1991) came into effect, while more restrictions lifted on 2001;
[7] All restrictions lifted in 1999
[8] More restrictions lifted in 2000
[9] All restrictions lifted in 2004
[10] With the exception of some outflows, almost all controls removed by 1995. FDI liberalized first. Inflows liberalized before outflows. Outflows by non-residents fully liberalized in 2001. Five-year program to eliminate controls in outflows in the context of accession to OECD 1995-2001.
[11] Almost all controls removed by 1994. Pension funds investments last to be liberalized.
[12] FDI liberalized first. Long-term flows liberated before short term flows.
[13] Real estate and pensions funds' investment last to be liberalized.
[14] Long-term flows liberalized before short-term flows; inflows before outflows. Liberalization sped up during OECD accession negotiations.
[15] Long-term flows liberalized before short-term flows; inflows before outflows. Most restrictions eliminated to meet EU requirements. OECD accession was an important anchor.
[16] After having introduced capital controls in 1995-99, credit operations liberalized first.
[17]) Information taken from Report on US holdings of foreign long-term securities (as of December 31, 1997) of `http://www.ustreas.gov/tic/flts.html`

Table 2: Exchange rate regimes of the CEE countries

	Bulgaria	Czech	Estonia	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia
1992	8	3	2	3	8	8	5	7	3	7
1993	8	3	2	3	8	8	5	7	3	7
1994	8	3	2	3	3	2	5	7	3	7
1995	8	3	2	6	3	2	6	7	3	7
1996	8	6	2	6	3	2	6	7	6	7
1997	2	7	2	6	3	2	6	7	6	7
1998	2	7	2	6	3	2	6	7	7	7
1999	2	7	2	6	3	2	6	7	7	7
2000	2	7	2	6	3	2	8	7	7	7
2001	2	7	2	4	3	2	8	6	7	7
2002	2	7	2	4	3	2	8	6	7	7
2003	2	7	2	4	3	2	8	6	7	7
2004	2	7	2	4	3	2	8	7	7	6
2005	2	7	2*	4	3*	2*	8	7	7*	4*
2006	2	7	2*	4	3*	2*	8	7	7*	4*
2007	2	7	2*	4	3*	2*	8	7	7*	9
2008	2	7	2*	8	3*	2*	8	7	7*	9
2009	2	7	2*	8	3*	2*	8	7	9	9
2010	2	7	2*	8	3*	2*	8	7	9	9
2011	2	7	9	8	3*	2*	8	7	9	9

Note: 1: Dollarization, 2: Currency board, 3: Fixed Exchange rates, 4: target zone, 5-6: crawling peg, 7: Dirty float, 8: Flexible exchange rates, 9: replaced by euro. * indicates participation in ERM II.

stock market Crash of 1987 and the 1997-1998 Asian and Russian crises) that reflect structural changes in the volatility process during the estimation period. Hamilton and Susmel (1994) introduced the SWARCH model incorporating Markov-switching and ARCH models. The idea behind the SWARCH model is the use of the Markov-switching specification to model these structural changes and identify breakpoints in an ARCH model of the conditional variance of stock market returns.

Within this framework, Li and Lin (2003) argue that the SWARCH model is more appropriate in comparison to the ARCH and GARCH models, in modelling the volatility of an emerging Asian stock market (Taiwan) during a period characterized by serious financial turmoil (such as the Asian crisis in 1997). Several studies (Turner *et al.* 1989; Hamilton and Lin, 1996; Schaller and van Norden, 1997; Rydén *et al.* 1998) applied the Markov-switching framework to model returns on indices of mature stock markets.

In this paper we apply the switching ARCH (SWARCH) model proposed by Hamilton and Susmel (1994), which has the following specification:

$$r_t = \mu + \alpha_1 r_{t-1} + \cdots + \alpha_p r_{t-p} + \varepsilon_t \tag{1}$$

$$u_t = \sqrt{h_t}\omega_t, \quad \omega_t \sim \text{Gussian or Student } t \text{ distribution}, \tag{2}$$

$$\varepsilon_t = \sqrt{\gamma_{S_t}} u_t \tag{3}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 \frac{1}{\gamma_{S_{t-1}}} + \alpha_2 \varepsilon_{t-2}^2 \frac{1}{\gamma_{S_{t-2}}} + \cdots + \alpha_q \varepsilon_{t-q}^2 \frac{1}{\gamma_{S_{t-q}}} \tag{4}$$

where r_t is the rate of return of the stock market index, and S_t is a latent variable (unobserved random variable) that can take the values $1, 2, \ldots,$ or k. The variable S_t is considered as the 'state' or 'regime' that the process is in at time t and is described by a k-state Markov chain given by:

$$Prob\left(S_t = j | S_{t-1} = i, S_{t-2} = k, \ldots, r_{t-1}, r_{t-2}, \ldots\right) = Prob\left(S_t = j | S_{t-1} = i\right) = p_{ij} \tag{5}$$

where $i, j = 1, 2, \ldots, k$. Under this specification if the market is at time $t-1$ in state i it will change to state j with the fixed probability p_{ij}. The transition probabilities can be collected in the following $k \times k$ transition matrix:

$$P = \begin{bmatrix} P_{11} & P_{21} & \cdots & P_{k1} \\ P_{12} & P_{22} & \cdots & P_{k2} \\ \cdots & \cdots & \cdots & \cdots \\ P_{1k} & P_{2k} & \cdots & P_{kk} \end{bmatrix} \tag{6}$$

where the sum of elements in each column in the above matrix should be equal to 1. For reasons of simplicity we restrict our analysis so as not to allow state 2 to come after state 1 (p_{12}), and state 1 to come after state 3 (p_{31}), in the presence of three regimes in the SWARCH model.

The system which consists of equations (1) to (6), is called as the k-state, q-th order Markov switching ARCH model (SWARCH(k,q)). Equation (1) describes the mean equation (AR(p) model), while the residual of the mean equation is modelled by equation (3), where it is assumed that u_t follows an ARCH(q) process (described by equations (2) and (4)). The underlying ARCH(q) variable u_t is then multiplied by the constant $\sqrt{\gamma_1}$ when $S_t = 1$, multiplied by $\sqrt{\gamma_2}$ when $S_t = 2$, and so on. The coefficient for regime 1 (γ_1) is normalized at unity, whereas $\gamma_1 \geq 1$ for $i = 2, 3, \ldots, k$. The SWARCH model in the presence of leverage effects is formulated as follows:

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 \frac{1}{\gamma_{S_{t-1}}} + \alpha_2 \varepsilon_{t-2}^2 \frac{1}{\gamma_{S_{t-2}}} + \cdots + \alpha_q \varepsilon_{t-q}^2 \frac{1}{\gamma_{S_{t-q}}} + \xi L_{t-1} \varepsilon_{t-1}^2 \frac{1}{\gamma_{S_{t-1}}},$$

where $L_{t-1} = 1$ if $\varepsilon_{t-1} \leq 0$ and $L_{t-1} = 0$ if $\varepsilon_{t-1} > 0$. Moreover, we investigate both Gaussian ($\omega_t \sim N(0,1)$) and Student-t (with unit variance and ω degrees of freedom) versions of the model.

The estimation of the SWARCH model is done by the maximization of the following likelihood function:

$$L = \sum_{t-1}^{T} \ln f\left(r_t | r_{t-1}, r_{t-2}, \ldots\right).$$

Byproducts of this estimation process are probability statements about the particular state/regime of the market under study, in time t. When these statements are based on information available through date t, the regime probability is called the 'filter probability' ($p\left(S_t, S_{t-1}, \ldots, S_{t-q} | r_t, r_{t-1}, r_{t-2}, \ldots, r_{-3}\right)$). On the other hand, if the

information set includes the full sample period (up to date T), the regime probability is called the 'smooth probability' ($p\left(S_T|r_T, r_{T-1}, \ldots, r_{-3}\right)$). The 'smooth probability' represents the ex-post statement made by a financial analyst or an econometrician about the state of the market at time t, based on the entire time series. For each model, the log-likelihood was minimized numerically using the optimization programme OPTIMUM in GAUSS 7.0 starting with steepest ascent and then switching to the BFGS algorithm.

4 Data and empirical results

The data used in this paper are weekly stock-price indices for the equity markets of ten new European Union member states. The sample period is not the same for the ten emerging CEE stock markets, since the opening date of the markets under examination varies from market to market. We use weekly data instead of daily to avoid the problem of greater noise that is associated with higher frequencies. In this way it is easier to isolate cyclical variations and to conduct the analysis of the driving moments of switching behavior. We note that Slovenia adopted the euro in 2007 whereas Slovakia in 2009 and Estonia 2011 respectively. The data set consists of the local stock indices of Bulgaria (BSE), Czech Republic (PX), Estonia (TALSE), Hungary (BUX), Latvia (RICI), Lithuania (LITIN), Poland (WIG), Romania (BET), Slovakia (SAX12) and Slovenia (SBI). The data spans the period from January 01, 1993 to June 29, 2012 for Hungary and Poland. For Slovak Republic it covers (17/09/1993-29/06/2012), Slovenia (07/01/1994-29/06/2012) and Czech Republic (08/04/1994-29/06/2012). For Estonia the sample covers the period 07/06/1996-29/06/2012, for Romania 19/09/1997 to 29/06/2012, for Bulgaria 02/01/1998-29/06/2012, for Lithuania 04/04/1997-29/06/2012 and finally for Latvia it runs from 07/11/1997 to 29/06/2012. All the national stock-price indices are used in local currency terms and based on weekly closing prices for each national market. When data were unavailable, because of national holidays, bank holidays, or any other reasons, stock prices were assumed to stay the same as those of the previous day. Expressing the stock price indices in their national currencies restricts their changes to the movements in the stock prices only avoiding distortions induced by numerous devaluations of the exchange rates that have taken place in the CEE region (see Voronkova, 2004). These stock market indices are transformed into weekly rates of returns taking the first difference of the natural log of each stock-price index. The data are taken from DATASTREAM.

4.1 Preliminary statistics

The summary statistics of stock-index returns in the ten Central and Eastern European markets are presented in Table 3. Specifically, we present information on the mean, standard deviation, skewness coefficient, kurtosis coefficient, the Jarque-

Bera normality test, and the Ljung-Box test (LB). As expected with emerging equity markets, the index returns series are negatively skewed (with the exception of Romania and Slovakia) and leptokurtic. Moreover, the Jarque-Bera test statistic reveals the typical non-normality of high frequency financial time series. The evidence from this statistic implies that it is likely that we could observe large positive or negative disturbances in these stock markets. In addition most of the stock return series are found to exhibit significant autocorrelation, as suggested by the Ljung-Box test statistic with 12 lags. Lack of market efficiency in the form of nonsynchronous trading of the stocks that are used to construct the respective index and price limitations imposed on the index or other types of market friction, resulting in a partial adjustment process, is a major reason for the presence of autocorrelation.

Table 3: Descriptive statistics of weekly index return series

	Bulgaria	Czech	Estonia	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia
Mean	0.002	0.0005	0.0038	-0.0006	-0.0012	0.0047	0.0051	0.0044	0.0023	0.0024
Standard Deviation	0.057	0.029	0.045	0.0368	0.0358	0.040	0.0543	0.046	0.040	0.0295
Skewness	-0.075*	-0.423*	-0.809*	-0.470*	-0.053*	-0.861*	-0.015*	0.1144*	2.841*	-0.0794*
Kurtosis	14.348*	1.998*	7.215*	3.481*	2.834*	8.954**	5.720*	3.5803*	30.72*	7.946*
Jarque-Bera Normality test	3457.63*	119.18*	1125.46*	194.57*	130.75*	2331.76*	917.53*	229.00*	25864.9*	1631.81*
Q(12)	8.25	25.16*	38.66*	55.62*	23.74*	33.19*	16.77*	10.22	109.68*	20.94*
$Q^2(12)$	23.77*	31.55*	183.71*	90.62*	63.42*	37.89*	312.67*	11.13	70.68*	62.90*
Obs.	403	607	494	359	390	673	673	427	636	620

Notes: All variables are first differences of the natural log of stock indices; JB is the statistic for the null of normality; Q(12) denotes the Ljung-Box test statistic for serial correlation with 12 lags respectively, $Q^2(12)$ denotes the Ljung-Box test statistic for squared returns with 12 lags. (*) denotes statistical significance at the 5 percent critical level.

4.2 The MS-ARCH model and regime identification

We now report and discuss our empirical results. We begin with the application of a battery of tests designed to test the ARCH effect for the stock returns against a Markov-switching ARCH (SWARCH) model and to identify the appropriate number of regimes to be allowed for. We then continue with the estimation of the appropriate SWARCH model for each CEE stock market. Finally, we discuss our empirical results in light of the financial crises of the 1990s and 2000s, as well the European Union accession of 2004.

We begin by estimating an AR(1)-GARCH(1,1)-t model in order to model the volatility of the CEE stock markets and to identify the existence of significant ARCH effects in the data for each country case. Prior to the estimation of the SWARCH models we conduct unit root and stationarity tests to determine the stochastic properties of the data. We employ the Elliot et al. (1996) and Elliot (1999) GLS

augmented Dickey-Fuller and Ng and Perron (2001) GLS versions of the modified Phillips-Perron (1988) unit root tests. For robustness we also apply the Kwiatkowski et al. (1992) KPSS stationarity test. The results show that we are unable to reject the null hypothesis of a unit root in the data for the levels of all ten series, whereas the first difference of the series are I(0) processes. The results are available upon request. Table 4 reports the estimates of the conditional mean and conditional variance equations and we argue that there is strong evidence for the presence of the significant ARCH effect. Higher-order GARCH processes were modelled but did not prove superior to the GARCH(1,1) specification. Given that different GARCH are nested within some higher order GARCH model, this task can be accomplished through a likelihood ratio (LR) test that has been developed by Engle (1982) and Bollerslev (1986) for the respective cases of the ARCH and GARCH models. The LR test statistic is specified as LR(number of constraints)=2[maxL(unconstrainted)-maxL(constrained)] and is asymptotically distributed as a χ^2 with degrees of freedom equal to the difference in the number of parameters under the null and the alternative hypothesis. The AR(1) coefficient in the mean equation is significantly positive for all markets except for Bulgaria, Latvia and Poland. This result is in line with the well documented fact that a positive sign of this coefficient for the case of emerging markets reflects price friction or partial adjustment (Antoniou *et al.* 2005). The magnitude of coefficient α_1 is quite high whereas the magnitude of coefficient β_1 is consistent with *a priori* expectations, and is large in most cases except for Bulgaria and Slovakia. Furthermore our results indicate that the volatility persistence measure $(\alpha_1 + \beta_1)$ is close to one for the majority of the markets examined (Hamilton and Susmel (1994) provide a rigorous and comprehensive analysis of the volatility persistence measure). This finding is consistent with the results reported by Edwards and Susmel (2001) and Diamandis (2008) for the Latin American countries, whereas according to Lamoureux and Lastrapes (1990) and Hamilton and Susmel (1994) the high volatility persistence is caused by the structural changes in the statistical process generating the volatility during the estimation period. Finally we note that the coefficients of the squared residuals as well as of the lagged variance terms in the variance equation are statistically significant, a result which is consistent with the presence of time-varying volatility of the stock returns and makes the use of the MS-ARCH (SWARCH) class of models the appropriate specification. Following Hamilton and Susmel (1994) we estimate a wide range of alternative SWARCH models in order to choose the most appropriate specification that captures the dynamics of each stock market under examination. The selection was made with the application of the conventional 'bottom-up' procedure which is constructed to identify Markovian shifts in order to select the most adequate specification of a k-regime qth order SWARCH for each stock return. We estimated models with $q = 0$ to 2 autoregressive terms in the ARCH process and for $k = 2$ or 3 number of regimes, under the Gaussian and Student-t distribution and with and without the leverage parameter ξ proposed by Glosten *et al.* (1993).

Table 4: Estimation of parameters of the AR(1)-GARCH(1,1)-t model $r_t = \mu + a_1 r_{t-1} + \varepsilon_t, \varepsilon_t = \sqrt{h_t}\omega_t, \omega_t \sim t(\omega), \omega > 2$, $h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1}$

	Bulgaria	Czech	Estonia	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia
μ	0.0019	0.0023*	0.0043*	0.0020	−0.0007	0.0041*	0.0031*	0.0051*	0.0002	0.0015*
	[0.0016]	[0.001]	[0.0010]	[0.0014]	[0.0015]	[0.0011]	[0.0012]	[0.0016]	[0.0009]	[0.0007]
a_1	0.0954*	0.1304*	0.1300*	0.1049*	0.1542*	0.0986*	0.0526	0.0970*	0.1194*	0.1721*
	[0.0516]	[0.040]	[0.0425]	[0.0579]	[0.0513]	[0.0400]	[0.0409]	[0.0474]	[0.0419]	[0.0395]
α_0	0.0013*	0.0000*	0.0000*	0.0000*	0.0001*	0.0000*	0.0000*	0.0000*	0.0004*	0.0000*
	[0.0007]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0001]	[0.0000]
α_1	0.7074	0.0818*	0.2173*	0.1445*	0.1741*	0.1690*	0.1451*	0.1399*	0.4439*	0.1004*
	[0.4201]	[0.0311]	[0.0708]	[0.0512]	[0.0681]	[0.0479]	[0.0314]	[0.0523]	[0.1654]	[0.0205]
β_1	0.2914*	0.8641*	0.8068*	0.8237*	0.7157*	0.7413*	0.8515*	0.8420*	0.3933*	0.8923*
	[0.1325]	[0.0467]	[0.0430]	[0.0527]	[0.0950]	[0.0637]	[0.0287]	[0.0461]	[0.1029]	[0.0175]
ω	2.5881*	7.9591*	3.4412*	5.0842*	4.9271*	4.9033*	6.9548*	3.8802*	3.0916*	19.248*
	[0.4043]	[2.6934]	[0.6599]	[1.3420]	[1.5098]	[0.8810]	[2.3024]	[0.7664]	[0.4922]	[9.4693]
L	701.13	1311.10	989.74	733.19	788.49	1306.769	1202.07	759.25	1329.06	1461.20
Pers.	0.9984	0.9459	1.0241	0.9682	0.8898	0.9103	0.9966	0.9819	0.8372	0.9927

Notes: L denotes the (log-likelihood function of the model), ω are the estimated degrees of freedom of the student-t distribution and Pers. Denotes the persistence measure $\alpha_1 + \beta_1$.
(*) denotes statistical significance at the 5%.

Moreover, in order to test whether the volatility of stock returns can be modeled within a single state framework or whether nonlinearities exist, we compare a general linear specification of ARCH effects with the chosen SWARCH specification. This is done since the GARCH specifications are not strictly nested with the SWARCH specifications. The ARCH process could be described as a special case of SWARCH under the constraint that $\gamma_1 = \gamma_2 = 1$. Since it is well known that the presence of nuisance parameters under the null hypothesis creates several problems, we cannot use the χ^2 distribution to determine the significance of the LR test proposed by Davies (1987). This occurs since the regularity conditions under which the Davies (1987) test is valid are violated, caused by the fact that the MS class of models have both a problem of nuisance parameters and a problem of 'zero score' under the null hypothesis. Therefore, the application of this test may lead to wrong identification of the number of regimes since the scores associated with the parameters of interest under the alternative hypothesis may be zero under the null.
To avoid this problem we apply the LR testing procedure suggested by Hansen (1992, 1996) and Ang and Bekaert (2000a,b). The LR test statistics are reported in Table 5, together with the estimates of the two-state Markov-switching ARCH models. The results strongly suggest that for most of the stock markets under examination, with the exception of Bulgaria and Lithuania, the hypothesis of no regime switch is rejected. The p-values for the LR tests are so small that we have little doubt that the null hypothesis would be rejected by any more rigorous testing procedures. Despite the acceptance of the null hypothesis of no regime switch for the markets of Bulgaria and Lithuania, we will continue our analysis taking into account these markets as well. Moreover, the LR test statistics suggest that for some markets the three-state SWARCH specifications may be appropriate. The null hypothesis of a two-

state SWARCH model against the three-state model is rejected, with the exception of Estonia and Poland at the 1% significance level. However, the use of the standard likelihood ratio tests is not the most appropriate, since the parameters P_{ij}, for the third state, are unidentified under the null hypothesis of two states.

Table 5: Estimation of the parameters of the AR(1)-SWARCH(2,1)-t model, $r_t = \mu + a_1 r_{t-1} + \varepsilon_t$, $u_t = \sqrt{h_t}\omega_t$,$\omega_t \sim t(\omega)$, $\omega > 2$ and $\varepsilon_t = \sqrt{\gamma_{S_t}}u_t$, $h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 \frac{1}{\gamma_{S_{t-1}}}$, $S_t = 1, 2$

	Bulgaria	Czech	Estonia	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia
μ	0.0018 [0.0016]	0.0026* [0.0010]	0.0037* [0.0011]	0.0043* [0.0012]	0.0013 [0.0014]	−0.0005 [0.0014]	0.0031* [0.0013]	0.0053* [0.0016]	0.0004 [0.0009]	0.0014* [0.0007]
a_1	0.0716 [0.0491]	0.1346* [0.0451]	0.1371* [0.0435]	0.0894* [0.0440]	0.0642 [0.0576]	0.1600* [0.0554]	0.0670 [0.0436]	0.1082* [0.0483]	0.1378* [0.0430]	0.1648* [0.0424]
α_0	0.0013* [0.0004]	0.0004* [0.0000]	0.0005* [0.0001]	0.0007* [0.0001]	0.0006* [0.0000]	0.0006* [0.0001]	0.0009* [0.0001]	0.0007* [0.0001]	0.0006* [0.0001]	0.0001* [0.0000]
α_1	0.3023 [0.2030]	0.1526 [0.1017]	0.0251 [0.0747]	0.1073 [0.1037]	0.0581 [0.0621]	0.1275 [0.1156]	0.2255* [0.0806]	0.0014 [0.0331]	0.2819* [0.1210]	0.1306* [0.0649]
ω	3.5814* [1.1130]	7.8711* [2.4049]	4.0171* [1.0857]	7.3666* [2.9415]	9.7567* [5.0177]	8.0586* [4.3099]	6.3578* [1.7411]	7.1852* [3.0389]	3.4740* [0.6098]	6.4739* [1.6254]
γ_2	22.8780 [15.6818]	2.3744* [0.4961]	10.609* [2.3251]	5.5673* [1.5739]	6.6237* [1.8280]	5.3494* [1.6697]	7.3329* [1.6944]	5.3802* [1.0508]	8.2193* [3.4675]	6.3250* [0.9865]
p_{11}	0.9842	0.9903	0.9848	0.9779	0.9913	0.9806	0.9953	0.9640	0.9906	0.9943
p_{22}	0.7705	0.9892	0.9602	0.9040	0.9528	0.9125	0.9821	0.9553	0.9245	0.9945
L	698.89	1311.02	977.12	1300.82	730.97	787.98	1184.07	756.45	1328.67	1463.36
Q(12)	8.51	5.35	9.12	7.22	6.15	9.56	5.91	3.22	8.98	4.16
$Q^2(12)$	4.19	7.11	6.22	8.31	8.19	4.33	7.89	1.01	4.19	2.29
L*	698.40	1305.03	949.20	1291.125	717.83	785.21	1164.56	745.18	1324.55	1421.11
L**	698.89	1313.53	977.15	1301.01	732.93	788.91	1184.15	756.50	1329.01	1463.59
L***	700.91	1315.39	985.47	1304.42	735.35	788.63	1197.78	758.55	1332.66	—
LR1	0.98^{+} [0.80]	11.98 [0.007]	55.84 [0.000]	19.40 [0.000]	26.28 [0.000]	5.54^{+} [0.13]	39.02 [0.000]	22.54 [0.000]	8.24 [0.04]	84.5 [0.000]
LR2	4.04^{+} [0.25]	8.74^{++} [0.03]	16.70 [0.000]	7.20^{+} [0.06]	8.76^{++} [0.03]	1.30^{+} [0.72]	27.42 [0.000]	4.20^{+} [0.24]	7.98^{++} [0.04]	—

Notes:
L*: AR(1)-SWARCH(1,1)-t log likelihood value
L**: AR(1)-SWARCH(2,1)-t log likelihood value
L***: AR(1)-SWARCH(3,1)-t log likelihood value
LR1: Likelihood Ratio test. Null hypothesis is no regime switch
LR2: Likelihood Ratio test. Null hypothesis is a two-state SWARCH model against the three-state model
Q(12): Ljung-Box test for standardized residuals with 12 lags, which is distributed χ_6^2.
$Q^2(12)$: Ljung-Box test for squared standardized residuals with 12 lags, which is distributed χ_6^2.
* Significant at the 5% level.
+ Acceptance of the Null hypothesis at the 5% significance level.
++ Acceptance of the Null hypothesis at the 1% significance level.
The number in the brackets reports the p-value for the estimated parameters and the likelihood ratio tests.

Given the rejection of the hypothesis of no regime switch, we continue our analysis with the discussion of the estimation results, as reported in Table 5. In all cases, the Ljung-Box Q-statistic for 12 lags suggests that there is no autocorrelation in the level of the standardized residuals or in the squared standardized residuals. In addition, we

found no evidence of ARCH effects we apply the ARCH test for up to order 12 in the standardized residuals, whereas the estimated degrees of freedom for the Student's-t distribution are statistically significant at the 5% level of significance. Therefore, we argue based on these diagnostic tests that the two- or three regime SWARCH model captures most of the dynamics in the stock returns of the ten CEE markets. Furthermore, several other interesting findings emerge from the present analysis. Firstly, the coefficients of the lagged innovation-squared in the ARCH process of the conditional volatility are all insignificantly different from zero, with the exception of Poland, Slovakia and Slovenia. Therefore, when we take into account the likelihood for the existence of a switching regime in the volatility generating process, the ARCH effect seems to be reduced or even disappear in most markets examined. We also estimated a SWARCH model which incorporates a leverage effect in the volatility process. The results indicate that, with the exception of the Czech Republic, there is no evidence for an asymmetric effect of negative news on conditional volatility. Thus, the unexpected negative surprises to returns do not cause a bigger impact on volatility than positive news.

Secondly, the switching parameters (the γ_2) are in all cases significantly different than one, with the exception of Bulgaria where the switching parameter is not statistically significant at the 5% level of significance. These results reveal that we are able to distinguish for all the markets, except for Bulgaria, a 'low' and a 'high' volatility regime, while the γ_2 parameter is the ratio between the two states. Specifically, in our two-state case, the 'high' volatility regime is on average 6.42 times higher than in the 'low' volatility regime. Moreover, in two extreme cases, for Estonia's stock market returns the 'high' volatility regime is on average 10.6 times higher than that in the 'low' volatility regime, while for the Czech Republic's stock market returns the 'high' volatility regime is only 2.3 times higher than that in the 'low' volatility regime.

Finally, the estimated transition probabilities (p_{11} and p_{22}) suggest that the estimated regimes are highly persistent. Particularly, the 'low' volatility regime would be expected to last on average for $(1-\widehat{p}_{11})^{-1} = 100.33$ weeks, while the 'high' volatility regime would last on average for 48.22 weeks. Thus, the CEE stock markets remain in the 'low' volatility state relatively more than in the 'high' volatility state.

In order to assess the regime qualification performance of the chosen Markov-switching models we calculate the Regime Classification Measure (RCM) developed by Ang and Bekaert (2002a,b). This measure is based on the fact that the ex-post (smoothed) probabilities p_t are close either to one or zero and therefore a good regime-switching model should classify regimes sharply. Therefore, the RCM for a model with two regimes may be calculated as follows:

$$RCM(2) = 400 \cdot \frac{1}{T} \sum_{t=1}^{T} p_t(1-p_t), \tag{7}$$

where T is the sample size, p_1 and $(1-p_1)$ is the smoothed probability to be in regime $j = 1, 2$ at time t, and RCM takes values between zero and one hundred. In

general the lower is the value of RCM the better the performance of the model is. The ideal model will have an RCM with a value close to zero. Weak regime inference implies that regime-switching models cannot distinguish among regimes based on the behaviour of data and this may be due to misspecification. A model which poorly distinguishes between regimes will have an RCM with a value close to 100. Table 6 reports the calculated RCM statistic for the full sample and we conclude that all countries are close to zero, implying a very satisfactory regime classification.

Table 6: Regime classification measure

Country	RCM
Bulgaria	–
Czech Republic	35.132
Estonia	16.045
Hungary	27.639
Latvia	9.51
Lithuania	26.068
Poland	10.096
Romania	31.045
Slovak Republic	14.772
Slovenia	7.6464

Note: The statistics for a model with two regimes are calculated as $RCM(2) = 400 \cdot \frac{1}{T} \sum_{t=1}^{T} p_t(1-p_t)$ where T is the sample size, p_t and $(1-p_t)$ is the smoothed probability to be in regime $j = 1, 2$ at time t, and RCM takes values between zero and one hundred. A value close to zero implies a very good discrimination between the two regimes whereas a value close to one hundred implies a model that poorly distinguishes between the two regimes.

We now move to the discussion of our results. With respect to the Czech Republic, the estimated smoothed probabilities reveal that the Czech stock returns are in the high volatility state during the first years of the period under examination. To save the space, smoothed probabilities are available upon request. Specifically following the financial liberalization process that began in September 1994, the domestic stock market experienced a substantial increase in volatility and stayed in the high volatility regime until mid 1995. Then, the stock market remained, for a period of almost two years (mid-1995 to mid-1997), in the low volatility regime. This was followed by a turbulent period (1997-2001) within which the Czech stock returns switched to the high volatility state. High volatility of stock returns was triggered initially by the currency crisis in May 1997 which was the result of balance of payments imbalances. By April 1997, due to a widening trade deficit and economic slowdown, the Czech Koruna reached a ten month low against its currency basket. As a result, in May 1997 the government decided to abandon the currency target band and the koruna depreciated by approximately 10%. This currency crisis was coupled by the financial crises prevalent around this time in Southeast Asia (late 1997), Russia (August-September 1998), Brazil (January 1999), Turkey (November2000-February 2001) and Argentina (January-February 2001), as well as the dot-com bubble (March 2000),

the terrorist attacks in US (September 2001) and the 2007-2009 financial turmoil. This sequence of negative situations in the world financial markets had a significant destabilizing effect on the Czech stock market. In an attempt to smooth the problems to the Czech economy, the government allowed the koruna to float almost freely against the major currencies and shifted the monetary policy to inflation targeting. Finally, we observe that the stock returns returned to the low volatility regime from the beginning of 2002 an event that can be attributed to the EU accession process whereas the return to the high volatility regime during the recent financial crisis. In November 2001, the European Commission outlined the timing and named countries involved in the enlargement.

The stock market returns in Estonia are mainly in the high volatility state during the period between November 1996 and February 1999. This period coincides with the significant rise of the TALSE index in 1996-1997, the first years after the establishment of the Tallinn stock exchange, the financial liberalization process that began in 1996, and the 1997-1998 Asian and Russian financial crises. Afterwards, Estonian stock returns tend to have long stays in the low volatility state, in a period that was characterized by exchange rate stability, since a currency board exchange rate system was introduced in 1999. Estonian stock returns switched to the high volatility state only a for few weeks at the end of 1999 (EU confirmed Estonia as a tier-one candidate), in the fall of 2001 (11th September terrorist attacks in US) and in September 2003 (Estonians vote overwhelmingly to join the European Union in a referendum). However, we further found that Estonian stock returns were again on the high volatility regimes during the 2007-2009 financial crisis.

Looking at the case of Hungary, we observe that the stock market is in the low volatility regime in the first years of the period. This may be the result of a steady transition to becoming a market economy which started well before the 1980s and possibly had a more stabilizing impact on the newly established stock market. The Hungarian stock returns stayed in the low volatility state, with few exceptions, such as the substantial increase in volatility in 1996 as a result of the implementation of the abolishment of capital controls. From October 1997 when the Southeast Asian financial crisis expanded, it moved to the high volatility regime. The high volatility regime in 1994 and also 1996 coincides with the start of the privatization of the banking sector and the dramatic increase in foreign direct investments respectively. Moreover, the high volatility regime observed in the period between May 1998 and April 1999 may be attributed to spill-over effects of the Czech, the Russian and the Brazilian crises. After this high volatility regime, the stock returns returned to the low volatility regime from 2001 onwards, possibly due to the good economic performance of the Hungarian economy and the implementation of the stability programme in order to successfully join the EU in 2004. However, the Hungarian stock market returned to the high volatility during the financial turmoil of 2007-2009. This was the result of the substantial capital outflow following the massive liquidation of investments by hedge funds and portfolio managers and a flight to quality.

With respect to the Baltic countries Latvia and Lithuania, we observed a similar behavior of the stock returns volatility. The financial liberalization process started in 1996 and 1999 respectively may have resulted in a high volatility regime for the stock returns. Moreover, between March 1998 and December 1998, the stock returns moved again to the high volatility regime, reflecting the political and financial crises in Russia. Russia threatened trade sanctions against Latvia in response to political disputes during the spring of 1998. Furthermore, the Latvian market was seriously affected by the financial crisis in Russia since Latvian companies had large exposures to Russia. The volatility remained in the low volatility regime from 1999 onward. However, this was disrupted by a short-lived high volatility pattern in 2003, which may have been caused in part, by the euphoria which arose among the market participants after the signature of the Treaty of Accession on April 16 2003. During the period between March to May 2003 the RICI index rose by about 65%. Again, as the financial crisis of 2007-2009 was unfolding with substantial negative effects on both economies their stock markets moved once again to the high volatility regime and remained there for the rest of the period.

In Poland, the initial period of high volatility in 1993-1995 seems to be associated with the burst of the speculative bubble, which according to Bolt and Milobedzki (1994) was caused by the change in the monetary policy implemented by the National Bank of Poland. In 1993, the National Bank of Poland reduced substantially the interest rates which made investments on the Warsaw Stock Exchange very attractive, given that the high inflation rates made returns on all commercial bank accounts negative. The burst of the bubble occurred since the trading on the WSE was based not on future corporate profits, but on hopes of increased share prices. In May 1995, Poland's exchange rate system moved from a crawling peg to less restrictive crawling bands, a fact that may explain the low volatility regime in the subsequent period. The low volatility regime observed in the period after the beginning of 1999 may be attributed to the floating exchange rate system introduced officially in April 2000 [unofficially the floating exchange rate system was instituted in July 1999, according to Kierzenkowski (2005)], and the increase of institutional ownership after the appearance of Polish pension funds on 19 May 1999 [see Bohl and Brzeszczynski (2006)]. We also note that in Poland's case, the financial liberalization process that began mainly in 1997 did not lead to an increase in volatility of stock returns. A period of high volatility regime then prevailed from mid 1997 to 1999, during which the Russian financial crisis was fully unfolding. The adoption of a floating exchange rate regime in 2001 and the announcement of the next round of enlargement of the EU contributed to the return of the stock market to the low volatility regime for the rest of the period. However, during the recent credit crunch of 2007-2009 the Polish stock market was also affected negatively and as a result the stock market moved to the high volatility regime once again.

Turning our attention to the Romanian stock market we observe that the stock market returns switched from the low volatility regime to the high volatility regime during

the first five years of the sample. Thus, we argue that the period of high volatility in 1997-1998 can be attributed to the financial liberalization process that began in 1998, the financial crises in Southeast Asia and Russia, and the period of high volatility in 1999 which coincides with the large depreciation of the Romanian lev against the US dollar. The low volatility regime appears to prevail from 2000 onwards, which may be due to the beginning – in February 2000 – of the formal discussion between Romania and the European Union about the potential accession as well as to the official talks on Romania's application to join NATO. However, the Romanian economy was hit negatively by the events during the 2007-2009 financial turmoil mainly due to the capital outflow which eventually led to a significant fall of the stock market and a large depreciation of the national currency leading to a switch to the high volatility regime.

Based on the estimated smoothed probabilities of the stock market returns in Slovakia it appears that the market remained in the low volatility regime for most of the period under examination. The stock returns volatility is in the high volatility regime in 1994, reflecting the instability of the young Slovakian stock market in the first years after the transition and the effects of the full scale restructuring programme implemented during that period. The financial liberalization process that took place in 1998 as well as the financial crises of 1997-1998 had a moderate impact on the domestic stock market. Furthermore, the period of high volatility in 1999 may be associated with the large depreciation of the Slovak Koruna and the political instability observed around this time. Following the initiation of the process to join the EU the stock market returned to the low volatility regime. The Slovakian stock market switched to the high volatility regime during the financial crisis of 2007-2009 as a result of the overall negative effects that the recent financial crisis had on the Slovakian economy.

Finally, in the case of Slovenia, the early period of high volatility in 1994-1999 coincides with dramatic effects that the transformation programme of the early 1990s had on the domestic economy, the financial crises in south-Asia (late 1997) and Russia (August-September 1998). Slovenian stock returns switched to the low volatility regime from 1999 onwards, although there was again a short period of high volatility in 2002-2003 that was mainly attributed to the completion of the financial liberalization process that was first implemented in early 1999, which was coupled with a rapid increase in the participation of foreign institutional investors in the share capital of the domestic companies listed in the Slovenian equity firms. The results for Poland, Czech Republic, Hungary, Slovenia and Slovakia are consistent with Linne (2002), Bialkowski (2004) and Moore and Wang (2007). The Slovenian stock market switched to high volatility regime following the negative events in the global economy during the 2007-2009 financial turmoil.

A common feature emerges from the results of the estimation of the SWARCH model and the derived smoothed probabilities. As it is clear from our analysis the Central and Eastern European stock market returns, with the exception of the Slovakian stock returns, switch to the high volatility regime during the period 1997-1998, a period

that coincides with the financial crises in Southeast Asia and Russia and this feature is again evident over the financial turmoil of 2007-2009. This finding may imply that these emerging European stock markets were affected by some kind of 'volatility contagion' throughout the crises turmoil. All CEE stock markets switched to the high volatility regime during the financial crisis of 2007-2009 a result that provides further evidence that the stock markets are affected by 'volatility contagion' effects provided that these economies tend to have common factors.

Table 7: Identification of 'unusually high volatility' episodes around major crises events

	Asian crisis 23/10/97	Russian crisis 17/08/98	Brazilian crisis 14/01/99	Dot-com bubble 13/03/00	Turkish crisis 11/00-02/01	US Terror. Attack 11/09/01	Financial crisis 2007-2009 15/09/08
Czech Republic	—	19/06/98 (28)	1/01/99 (18)	—	—	—	10/10/08 (7)
Estonia	24/10/97 (22)	27/03/98 (40)	1/01/99 (10)	—	—	14/09/01 (9)	10/10/08 (9)
Hungary	31/10/97 (7)	31/07/98 (21)	25/12/98 (14)	—	24/11/00 (3)	—	17/10/08 (17)
Latvia	—	27/03/98 (39)	—	—	—	—	
Lithuania	07/11/97 (5)	19/06/98 (31)	—	—	—	14/09/01 (6)	
Poland	—	24/07/98 (15)	—	—	—	—	
Romania	17/10/97 (14)	10/07/98 (22)	—	—	05/01/01 (2)	—	17/10/08 (14)
Slovak Republic	—	—	—	—	—	—	—
Slovenia*	—	—	—	—	—	—	—

Notes: Each date refers to the week that each CEE market started being in the 'unusually high volatility' state (state 3) around the time some major financial crisis occurred. The number in parentheses corresponds to the weeks each market was in the 'unusually high volatility' state during each crisis. The dash (–) means the market was not in the third state during the given crisis.
(*) the estimation of the SWARCH (3,1) specification was not possible for the Slovenian market.

Following Edwards and Susmel (2001), we investigate this issue further by estimating, for the markets examined, a three-regime SWARCH specification. The third regime is called 'unusually high volatility' and the results are reported in Table 7. According, to these results, most CEE stock returns had a long stay in the 'unusually high volatility' regime around the 1998 Russian crisis period and during the 2007-2009 financial turmoil. Moreover, the Baltic markets are those that seem to be affected more by 1998 Russian financial crisis event, since the Baltic States have relatively stronger political, financial and trade relationships with Russia, as they were former Soviet Union member states (see Black *et al.*, 2000). Moreover, it is observed that the Southeast Asia crisis had a smaller impact on the emerging CEE stock markets. Only the stock returns in Estonia, Hungary, Lithuania and Romania are in the 'unusually high volatility' regime during the Southeast Asia crisis period. Finally, the fact that

most of these stock markets experienced a significant increase in the stock returns volatility ('unusually high volatility' regime), particularly around the period of the 1998 Russian crisis as well as during the financial crisis of 2007-2009, is indicative, but does not constitute statistical evidence in favor of the 'volatility contagion' hypothesis (see Edwards and Susmel (2001) for a more detailed discussion).
An additional interesting feature of our results is that the European Union accession process appears to be an important factor that acts as a stabilizer in the volatility of these stock markets. Stock returns seem to be in the low volatility regime during the early 2000s, long before the entry into the EU in May 2004, since the date of entry was known among the market participants prior to that date (Romania joined the EU in January 2007). Moreover, the lifting of the restrictions on foreign investors seemed to cause a switch to the high volatility regime in the short-run but acted as another stabilizing factor of stock markets' volatility in the long-run. This result is in line with the finding of Bohl and Brzeszczynski (2006), who concluded that the increase of institutional ownership after the establishment of Polish pension funds on 19 May 1999 reduced the Polish stock returns volatility. An anonymous referee has pointed out that our main conclusions maybe false because the global factor was not included in the analysis. Recently, Syllignakis and Kouretas (2011) examined the conditional correlations of the ten CEE stock markets with respect to the US and the German stock markets. The results of that analysis are in line with the main finding in the present paper in the sense that the financial crisis in Asia had very little impact on the bilateral correlations of the CEE stock markets, whereas the Russian crisis had some effect but no contagion effects were detected. In addition, Syllignakis and Kouretas (2011) show that increased volatility after financial liberalization can be attributed to the herding behaviour due to increased participation of foreign investors in the CEE stock markets, particularly after the accession of the CEE countries in the European Union. Furthermore, Syllignakis and Kouretas (2010) show that the CEE stock markets exhibited considerable smooth convergence and shared common factors with the US and German stock markets leading to a rather smooth transition path towards the EU accession in 2004.

5 Summary and concluding remarks

In this paper, we used a Markov-switching ARCH (SWARCH) model to examine the volatility patterns through time for a group of ten new EU members, Central and Eastern European stock markets. For this purpose we employed weekly stock price data for the period January 1993 to June 2012 for the CEE countries: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. The Markov-switching specification of the SWARCH model is shown better to be the appropriate specification to describe the dynamics of the stock market returns under examination, since it reduces the high volatility persistence problems faced by standard ARCH models.

The main findings that emerge from our analysis are summarized as follows. First, using the SWARCH specification, we were able to identify two or in some cases three regimes for the volatility of the ten Central and Eastern European countries. In addition, based on a Regime Classification Measure we show that our chosen SWARCH specification performed well in distinguishing between the two or three regimes for all cases. Second, with the exception of Bulgaria, a 'low' and a 'high' volatility regime has been shown to be statistically significant. Third, based on the estimated transition probabilities, we show that the estimated regimes are highly persistent. We also find that in most cases changes in volatility have been associated with financial liberalization. Volatility of stock returns have increased as a result of the financial liberalization programme in all countries apart from Poland and Slovakia where a moderate effect on volatility is detected. Fourth, the estimation of the three-regime SWARCH specification also leads to the conclusion that, apart from Slovenia, all other stock markets experienced very high volatility during the major financial crises for the period 1997-2001 as well as over the 2007-2009 financial turmoil. Finally, we argue that the European Union accession process has acted as a stabilizer for the smoothing of volatility of these emerging capital markets.

Acknowledgements

The authors acknowledge generous financial support from PENED 2003 (research grant (03ED46) co-financed by E.U.-European Social Fund (75%) and the Greek Ministry of Development-GSRT (25%). An earlier version of this paper was presented at the 12th International Conference on Macroeconomic Analysis and International Finance, University of Crete, 29-31 May 2008, the 2008 Annual Conference of the European Financial Management Association, Vouliagmeni, Greece, 25-28 June 2008, the 2008 International Conference on Policy Modeling-EcoMod, Berlin 2-4 July 2008, the 6th Summer School on Stochastic Finance, Athens University of Economics and Business, 20-23 July 2009 and the 14th International Business Research Conference, Dubai, 28-30 April 2011 and thanks are due to conference participants for many helpful comments. We thank Panayiotis Diamandis, George Karathanassis, Dimitris Georgoutsos, Aneta Hryckiewicz, Dimitris Moschos, Ekaterini Panopoulou, Angelo Ranaldo, Andrew Rose, George Tavlas and Leonidas Zarangas for many helpful comments and discussions. We also thank Rauli Susmel for providing us his GAUSS code for the estimation of the SWARCH model. The comments of an anonymous referee are gratefully acknowledged. The usual caveat applies.

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