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Modeling equity market integration using smooth transition analysis: A study of Eastern European stock markets

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Abstract

This paper assesses the extent to which the equity markets of Hungary, Poland the Czech Republic and Russia have become less segmented. Using a variety of tests it is shown there has been a consistent increase in the co-movement of some Eastern European markets and developed markets. Using the variance decompositions from a vector autoregressive representation of returns it is shown that for Poland and Hungary global factors are having an increasing influence on equity returns, suggestive of increased equity market integration. In this paper we model a system of bivariate equity market correlations as a smooth transition logistic trend model in order to establish how rapidly the countries of Eastern Europe are moving away from market segmentation. We find that Hungary is the country which is becoming integrated the most quickly.

JEL classification: G14

Keywords: International diversification; Equity market integration; Logistic trend function

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1. Introduction

It is now well documented that there has been a decline in the potential benefits which arise from international diversification because of the increasing degree of co-movement between national equity markets, see for example Taylor and Tonks (1989), Campbell and Hamao (1992) or Eun and Shim (1989). However, as shown by Bekaert and Harvey (1995), Harvey (1995) and Korajczyk (1996), a feature of emerging markets is that they appear to exhibit relatively low correlations with developed equity markets and can therefore provide diversification opportunities which may be unavailable in developed markets.

Partly as a consequence of diminishing diversification benefits in established markets, investors have appeared to focus to a greater extent on previously under-utilized or emerging markets. A consequence of such interest has been that many emerging markets have grown from tiny markets with little volume to become important sources of capital with a high return record. This is shown by Goetzmann and Jorion (1999) who find that returns in a sample of emerging markets are three times higher than for a sample of developed markets.

In order to assess the extent of equity market integration in four Eastern European countries we isolate the importance that domestic and foreign factors exert on the variation of a countries equity returns. This is achieved by analyzing the variance decompositions obtained from a vector autoregressive representation of market-wide equity returns. Since a market that is segmented from the rest of the world is not influenced by global factors, if the Eastern European markets are segmented the variance decompositions will indicate that their return variation is almost exclusively caused by domestic factors.

We also apply a smooth transition logistic trend function to a system of bivariate monthly return correlations to identify the speed of market integration in each country. This is the first time that such models have been applied as a test of market integration. The advantage of logistic trend models is that they can indicate the speed at which a market is becoming integrated, information which cannot be reliably attained from more conventional tests of market integration such as correlation analysis or variance decomposition analysis. An assumption of the smooth transition trend function is that it assumes market integration takes place as a gradual process, which in reality is likely to be the case even for countries that adopt dramatic liberalization policies.

We find that in the cases of Poland and Hungary, a significant movement towards market integration has been achieved by the end of our sample period. However, it is Hungary that is becoming integrated the most rapidly. Some reduction in market segmentation is experienced by the Czech Republic but very little movement away from segmentation is exhibited by the Russian equity market overall, although it does appear to experience short bursts of increased integration.

The remainder of this paper is set out as follows. Section 2 discusses previous work which has studied equity market integration. Section 3 examines the data and looks at the changing level of integration in Eastern Europe. Section 4 estimates the smooth transition model. Section 5 provides a summary and conclusions to the paper.

2. Financial market linkages in developed markets

A number of recent papers have shown that the potential for international diversification of the sort outlined by Levy and Sarnet (1970), Grubel and Fadner (1971), Lessard (1973) and Solnik (1974) has diminished because world equity markets are characterized by an increased level of harmonization. Empirically the reduced benefits of international diversification are now well documented. Taylor and Tonks (1989) have suggested that the long run benefits arising from diversification out of the UK equity market have been reduced due to the existence of an error correction process between the UK market and other major equity markets, which implies increased co-movement. Similarly, Kasa (1992) indicates that a common stochastic trend lies behind the co-movement of many major equity markets.

Evidence of increased world-wide equity market integration has also been supported by Campbell and Hamao (1992) who found that predictable components in excess stock returns for the US and Japan could be forecast from domestic economic variables existing in the other's country. It is not surprising that close links between equity markets appear to exist. Cho et al. (1986) tested an international version of the arbitrage pricing model using equity data and concluded that there may be as few as three or four common factors driving equity prices. Heston et al. (1995) find evidence that rewards for risk are identical across a wide range of countries, which they propose is evidence of market integration.

Commonality in the behavior of stock market prices is obviously disappointing for investors since this can only increase the correlation between markets and therefore reduce the gains from international diversification. Evidence from Eun and Shim (1989), however, has suggested that the reduced gains from international diversification have been asymmetric as innovations in the US stock market are quickly transmitted to other markets, whereas no single foreign market can significantly explain movements in the US market.

More recent work has shown that correlations between markets and, therefore, the degree of integration, can vary over short periods (see Bekaert and Harvey, 1995) and depend on whether world markets are rising or falling (Longin and Solnik, 2001). Kaplanis (1988) discovered that the stability of correlation and the covariance matrix of monthly returns to numerous national equity markets was unstable over a 15-year period. Koch and Koch (1991) studied lead lag relationships among eight national stock markets; their results point to growing regional interdependence over time. An explanation for unstable correlations over time is also found in the work of Longin and Solnik (1995) who show that changes in the correlation between markets can be explained by changes in the conditional covariance.

The seemingly low level of return correlation between emerging markets has encouraged the flow of portfolio investment to many emerging markets as investors capitalize upon potential diversification benefits. However, as this paper will show, as international investment increases the emerging markets begin to become more integrated and the degree of linkage with other markets increases, which reduces

Table 1
Equity portfolio inflows 1994–1999

	Poland	Hungary	Czech Republic	Russia
1994	n/a	224	497	44
1995	219	n/a	1236	46
1996	749	n/a	601	2154
1997	599	1004	378	1266
1998	1734	556	1095	714

The table presents the figures capital inflows for equity investment (in millions of US dollars) for each of the specified countries. Source: *International Financial Statistics*. An n/a means no figures were recorded.

diversification opportunities. As such, an emerging market can only provide significantly enhanced diversification benefits for a relatively short time.

3. Data and summary information

Table 1 reports information about the value of equity portfolio inflows for each of the four Eastern European countries, in millions of US dollars, obtained from *International Financial Statistics*. Equity portfolios are reported for each of the years 1994–1999. These figures indicate an upward movement in equity portfolio investment since 1994 for all countries.[1]

Daily equity market-wide information was obtained from *Datastream* for the four Eastern European countries and for Germany, France, Japan, the UK and the US for the period July 1994 until December 1999. Summary return information for all nine equity markets is presented in Table 2. The high return, high volatility of emerging markets which was discussed by Goetzmann and Jorion (1999) is evident in the mean returns and standard deviations of the Eastern European markets. As a group, the Eastern European markets have the highest standard deviation of the countries in the sample. In the cases of Poland, Hungary and Russia, the standard deviation of daily returns is approximately 2.8, 2 and 3½ times that of the UK and the US, respectively. Excluding the Czech Republic, the Eastern European markets also provide the highest returns with Russia, Poland and Hungary providing a daily percentage return of 0.24%, 0.12% and 0.19%, respectively, while the US provides a return of only 0.091%.

In the first instance, to gauge the level of market segmentation present the daily bivariate correlation coefficients between the returns of the four representative Eastern European markets and those of the developed markets is calculated. The daily correlation coefficients, which are calculated using the full sample, are presented in Table 3. As we can see, during this period the correlations between the Eastern European markets and those elsewhere in the world are considerably lower than for those between developed markets. Typically, the correlations between

[1] Although, a decline in equity portfolio investment appears to have been experienced during 1997.

Table 2
Daily market-wide returns 1994–1999

	$R\%$	σ	Min	Max
UK	0.060	0.0088	−0.041	0.054
US	0.091	0.0087	−0.075	0.056
Germany	0.070	0.0117	−0.098	0.061
Japan	0.031	0.0154	−0.139	0.239
France	0.064	0.0101	−0.075	0.061
Poland	0.124	0.0249	−0.113	0.147
Hungary	0.188	0.0180	−0.180	0.166
Czech Republic	−0.041	0.0107	−0.071	0.136
Russia	0.244	0.0389	−0.720	0.216

$R\%$ is the daily percentage market return, σ is the standard deviation of daily returns, Min and Max are the minimum and maximum observations, respectively.

Eastern European countries and other markets are below 0.3, whereas correlations between developed markets are typically above 0.3 and are frequently above 0.5. However, the correlations for the whole period mask the progress towards integration that has been made in a number of countries.

A clear reduction of market segmentation in Poland and Hungary can be observed if we look at the correlations on a year-by-year basis which are presented in Table 4(a)–(d). As we can see from these tables there is a noticeable increase in the size of the correlations between 1995 and 1998. For example, during 1995 the correlation coefficient between the returns of Hungary and Germany was 0.1927, but had risen to 0.5881 by 1998. Similarly, the correlation coefficient between Poland and Germany rose from 0.1517 in 1996 to 0.5408 by 1998. Similar patterns can be observed between other countries. This pattern is, to a lesser extent, also reflected in the correlations of the Czech Republic.

In the case of Russia, correlations tended to rise until 1997 then decline thereafter. A rise in the correlations up to 1998 is consistent with the significant attention directed at the Russian market by foreign investors.[2]

Even more illustrative of the changing correlation patterns is Table 5, which presents the mean correlation coefficients between Eastern European countries and the developed countries on a year-by-year basis. This table indicates that the correlation coefficient between developed and Eastern European markets has been steadily rising for Hungary and Poland, rose to a lesser extent for the Czech Republic and rose up until 1997 for Russia.

A valuable piece of information which cannot be extracted from the return correlations is how one equity market responds to shocks that occur elsewhere in the

[2] By 1997 Russia was consistently reported to be the best performing emerging market by the International Finance Corporation. In addition, it was widely reported that large fund management inflows were being directed at Russia. However, the collapse of the Russian equity market in 1998 which led it to be rated as the worst performing of 32 emerging markets by the International Finance Corporation halted further investment expansion in Russia. See for example, New York Business Wire, October 21 and April 25, 1996.

Table 3
Daily correlations for the period 1995–1999

	Japan	Russia	Germany	France	Hungary	Czech Republic	UK	US	Poland
Japan		0.0291	0.0719	0.1209	0.0045	0.0035	0.0637	−0.0582	0.0423
Russia			−0.0070	0.0657	0.0086	−0.0077	0.0512	−0.0582	0.0034
Germany				0.5149	0.4142	0.1685	0.7219	0.6448	0.3115
France					0.2290	0.0064	0.4184	0.3552	0.2063
Hungary						0.1829	0.6429	0.5460	0.2641
Czech Republic							0.1660	0.1957	0.2297
UK								0.6441	0.3102
US									0.2901
Poland									

world. A possible approach, which will allow us to extract more information, is to model the equity returns as a vector autoregressive process (VAR). The VAR has the advantage of providing variance decompositions which allow us to partition the proportion of the variation in national equity market returns caused by domestic and foreign factors.

The daily stock returns of the four Eastern European and five developed markets have been modeled as a nine variable vector autoregression as follows.[3]

$$R_t = C + \sum_{s=1}^{k} A_s R_{t-s} + e_t, \tag{1}$$

where, R_t is a $n \times 1$ column vector of equity returns for different countries. The C and the A_s are, respectively, $n \times 1$ and $n \times n$ coefficient matrices, and k is the lag length, here a log likelihood ratio test suggested that $k = 18$. In this model, the e_t is an $n \times 1$ column vector of forecast errors. By successive substitution on the right hand side of Eq. (1), we can obtain a moving average representation as follows,

$$R_t = B_s \sum_{s=0}^{\infty} e_{t-s}, \tag{2}$$

which represents R_t as a linear combination of current and past one-step ahead forecast errors or "innovations". The i, jth component of B_s shows the response of the ith market in s periods, after a unit random shock to the jth market. In order to observe the distinct response patterns the VAR system may display, we choose a lower triangular matrix V and obtain orthoganalized innovations u from $e = Vu$.

[3] The VAR has then been ordered according to which equity market leads another. This corresponds to the following ordering which closely reflects the different trading times: Japan, Russia, Germany, France, Hungary, Czech Republic, UK and US.

After making orthoganalized[4] transformations to e_t, Eq. (3) can be re-written as follows,

$$R_t = \sum_{s=0}^{\infty} B_s V u_{t-s} \tag{3}$$

$$= \sum_{s=0}^{\infty} C_s u_{t-s}, \tag{4}$$

where $C_s = B_s V$. The i, jth component of C_s represents the impulse response of the ith market, in s periods, to a shock of one standard error in the jth market.[5] The $\sum_{s=0}^{T} C_{ij_s}^2$ is the component of the forecast error variance in the $T+1$ step ahead forecast of R_i, which is accounted for by innovations in R_j. The decomposition of the forecast error variance provides a measure of the overall relative importance of each market in generating the fluctuations in stock returns, in their own and other markets. As such, the analysis of variance decompositions can indicate whether a market is integrated or segmented.

The variance decompositions are presented for the full sample in Table 6, and for the two sub-periods of July 1994 to December 1996 and August 1996 to July 1999 in Table 7(a) and (b), respectively.

Table 6 shows that during the full sample, for all four Eastern European equity markets there appears to be strong evidence of market segmentation. In all cases, the origin of at last 90% of the variation in market returns is domestic. However, this can be contrasted with the results of the UK, France and Germany, where non-domestic factors account for a much higher fraction of the variation in domestic returns.

Quite a marked difference is observable in the variance decompositions of the two sub-samples. In the first sub-sample, all Eastern European markets appear to be heavily segmented. However, in the second sub-sample, Poland and Hungary appear to have made significant progress towards equity market integration. In both cases almost 40% of the variation in equity market returns is caused by external factors. For both Hungary and Poland, therefore, this suggests that the degree of market integration has increased over the sample period. But Russia and the Czech Republic appear to have made little progress towards integration since domestic factors explain at least 85% of their return variation.

A benefit of the variance decompositions is that they allow us to identify the individual external influences on a market and can indicate the extent of bilateral integration. Interestingly, for Poland and Hungary it is the US and Germany that appear to have the dominant external influence on their markets. The US appears to account for about 10% of the variation in each of these markets, while Germany accounts for about 9% of the variation. Although much smaller in magnitude, the

[4] Choleski orthoganalization is used in this paper.

[5] A detailed discussion of the moving average representation can be found in Sims (1980).

Table 4
Daily correlations 1995–1998

	Japan	Russia	Germany	France	Hungary	Czech Republic	UK	US	Poland
(a) Daily correlations 1995									
Japan	–	0.0749	0.1598	0.1781	0.0051	0.1065	0.0627	0.0144	0.2118
Russia		–	−0.1579	−0.1137	0.1878	−0.0398	0.2978	−0.1469	−0.1313
Germany			–	0.4805	0.1927	0.0807	0.6431	0.3918	0.1517
France				–	−0.0049	−0.1229	0.5607	0.2609	0.0939
Hungary					–	0.1694	0.03951	−0.1862	0.3604
Czech Republic						–	−0.0303	−0.1673	0.1131
UK							–	0.4785	0.0189
US								–	−0.1212
Poland									–
(b) Daily correlations 1996									
Japan	–	0.2959	−0.0354	0.1556	−0.0007	−0.0049	0.0692	0.0681	0.0022
Russia		–	0.1066	0.0880	0.0256	0.1907	0.0189	0.1322	0.0559
Germany			–	0.2035	0.3565	0.0320	0.5209	0.5417	0.2924
France				–	0.3997	0.2385	0.5275	0.1042	0.3411
Hungary					–	0.2385	0.3075	−0.0456	0.6402
Czech Republic						–	0.1417	−0.0193	0.1113
UK							–	0.4677	0.1484
US								–	0.2801
Poland									–
(c) Daily correlations 1997									
Japan		0.1100	0.1410	0.1314	0.1094	−0.1538	0.0686	0.0509	0.1701
Russia			0.4408	0.3313	0.5641	0.2887	0.4175	0.3131	0.4122
Germany				0.7456	0.5322	0.1459	0.5811	0.6653	0.3277
France					0.4408	0.0696	0.4814	0.6631	0.2464
Hungary						0.1873	0.4556	0.4591	0.3003
Czech Republic							0.1585	0.0723	0.293
UK								0.4175	0.3105
US									0.2495
Poland									–
(d) Daily correlations 1998									
Japan	–	−0.1341	0.1479	0.0701	−0.0177	0.1694	0.0724	0.0412	−0.0548
Russia		–	0.1051	−0.0620	0.0503	−0.0317	0.0621	−0.0146	0.1346
Germany			–	0.8673	0.5881	0.3139	0.8645	0.7163	0.5408
France				–	0.4222	−0.1229	0.5607	0.2609	0.4618
Hungary					–	0.4172	0.5795	0.4447	0.5426
Czech Republic						–	0.3326	0.3869	0.4607
UK							–	0.7713	0.6516
US								–	0.5993
Poland									–

Russian equity market also appears to exert a consistent influence on both the Polish and Hungarian equity markets, while the markets of Russia, Germany, Hungary and Poland appear to have a consistent influence over the Czech equity market. The only consistent external influence on its equity market appears to come from Hungary.

Table 5
Mean correlation coefficients between Eastern European countries and developed countries 1995–1998

	Russia	Hungary	Czech Republic	Poland
1995				
Eastern Europe	0.0056	0.2392	0.0809	0.1141
Developed	−0.0092	0.0126	−0.0266	0.0710
1996				
Eastern Europe	0.0907	0.3014	0.1807	0.2691
Developed	0.1283	0.2035	0.0776	0.2128
1997				
Eastern Europe	0.4217	0.3351	0.2563	0.3352
Developed	0.3225	0.2608	0.0585	0.2608
1998				
Eastern Europe	0.0511	0.3367	0.2820	0.3793
Developed	−0.0087	0.4034	0.2160	0.4397

4. Explaining the change in correlations

Smooth transition analysis is an approach to modeling deterministic structural change in a time series regression. These models aim to identify any change as a single structural break, denoting it as a smooth transition between regimes over time. In this section we employ a variation of the simple non-linear smooth transition logistic trend model[6] suggested by Granger and Terasvirta (1993), applied more recently by Leybourne et al. (1997) and Leybourne and Mizen (1999). Since equity market integration is likely to be a gradual process smooth transition models are ideally suited to measuring market integration, although they have not previously been utilized in this context. The smooth transition model is applied to bivariate equity market correlations, which have been calculated for each month using the daily returns within each month. Thus, it is possible to observe a time series of equity market correlations. The smooth transition model for equity market correlations is represented by Eqs. (5) and (6). Because equity market integration cannot drift upwards independent of time, unlike the model presented by Granger and Terasvirta (1993) Eqs. (5) and (6) has no slope.

$$\rho_{ij,t} = \alpha + \beta S_t(\gamma,\tau) + v_t, \tag{5}$$

$$S_t(\gamma,\tau) = (1+\exp(-\gamma(t-\tau T)))^{-1}, \quad \gamma > 0 \tag{6}$$

where, $\rho_{ij,t}$ is a bivariate monthly correlation coefficient between the Eastern European equity market i and the developed equity market of country j in month t. The α and β are coefficients. The parameter τ determines the timing of the transition

[6] The trend component has been removed as there is no reason for equity market correlations to exhibit a trend increase.

Table 6
Variance decomposition 1994–1999

	Japan	Russia	Germany	France	Poland	Hungary	Czech Republic	UK	US
Japan	94.66	0.77	0.59	0.70	0.35	0.65	0.90	0.53	0.83
Russia	0.87	93.72	0.50	0.76	0.55	1.05	0.36	0.19	1.97
Germany	1.50	1.41	74.81	7.83	0.35	0.59	0.29	1.521	1.68
Hungary	0.68	3.91	5.93	1.52	1.69	76.76	0.60	1.59	7.29
Czech Republic	6.69	0.98	1.59	0.37	0.43	3.09	90.65	1.19	0.99
France	2.21	0.90	29.61	57.97	0.18	0.90	0.31	0.47	7.43
UK	1.94	1.52	21.35	17.13	0.36	1.46	0.76	47.64	7.84
US	0.87	0.51	6.86	5.93	0.34	0.97	1.05	2.71	80.77
Poland	0.21	0.65	1.80	1.02	91.23	0.57	0.58	0.55	3.38

midpoint, it indicates when half of the move towards integration between country i and j has taken place, and it is endogenously determined. The parameter γ measures the speed of adjustment. For $\gamma > 0$, we have $S_{-\infty} = 0$, $S_{+\infty} = 1$ and $S_{\tau T} = 0.5$. For small values of γ, S_t traverses the interval (0,1) very slowly, suggesting a gradual movement towards integration. In the limiting case, $\gamma = 0$ and $S_t = 0$ for all t so no integration takes place. Alternately, for large γ, S_t traverses the interval from 0 to 1 very rapidly, and as γ approaches $+\infty$ the function changes from 0 to 1 instantaneously at time τT. In this model, it is assumed that ρ_{ij} is stationary around a mean which changes from an initial value of α (prior to integration) to $\alpha + \beta$.

Table 7
Variance decomposition 1994–1996

	Japan	Russia	Germany	France	Poland	Hungary	Czech Republic	UK	US
(a) Variance decomposition 1994–1996									
Japan	89.12	0.15	2.65	1.72	1.90	1.11	1.37	1.07	0.88
Russia	0.52	94.17	0.46	1.32	0.96	1.03	0.24	0.99	0.29
Germany	3.23	0.52	76.95	7.72	1.39	0.76	0.89	1.04	7.50
Hungary	0.88	0.68	1.46	1.69	2.64	89.69	0.68	1.57	0.72
Czech Republic	0.42	1.16	0.44	0.68	1.34	1.50	91.49	2.22	0.73
France	2.21	0.57	26.28	64.68	0.47	0.74	0.51	0.32	4.21
UK	3.67	0.52	13.62	20.57	1.12	1.20	1.04	52.36	5.90
US	3.67	0.52	13.62	20.57	1.12	1.20	1.04	52.36	5.90
Poland	0.53	1.24	0.98	1.08	91.52	1.02	1.97	0.57	1.11
(b) Variance decomposition 1997–1999									
Japan	91.03	1.78	0.93	0.65	0.36	0.36	1.09	0.84	1.49
Russia	1.29	87.13	1.17	1.39	1.26	2.05	0.58	0.85	4.27
Germany	1.19	3.68	67.91	9.45	0.40	1.29	0.62	2.07	13.37
Hungary	0.89	7.33	8.97	2.97	5.20	60.11	1.04	2.75	10.72
Czech Republic	1.26	1.61	2.82	0.63	2.17	3.29	85.82	1.21	1.18
France	2.68	2.27	31.82	48.89	0.90	1.98	0.57	1.12	9.69
UK	1.75	3.98	26.19	14.50	0.80	2.61	0.74	40.62	8.81
US	1.22	1.02	9.14	8.94	1.19	1.39	1.31	2.72	73.85
Poland	1.05	4.60	8.65	4.20	65.66	1.94	0.93	2.09	10.84

Thus, α is a measure of market integration in the first regime and β is the increase (if β is positive) or decrease (if β is negative) in market integration in the second regime.

Care should be taken when employing a smooth transition model, as a series with a smooth transition adjustment can look very similar to a series that is I(1). This arises because an I(1) process can also be considered as one in which shocks cause a permanent change in levels. The difference is that shocks are stochastic rather than deterministic, and occur on a regular basis. For this reason, prior to the application of the smooth transition model it is good practice to test the series to determine whether it is stationary or I(1). If the series is I(1), a smooth transition model may be applied.[7] After the smooth transition model has been estimated, it is then important to test the residuals of this process, which no longer contain the deterministic component. If the residuals are stationary there is justification for the series being stationary, having a permanent change, which is a smooth transition process.

In order to identify the speed of adjustment towards equity market integration, it is necessary to observe integration with respect to many countries. Therefore, instead of estimating the smooth transition model as a single equation, it is estimated as a panel simultaneously using all five bivariate cross correlations between the Eastern European country i and the developed market of country j. In this model, the cross equation coefficients are constrained to be equal, ensuring that the coefficients give an estimation of world integration rather than bilateral integration. This requires the estimation of the following model using a non-linear least squares algorithm.

$$P_i = A_i + S_i B_i + V_i \tag{7}$$

$$\begin{pmatrix} \rho_{i1,t} \\ \vdots \\ \rho_{i5,t} \end{pmatrix} = A_i + \begin{pmatrix} S(\gamma\tau) \\ \vdots \\ S(\gamma\tau) \end{pmatrix} B_i + \begin{pmatrix} v_{i1,t} \\ \vdots \\ v_{i5,t} \end{pmatrix}$$

$$i = 1\ldots4 \quad j = 1\ldots5$$

where P_i is a $T \times 5$ column vector of all bivariate monthly correlations $\rho_{ij,t}$ between Eastern European country i and the developed market j for month $t = 1\ldots T$. $S(\gamma,\tau)$ is a $T \times 5$ column vector containing the logistic trend function $S_t(\gamma,\tau) = (1 + \exp(-\gamma(t - \tau T)))^{-1}$, $\gamma > 0$, A_i and B_i are single coefficients. The V_i is a $T \times 5$ column vector of errors. The advantage of this model, therefore, is that a single coefficient indicates the speed of market integration and a single coefficient can measure the progress of market integration. This therefore provides information which cannot be obtained from correlations or from variance decompositions.

Table 8 contains the computed ADF tests, calculated from the bivariate correlations. Ten of the bivariate correlations are found to be non-stationary at a 5% level and 10 are found to be stationary. These ADF tests provide some

[7] If the series is I(0) no structural break is indicated and therefore no change in the level of market integration. As such, a smooth transition process is not suggested.

Table 8
Computed augmented Dickey–Fuller statistics: prior to the fitting of the smooth transition model

	Russia	p	k	Hungary	p	k	Poland	p	k	Czech Republic	p	k
UK	−2.4215	0.14	2	−2.1725	0.21	2	−3.1946	0.02	2	−3.8065	0.00	2
US	−4.1560	0.00	2	−3.6601	0.01	2	−2.6901	0.08		−2.4982	0.12	6
Germany	−3.7308	0.00	2	−2.7100	0.07	4	−3.96	0.00	3	2.8051	0.06	3
Japan	−4.261	0.00	3	−3.9315	0.00	2	−2.7054	0.07	3	−2.7061	0.07	5
France	−2.4981	0.12	2	−2.6691	0.08	4	−3.7301	0.00	2	−3.7308	0.00	2

In this table the augmented Dickey–Fuller test statistic for the bivariate correlation coefficient of the country at the header of the table with the country noted at the beginning of each row is presented. The p is the probability value of the test statistic and k is the optimal lag length for the augmented Dickey–Fuller test. The ADF statistics have been computed with a constant but without a trend.

information about bilateral integration. For the 10 correlations which are non-stationary, there is some indication that the level of bilateral co-movement between stock markets may have altered. For the remaining correlations, found to be stationary, there is no evidence of a shift in the level of integration.

The next step is to estimate the smooth transition model excluding the correlations which were found to be stationary. The results from the estimation of the smooth transition model are contained in Table 9 and suggest an increase in market integration for Poland, Hungary and the Czech Republic as $\gamma > 0$ for all three countries. Since γ is largest for the Czech Republic, the transition towards integration is faster than for Hungary or Poland. There is little difference between the transition midpoints of all three countries. In the case of Poland it is approximately 59% (September 1997), for Hungary it is approximately 49% (February 1997) and for the Czech Republic it is approximately 58% of the sample (August 1997).

In the case of Russia, there is no movement towards integration as $\gamma = 0$ The results presented here are consistent with the results presented in Section 3, which indicated unstable movements towards market integration for Russia. The highest R^2 is for Hungary, suggesting that for this country the smooth transition model explains a greater proportion of the variation in monthly correlations than for any other country. The R^2 is 23% for Hungary, 18% for Poland and 15% for the Czech Republic.

Table 9
Results from the adjusted smooth transition model 1994–1999

	α	β	γ	τ	$\bar{R}^2$
Russia	0.0132 (2.08)	0.3105 (1.01)	1.9351 (1.35)	0.5316 (1.73)	0.09
Poland	0.1964 (2.69)	0.5295 (3.54)	0.5639 (2.50)	0.5937 (5.36)	0.18
Hungary	0.2951 (8.93)	0.3729 (7.21)	1.4350 (3.24)	0.4893 (10.26)	0.23
Czech Republic	0.3138 (4.36)	0.1987 (2.21)	1.0538 (2.31)	0.5832 (2.84)	0.15

This table presents the results obtained from the estimation of the logistic trend model. Where α is a constant, is the coefficient on the logistic time trend. The γ captures the speed of adjustment and τ reflects the transition midpoint. In this model we only include those bilateral correlations which were found to be non-stationary when augmented Dickey–Fuller tests were applied to the correlations.

Table 10
The results of the augmented Dickey–Fuller tests: applied to the residuals of the adjusted smooth transition model

	Russia	k	Hungary	k	Poland	k	Czech Republic	k
UK	−3.203	2	−4.957	4		2	n/a	
US	n/a		n/a		−4.303	3	−4.485	2
Germany	n/a		−4.586	2	n/a		−4.483	2
Japan	n/a		n/a		−4.414	2	−4.357	6
France	−4.272	3	−4.514	2	n/a		n/a	

This table contains the computed ADF statistics (with no trend). Critical values have been obtained from Leybourne et al. (1998). At a 5% level the critical value is −4.30.

After applying the smooth transition model, we compute the ADF statistics from the residuals and use the critical values suggested by Leybourne et al. (1998). These are appropriate given the non-linear form of the smooth transition model. These results are contained in Table 10 and suggest that almost all of the residuals are stationary, justifying the use of the smooth transition model. The exceptions are found for Russia. Neither of the bivariate correlations which included Russia were found to be stationary. For these correlations, a smooth transition process is not justified.

5. Summary and conclusions

Using a variety of tests, this paper has investigated whether the Eastern European equity markets of Hungary, Poland, Russia and the Czech Republic are heavily segmented or instead are integrated. This paper finds that early on during the recent history of the Eastern European markets, all four markets could be described as heavily segmented. However, over time, the degree of segmentation experienced by some of these markets has declined significantly.

The stocks markets of Hungary and Poland appeared to have made rapid progress towards becoming an integrated market. Variance decomposition analysis indicates that for these two countries their equity markets are being influenced by the performance of external equity markets to a greater extent than was previously the case.

The Czech Republic is also making some progress towards market integration, but it seems to be progressing at a much slower pace than has been experienced by Hungary and Poland. We find the weakest progress towards market integration in Russia. Despite a promising move towards integration up until 1997, the Russian equity market remains the most heavily segmented Eastern European market out of the four studied in this paper.

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