Sensitivity of Equity Returns to Exchange Rates in Central European Countries

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Abstract:

We examine co-movements between equity returns and the EUR values of the local currencies in the three Central European countries that follow autonomous monetary policies with flexible exchange rates: Poland, the Czech Republic and Hungary. We devise a model of equity returns and changes in logs to exchange rates. We test the model with Bai-Perron multiple breakpoint regressions and two-state Markov switching tests that enable us to highlight the time-varying characteristics in the nexus between equity returns and exchange rates. We use daily data for the sample period starting from the euro inception on January 4, 1999 and ending September 12, 2018. Our tests indicate that sensitivity of equity returns to changes in the euro values of local currencies was very low in all three countries prior to their EU accession in May 2004. It became positive and significant at the onset of and through the 2008-2010 financial crisis. More recently, it continues to be positive and significant in the cases of Poland and Hungary, but not the Czech Republic.

Keywords: Equity Returns, Exchange Rates, Uncovered Equity Parity Return Condition, Central European Countries.

JEL Classification: F31, F36, G15.

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I. Introduction

This paper examines co-movements between equity returns and exchanges rates in Central European EU member countries (CECs) that follow autonomous monetary policies with flexible exchange rates: Poland, the Czech Republic and Hungary. We exclude the CECs that have already adopted the euro and those whose monetary policies are based on fixed exchange rates the euro. In essence, we test whether the Uncovered Equity Return Parity Condition (URP) holds or breaks in these countries during the sample period that begins with the introduction of the euro (EUR) on January 5, 1999 and ends on September 12, 2018. URP has been applied to explain the dynamics of exchange rates. It states that a local currency is expected to appreciate when returns in domestic equity markets are lower than returns in another country or region's markets under the assumption that investors are risk neutral. In other words, lower or declining returns in local equity markets must be compensated with the local currency appreciation. This implies an inverse relationship between local market returns and the local currency value in an underlying international currency, in our case EUR[1].

Considering key findings in the prior literature, it is plausible to assume that the relationship implied by the URP condition does not hold in CECs. It is because financial markets in these countries have become increasingly open, more developed and integrated with the EU and the euro area markets (Grambovas, 2003; Syriopoulos, 2004; Fedorova and Saleem, 2010; Nitoi et al., 2018). At the same time they have become more susceptible to exogenous shocks and contagion effects. The ongoing integration of financial markets has contributed to higher trading volumes of equities and enhanced transmission of cross-market returns. As a result, capital flows from the euro area and other EU financial areas to Central Europe have increased equity market returns and contributed to appreciation of local currencies in EUR, thus not conforming to the URP condition (Nitoi, et al, 2018). As the integration has not been smooth co-movements of equity returns and exchange rates have been disrupted. A range of exogenous disturbances including the global financial crisis, the sovereign debt crisis in the euro-periphery countries and asymmetric monetary policy responses to crisis-induced shocks (Orlowski, 2012 and 2016) has caused the disruptions. Nevertheless, we assume that the integration of CECs with the euro-area equity and foreign exchange markets is moving forward.

The co-movements between equity returns and exchange rates have been found as unstable and time-varying in the prior literature that has mainly employed dynamic conditional correlation as well as cointegration with vector error correction tests (Grambovas, 2003; Syriopoulos, 2004; Hau and Rey, 2006; Fedorova and Saleem, 2010; Nitoi et al., 2018). We employ different analytical procedures in order to ascertain dynamic changes, possible structural breaks and discernible phases in the evolving co-movements between equity returns and exchange rates in

[1] For the discussion of the URP condition and its empirical analysis in selected global financial markets, see for instance Capiello and De Santis (2005), Hau and Rey (2006), Melvin and Prins (2015), and Djeutem and Dunbar (2018).

CECs. We devise a model of responsiveness of log changes in equity returns to log changes in EUR values of local currencies and EUR values of the US Dollar (USD). The two exchange rates as exogenous variables allow for examining the relative importance of capital flows from the EU vs global financial markets for local equity returns. The model is empirically tested with the Bai-Perron Multiple Breakpoint (MBP) regression that helps identify possible structural breaks and phases in the integration of CECs equity markets with EU and global foreign exchange markets. The time-varying characteristics of this integration are further verified with the Two-State Markov Switching (MS) regression. Its time-varying properties are shown on graphs presenting filtered regime switching probabilities between high and low elasticity 'states' for the three examined markets and currencies.

The underlying analytical model is shown and discussed in Section II. The results of its MBP estimation for the three CECs are analyzed in Section III. They are compared with the Markov switching estimation presented in Section IV. Section V encapsulates the main findings. .

II. Elasticity Model of Equity Returns and Exchange Rates

Most of the literature investigating the relationship between equity market returns and exchange rates focuses on a causal impact of changes in equity returns on the exchange rates. As stated by the URP, a local currency will appreciate when returns in domestic equity markets are lower than returns in foreign markets, which entails a perfect balance between equity and exchange rate risks for risk-neutral investors. However, a prevalent outcome of the empirical research on URP is that such balancing condition does not always hold (Capiello and deSantis, 2005; Cenedese et al., 2015; Djeutem and Dunbar, 2015). A counterfactual evidence has been also provided in the literature. Among others, Hau and Rey (2006) prove that net equity flows into foreign markets are positively correlated with a foreign currency appreciation, which was strongly supported among 17 OECD countries during the time-frame of their analysis. More recent analyses pertaining to CECs markets by Islami and Welfens (2013) and Nitoi et al., (2018) point out that the transmission of returns between equity and foreign exchange markets is not uniform among these countries and it is subject to increased variance over time.

We intend to delve deeper into interactions between equity and foreign exchange risks returns. Our underlying model focuses on association between local equity market returns and local currency value in EUR as well as USD value in EUR. It can be specified as:

$$SMI_t = \alpha_0 + \alpha_1 (e^{LC})_t + \alpha_2 \left(e^{USD}\right)_t + \mu_t \quad (1)$$

where SMI is the local stock market index, e^{LC} is the EUR value of a unit of local currency and e^{USD} is the EUR value of one USD.

In order to determine exchange rate elasticity of equity returns, Eq. 1 can be transformed into a double-logarithmic function specified as:

$$\Delta \log\left(SMI\right)_t = \beta_0 + \beta_1 \Delta \log\left(e^{LC}\right)_t + \beta_2 \Delta \log\left(e^{USD}\right)_t + \mu'_t \qquad (2)$$

where β_1 and β_2 are exchange rate elasticity coefficients of local equity market returns with respect to the local currency values in EUR and USD in EUR respectively.

A high, positive estimated $\widehat{\beta}_1$ coefficient suggests that returns to equities are elastic, i.e. highly sensitive to changes in local currency values in EUR. It further implies strong integration of local equity markets with foreign exchange markets within the EU. A positive estimated $\widehat{\beta}_2$ coefficient infers integration of local equities with global financial markets and exchange rates. It suggests that local equities and the USD denominated assets are substitutes for international investors. Adversely, a negative value of this coefficient would infer complementarity between local equities and the USD assets to investors.

III. Multiple Breakpoint Estimation

Simple ordinary least square regression estimations of the relationship prescribed by Eq. 2 for the equity markets and currencies of Poland, the Czech Republic and Hungary have provided inconclusive, unstable results that we do not choose to report. Instead, we aim to examine these relationships in perceptible time intervals identified by discernible structural breaks. For this purpose we employ the Bai-Perron MBP regressions.

Our MBP tests use daily data of exchange rates and equity market indexes for the sample period that starts with the EUR inception in January 5, 1999 and ends with the most recent observation on September 12, 2018. The sample includes 4997 daily data extracted from Bloomberg. The MBP tests for the three CECs are optimized by assuming L+1 vs. L sequentially determined breaks and they allow error terms to differ across breaks. The optimal number of breaks is obtained by minimizing the Akaike Information Criterion. The results of MBP estimations of Eq. 2 are shown in Table 1.

….. insert Table 1 around here …..

The regression for Poland's estimates log changes in the Warsaw Stock Exchange WIG index as a function of log changes in the Polish Zloty (PLN) value in EUR and the USD value in EUR. The MBP test identifies two discernible breakpoints on January 6, 2006 and on May 6, 2009, which implies three distinctive periods. During the initial Period I, percent changes in WIG are positively related to percent changes in both exchange rates. Elasticity of market returns to PLN value in EUR is statistically significant but very low (the estimated coefficient is very small). This suggest a weak integration of Poland's equity market with the foreign exchange market, and therefore, a relatively low impact of external capital inflows on prices of Polish equities. Similarly, elasticity of equity prices to the USD exchange rate is also low, albeit positive and statistically significant. The elasticity coefficient are very different during Period II that includes the peak and the immediate aftermath of the global financial crisis. Specifically, Polish equity returns show high positive sensitivity to changes in the PLN in EUR exchange rate, indicating more active capital flows between the euro area and Polish markets. Evidently, higher returns on Polish equities are associated with the PLN appreciation, but at the same time with the USD depreciation as implied by the negative $\widehat{\beta}_2$ coefficient. The negative sign of this coefficient underpins resiliency of Polish equity markets during the crisis period, but it also highlights disparity of monetary policies pursued by the National Bank of Poland (NBP) and major international central banks. The NBP adhered to its inflation target rather strictly by keeping high positive interest rates, while others engaged in quantitative easing with zero-bound rates. During the most recent Period III covering the post-crisis era, the estimated $\widehat{\beta}_1$ coefficient is even higher and more statistically significant, implying a strong integration between the Polish and the euro-area financial markets.

Somewhat different dynamic changes are observed for the Czech Republic. The initial Period I has a longer time span extending from the euro inception until the peak of the financial crisis. The estimated $\widehat{\beta}_1$ and $\widehat{\beta}_2$ coefficients are insignificant indicating low elasticity of equity returns in the Prague stock market index PX and both exchange rates, i.e. the EUR values of the Czech Koruna (CZK) and the USD. During the peak of the crisis and its aftermath covered by Period II, the elasticity of PX returns to the EUR value of CZK is high and positive. Similarly to the Polish case, the elasticity of Czech equity market returns to the USD in EUR exchange rate is negative. This combination the elasticity coefficients implies an increasing integration of the Czech and the euro-area financial markets, as well as the disparity between monetary policies of the Czech National Bank (CNB) and the key international central banks. CNB has been consistently following a disciplined form of inflation targeting supported with positive nominal target interest rates during the entire examined sample period. There is a somewhat puzzling plunge in the value of the estimated $\widehat{\beta}_1$ coefficient, which also becomes statistically insignificant during the most recent Period III. However, the $\widehat{\beta}_2$ coefficient is positive and statistically significant, indicating a pronounced integration of the Czech with the global financial markets.

Our MBP test for returns to Hungarian equities included in the Budapest Stock Exchange Index (BUDEX) identifies three distinctive breakpoints and four sub-periods. The initial Period I nearly perfectly matches the time between the EUR inception and the country's accession to the EU in May 2004. Period II covers the post-accession era ending in September 2008 i.e. right before the peak of the global financial crisis. There are two discernible sub-periods during the post-crisis era. During the initial Period I, returns to Hungarian equities are negatively associated with the Hungarian Forint (HUF) value in EUR and positively related to the USD value in EUR. The post EU accession Period II shows a major reversal in these relationships. Returns to equities are now positively associated with the HUF value in EUR suggesting acceleration of portfolio capital inflows from the euro area to the Hungarian stock market. The relationship between equity returns and the USD exchange rate becomes insignificant. These directional changes are further augmented in Period III. The positive association between Hungarian equity returns and the HUF value in EUR becomes stronger and more statistically significant, while their relationship with the USD in EUR exchange rate turns negative. However, these relationships are considerably weakened during the most recent Period IV, although the nexus between equity returns and the HUF in EUR exchange rate remains positive and statistically significant.

In sum, the dynamic changes in the relationships between equity returns and exchange rates in the three examined CECs do not follow a uniform pattern. On the common ground, the link between equity returns and local currency values in EUR is rather weak during the early period. During the post EU accession and the financial crisis sub-periods, this relationship for the Polish and the Hungarian financial markets becomes significantly stronger. It is also somewhat stronger for the Czech markets, although Czech equity returns show a pronounced positive relationship with the USD in EUR exchange rate, implying a strong impact of global financial conditions and capital flows on Czech equity returns. During the most recent sub-period, associations between equity returns and local currency values in EUR assume a divergent path. The relationship becomes stronger for Poland, somewhat weaker for Hungary and insignificant in the Czech case. In hindsight, our results confirm a weak support for URP and the lack of uniformity in interactions between equity returns and exchange rates evidenced in the prior literature (Grambovas, 2003; Syriopoulos, 2004; Katechos, 2011; Islami and Welfens, 2013; and Cenedese et al., 2015)[2].

IV. Two-State Markov Regime Switching Tests

The above MBP analysis shows that the interactions between local equity market returns and the two exchange rates prescribed by Eqs. 1 and 2 are time-varying, unstable during the obtained time intervals. Their time-varying patterns can be further investigated with a Two-State Markov Regime Switching (MS) process, which allows for identifying the timing of shifts between two discernible States, i.e. two different patterns of interactions between the dependent and independent variables.

As our analysis is focused mainly on the interactions between returns to equities in CECs and local currency values in EUR, we devise a Markov process derived from Eq.2 that assumes changeable variations in these two variables in States I and II, given a common pattern in log changes in the USD value in EUR. By doing so, we aim to ascertain dynamics of integration

[2] Several earlier studies provide some evidence supporting URP. See for instance: Forbes and Rigobon, 2002; Capiello and de Santis, 2005; Hau and Rey, 2006.

between local equity markets and exchange rates against the EUR. We assume that State I adheres to the URP condition whereas increases in local market returns should correspond with the local currency depreciation, implying an inverse relationship between these two variables. State II should then follow the opposite process characterized by a strong positive relationship between local equity returns and the local currency value in EUR. We aim to examine which of these two directional relationships has been prevalent during the entire sample period and what has been the exact timing of possible switches between both States.

Following the above-stated assumptions, the Two-State Markov process is devised as follows. State I prescribed by Eq. 3 reflects a presumed inverse relationship between equity returns and the local currency values in EUR:

$$\Delta \log(SMI)_{t|St=1} = c_1 + \gamma_{11}\Delta \log(e^{LC})_t + \gamma_2 \Delta \log(e^{USD})_t + \varepsilon_{1t} \qquad \varepsilon_{1t} \rightarrow N(0,1) \qquad (3)$$

Our initial assumption is that γ_{11} should be negative in State I, in consistency with URP. This implies that an increase in domestic equity returns is matched by local currency depreciation.

State II is specified by Eq.4:

$$\Delta \log(SMI)_{t|St=2} = c_2 + \gamma_{12}\Delta \log(e^{LC})_t + \gamma_2 \Delta \log(e^{USD})_t + \varepsilon_{2t} \qquad \varepsilon_{2t} \rightarrow N(0,1) \qquad (4)$$

By assumption, State II reflects a positive relationship between equity returns and local currency rates in EUR. Estimated coefficient γ_{12} should be positive in State 2. The EUR value of USD is treated as a common non-switching regressor in both States with the same elasticity coefficient γ_2. This allows us to focus the analysis on changeable dynamics in the relationship between local equity returns and local currency values in EUR, conditional on the exogeneous pattern of the USD in EUR exchange rate.

The transition probability matrix for switching the process between the two States at any given period is :

$$P = \begin{bmatrix} p_{11} p_{21} \\ p_{12} p_{22} \end{bmatrix} \qquad (5)$$

The Markov switching tests also consider as common non-switching regressors the autoregressive (AR) terms in the order of p that is optimized by minimizing the Akaike Information Criterion. The results of Markov switching estimations for the three analyzed CECs equity markets are shown in Table 2.

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The results shown in Table 2 identify a negative relationship between returns to Polish equities and changes in log of PLN in EUR exchange rate in State I, while State II follows a positive relationship between these variables. The absolute value of the positive estimated coefficient $\hat{\gamma}_{12}$ is considerably higher than the absolute value of $\hat{\gamma}_{11}$, which indicates very strong interactions between these variables when the process turns into a positive relationship. However, the weak inverse relationship prescribed by State I dominates the Markov process in the case of Polish equities, as the probability of staying in this State on any given day is 61 percent and the expected duration of State I is 2.6 days. This implies that the PLN appreciation against the EUR is associated with lower returns to Polish equities. This further suggests prevalence of portfolio diversification of international investors involving Polish equities. State II is subordinate as the probability of remaining in it on any given day is 37 percent and its expected duration is 1.6 days. The estimated sensitivity of returns to Warsaw WIG equities to the USD in EUR exchange rate is continuously negative as implied by the negative sign of $\hat{\gamma}_2$. The USD appreciation is associated with higher returns to Polish equities indicating some co-movement with global financial markets and positive contagion effects. The positive AR(1) and the negative AR(2) coefficients of roughly the same absolute magnitude indicate some transmission of shocks from a previous day only.

The corresponding distribution of filtered regime probabilities for the Polish equity returns is shown in Figure 1A that reflects time-varying probability of remaining in the dominant State I on any given day during the entire sample period. It indicates a significant derailment of State I before the EU accession, followed by a more stable co-movement during the 2004 -2008 sub-period. There is also a repeated instability of State I during the financial crisis period followed by its more stable path since mid-2012.

The estimated Markov switching process is quite different for the Czech equity returns. The dominant State I shows a weak positive relationship between returns to Prague equities and the CZK value in EUR. State II is prescribed by a strong positive relationship. Nevertheless, State I clearly dominates the Markov process. Its expected duration is 63.8 days and the probability of remaining in this weak positive co-movement is 98 percent. The link between returns to Prague equities and the USD in EUR exchange rates is negative, although weaker than in the Polish case. The preponderance of State I is further confirmed by the time distribution of filtered regime probabilities for State I shown in Figure 1B. Evidently, the link between returns to Prague equities and the CZK in EUR value is rather weak during the examined sample period. There are however several episodes of switching to a strong positive co-movement, most notably during the peak of the financial crisis in 2008 and at times of eruptions of the euro-periphery sovereign debt crisis episodes afterwards. At times of external financial distress, the CZK appreciation in EUR corresponds with higher returns on Czech equities indicating very active short-term capital inflows to Czech equities.

The Markov process for returns on the Hungarian equities has somewhat different characteristics. The dominant State I indicates a statistically insignificant link between returns on Budapest equities and the HUF in EUR exchange rate, its expected duration of 3.9 days is longer than that for State II (of 1.8 days) and the probability of remaining in it is higher. The link to the USD in EUR value is also negative, albeit weaker than in the Polish case. Unlike in the previous two cases, there is a significant transmission of negative shocks from two days before as implied by a significant negative value of estimated AR(2) coefficient. The time-varying distribution of filtered regime probabilities for State I for the Hungarian series is shown in Figure 1C. The dominant State I is rather derailed at all times, particularly at times of financial distress. The relationship in the Hungarian case is certainly more unstable than in the Czech case. However, the process becomes clearly more stable during the most recent time period since 2016.

….. insert Figures 1 A-C around here …..

In sum, our Markov switching tests show considerable differences in interactions between returns on CECs equities and local currency values in EUR. Nevertheless, there are at least two common characteristics. First, there are strong, positive co-movements between equity returns and exchange rates against the EUR at times of financial distress showing signs of contagion and lower portfolio diversification. Second, the relatively weak relationship between equity returns and the exchange rates against the EUR that dominates the Markov process is quite stable during the recent two-year period in our sample, indicating a gradually more pronounced portfolio diversification among investors in EU wide equities.

V. Conclusions

The main objective of our study is to examine co-movements between equity returns and EUR values of local currencies in the three Central European countries that follow autonomous monetary policies with flexible exchange rates: Poland, the Czech Republic and Hungary. For this purpose, we devise a model of equity returns, i.e. changes in logs of equity indexes and changes in logs of exchange rates. These co-movements are unstable and time-varying, as found also in the prior literature. Prior studies, however, have employed mainly dynamic conditional correlation as well as cointegration with vector error correction tests. In order to identify specific timing of structural breaks and exogenous shocks, we apply different testing procedures, namely Bai-Perron multiple breakpoint regressions and two-state Markov switching tests. Our sample period includes daily data starting from the euro inception on January 4, 1999 and ending September 12, 2018.

The multiple breakpoint regressions indicate low, statistically insignificant sensitivity of equity returns to changes in EUR values of local currencies for all three countries prior to their EU accession in May 2004. This sensitivity becomes positive and significant prior to and through the 2008-2010 financial crisis. It continues to be positive and significant for the Polish and Hungarian but not the Czech equity market during the latest period. Overall, we confirm that the Uncovered Equity Parity Return condition does not hold well in CECs.

Utilizing the two-state Markov switching tests we find that correlations between equity returns and percent (log) changes in exchange rates are not uniform in the three CECs. There are however some common characteristics. Chief among them is a rather low correlation between equity returns and local currency rates in EUR at normal market conditions. These co-movements become much stronger at times of financial distress, which indicates a pronounced transmission of contagion effects from the euro area markets. We also find that correlations between returns in the three equity markets and USD in EUR exchange rate are consistently negative, which indicates that the USD depreciation corresponds with higher returns in CECs equities. This suggests that capital outflows from US (and other mature global) stock markets to Central European equities in search for higher returns. This in turn leads us to suggest that the Central European equity markets display some characteristics of frontier markets to international investors.

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Table 1: Bai-Perron multiple breakpoint regression estimation of Eq. 1

Dependent variables: changes in logs of local equity market indexes
Independent variables: changes in logs of EUR values of a local currency and changes in logs of EUR values of one USD.
Sample period: January 5, 1999 – September 12, 2018 (4997 included observations)

Dependent var., Δlogs of → Sub-periods based on breakpoints ↓	**Warsaw Stock Exchange WIG**	**Prague Stock Exchange PX**	**Budapest Stock Exchange BUDEX**
Period I	01/05/1999-01/02/2006 1773 observations $\hat{\beta}_0$ = 0.001 (1.80)* $\hat{\beta}_1$ **=0.099 (4.13)***** $\hat{\beta}_2$ **=0.127 (4.07)*****	01/05/1999-09/15/2008 2457 observations $\hat{\beta}_0$ = 0.001 (1.74)* $\hat{\beta}_1$ =0.078 (1.26) $\hat{\beta}_2$ =-0.006 (-0.32)	01/05/1999-04/13/2004 1332 observations $\hat{\beta}_0$ = 0.001 (0.10) $\hat{\beta}_1$ **= -0.081 (-3.26)***** $\hat{\beta}_2$ **=0.199 (3.19)*****
Period II	01/03/2006- 05/05/2009 842 observations $\hat{\beta}_0$ = -0.001 (-0.43) $\hat{\beta}_1$ **=0.535 (7.97)***** $\hat{\beta}_2$ **= -0.557 (-6.98)*****	09/16/2008-12/18/2012 1087 observations $\hat{\beta}_0$ = -0.001 (-0.19) $\hat{\beta}_1$ **=0.446 (4.46)***** $\hat{\beta}_2$ **= -0.639 (-8.48)*****	04/14/2004-09/18/2008 1128 observations $\hat{\beta}_0$ = 0.001 (0.86) $\hat{\beta}_1$ **=0.733 (8.99)***** $\hat{\beta}_2$ =0.076 (1.01)
Period III	05/06/2009-09/12/2018 2382 observations $\hat{\beta}_0$ = 0.001 (1.37) $\hat{\beta}_1$ **=0.746 (18.59)***** $\hat{\beta}_2$ **= -0.100 (-2.88)*****	12/19/2012-09/12/2018 1453 observations $\hat{\beta}_0$ = 0.001 (0.11) $\hat{\beta}_1$ =0.043 (0.49) $\hat{\beta}_2$ **= 0.158 (3.79)*****	09/19/2008-10/18/2012 1041 observations $\hat{\beta}_0$ = 0.001 (0.43) $\hat{\beta}_1$ **=0.943 (12.93)***** $\hat{\beta}_2$ **= -0.504 (-6.25)*****
Period IV	NA	NA	10/19/2012-09/12/2018 1496 observations $\hat{\beta}_0$ = 0.001 (1.87)* $\hat{\beta}_1$ **=0.602 (8.97)***** $\hat{\beta}_2$ = -0.077 (-1.55)
Diagnostic stats.: F-statistics Log likelihood AIC DW	 62.78 15002 -6.001 1.94	 29.51 14541 -5.816 1.97	 60.30 14168 -5.666 1.97

Notes: Bai-Perron multiple breakpoint regressions with L+1 vs. L sequentially determined breaks. The number of breaks is obtained by a minimum Akaike information criterion (AIC). Standard errors and covariances are Newey-West heteroscedasticity and autocorrelation consistent (HAC). The tests allow for heterogeneous error distribution across breaks. DW is Durbin Watson statistics. Z-statistics are in parentheses. *** denotes significance at 1%, ** at 5% and * at 10%.

Source: Author's own estimation based on Bloomberg data.

Table 2: Markov Switching Estimations of Equity Returns in Relation to Exchange Rates.

Changes in Logs in Warsaw WIG, Prague PX, Budapest BUDEX Equity Market Indexes as a Function of Changes in Logs of Exchange Rates. Estimations of Eqs. 3-5. Sample period: *January 5, 1999 – September 12, 2018 (4998 daily observations).*

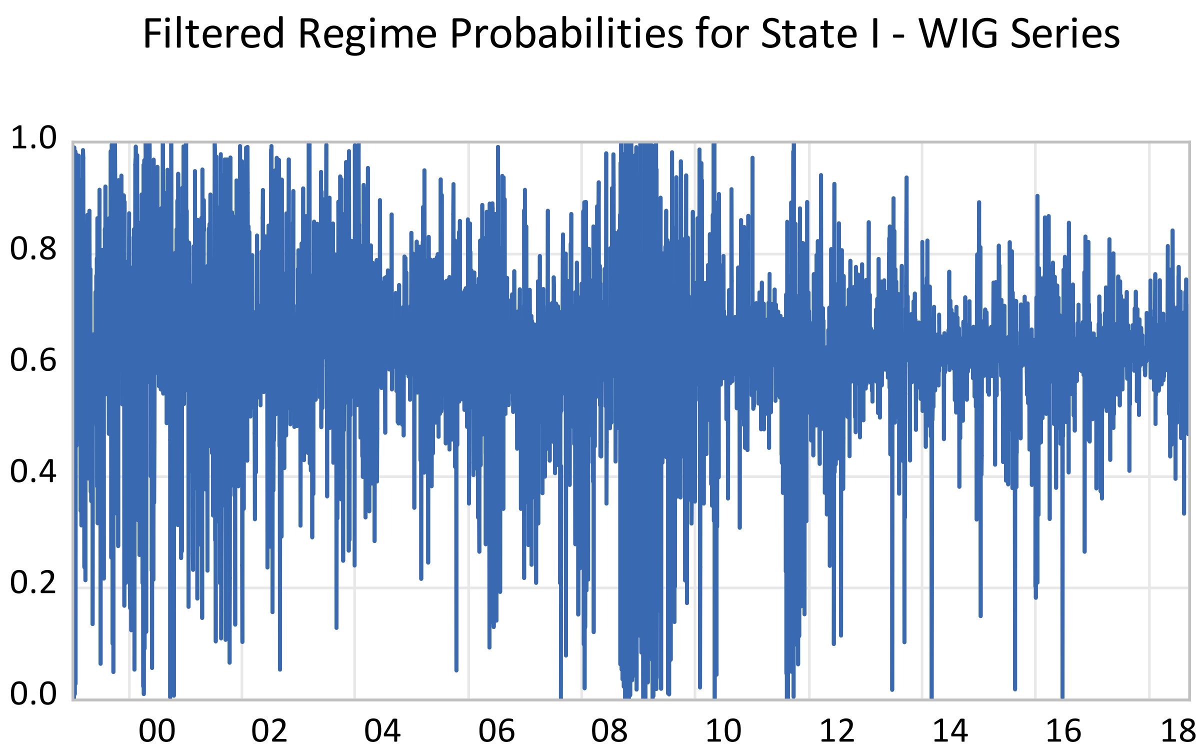
Log of →	**Warsaw WIG**	**Prague PX**	**Budapest BUDEX**
State I	$\hat{c}_1$= 0.001** (1.78) $\hat{\gamma}_{11}$= -0.089*** (-3.41)	$\hat{c}_1$= 0.001* (1.62) $\hat{\gamma}_{11}$= 0.119*** (2.69)	$\hat{c}_1$= 0.001 (0.55) $\hat{\gamma}_{11}$= 0.022 (1.10)
State II	$\hat{c}_2$ = -0.001 (-0.09) $\hat{\gamma}_{12}$ = 1.325*** (12.76)	$\hat{c}_2$ = -0.001* (-1.86) $\hat{\gamma}_{12}$ = 7.207*** (16.25)	$\hat{c}_2$ = 0.001 (1.57) $\hat{\gamma}_{12}$ = 1.987*** (18.97)
Common non-switching regressors: USD in EUR Log σ AR(p) terms	$\hat{\gamma}_2$ = -0.141***(-4.92) Log σ = -4.477*** AR(1) =0.027* AR(2) = -0.020	$\hat{\gamma}_2$ = -0.060***(-3.99) Log σ = -4.380*** AR(1) =0.027*	$\hat{\gamma}_2$ =-0.084***(-2.55) Log σ = -4.307*** AR(1) =0.005 AR(2) = -0.041**
Diagnostic tests:	Log likelihood = 15017 Akaike IC = -6.009 DW = 1.98	Log likelihood = 14636 Akaike IC = -5.856 DW = 1.99	Log likelihood = 14172 Akaike IC = -5.670 DW = 1.99
Constant transition probabilities: Probability of staying (switching)	State I = 0.61 (0.39) State II = 0.37 (0.63)	State I = 0.98 (0.02) State II = 0.28 (0.72)	State I = 0.75 (0.25) State II = 0.45 (0.55)
Constant expected durations	State I = 2.62 days State II = 1.58 days	State I = 63.84 days State II = 1.38 days	State I = 3.93 days State II = 1.81 days

Notes: as in Table 1, z-statistics are in parentheses.

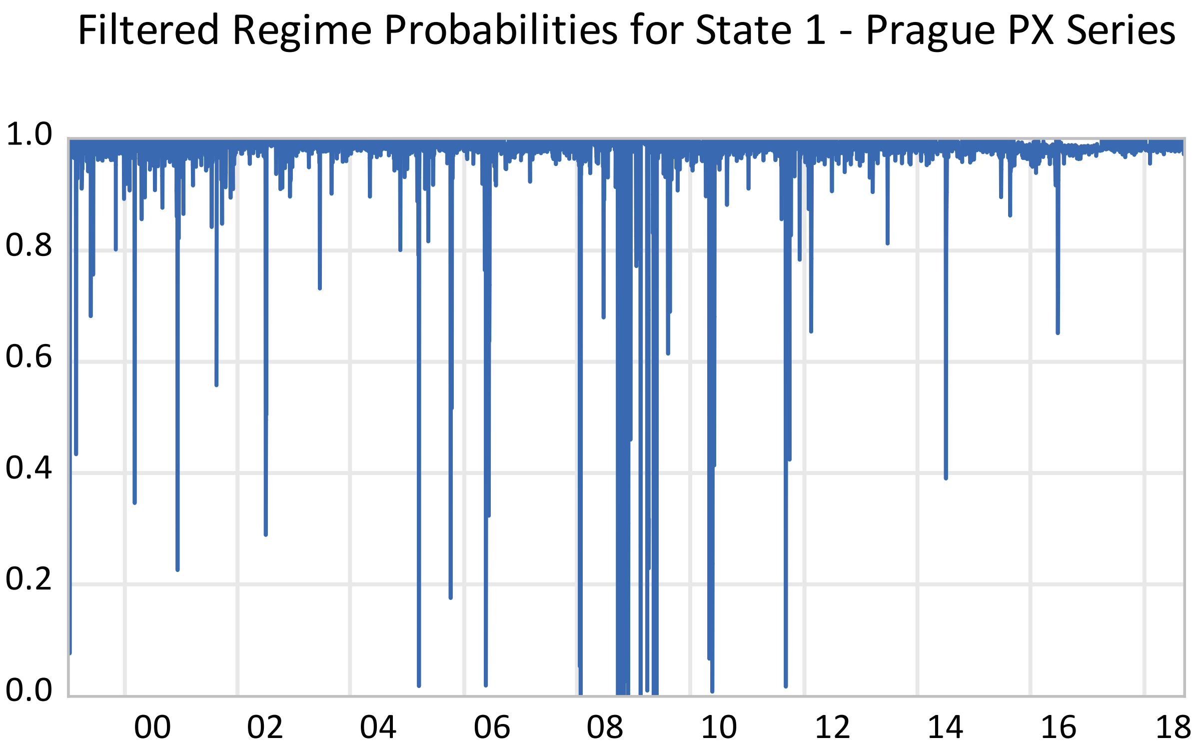
Source: as in Table 1.

Figure 1: Markov Switching Filtered Regime Probabilities: Probability of Staying in the Dominant State I Derived from Estimations of Eqs. 3-5.

1A:



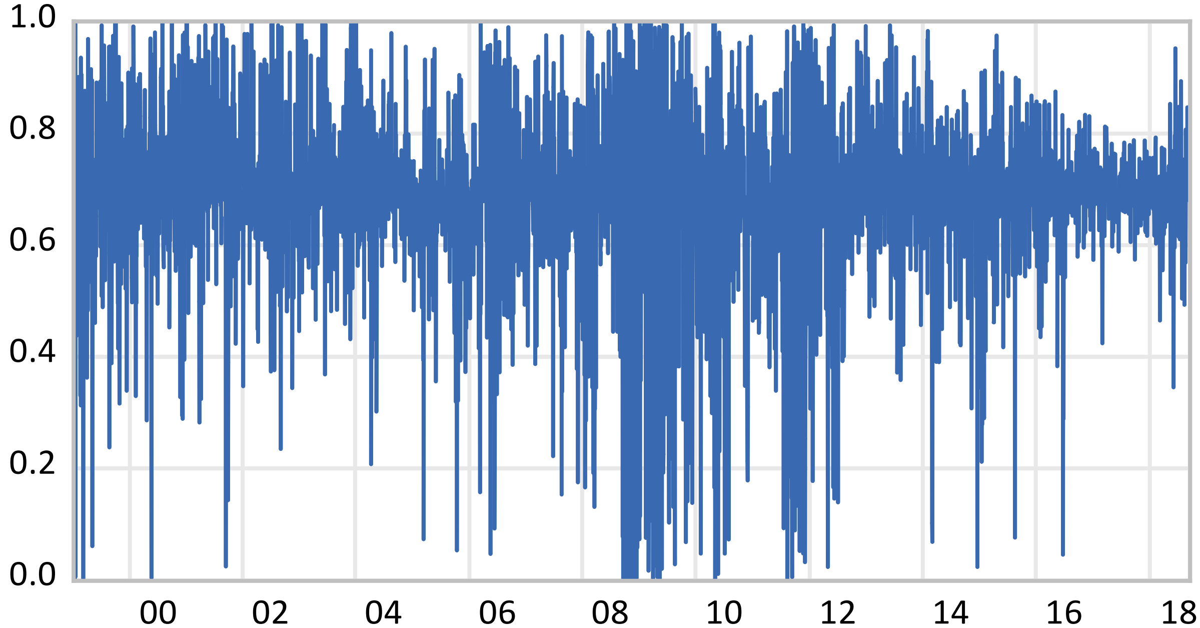
1B:



Filtered Regime Probabilities for State 1 - Prague PX Series
1.0
0.8
0.6
0.4
0.2
0.0
00
02
04
06
08
10
12
14
16
18

1C:

Filtered Regime Probabilities for State 1 - Budapest BUDEX Series



Source: as in Table 1.