5. Inflation Contagion Effects in the Baltic Countries: A Time-varying Coefficients VAR with Stochastic Volatility Analysis

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Abstract

Despite the recent progress in ensuring price stability, inflation persistence still is a key policy issue for the Central and Eastern European countries. Among various structural and functional determinants of potential inflation tensions, the increase in the degree of openness and the regional interdependences are playing an important role. The case of the Baltic countries can provide some interesting empirical evidence for the transmission of exogenous inflation shocks in the case of small open economies and can highlight the transmission channels which are associated with the existence of 'dual inflation'. We propose a two-fold approach to this topic: (i) we advance a simple model aiming to capture some mechanisms which might produce inflation contagion effects; (ii) we test for the existence of such effects between the Baltic countries for January 1996 and April 2015.

Keywords: Baltic countries; inflation; Time-Varying Coefficients VAR; stochastic volatility

JEL Classification: C22, E31

1. Introduction

The EU new member countries are characterized by deep structural, functional, institutional and cultural transformation. As a consequence, there are several sources of potential intrinsic instability both at the level of real and nominal sectors. As it concerns price stability,

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after high inflation episodes at the beginning of the 1990s, these countries had succeeded to drop inflation to single digit levels by the commitment of their central banks to stability-oriented monetary policies, the implementation of adequate monetary anchors and a set of macroeconomic policies aiming to promote the global stability.

Still "despite currently low inflation rates, however, inflation continues to be an issue of key policy concern" (Arratibel *et al.,* 2002, p. 5).

Some of the sources of persistence of potential inflation tensions may be related to the increase in the degree of openness of the transition economies and the broadening of real and financial integration with the developed countries from the European Union.

Arratibel *et al.* (2002) does not find evidence that in Central and Eastern Europe countries the productivity growth differences (and the Balassa-Samuelson effect have played a major role in driving inflation dynamics. Yet, inflation in non-tradable goods has tended to exceed that of tradable goods (leading to a 'dual inflation') and it was influenced by some distinctive determinants. Also, Darvas and Varga (2013, p. 10) conclude that in most of the Central and Eastern European countries inflation persistence has declined since 1995, with the main exceptions of the Czech Republic, Slovakia and Slovenia. The results of Nath and Tochkov (2011, p.19) suggest that "over the past two decades, there was, in general, a decisive shift of the distribution of CEE inflation rates towards the EA reference level, which was accompanied by intradistributional convergence within the CEE sample. However, these convergence tendencies were not uniform".

Among the transition economies, the Baltic countries can be considered a distinctive group with substantial anti-inflationary performance. Meanwhile:

"The economies of the Baltic countries underwent multiple structural changes within a short time period, complicating any determination of the effects of inflation factors. Continuous economic adjustment to the rules of the market economy together with the accession to the European Union strongly affected the traditional cyclical development of the economies". (Benkovskis *et al.*, 2009, p. 6).

Hence, the Baltic countries can provide some interesting empirical evidence for the transmission of exogenous inflation shocks in the case of small size open economies and can highlight the transmission channels which are associated with the existence of 'dual inflation'.

We propose a two-fold approach to this topic. First, we advance a simple model aiming to capture some mechanisms which might produce inflation contagion effects for the case of two small open economies which are involved in significant bilateral exchanges.

Second, we test for the existence of such effects among the Baltic countries. As Hansen and Vanags (2006) argue, a significant analytical issue is to reconcile the 'common Baltic acceleration' process with the fact that levels of inflation in the three Baltic countries remain relatively different (while they display some significant inter-linkages in terms of reciprocal trade). There are some transmission channels for the effects of 'imported inflation' arising from trade connections among these countries (as well as between each of them and European Union), but the induced effects are far from linear. Indeed, this is the main motivation of applying the *Time-Varying Parameter VAR with stochastic volatility model* in the context of these countries. Furthermore, these economies had been subjected to fast structural changes and, as a consequence, to various endogenous and exogenous associated shocks. For them, the catching-up with other European countries is still an on-going process, to which the following are added: the harmonisation of the tax systems, the importance of global energy prices or increases in state-regulated prices. Nevertheless, one

can argue that the introduction of euro in the Baltic countries did not necessarily contributed to major changes in inflation patterns since these countries have already fixed exchange rates against the euro for several years. Rather, the issues related to the 'real convergence' with old Member States remain an important factor of potential inflation pressure.

To our knowledge, there are only a few papers dealing with inflation processes in the Baltic countries as an integrated regional system of economies; nevertheless, these works consider to a lesser extent the time variation effects in the potential transmission channels for inflation among the respective economies. Therefore, the exploration of such effects can provide more insights for the case of economies that are better described as 'small, open and highly integrated'.

The following section develops the proposed model. The next sections include the description of the considered Time-Varying Coefficients VAR with stochastic volatility framework and the results and comments, respectively. The last section concludes.

2. Theoretical Framework

Our argument can be formally captured by a simple model of open economy, "A", formed by N^A agents with heterogeneous preferences. This economy is supposed to display a certain degree of economic convergence and to engage in intensive real and financial exchanges with another small open economy, "B". The global utility function for economy "A", U_t^A, can be described as:

$$U_t^A : \alpha_{1,t}^A \left(\pi_t^A \right) - \alpha_{2,t}^A \left(\pi_t^A \right)^2 - \beta_t^A \left(y_t^A - y_n^A \right)^2 + \varphi x_t^A \qquad (1)$$

Here π_t^A is the inflation rate in country "A" during the current period t, y_t^A is the economic output while y_n^A is its 'natural' level. x_t^A is a matrix of other economic and social factors that can affect the social utility.

The non-linear inflation term aims to reflect the potential existence of a threshold effect in the relationship between inflation and economic growth. For instance, Lee and Wong (2005, p. 67) argue that: "inflationary threshold indeed exists in the relationship between financial development and economic growth". Sarel (1996, p. 199) finds evidence of a significant structural break in the function that relates economic growth to inflation. Pollin and Zhu (2005, p.11) document the existence of a wide range of inflation rates that are very likely to be associated positively with economic growth. However, in the long run high and persistent inflation is detrimental to stable growth. Hence, the society can tolerate only a moderate inflation up to a specific threshold.

We also include the output gap, $\left(y_t^A - y_n^A \right)$, as a determinant of social utility. This follows the argument of Svensson (2000, p. 5).

One may notice that this model implicitly assumes that inflation is not a 'purely monetary' process. Instead, joint effects of monetary and structural determinants are considered. More exactly, we argue that for the small economies there are several endogenous and exogenous sources of shocks that can push prices 'far from equilibrium'.

Further, we consider the following functional equation of inflation:

$$\pi_t^A = \sum_{i=t-l}^{t-1} \xi_i^A \pi_i^A + \gamma_1^A u_t^A - \gamma_2^A \left(u_t^A\right)^2 + \vartheta_t^A m_t +$$

$$+ \sum_{i=t-l+1}^{t-1} v_i^A \left(\pi_{i-1/i}^{*A} - \pi_i^A\right) + \theta_t^A \pi_t^B + \mu_t =$$

$$= \theta_t^A \pi_t^B + S_t, \quad S_t = \left[\begin{array}{c} \sum_{i=t-l}^{t-1} \xi_i^A \pi_i^A + \gamma_1^A u_t^A - \gamma_2^A \left(u_t^A\right)^2 + \vartheta_t^A m_t + \\ + \sum_{i=t-l+1}^{t-1} v_i^A \left(\pi_{i-1/i}^{*A} - \pi_i^A\right) \end{array} \right] \quad (2)$$

This specification includes: (a) an autoregressive component of inflation counting for hysteresis effects in the inflation dynamics, $\sum_{i=t-l}^{t-1} \xi_i^A \pi_i^A$; (b) a non-linear specification of the Phillips curve linking inflation and unemployment, u_t^A (see for arguments Musso *et al.*, 2009); (c) the monetary component of inflation, m_t ; (d) the inflation expectations errors from previous periods, which describe the existence of possible changes in agents' risk profiles as they learn about these errors and adjust their forecasting mechanisms, $\pi_{i-1/i}^{*A} - \pi_i^A$ (with $\pi_{i-1/i}^{*A}$ being the expected inflation at the end of period *i-1* for period *i* ; (e) a mixture of endogenous and exogenous shocks, μ_t . The main variable of interest here is the inflation rate in country "B", π_t^B . If there are free movements of goods and capital between country "A" and country "B", then the consumption of the country "A" residents will include tradable and non-tradable domestic goods as well as tradable goods from country "B". We suppose that the residents of country "A" are able to observe the prices in country "B" and to shift the structure of their consumption according to the current evolution of such prices. Hence, there will be an 'imported inflation' component affecting the local prices.

In greater detail, this specification entails the existence of some hysteresis mechanisms as well as 'downside rigidities' in price dynamics. Also, it considers some market friction factors, imperfect information (costly, asymmetrically distributed, incomplete and only partially relevant) and 'bounded rationality' for the decisions of the economic agents.

By imposing $\dfrac{\partial U_t^A}{\partial \pi_t^A} = 0$, and by taking into account relations (1) and (2) we obtain the 'optimal' level of inflation in country "A", $\pi_t^{opt,A}$ and, equivalent, the level of inflation in country "B" that maximizes the utility of agents from "A", $\pi_t^{opt,B/A}$:

$$\pi_t^{opt,A} = \frac{\alpha_{1,t}^A}{2\alpha_{2,t}^A} \Leftrightarrow \pi_t^{opt,B/A} = \frac{1}{\theta_t^A} \left\{ \frac{\alpha_{1,t}^A}{2\alpha_{2,t}^A} - S_t \right\} \quad (3)$$

One should notice that relation (3) does not actually determine the optimal inflation levels in country "B". Rather, $\pi_t^{opt,B/A}$ is that inflation which appears to be optimal from the point of view of country "A" agents' utility maximization. Of course, from the standpoint of agents from country "B", there might be another optimal level of internal inflation. In other words, from the perspective of economy "A" (as this is the reference), the *de facto* inflation from "B"

remains an exogenous variable. Nevertheless, there is a level of inflation in "B" that is perceived by the subjects from "A" as 'optimal' (if they account for the impact exercised by the linkages between "A" and "B" on internal inflation dynamics - *i.e.* for the 'imported' component of this).

If *de facto* inflation in country "A" deviates from this 'optimal' level such as $\pi_t^A = \pi_t^{opt,A} + \Theta_t$, relation (3) allows us to write down this observed inflation as:

$$\pi_t^A = \frac{\alpha_{1,t}^A}{2\alpha_{2,t}^A} + \Theta_t \Leftrightarrow \frac{1}{\theta_t^A}\left\{\frac{\alpha_{1,t}^A}{2\alpha_{2,t}^A} - S_t\right\} + \Theta_t \qquad (4)$$

According to relation (4), the path of inflation in country "A" will be influenced by: (1) the relative importance of 'imported inflation' for the local markets prices; (2) the specific parameters for the inclusion of inflation in the country "A" residents' utility function; (3) a complex of determinants located on labour market and in the nominal sector (as these are by captured by unemployment rates and monetary shocks) ;(4) the forecast errors from previous periods (and the involved prediction mechanisms which is specific for the residents of country "A"); (5) various nominal and real shocks.

Despite its simplicity, the model is able to capture some important features of the considered setting. First, in a steady-state case, internal inflation appears to be driven mainly by its 'imported' component $\left(\theta_t^A \pi_t^B\right)$ since $E\left[S_t\right] = 0;\ E\left[\mu\right] = 0$.

Second, the dissimilarities between the inflation patterns of two small open economies are a consequence of the differences between their real and labour markets as well as between the determinants of money supply (the importance of the banking sector in the financial intermediation processes, the design of the monetary policy or the overall financial stability). For instance, in the Baltic countries case, Hansen and Vanags (2006, p. 22) show that "overheated labour, goods and property markets all of which interact to generate accelerating inflation".

Third, the importance of social inflation tolerance largely influences its *de facto* dynamics. Exogenous changes in this variable may lead to a 'decoupling' of the inflation rates among the countries.

A testable prediction of the frame synthesised by relation (4) is that for two small open economies which are engaged in significant bilateral trade *their inflation paths will be associated in a possible non-linear way. Since the involved parameters are time-varying, this relation may be subject to regime-shifts.*

In the next sections, we test this implication for the case of the Baltic countries by involving a Time-Varying Parameter VAR (TVP-VAR) with stochastic volatility frame.

3. Time-Varying Parameter VAR with Stochastic Volatility Model

A large body of literature is dealing with time variation in multivariate linear structures. In this literature, a particular interest is related to approaches involving time varying variances in the context of VARs with drifting coefficients (Cogley and Sargent, 2005; Primiceri, 2005; Nakajima, 2011; Meng *et al.*, 2018). The key argument consists in the fact that a specific feature of Time-Varying Coefficients VAR is that impulse response functions and the second

moments (variances and co-variances) are time-varying. As Darvas and Varga (2013, p.2) argue:

"Time-varying coefficient analysis of inflation persistence in CEE countries seems inevitable. These countries went through substantial structural changes when transformed their economies and institutions from a socialist to a market one. The transformation process was a gradual one and the economies of these countries probably still changing at a faster pace than mature economies. These arguments imply that it is rather difficult to set a date from which constancy of the parameters could be assumed on safe grounds".

Hereafter, the effects and the contributions of a shock may change over time. However, "In many cases, a data-generating process of economic variables seems to have drifting coefficients and shocks of stochastic volatility. If that is the case, then application of a model with time-varying coefficients but constant volatility raises the question of whether the estimated time-varying coefficients are likely to be biased because a possible variation of the volatility in disturbances is ignored" (Nakajima, 2011, p.108). Hence, in order to avoid misspecifications of the model, stochastic volatility should be assumed. A key issue at this point is that in any inflation model there might be an important uncertainty in the relationship between this key macroeconomic variable and its determinants. For instance, Abdelsalam (2017) discusses the issues that might arise in any Phillips Curve model. In this context, the time-varying parameter VAR might help in overcoming the difficulties related to such uncertainty.

Following this literature, the time-varying parameter VAR model is specified as:

$$y_t = \sum_{i=1}^{s} B_{i,t} \, y_{t-1} + \varepsilon_t, \ \ \varepsilon_t \sim N(0, \Omega_t) \qquad (5)$$

Here $t = s+1, ..., n$, $y_t = \begin{pmatrix} \pi_t^{Estonia} \\ \pi_t^{Latvia} \\ \pi_t^{Lithuania} \end{pmatrix}$ is the inflation rates $(3x1)$ vector, $B_{1,t}, ..., B_{s,t}$ are

$(3x3)$ matrices of time-varying coefficients, and Ω_t is a $(3x3)$ time-varying covariance matrix. A recursive identification is assumed by the decomposition $\Omega_t = A_t^{-1} \sum_t \sum_t A_t^{'-1}$ where A_t is supposed to be a lower-triangular matrix with the diagonal elements equal to one, and $\sum_t = diag(\sigma_{1,t}, ..., \sigma_{k,t})$. Let β_t be the stacked row vector of $B_{1,t}, ..., B_{s,t}$. Also let $a_t = (a_{1,t}, ..., a_{q,t})'$ be the stacked row vector of the free lower-triangular elements of A_t and, respectively, $h_t = (h_{1,t}, h_{2,t}, h_{3,t})$: (with $h_{i,t} = \log(\sigma_{i,t}^2)$). Then, the time-varying parameters are supposed to follow a random walk process

$$\begin{cases} \beta_{t+1} = \beta_t + u_{\beta,t} \\ a_{t+1} = a_t + u_{a,t} \\ h_{t+1} = h_t + u_{h,t} \\ \begin{pmatrix} \varepsilon_t \\ u_{\beta,t} \\ u_{a,t} \\ u_{h,t} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right) \end{cases} \qquad (6)$$

In relation (6), $\beta_{s+1} \sim N\left(\mu_{\beta_0}, \Sigma_{\beta_0}\right), a_{s+1} \sim N\left(\left(\mu_a, \Sigma_{a_0}\right)\right.$ and $\sum_a, \sum_h, \sum_\beta$ are assumed in our specification to be diagonal.

Such specifications of the innovations and parameters are also used in the literature in the context of different financial and macroeconomic variables analysis (see, for example, Meng *et al.,* 2018).

Nevertheless, several aspects can be considered in respect to this specification. First, the assumption that A_t is a lower-triangular matrix aims to allow for recursive identification for the VAR system. Such assumption can be viewed as being quite a general one to describe the implied economic structures. Still, greater details of this structure may require a more complex approach to the identification problem (Christiano *et al.*, 1999). Second, the corresponding parameters are supposed to follow a non-stationary (*i.e.,* random walk) in order to capture the potential regime-shift cases at the data level (via both temporary and permanent shifts in the coefficients when a finite number of switching regimes is involved). However, allowing time variation in all parameters in the VAR model may cause an over-identification problem. Thus, an appropriate choice of priors for the covariance matrix of the disturbance in the random walk process is of paramount importance (see Primiceri, 2005; Koop and Korobilis; 2010, Nakajima; 2011 for a discussion). We suppose that the priors $\left(\sum_\beta\right)_i^{-2}, \left(\sum_a\right)_i^{-2}, \left(\sum_h\right)_i^{-2}$ (the *i-th* diagonal element of the matrices) follow a *Gamma* distribution. Finally, an important task is to identify the appropriate number of lags to be involved. We perform such task by involving the Bayesian Info Criterion (BIC) for the basic VAR model with all observations. So, a single lag is retained. Hence, the involved adjustment processes are carried out in the short run implying a fast transmission of the prices information.

The implementation is carried out via a Markov Chain Monte Carlo (MCMC) algorithm in the context of a Bayesian inference (which seeks to maximize the un-normalized joint posterior distribution by collecting samples of the target distributions, which are marginal posterior distributions, later to be used for inference). *Gibbs sampling* approach is involved even if this is less generalizable than others like Random-Walk Metropolis (RWM) approach since, for instance, this last algorithm is not immune to potential correlation issues.

One should notice that MCMC is a smoothing algorithm and, hence, it provides smoothed estimates, (*i.e.,* estimates of the parameters of interest based on the entire available set of data). As Primiceri (2005) argues, the suitability of smoothed estimates, as opposed to filtered ones, cannot be established on an a priori basis. Nonetheless, since the objective here consists in an investigation of the true evolution of the unobservable states over time, the choice of such smoothed estimates can be viewed as suitable. This framework provides

a great amount of flexibility. Still, there is a price of such flexibility: the dificulty to isolate the involved sources of uncertainty (in the sense that the different types of shocks cannot be easily separable and orthogonalized for each equation).

However, we argue that this can provide a more realistic picture since in a time-varying specification one might expect an adaptive learning process to the endogenous and exogenous shocks frapping the implied economies and translated at the levels of the prices formed on their internal markets. Insights about such process can be provided by the systematic and non-systematic components of the model, respectively.

4. Baltic Inflation Data

Our data sample represents the inflation rates based on Indices of Consumer Prices and covers a time span between January 1996 and April 2015 (monthly data; average of observations through period; 2005 = 100). Data are provided by European Central Bank Statistical Data Warehouse (*http://sdw.ecb.europa.eu/*).

The data are neither seasonally nor working-day adjusted. Hence, as a preliminary step, we seasonally adjust the data by using the TRAMO ("Time Series Regression with ARIMA Noise, Missing Observations and Outliers") and SEATS ("Signal Extraction in ARIMA Time Series") methodology developed by Gómez and Maravall (1996, 1998). Also, in order to ensure the comparability, the inflation seasonally adjusted data are rescaled (in order to have a zero mean and a standard deviation of one) by transforming them into their *z-scores*:

$$\pi_t^z = \frac{\pi_t - \bar{\pi}}{\sigma_\pi}.$$

Table 1 shows the main statistics. The values of the Jarque-Bera tests clearly reject their normality. Also, the unit roots (with single structural break) tests of Zivot and Andrews (1992) rejects the null of unit root with a structural break in both the intercept and trend.

Table 1

Main Statistics of the Inflation Data

	Estonia	Letonia	Lithuania
Mean	0.000	0.000	0.000
Median	-0.202	-0.278	-0.511
Maximum	1.590	1.403	1.578
Minimum	-1.788	-1.497	-1.827
Std. Dev.	1.000	1.000	1.000
Skewness	0.145	0.189	0.357
Kurtosis	1.733	1.364	1.653
Jarque-Bera	16.336	27.254	22.489
Probability	0.000	0.000	0.000
Zivot-Andrews Unit Root Test (Null Hypothesis: Inflation has a unit root with a structural break in both the intercept and trend)	-3.489 (p=0.000)	-3.518 (p=0.000)	-4.271 (p=0.000)

However, the existence of some potential structural breaks cannot be excluded. For instance, the test of Bai and Perron (2003) for simultaneous estimation of multiple breakpoints (which is implemented following the ideas described in Zeileis *et al.* (2003) in

the R language package 'strucchange' developed by Zeileis *et al.*, 2015) suggests that there are five structural change points in inflation for Estonia and Latvia and four such points for Lithuania, respectively.

<div align="right">**Table 2**</div>

Bai and Perron (2003) Multiple Breakpoints Test on Transformed Data Levels

Country	Breakpoint at date:
Estonia	October 1998; August 2001; December 2004; October 2007; March 2011
Latvia	October 1998; December 2001; December 2004; October 2007; February 2011
Lithuania	September 1998; February 2005; December 2007; February 2011

This may be a supplementary argument for involving TVP-VAR frame since it is able to deal with the likelihood of structural shifts in the model parameters (Cogley and Sargent, 2005; Nakajima, 2011; Barnett *et al.*, 2012).

5. Results and Comments

We estimate the model by drawing N=10000 samples, after the initial 1,000 samples in the burn-in period are discarded. We set the following tight prior specifications:

$$\left(\sum\nolimits_{\beta}\right)_i^{-2},\left(\sum\nolimits_a\right)_i^{-2},\left(\sum\nolimits_h\right)_i^{-2} \sim \text{Gamma}(0.5;10^{-6})$$

Table 3 includes the estimates for posterior means, standard deviations, the 95 percent credible intervals, the convergence diagnostics proposed by Geweke (1992), and the inefficiency factors (computed using the MCMC sample). The null hypothesis of the convergence to the posterior distribution is not rejected for the parameters at the 5 percent significance level based on the convergence diagnostics statistics. Also, the inefficiency factors are relatively low (with the potential exception of h_1, h_2 parameters; but even for these, the inefficiency factor is about 100, which implies that we obtain N/100=100 uncorrelated samples that can be considered sufficient for the posterior inference).The inverse of the inefficiency factor can be seen as a measure of 'relative efficiency' (Geweke,1992): for an inefficiency factor equal to *m*, one need to draw the MCMC sample *m* times as many as the uncorrelated sample.

<div align="right">**Table 3**</div>

Estimation Results of the TVP-VAR Model Parameters

	Mean	Standard deviation	95% interval	Convergence diagnostics	Inefficiency
β_1	0.002	0.000	[0.0019;0.003]	0.249	17.970
β_2	0.002	0.000	[0.0019;0.0029]	0.191	9.770
a_1	0.006	0.001	[0.0034;0.0089]	0.279	47.570
a_2	0.006	0.002	[0.0033;0.0118]	0.509	77.330
h_1	0.007	0.002	[0.0036;0.0126]	0.000	106.370
h_2	0.108	0.037	[0.0514;0.1958]	0.880	96.350

As Figure 1 shows, after discarding the initial 1,000 samples, the sample paths look relatively stable and the sample autocorrelations tends to drop. Hence, it may be considered that the sampling method produces the samples with enough low autocorrelation.

Figure 1
**Estimation Results of Selected Parameters in the TVP-VAR Model**
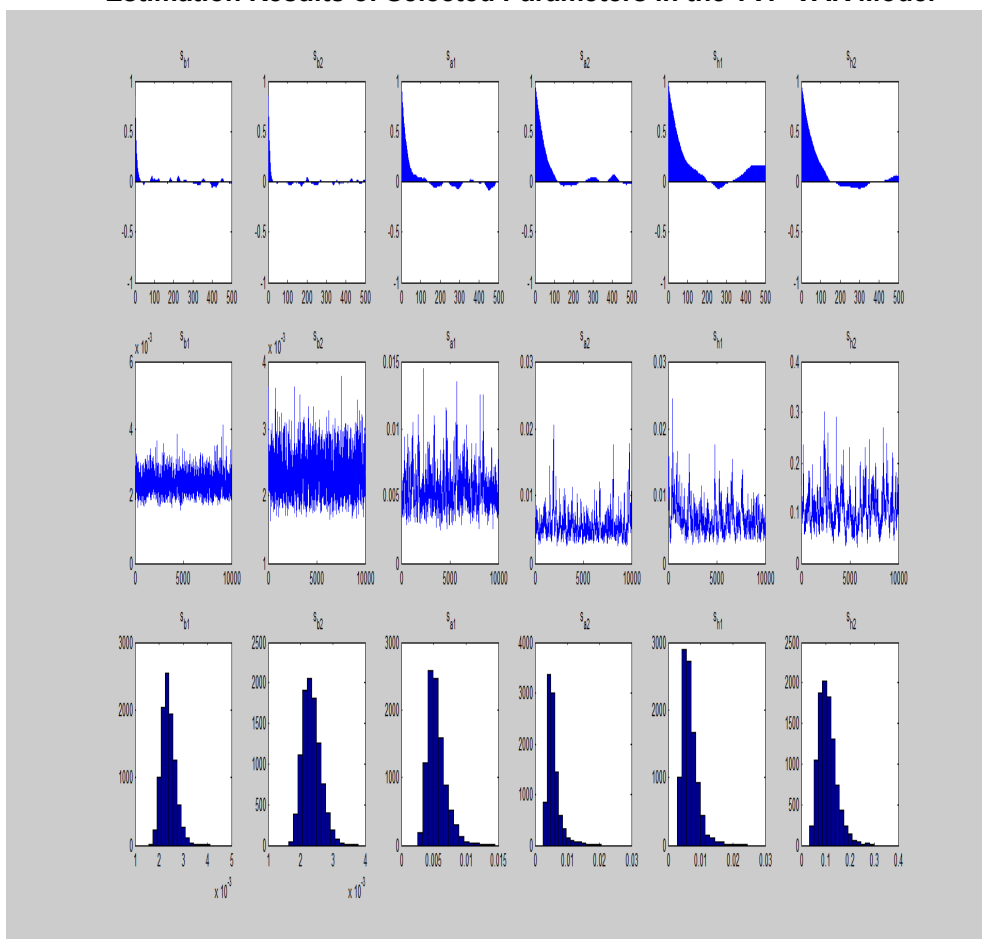
Notes: Sample autocorrelations (top), sample paths (middle), and posterior densities (bottom).

Figure 2 displays the posterior estimates of the stochastic volatility. Stochastic volatility of inflation in Latvia unveils a spike around mid-2008 during the financial and real turmoil. After this period, it slowly declines with some fluctuations around the downward trend. For Estonia and Lithuania, the estimates are exhibiting a strong upward trend. Still, there is a short period in the last quarter of 2004/first quarter of 2005 when inflation volatility is decreasing. Overall, it appears that the estimates are reflecting similar patterns for inflation volatility in Estonia and Lithuania while in Latvia this follows a quite distinctive path.

Figure 2

Posterior Estimates of $\sigma^2{}_{h_{i,t}} = \exp\left(h_{i,t}\right)$ **(Posterior Means and One-standard Deviation Bands)**
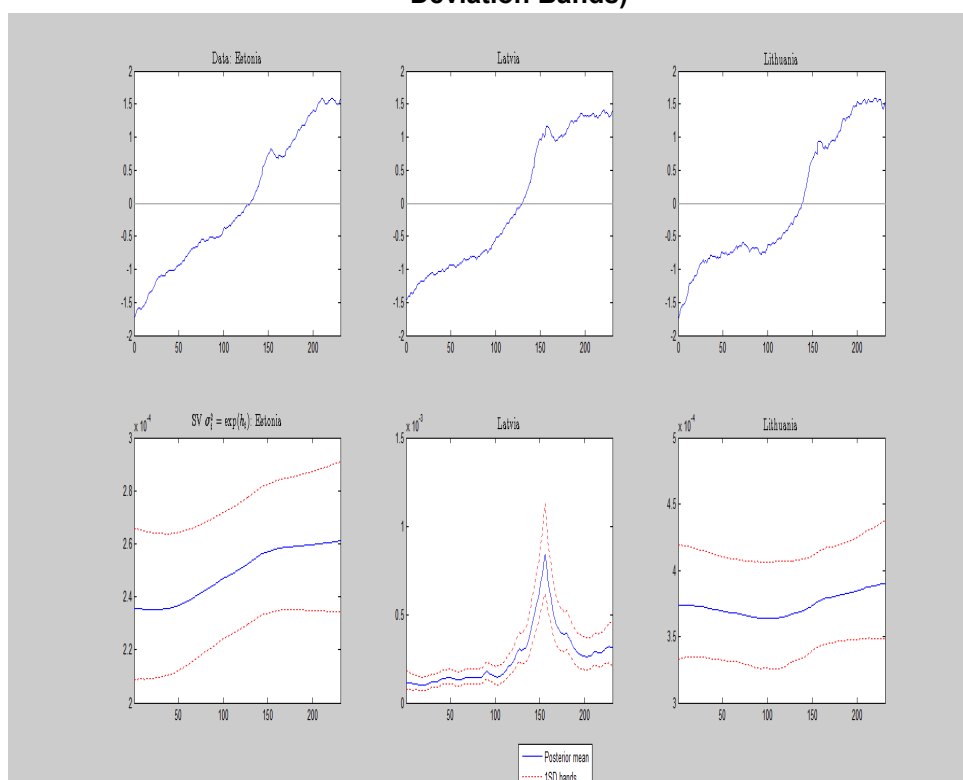
The simultaneous relationships between inflation rates are specified by the lower-triangular matrix A_t. The posterior estimates of the free elements in A_t, which are denoted by $a_{i,t}$ are plotted in Figure 3, which reflects the size of the simultaneous effect of other variables to one unit of the structural shock based on the recursive identification. These reciprocal relations between inflation shocks for Estonia and Latvia, Estonia and Lithuania, and Latvia and Lithuania, respectively, are remarkably stable over time with only some small adjustments post-2010.

Figure 3

**Simultaneous Relations for** $\pi_t^{Estonia}, \pi_t^{Latvia}, \pi_t^{Lithuania}$
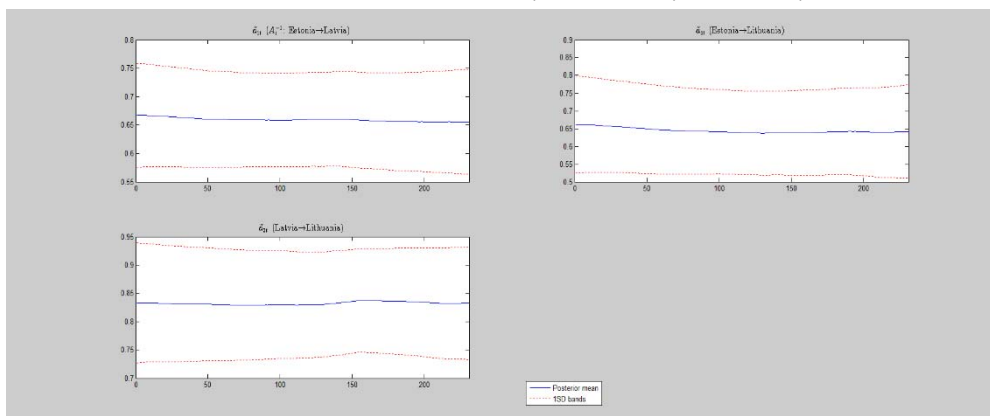
Of course, this is not a direct test for the stability of the driven mechanism *per se*. Nevertheless, it indicates that the exogenous inflation shocks are absorbed by internal markets in a comparable manner over the analysis time span.

As for any VAR model, the central part of the TVP-VAR is represented by the impulse-response analysis. The responses are computed at all points in time by using the estimated time-varying parameters.We follow the procedure from Nakajima (2011) which compute the impulse responses by fixing an initial shock size equal to the time-series average of stochastic volatility over the sample period, and using the simultaneous relations at each point in time while the estimated time-varying coefficients are used from the current date to future periods in order to work out the recursive innovation of the variable. Figure 4 shows the responses on the one-month, two-quarters, and one-year horizons over the considered time span.

Figure 4

Posterior Means of Time-varying Impulse Response

$$\pi_t^{Estonia}, \pi_t^{Latvia}, \pi_t^{Lithuania}$$
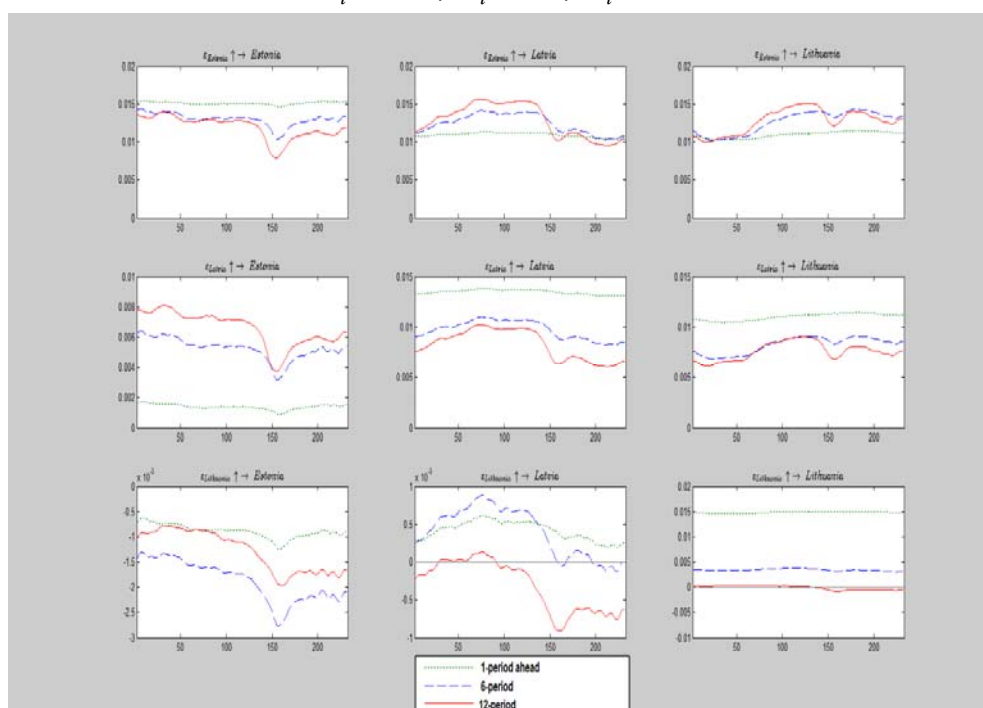
Note: Time-varying responses for one-month (dotted line), two-quarters (dashed line),and one-year (solid line) horizons.

The response of inflation in Latvia to a shock to Estonia's inflation is shown to systematically increase until around mid-2008 for the two-quarters and one-year horizons. After this point, there is a substantial decline, while it still remains a positive one. For one-month horizon, the responses are displaying a high degree of stability around the same level for the entire period of analysis.

The mentioned post-2008 decline in the response to a shock to Estonia's inflation appears to be less obvious in the case of Lithuania. For this case, the largest time variation in the response corresponds to a one-year horizon.

Correlatively, the response of inflation in Estonia to a shock to Latvia's inflation slowly declines until reaches a minimal level in mid-2008. After this, it slowly starts to increase. A relatively similar pattern (with the exception of post-2010 behaviour) is reflected by the responses of inflation dynamics in Lithuania.

Interestingly, the most distinctive effect is produced, for the other two countries inflation, by a shock to Lithuania's inflation.

For such shocks, the responses are reaching negative values and are declining over the analysis period for all considered time horizons. A possible explanation is that the residents from Estonia and Latvia are able to substitute in their consumption more frequently the

tradable goods from Lithuania as their internal prices tend to increase. In absolute terms, the amplitude of the associated effects is significantly higher as compared to the previous cases.

Overall, these results point towards the fact that the evolutionary paths of inflation in the Baltic countries are inter-linked up to a certain extent (with some differences in the induced bilateral effects, but without overreactions or pathological responses).

Several explanations can be found in the literature in support to our findings. First, the Baltic countries are a group of open small economies with strong economic reciprocal connections, as well as with a significant sensitivity to imported energy prices (see for a similar argument Benkovskis *et al.*, 2009). Second, as the patterns of time-varying impulses suggest, the peaks in bilateral 'imported inflation' are placed around some structural breaks identified by the Bai and Perron (2003) tests at the level of data.

Thus, the hypothesis of the existence of common driving events, which are explicitly neglected by the model (such as Russian financial crisis in 1998-1999, the European Union accession in 2004, the 2007-2010 crisis and the post-2010 financial and real turmoil, or the changes in international prices of oil and energy), along with the internal cyclical demand factor impacting inflation processes in these countries, cannot be dismissed.

Third, as the involved explanatory framework points out, the external expected inflation can play an important role in the evolution of the domestic one: the agents from each individual Baltic country can observe the inflation dynamics in the other two and can correspondingly adjust their internal consumption, investment and savings decisions.

Fourth, "similar" does not mean "identical": there are some specific factors at the level of each Baltic country that can contribute to the existence of some distinctive features in the inflation patterns. Just to provide an example, for all three countries the dependence on imported natural gas is substantial, but the degree of such dependence is somewhat lower in Estonia than in Latvia and Lithuania (Benkovskis *et al.*, 2009).

6. Conclusions

This paper seeks to provide some conceptual explanations as well as to deliver some empirical evidence for the potential existence of some contagion effects in the inflation patterns of the Baltic countries. We employ a Time-Varying Parameter VAR with stochastic volatility framework in order to consider potential structural changes in the data.

The estimates of the stochastic volatility show a relatively distinctive behaviour in the case of Latvia. Also, our findings suggest that during January 1996 and April 2015 there were several regime-shift episodes leading to changes in the impact caused by individual inflation dynamics. Still, there is no support for the occurrence of some significant breaks in the inter-linkages between Baltic inflation rates (even if there appears to be a certain post-2010 decline in the associated impacts). Finally, it appears that the regional influence of Lithuania's inflation exhibit some idiosyncratic features.

Of course, these findings should be better clarified by a more detailed analysis both at conceptual as well as empirical level.

Still, even in this stage, these show the fact that the implementation of national policies oriented toward prices (and, broadly, overall financial) stability should account for the contagion effects which are of a noteworthy importance for these open integrated economies.

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