Time Varying VAR Analysis for Disaggregated Exchange Rate Pass-through in Tunisia

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Abstract

Our paper follows the "Time Varying Parameter VAR with Stochastic Volatility" (TVP VAR) approach developed by Primiceri (2005): Bayesian estimation with time varying coefficients and stochastic volatility. Our paper contributes to the literature by examining if the impact of monetary and exchange rate shocks have varied over time in Tunisia through a disaggregated analysis of exchange rate pass-through by introducing time variability in two ways; firstly, by assuming That all the coefficients of the VAR model are variant in time, and secondly, in the temporal variance-covariance matrix, that is the error term's volatility of the VAR model. The multivariate stochastic volatility aims at capturing the heteroskedasticity of shocks and non linearities in the simultaneous relationships between the variables of the model. In fact, it allows us to capture abrupt and progressive changes in state variables. Given the structural and institutional changes in the Tunisian economy over the last few decades, it is important to emphasize the possibility of such a temporal variation in the empirical methodology. To the best of our knowledge, this work is among the first to apply the TVP-VAR approach with stochastic volatility to the shocks of monetary and exchange rate policies in Tunisia.

Overall, the findings confirm that the modeling approch; i.e the TVP-VAR, is the best tool to analyze the impact of these shocks in Tunisia. The results of the study can help the short- and long-term decision-makers in Tunisia to adopt appropriate strategies for conducting monetary policy as well as containing inflation.

Keywords: TVP VAR approach – Bayesian estimation – Disaggregate Analysis – Exchange rate Pass-through – Monetary policy – Tunisia

JEL Classification: *C11, C32, E31, E42, E52, E61, F31, F41, O55*

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1. Theoretical background

Since the 2000s the issue of exchange rate pass-through in international economy has received a great attention, not only in central banks policies but also in the academic literature. Indeed, for a small open economy in transition such as Tunisia, research attempts have been based on traditional econometric models and lead to inconclusive results. In this paper, we try to enrich the literature on: "Measuring pass-through in Tunisia: it is a necessary step to conduct a monetary policy?", a literature that has so far provided a limited answers for the case of Tunisia especially on the empirical level. Therefore, changes in economic policies in some transition countries are associated with the development of econometric methods in the literature.

In this context, the pronieer approach by Primiceri (2005) allows the variance-covariance matrix of shocks as well as the coefficients to be variable over time in addition to the Bayesian estimate by the famous "Time Varying Parameter VAR with Stochastic Volatility" approach (hereafter, theTVP VAR). Indeed, in the framework of analysis of monetary policy, Primiceri (2005) is the first study that used the VAR approach with time-varying parameters and stochastic volatility in an autoregressive vector model (TVP VAR) with Bayesian estimation.

In the same line of thought, Arratibel and Michaelis (2014) follow Primiceri (2005) using the TVP VAR to see whether the price and output response to interest rate changes and exchange rate shocks has changed (Over the period 1996 to 2012) in the Polish economy. The empirical findings show that: production appears more sensitive to an interest rate shock at the beginning of the study period. The exchange rate shock also has a time-varying effect on output. The impact of an exchange rate shock on prices appears to decrease slightly over time.

Nakajima (2011) aims to provide a comprehensive overview of the estimation methodology for the time-varying parameters approach with stochastic volatility for the VAR (TVP-VAR) model, both in methodology and empirical applications. The TVP-VAR model, combined with stochastic volatility, allows us to grasp the possible changes in the underlying structure of the economy in a flexible and robust manner. In this regard, as shown in paper simulation exercises, the incorporation of stochastic volatility into the TVP estimate significantly improves the estimation performance. The Monte Carlo Markov chain (MCMC) method is used to estimate TVP-VAR models with stochastic volatility. As an example of empirical application, the TVP-VAR model with stochastic volatility is estimated using Japanese data with significant structural changes in a dynamic relationship between macroeconomic variables.

The study by Jooste and Jhaveri (2014) on South Africa also used TVP VAR (1981q4-2012q4) by decomposing the pass-through into a number of time-varying pulses. This has the advantage of providing a deeper understanding of pass-through over time and across various schemes. Their results confirm that the pass-through has decreased over time, but is subject to a low and stable inflation environment. Also the volatility of exchange rates leads to a higher degree of pass-through.

Shioji (2015) argued that the exchange rate could be a powerful channel for transmitting the effects of "unconventional" monetary policies in Japan. It is shown that the pass-through of exchange rates on domestic prices, formerly considered as quasi-extinction, has become strong in recent years. This is especially true for items that households frequently purchase. Evidence based on a TVP-VAR indicating that a depreciation of 25% of the yen would produce a 2% increase in the prices of these items. This could have an added benefit of raising public expectations about future inflation, as their beliefs are often said to be influenced by their daily observations of the prices of those items they frequently buy.

2. Empirical Methodology: The TVP-VAR model

Primiceri (2005) and Nakajima (2011) provide a comprehensive overview of the empirical methodology for the time-varying parameter VAR approach with a stochastic volatility (TVP VAR).

The structural VAR representation of a multivariate time series model with coefficients and errors of time-varying structural innovations is defined as follows:

$$B_t Y_t = d_t + C_{1,t} Y_{t-1} + \ldots + C_{p,t} Y_{t-p} + \sum_t \upsilon_t \qquad \textbf{(1)}$$

With :

Y_t : is a vector of 4 endogenous variables (exchange rate, import price, producer price, consumer price)

d_t : is a constant time varying vector

$C_{i,t}$: is a 4*4 matrix of the time varying coefficients of the delayed endogenous variables

B_t : is the matrix of contemporary coefficients varying in time. B_t is lower triangular with a value of 1 on the elements of the diagonal, whereas the matrix of the standard error Σ_t, which is varying in time, is diagonal

V_t : is a vector of structural innovations $\sum t$, which are assumed to follow a multivariate standard normal distribution

$$B_t = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ b_{21},t & 1 & \ddots & \vdots \\ b_{31},t & b_{32},t & 1 & 0 \\ b_{41},t & b_{42},t & b_{43},t & 1 \end{pmatrix} \text{ and } \sum t = \begin{pmatrix} \sigma_1,t & 0 & \cdots & 0 \\ 0 & \sigma_2,t & \ddots & \vdots \\ \vdots & \ddots & \sigma_3,t & 0 \\ 0 & \cdots & 0 & \sigma_4,t \end{pmatrix} \quad (2)$$

The representation of the reduced form of the structural model (1) is defined as follows:

$$Yt = C_t + A_{1,t} Y_{t-1} + \ldots + A_{p,t} Y_{t-p} + \varepsilon_t \quad (3)$$

With :

$A_t = B^{-1}{}_t C_t$ is a matrix of the time varying delayed coefficients, $c_t = B^{-1}{}_t d_t$ the vector of the time varying of the constant and $\mathcal{E}_t = B^{-1}{}_t \Sigma_t v_t$ is the vector of the reduced form of the residuals. Depending on the structure of the matrix of the contemporary coefficients B_t and the standard errors of the structural matrix of the innovations Σ_t. we can assume that the reduced form of the residues $\mathcal{E}_t$ follows a normal multivariate distribution:

$$\varepsilon_t \rightarrow \mathcal{N}(0,\Omega t) \quad (4)$$

Ω_t is a symmetric and positive matrix of time-varying variances-covariances which satisfies the following equality:

$$B_t \Omega_t B'_t = \sum_t \sum'_t \quad (5)$$

Allowing this heteroskedasticity to vary over time in innovations is important for our purpose since it allows for changes in the size of shocks and their immediate impact.

We denote by the column vector which contains the stacked columns of the matrix A_t of the delayed coefficients $a_t = (c_t\ A_{1t}\ \ldots\ldots\ldots\ A_{pt})'$, $bt = (b_{21t}\ b_{31t}\ b_{32t}\ b_{41t})'$ the column vector which groups together the elements of the matrix of the contemporary coefficients B_t, and ht as the column vector which contains the diagonal elements of the matrix of standard errors Σt, such that $h_t = ln(\sigma_t)$, $\sigma_t = (\sigma_{1,t} \ldots \sigma_{4,t})'$

The parameters a_t , b_t and h_t evolve as follows:

$$\begin{cases} \alpha_t = \alpha_{t-1} + \omega_t \\ b_t = b_{t-1} + \varsigma_t \\ h_t = h_{t-1} + \eta_t \end{cases} \qquad \textbf{(6)}$$

This random walk specification has two main advantages. First, it allows to model sudden breaks in the evolution of the parameters that could occur during the estimation period. Second, it also allows to model gradual changes in the relationship between variables. Innovations in the reduced form model are assumed to be normally distributed jointly:

$$\begin{pmatrix} \upsilon t \\ \omega t \\ \zeta t \\ \eta t \end{pmatrix} \backsim \mathcal{N}(0,\mathcal{V}) \; with \; \mathcal{V} = \begin{pmatrix} I_4 & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{pmatrix} \qquad (7)$$

Where the matrix V is diagonal with I4, Q, S and W the elements on the diagonal corresponding to the matrix covariance of structural innovations v_t, innovations of delayed coefficients w_t, innovations of contemporary coefficients ζ_t and innovations of standards errors ($h_t = \log\sigma_t$) η_t, respectively.

3. Data and estimation :

The sample period for Tunisia is from 1990Q1 to 2015Q4, which contains periods of crisis, structural changes in the inflation regime, the date of the revolution and the post-revolution period.

For our study, we will try to analyze a disaggregated pass-through. To that end, firstly, we tried to decompose the consumer price index into 3 subgroup-price index: fresh food price index (Fresh_Food CPI), administrated price index (adm_CPI), core price index (core_CPI).

For aggregate analysis : The variables are: NEER – IMP – PPI – CPI (TVP VAR model 1)[2]

[2] NEER: nominal effective exchange rate, IMP = import price index, PPI = producer price index, as proxy we have used the industrial sales price index (ISPI), CPI = consumer price index. All the variables are seasonally adjusted with the X13 program in eviews, they are in logarithm and they are stationary after the first difference

For disaggregate analysis : The variables are:

NEER – IMP – PPI – CPI_adm (TVP VAR model 2)

NEER – IMP – PPI – CPI_fresh food (TVP VAR model 3)

NEER – IMP – PPI – CPI_core (TVP VAR model 4)

To estimate our TVP-VAR model, a crucial first step is to run a bayesian estimation which allows us to extract the priors and then evaluate the posteriori distributions of the parameters. To this end, we estimate a time-invariant VAR model over the period 1990Q1-2002Q4. In other words, the first 13 years of the above-mentioned data are used as the training sample to get the priors for the estimation of TVP VAR model later.

We follow Canova (2007) and Canova and Ciccarelli (2009) who use this method of bayesian estimation in the TVP VAR approach. Therefore, we conduct an OLS estimate on a time-invariant VAR model to calibrate our priors. ($B_{OLS,}$ $A_{OLS,}$ Log $(\sigma_0)_{OLS}$). Following Cogley and Sargent (2005), the hyperparameters Q and S follow the inverse-Wishart distribution prior (IW), and W which is based on the inverse-Gamma distribution prior (IG). [3]

Finally, to obtain the posterior distribution, 100 000 iterations of the Gibbs sampler are used and we drop the first 50 000 iterations for convergence. The auto-correlation functions of the prints disappear fairly quickly. In addition, the convergence diagnoses reveal satisfactory results.[4] (See Figures 2-3-4-5)

4. Results

(L design the Log and D design the first difference : dlNEER – dlIMP – dlPPI – dlCPI). The information conditions SC, AIC and HQ give two lags (p=1). The exogenous variables used are: dummies variables of revolution 2011, of financial crisis in 2008, of Jerba attack in 2002 - MMR – and bilateral exchange rate EUR/USD.

[3] we limit the matrix W to be diagonal for the reduction of dimensionality of the estimate.
We use Kalman filter to generate state vector of time vaying parameters and time varying variance-covariance matrix, and estimates parameters using bayesian estimation (Gibbs sampler).
State space model: | y(t)=Z(t).alpha(t)+d+epsilon(t) | Alpha(t)=T.alpha(t-1) +c+R.neta(t)
H(t)=E [epsilon(t).epsilon(t)'] variance-covariance matrix of measurement
Q=E [neta(t).neta(t)'] variance-covariance matrix of state
Alpha(t) is the vector of time-varying parameters

[4] param.S=100000 Number of simulations ; param.L=50000 Number of burning period to be discarded ; param.thin=3 Number of thinning ; param.k2Q=0.01parameter in the prior of variance-covariance matrix of state equation alpha (for estimated parameters): eq (6) and (7) ; param.k2S=0.1parameter in the prior of variance-covariance matrix of contemporaneous coefficient b : eq (6) and (7) ; param.k2W=0.01parameter in the prior of variance-covariance matrix of standard errors : eq (6) and (7)

As a first step, we look for evidence on if the impact of exchange rate shocks in Tunisia has changed over time. In particular, we compute the marginal likelihood estimator for the time-constant coefficients of the VAR model and the time-varying parameters VAR with stochastic volatility (TVP-VAR). The model that gives the greatest marginal likelihood is the best. We follow Nakajima et al. (2011) for the harmonic mean of the marginal likelihood estimator. The marginal likelihood value for the TVP-VAR is 435,725, which is greater than the marginal probability estimate for the constant VAR 261,586. This suggests that the TVP-VAR model with stochastic volatility is indeed the best model for Tunisia than the constant VAR.

We begin by considering whether CPI's response to unexpected exchange rate shocks, regardless of their underlying source, has changed over time. We can identify at least three periods in the magnitude of the CPI's responses to a nominal exchange rate shock (appreciation shock): 2008Q2: period of financial crisis, 2011Q2: period of the Tunisian revolution, 2014Q1: Decrease in the price of oil).

Our interest here is to detect the possible structural changes in the Tunisian economy and to have a first idea on the relation between exchange rate and inflation, which is variable over time. The preliminary results, Figures 2-3-4-5 show the dynamics of the contemporary relationship between the CPI and the exchange rate. The positive changes in the exchange rate, which refers to the appreciation of the Tunisian dinar, trigger a contemporary reduction in prices, especially after 2011.

On the other hand, to understand the underlying mechanisms that have led to domestic price fluctuations, we represent the Variance Decomposition or Forecast Error Variance Decomposition (FEVD) and the Historical Decomposition in Figures 2-3-4-5. These two complementary tools are used to analyze the evolution of the size of structural innovations and to measure the contribution of each innovation to the evolution of inflation. Although the forecast error variance decomposition (FEVD) consists in decomposing the variance of the CPI forecast error in h future periods, the historical decomposition consists in explaining the observed values of CPI in terms of structural shocks. With respect to impulse responses, we allow the FEVD to vary with time, allowing an alternative dynamic in the composition of the shocks that cause the variances.

As illustrated in Figures 2-3-4-5, the variance and the historical decompositions of forecast error provide similar results, underlining the robustness of our results. The shock on the

NEER has a contemporary impact on inflation. In addition, they show that after the Tunisian revolution, there was an exchange rate pass-through on the controlled prices (for food and energy prices) ; this result contradicts the prevailing theory that says there is no pass-through for controlled prices.

5. Conclusion

Nowadays, Tunisia (which is in a transitional phase) is maintaining a more flexible exchange rate regime by gradually liberalizing its capital accounts and following monetary policies that target price stability. Therefore, measurement and analysis of the degree of nominal exchange rate's transmission in inflation is of a great importance to conduct a proper monetary policy. Furthermore, heterogeneity in the structure of the consumer price index, as a proxy of inflation, leads us to think of a heterogeneous pass-through. Hence, for a disaggregated analysis of the pass-through, we need to breakdown the consumer price index. A contribution to the literature that has not been processed.

In order to study whether the relationship between prices and the exchange rate presents a structural and persistent break and to capture the possible non-linearities in this price response to exchange rate fluctuations, we have allowed the parameters to vary over time with stochastic volatility which illustrates the TVP VAR analysis of exchange rate pass-through. The results confirm the importance of the TVP VAR approach in the Tunisian context which present significant structural changes and dynamic relationships between macroeconomic variables, especially after revolution. In addition, our results confirm the importance of a disaggregated analysis to study exchange rate pass-through, and may help decisions-makers, in the short or the long term, to adopt the appropriate strategies to conduct monetary policy and to contain inflation.

Overall, our findings point out the importance of using a time-varying framework in analyzing the impact of these shocks in Tunisia. The results of the study can help the short- and long-term decision-makers in Tunisia to adopt appropriate strategies for conducting monetary policy and containing inflation.

To avoid inconsistencies between monetary and fiscal policies and to ensure that monetary policy effectively controls inflation, a strategy of a policy mix must be well established in Tunisia.

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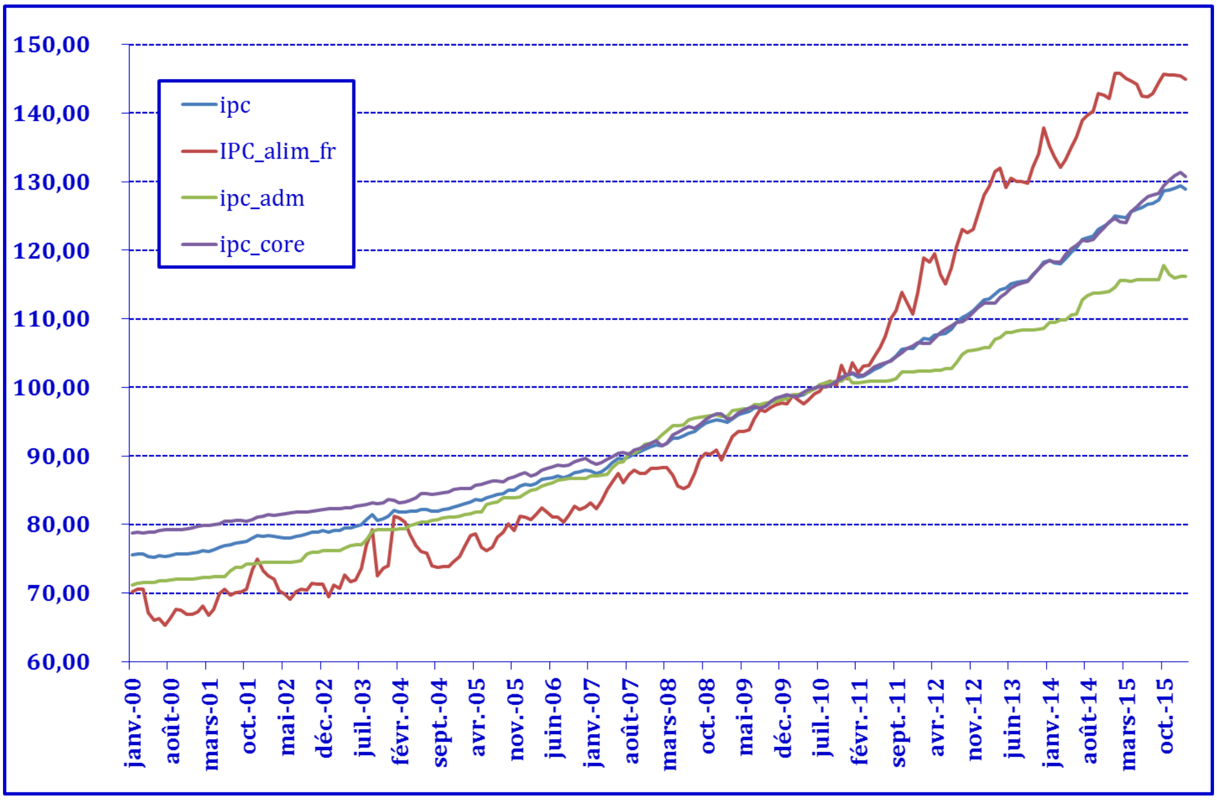
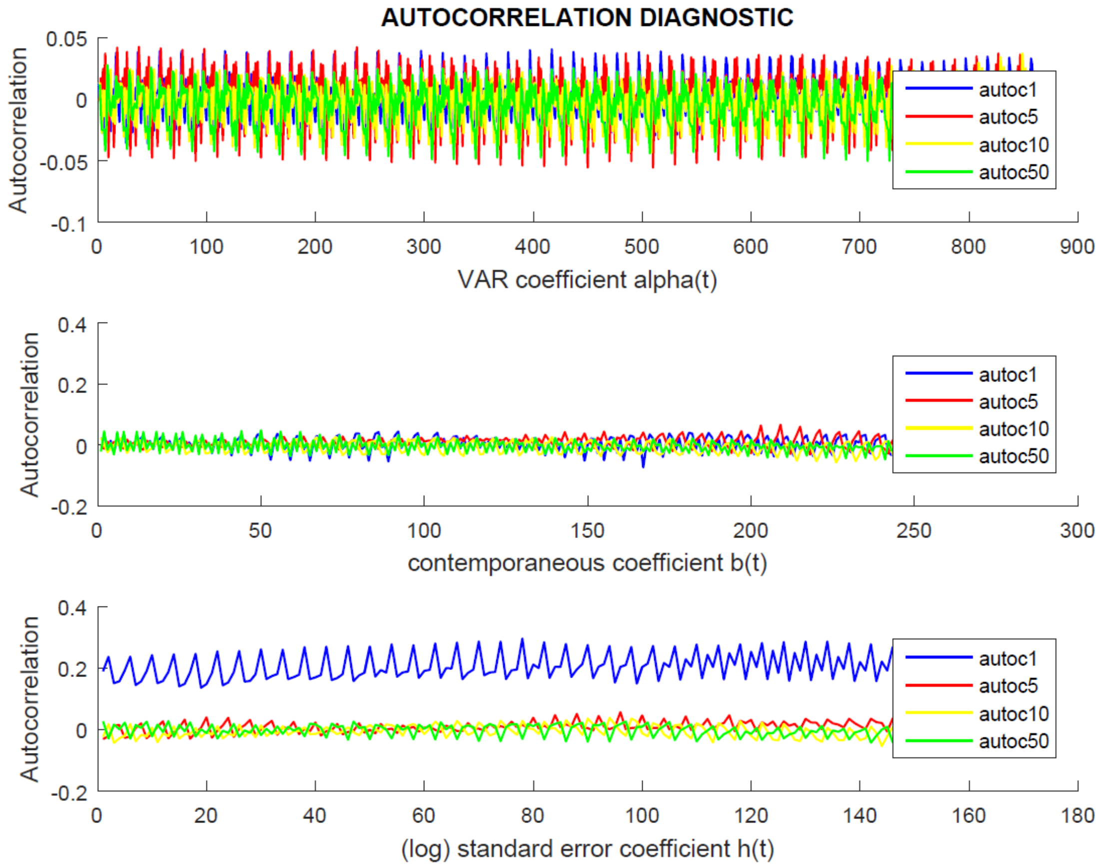
Annexes

1/ Figure 1 : Graph of Variables

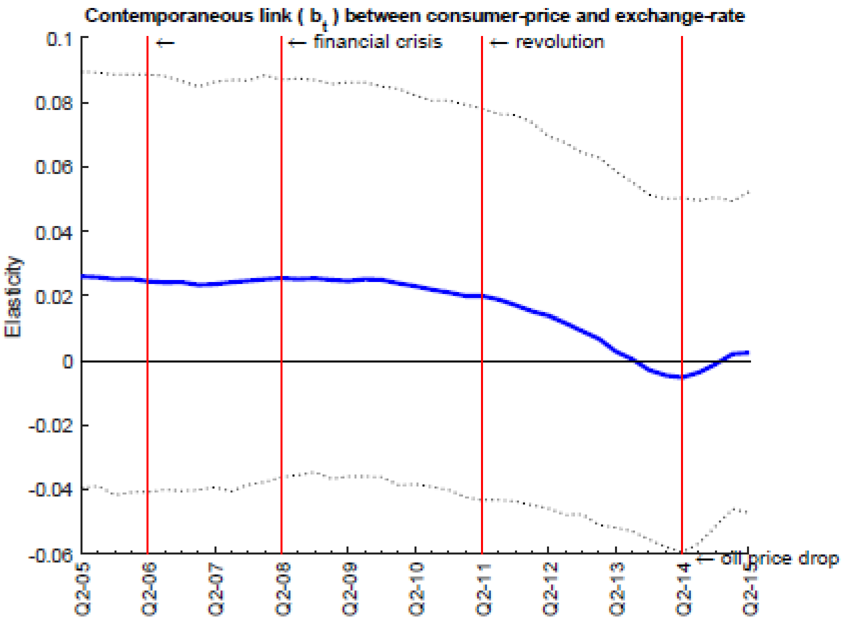


2/ Figure 2 :

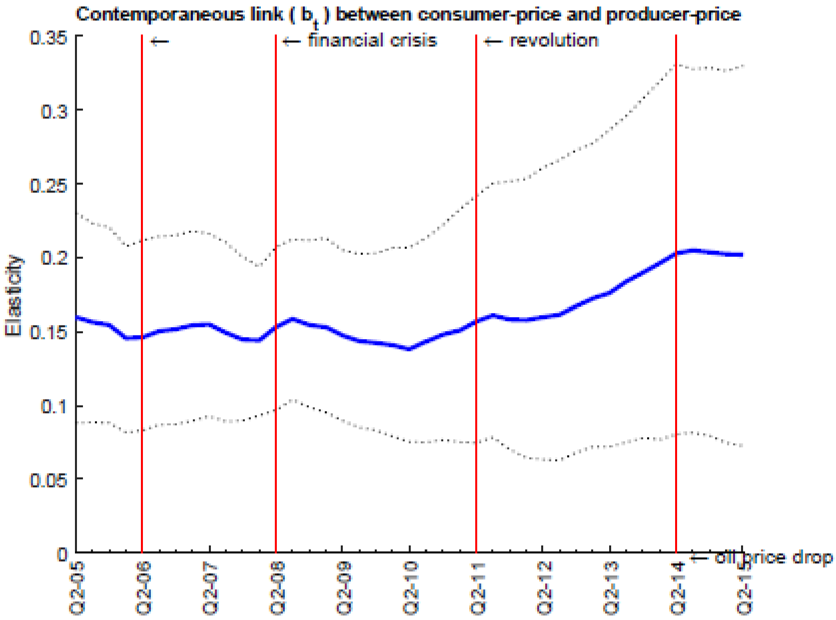
TVP VAR model 1 : NEER – IMP – PPI – CPI

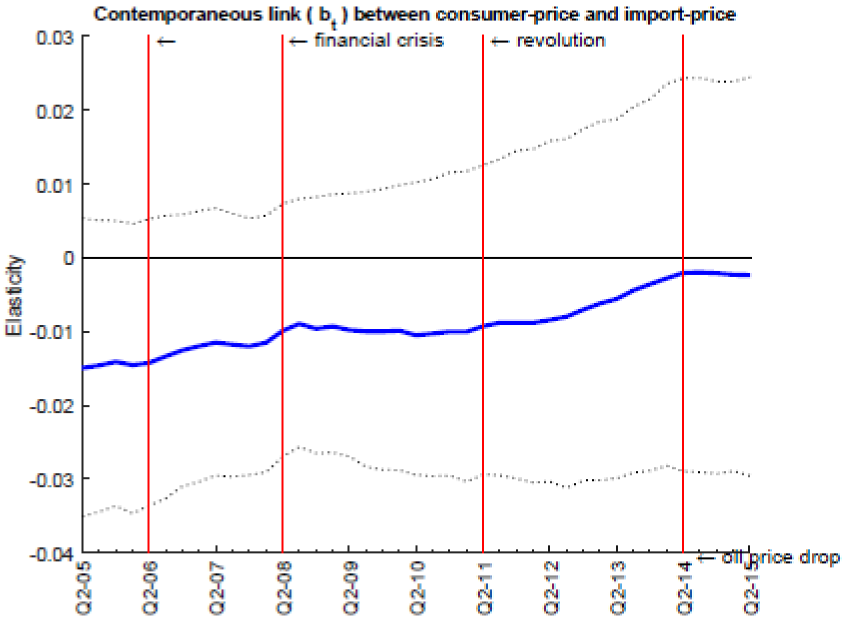


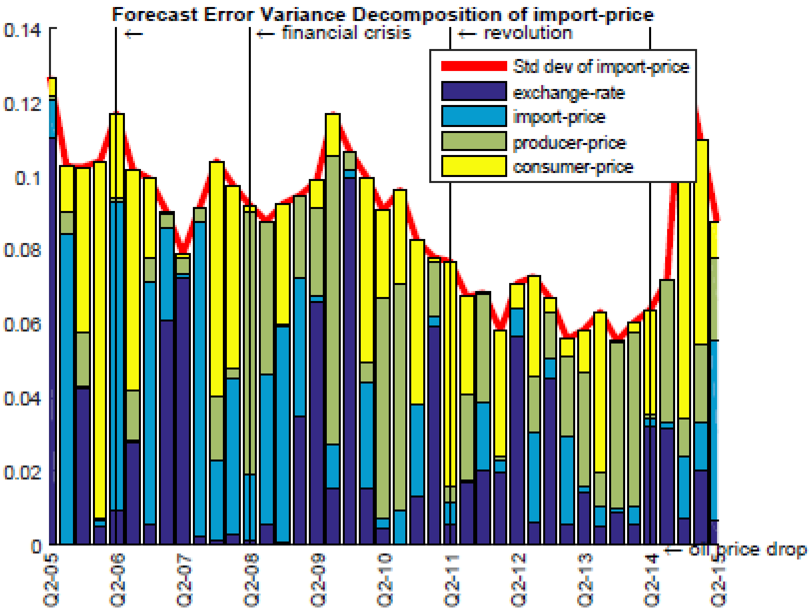
AUTOCORRELATION DIAGNOSTIC
Autocorrelation
autoc1
autoc5
autoc10
autoc50
VAR coefficient alpha(t)
contemporaneous coefficient b(t)
(log) standard error coefficient h(t)



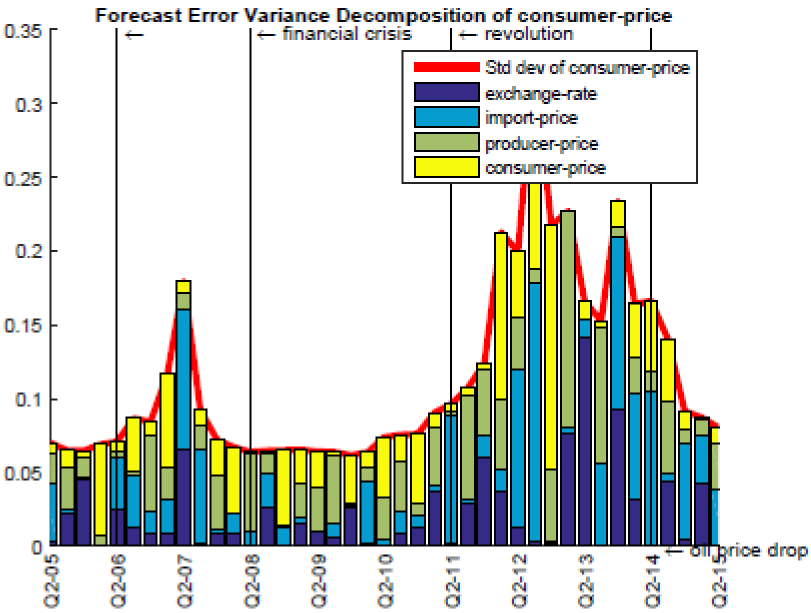
Contemporaneous link (b_t) between consumer-price and exchange-rate
← financial crisis
← revolution
← oil price drop
Elasticity
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14


Contemporaneous link (b_t) between consumer-price and producer-price
←
← financial crisis
← revolution
← oil price drop
Elasticity
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15

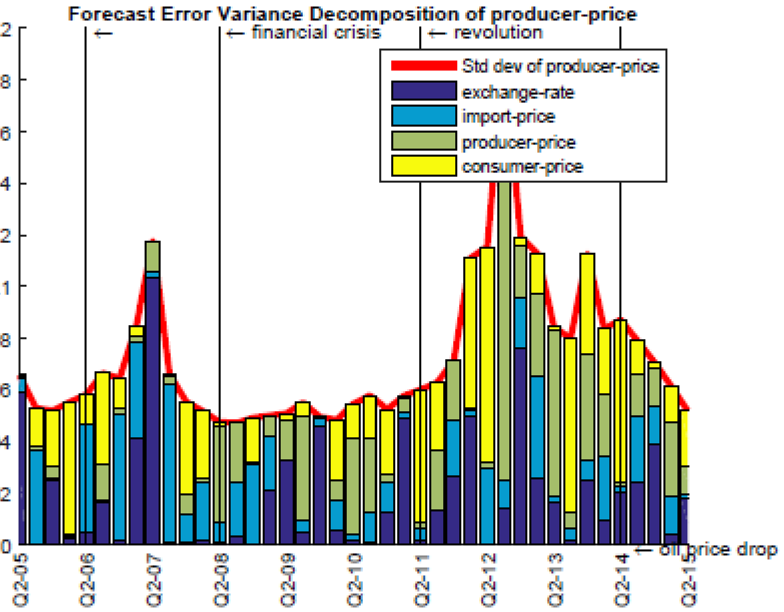

Contemporaneous link (b_t) between consumer-price and import-price
←
← financial crisis
← revolution
← oil price drop
Elasticity
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15



Forecast Error Variance Decomposition of import-price
← financial crisis
← revolution
← oil price drop
Std dev of import-price
exchange-rate
import-price
producer-price
consumer-price
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15

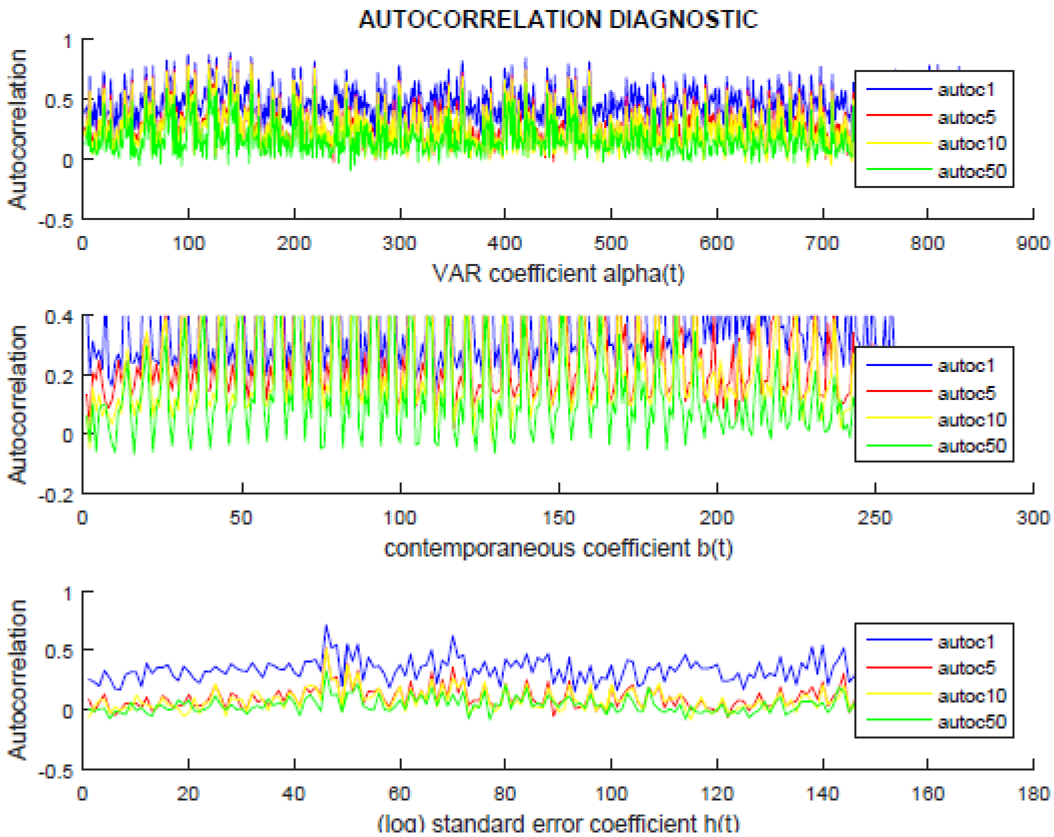


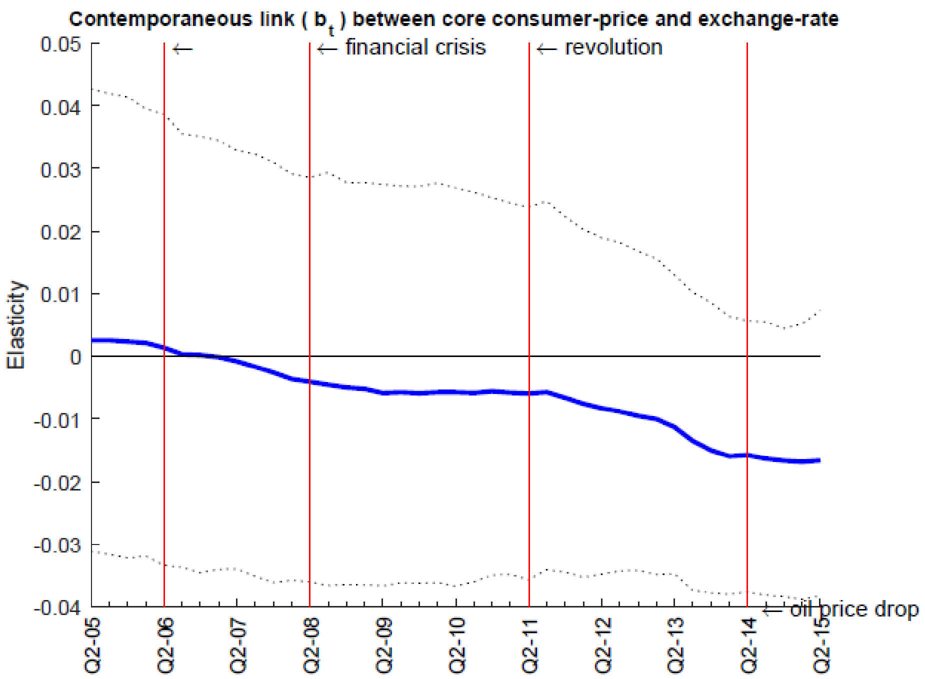
Forecast Error Variance Decomposition of consumer-price
← financial crisis
← revolution
← oil price drop
Std dev of consumer-price
exchange-rate
import-price
producer-price
consumer-price
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15



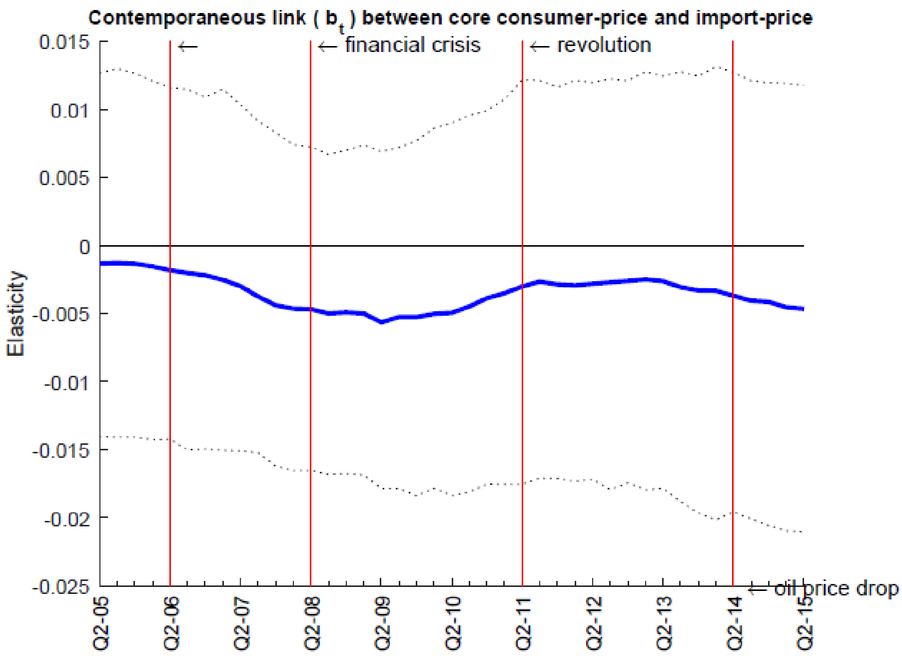
3/ Figure 3 :

TVP VAR model 4 : NEER – IMP – PPI – CPI_core

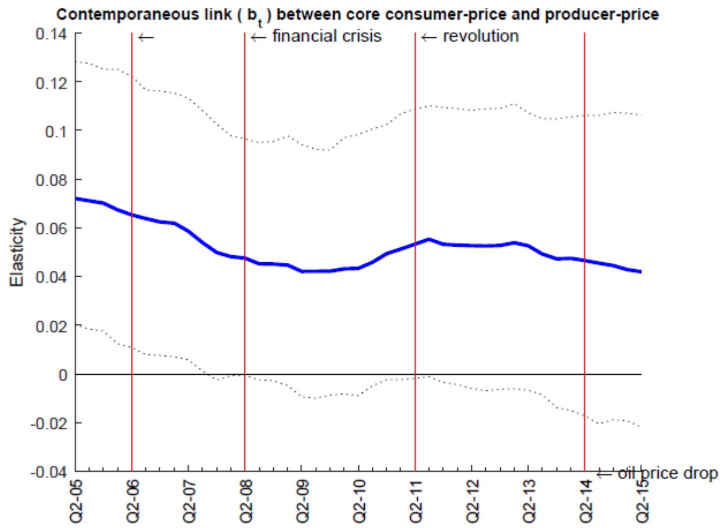




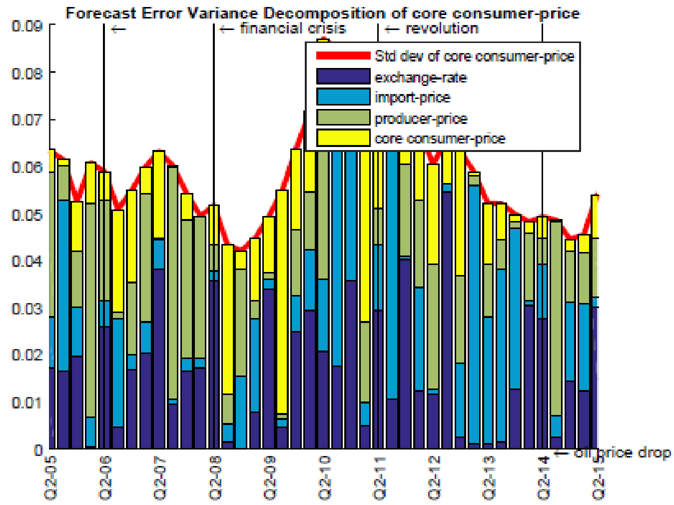
Contemporaneous link (b_t) between core consumer-price and exchange-rate
←
← financial crisis
← revolution
← oil price drop
Elasticity
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15



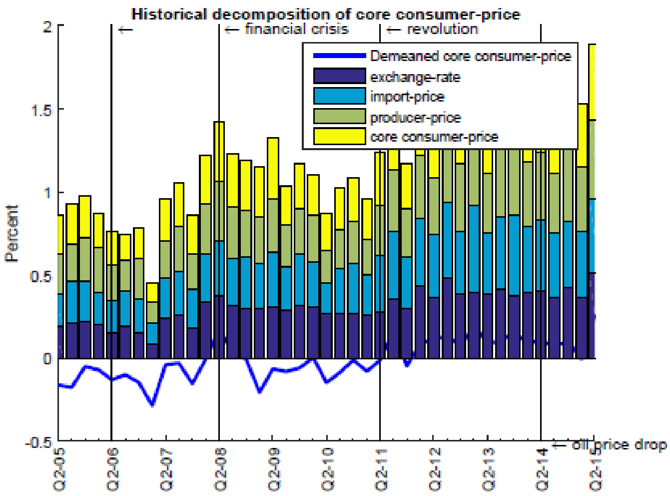
Contemporaneous link (b_t) between core consumer-price and import-price
←
← financial crisis
← revolution
← oil price drop
Elasticity
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15



Contemporaneous link (b_t) between core consumer-price and producer-price
← financial crisis
← revolution
← oil price drop
Elasticity
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15



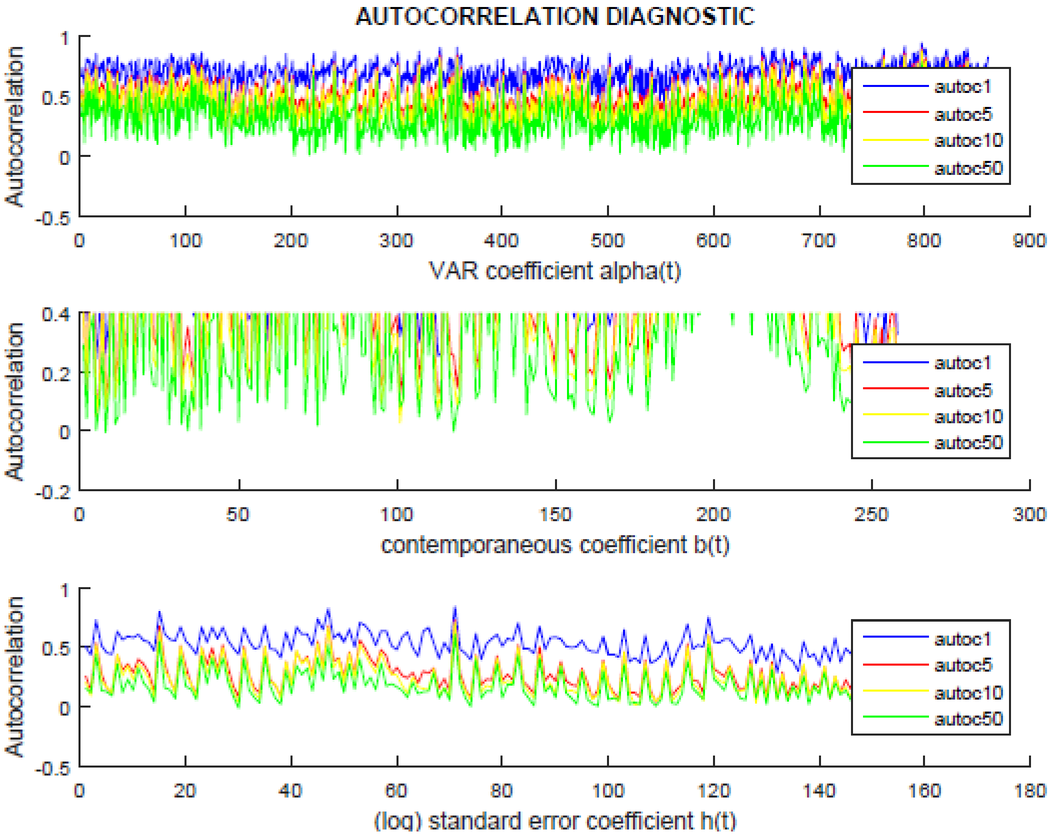
Forecast Error Variance Decomposition of core consumer-price
← financial crisis
← revolution
← oil price drop
Std dev of core consumer-price
exchange-rate
import-price
producer-price
core consumer-price
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15

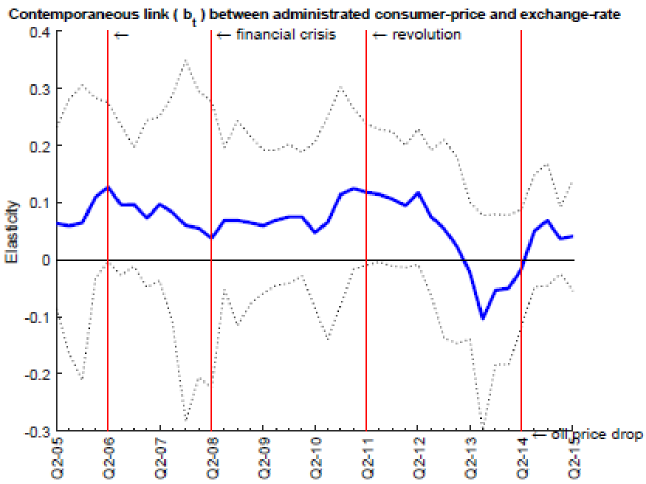


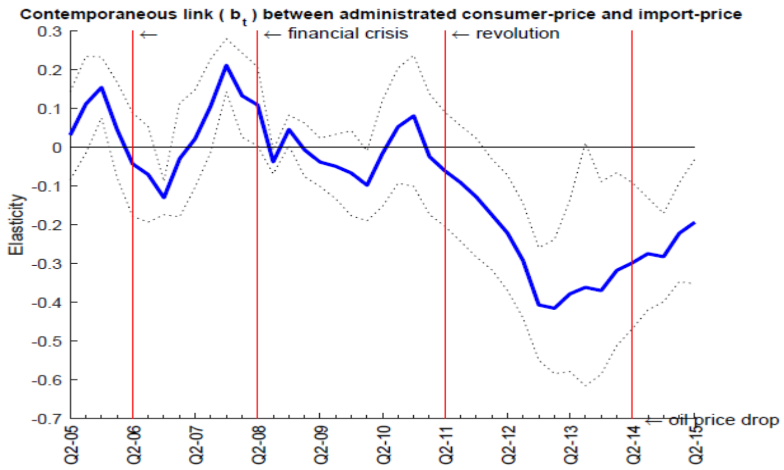
Historical decomposition of core consumer-price
← financial crisis
← revolution
← oil price drop
Demeaned core consumer-price
exchange-rate
import-price
producer-price
core consumer-price
Percent
2
1.5
1
0.5
0
-0.5
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15

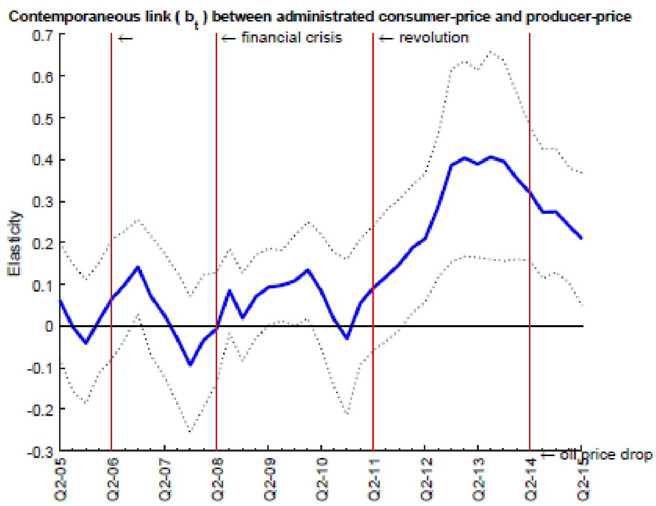
4/ Figure 4 :

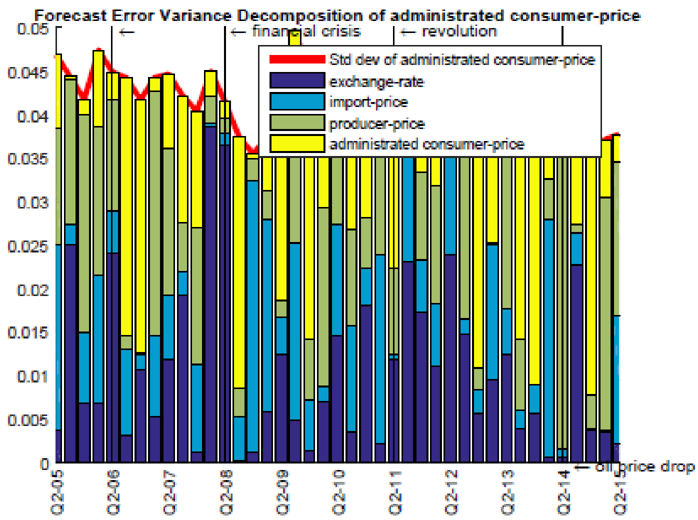
TVP VAR model 2 : NEER – IMP – PPI – CPI_adm

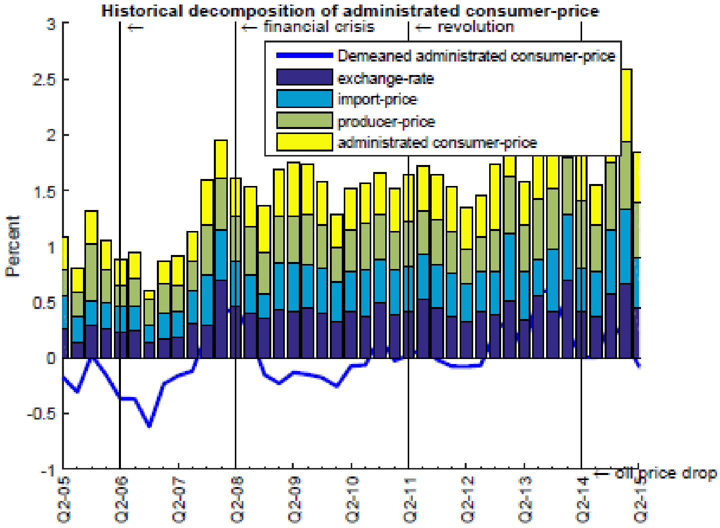





Contemporaneous link (b_t) between administrated consumer-price and import-price
← financial crisis
← revolution
← oil price drop
Elasticity
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15

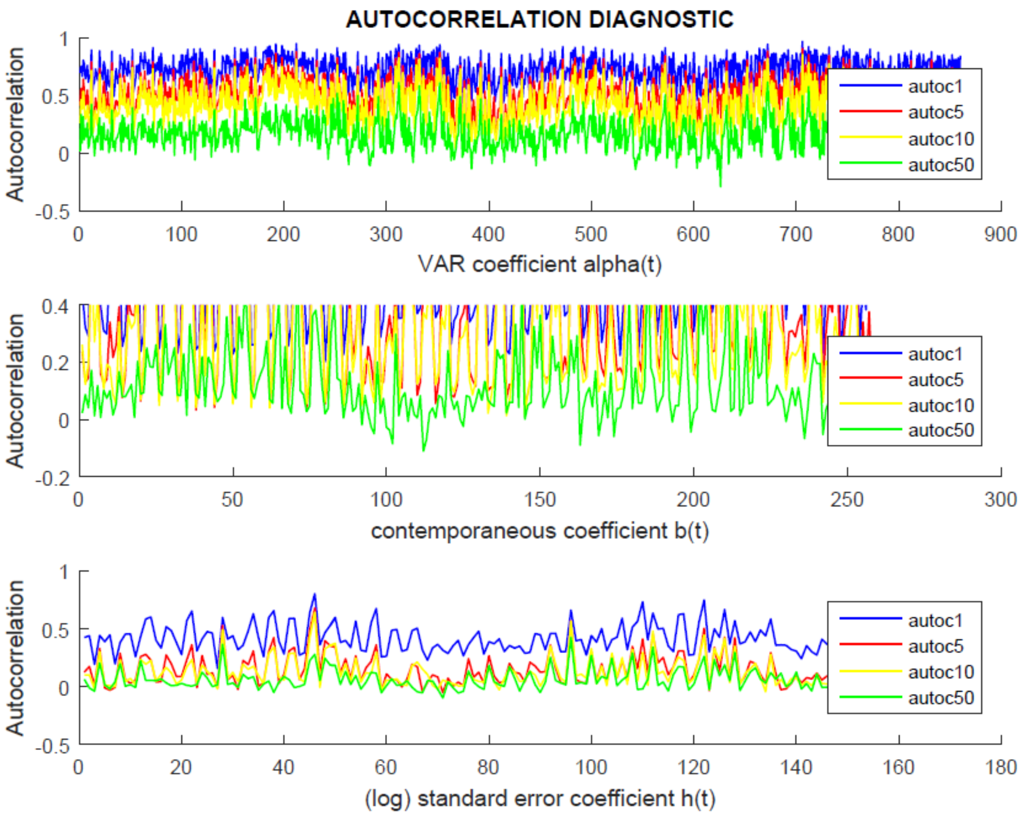

Contemporaneous link (b_t) between administrated consumer-price and producer-price
← financial crisis
← revolution
← oil price drop
Elasticity
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15

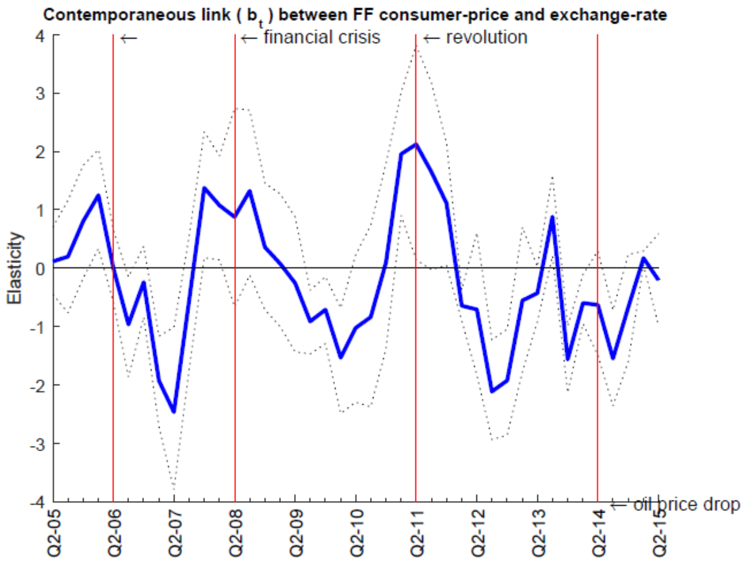

Forecast Error Variance Decomposition of administrated consumer-price
← financial crisis
← revolution
← oil price drop
Std dev of administrated consumer-price
exchange-rate
import-price
producer-price
administrated consumer-price
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Q2-05
Q2-06
Q2-07
Q2-08
Q2-09
Q2-10
Q2-11
Q2-12
Q2-13
Q2-14
Q2-15

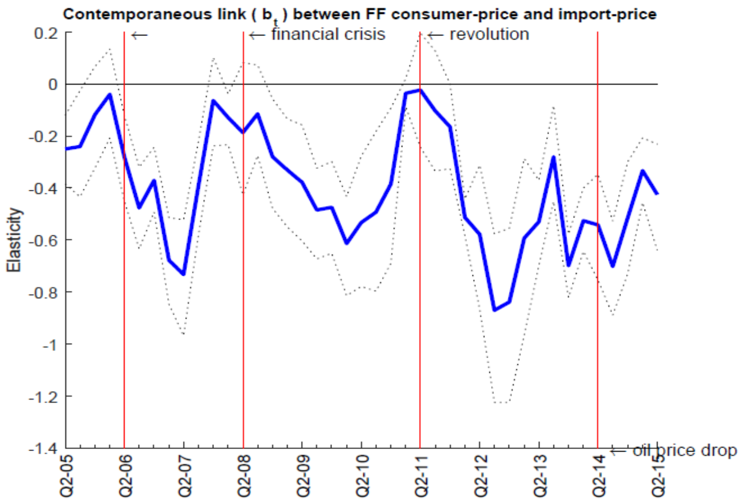


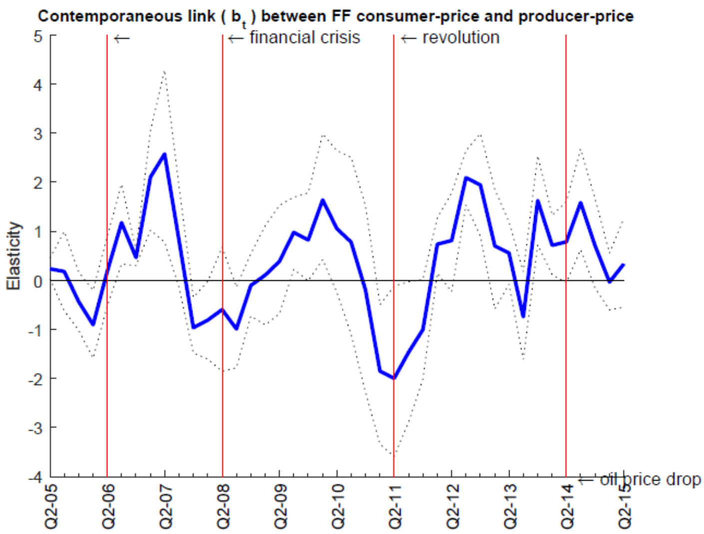
5/ Figure 5 :

TVP VAR model 3 : NEER – IMP – PPI – CPI_fresh food




Contemporaneous link (b_t) between FF consumer-price and exchange-rate
Elasticity
← financial crisis
← revolution
← oil price drop
Q2-05 Q2-06 Q2-07 Q2-08 Q2-09 Q2-10 Q2-11 Q2-12 Q2-13 Q2-14 Q2-15


Contemporaneous link (b_t) between FF consumer-price and import-price
Elasticity
← financial crisis
← revolution
← oil price drop
Q2-05 Q2-06 Q2-07 Q2-08 Q2-09 Q2-10 Q2-11 Q2-12 Q2-13 Q2-14 Q2-15


Contemporaneous link (b_t) between FF consumer-price and producer-price
Elasticity
← financial crisis
← revolution
← oil price drop
Q2-05 Q2-06 Q2-07 Q2-08 Q2-09 Q2-10 Q2-11 Q2-12 Q2-13 Q2-14 Q2-15