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Abstract

This study examines the short-run and long-run dynamics binding energy consumption to GDP using a structural vector error correction (SVECM) model during the period 1971-2009. In addition, a comparative study between Tunisia, the USA and Sweden is conducted. Results spread over two axes. First, the cyclical component of the model indicates that the instantaneous impact of a short run shock on energy is generally positive. However, the impact of this shock on output is positive in the USA and Sweden and negative in Tunisia. Therefore, it seems that unlike a small country like Tunisia where the productive system is directly penalized, developed countries are better able to cope with a transitory shock and find alternatives to productivity gains. Secondly concerning the trend component of the model, we conclude that the effect of a long run shock on energy consumption is positive in Tunisia while it is negative in the USA and Sweden. The effect of a long run shock on production for both the developed countries is positive and increasing. This findings seems interesting insofar as it reflects the willingness of developed countries substitute current energy sources by renewable and cleaner sources. It also reflects Tunisian dependence to current sources of electricity.

Keywords: Energy consumption, GDP, SVEC model, Tunisia.

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1. Introduction

During the past three decades, several studies have investigated the relationship between energy consumption and economic growth using different methodology, yet no consensus has ever been reached (see Ozturk (2010)). Previous studies have focused on cointegration and causality analysis to examine the relationship between energy use and economic growth and only few studies have examined the impact of energy use shocks on national income and vice versa. In fact, many studies based on VAR and VECM models make the results difficult to interpret and allow only to long-run restrictions. However, Structural VARs impose an economic model on the contemporaneous movements of the variables and therefore impose both short- and long-run restrictions.

The purpose of the current study is to investigate the impact of short-run shocks on energy consumption and income and the effect of long run shocks on both variables in Tunisia. This is motivated by two main reasons: first, researche about Tunisia as a specific country is very rare as shown in table 1 (see Belloumi (2009) and Fodha and Zaghdoud (2010)); second, the previous research was limited to the study of causality between the variables of the model in its reduced form or in the best case to the identification of the short-term dynamic in a structural framework (see for example see Narayan et al. (2008)). To fill the gap in the literature, we consider a structural vector error correction model (SVECM) framework to capture the short-run and long-run dynamics binding energy consumption to GDP in Tunisia through the model's cycle-trend dichotomy. A comparative study with the U.S.A and Sweden is then conducted. To capture those dynamics, we perform impulse response function (IRF) and forecast error variance decomposition (FEVD) analyses. At this level, we employ variance decomposition analysis to evaluate the overall importance of each shock in the determination of energy consumption and economic growth in Tunisia.

The rest of the paper is organized as follows. Section 2 provides an overview of the literature on energy use-income nexus in Tunisia. Section 3 discusses the methodology employed. Section 4 provides the empirical results. Section 5 presents short run and long run economic implications and the last section presents the conclusion.

2. Literature review on energy use-income nexus in Tunisia

The literature on the causal relationship between energy use and economic growth started with the seminal work of Kraft and Kraft (1978). In this study, a unidirectional causality was found running from income to energy consumption in the United States. Empirical studies were later extended to cover many other countries. However, the number of papers that have examined causality between energy use and GDP in Tunisia is small.

The empirical literature on Tunisia can be viewed in two different ways: as a specific country or among a multi-country studies (see table 1). First, we begin by surveying studies in which Tunisia is a specific country. Belloumi (2009) investigated the causal relationship between energy consumption and economic growth during the period 1971-2004. He found a long-run bidirectional causal relationship and a short-run causality running from energy consumption to GDP in Tunisia based on the VEC model. Fodha and Zaghdoud (2010) investigated the relationship between economic growth and two pollutants (SO2 and CO2) over the period 1961-2004 using time series data and cointegration analysis. They found a long-run relationship between the per capita emissions of two pollutants (per capita Sulfur dioxide (SO2) and per capita Carbon dioxide (CO2)) and per capita income.

Second, we review other studies in which Tunisia is among a multi-country panel. Wolde-Rufael (2005) investigated the long-run causality relationship between per capita energy use and per capita income for 19 countries during 1971-2001, using the cointegration technique proposed by Pesaran et al. (2001) and also the causality test proposed by Toda and Yamamoto (1995). He found that energy consumption and GDP are neutral to each other in Tunisia. Wolde-Rufael (2006) investigated the long-run and causal relationship between real GDP per capita and electricity per capita consumption in 17 African countries for the period 1971-2001 using the cointegration test proposed by Pesaran et al. (2001) and the Toda and Yamamoto (1995) causality test. He found unidirectional causality running from electricity consumption to economic growth in Tunisia but no long-run relationship between these series. In 2009, the same author has re-examined the causal relationship between economic growth and energy consumption in seventeen African countries for the period 1971-2004 using a multivariate framework by including labor and capital as additional variables. For Tunisia, he found a unidirectional causality running from energy consumption to economic growth. Sari and Soytas (2007) examined the relationship between economic growth and energy in six African countries using the generalized variance decompositions and generalized impulse response techniques for the 1971-2002 period. They found that neutrality of energy does not seem to hold.

Ozturk et al. (2010) analyzed the causal relationship between energy consumption and economic growth for 51 countries from 1971 to 2005 using a panel cointegration and causality analysis. These countries are divided into three groups: low income, lower middle income and upper middle income countries. The test results indicate that there is cointegration between energy consumption and real GDP for all three income groups. In addition, they found a long-run causality running from GDP to energy consumption for low income countries and a bidirectional causality for middle income countries. Eggoh et al (2011) explore the relationship between energy consumption, economic growth and auxiliary variables (consumer price index, total labor force and real gross fixed capital formation) for 21 African countries during the period 1870-2006. They used the Westerland (2006, 2007) panel cointegration and panel causality tests and found a long-run equilibrium relationship between real GDP, energy consumption, consumer price index, labor and capital). Recently, Arouri et al. (2012) explored the relationship between CO2 emissions, energy consumption and real income for 12 MENA countries over the period 1981-2005. They implemented recent bootstrap unit root tests and the panel cointegration technique and found a significant long-run impact of energy consumption on CO2 emissions while income exhibits a quadratic relationship with CO2 emissions.

Table 1: Summary of empirical studies on energy use-GDP nexus for Tunisia.

Authors	Period	Methodology	Country causality
Tunisia as a specific-country studies			
Belloumi (2009)	1971-2004	Causality, VECM	EC$\longleftarrow\longrightarrow$Y (long-run)
Fodha and Zaghdoud (2009)	1961-2004	Cointegration and Granger Causality	CO2, SO2$\longrightarrow$Y (long-run)
Tunisia among multi-country studies			
Wolde-Rufael (2005)	1971-2001	Pesaran et al's cointegration test Toda-Yamamoto's Granger causality	EC$-$Y
Wolde-Rufael (2006)	1971-2001	Pesaran et al's cointegration test Toda-Yamamoto's Granger causality	ELC$\longrightarrow$Y
Wolde-Rufael (2009)	1971-2004	Variance decomposition Toda-Yamamoto's Granger causality	EC$\longrightarrow$Y
Ozturk et al. (2010)	1971 to 2005	Panel cointegration and causality analysis	EC$\longleftarrow\longrightarrow$Y
Eggoh et al. (2011)	1970-2006	Westerland's panel cointegration Panel cointegration	EC$\longleftarrow\longrightarrow$Y (long-run)
Arouri et al. (2012)	1981-2005	Boostrap unit root test Panel cointegration	EC$\longrightarrow$CO2 emissions Y^2 $\longrightarrow$CO2 emissions

Note: $\longrightarrow$, $\longleftarrow\longrightarrow$ and $-$ represent, respectively, unidirections causality, bidirectional causality and no causality. Abbreviations are defined as follows: EC = energy consumption, Y = GDP, ELC = electricity consumption.

3. Methodology

Our paper aims at exploring the dynamic relationship between energy consumption and GDP in Tunisia using a multivariate framework. Most studies which used the VAR (Vector auto-regressive) model to examine this relationship are limited to the study of causality between the variables of the model in its reduced form, or in the best case to the identification of the short run dynamics in a structural framework[1]. We propose to capture both the short run and the long run dynamics binding energy consumption to GDP using a SVECM. We believe that this issue should be treated with great sensitivity and interest than simply infering the direction of causality between variables wich is certainly a very useful issue but remain insufficient to understand the mechanisms linking these two variables . It is also worth noting that the fact to settle for the reduced form of a multivariate model and draw conclusions from it may distort economic analysis and lead to misleading interpretations.

3.1. SVAR approach

The SVAR (structural vector autoregressive) approach , which was designed to overcome the limitations and difficulties encountered by standard VAR models, seeks to specify an economically interpretable framework . It consists in tracing the transmission of an impulse of an economic policy to the economy and thus allows for predicting the model variables studied on the basis of a given change in this policy[2].

This methodology owes its emergence and its growth to the contribution of the pioneering work of Sims (1986), Bernanke (1986) and Blanchard and Watson (1986). The main common feature of these approaches is the attempt to establish instantaneous relationships between macroeconomic variables within a theoretical and a structural framework[3]. The idea on which the authors designed the SVAR approach is to try to isolate or identify a series of independent shocks through a number of identifying restrictions based on economic fundamentals. The attempt to identify these shocks goes back to the fact that they are considered as the ultimate source of stochastic variations of the endogenous variables in a VAR model[4]. The identifying restrictions are called short run restrictions insofar as they express the absence of instantaneous responses of some series to some structural impulses. The second alternative to identify SVAR models, proposed by Shapiro and Watson (1988) and Blanchard and Quah (1989), consists in imposing identifying restrictions on the long run dynamic multipliers of

[1] The main uses of VAR processes lie at the study of causality between variables, the forecast error variance decomposition and the analysis of the impulse response function.

[2] Structural VAR methodology is commonly used in two major areas of research: the interpretation of business cycle fluctuations of macroeconomic variables and the identification of effects and transmission mechanisms of economic policies.

[3] With regard to standard VAR models, however, these correlations are captured by the variance-covariance matrix of canonical innovations.

[4] Add to this first motivation the fact that it is necessary to preserve the model in its structural form to ensure the independence of shocks.

structural shocks. Indeed, long run restrictions act to express the absence of effect of some persistent structural impulses on some components of the system. The fact that the impact of these impulses spread over a long period implies nonstationarity of one or more variables in the model, since the shocks continue to accumulate over time due to their permanent nature.

The structural model is given as follows:

$$B_0 Y_t = \sum_{i=1}^{p} B_i Y_{t-i} + w_t \tag{1}$$

where B_0 denotes a $(N \times N)$ matrix with terms equal to unity on the main diagonal and which represents relations of simultaneity between the N variables constituting Y_t, the vector $w_t = (w_{1t} \ldots w_{Nt})'$ contains the N structural innovations and square matrices B_i, for $i = 1, \ldots, p$, contain the structural parameters of the model.

The reduced form of this model is given by:

$$\begin{aligned} Y_t &= \sum_{i=1}^{p} B_0^{-1} B_i Y_{t-i} + B_0^{-1} w_t && (2) \\ &= \sum_{i=1}^{p} A_i Y_{t-i} + \varepsilon_t && (3) \end{aligned}$$

The vector $\varepsilon_t = (\varepsilon_{1t} \ldots \varepsilon_{Nt})'$ contains the N non-systematic influences, also called canonical innovations, associated with the variables of the model. Square matrices A_i, for $i = 1, \ldots, p$, contain the model parameters related to the vectors Y_{t-i} for a lag order p. The variance-covariance matrix Σ_ε is an $(N \times N)$ symmetric matrix describing the structure of interdependence of canonical stochastic innovations ε_t.

The structural VAR representation is derived from the canonical representation VAR assuming that the vector of canonical innovations ε_t is a linear combination of structural innovations w_t of the same date:

$$\varepsilon_t = B_0^{-1} w_t \tag{4}$$

The main problem with the issue of identification of a structural VAR model is the determination of the matrix B_0. It is precisely this unknown matrix B_0 which assumes that we should first pass through the estimation of the reduced form of the VAR to calculate the structural form. To facilitate the identification of the parameters of B_0^{-1} (or B_0) we generally assume the normalization of the variance of the structural form innovations $v(w) = \Omega = I$. Consequently, we have $\Sigma_\varepsilon = B_0^{-1}(B_0^{-1})'$ or $B_0 \Sigma_\varepsilon B_0' = \Omega = I$. This last condition mainly implies that structural innovations w_t are uncorrelated and that their variances are equal to unity. It also provides information about the number of restrictions needed to determine B_0 and to identify the structural form. Indeed, given the symmetry of the variance-covariance matrix Σ_ε, $\frac{N(N+1)}{2}$ restrictions are provided by the model. However, B_0 contains N^2 unknown elements, we need therefore at least $\frac{N(N-1)}{2}$ restrictions to identify the structural form. In other words, if we consider that the number of structural parameters is $(p+1)N^2$ and that the number of estimated parameters of the reduced VAR is $pN^2 - \frac{N(N+1)}{2}$, we should obviously impose at least $\frac{N(N-1)}{2}$ restrictions. In the case of a bivariate model like ours ($N = 2$), we need $\frac{N(N-1)}{2} = 1$ additional identifying restriction.

3.2. Cointegration

The above two approaches for the identification and calculation of structural parameters assume that the VMA (Vector Moving Average) representation of the VAR model in question exists. Insofar as the existence of the VMA representation is conditioned by the stationarity of the VAR process considered, these approaches were applied to stationary patterns in level or in difference. Indeed, when the vector Y_t grouping the variables of the model contains components $I(1)$[5], VMA representation of Y_t can only exist after having differentiated the non-stationary series. This solution is plausible if the econometric tests reveal an absence of cointegration relationships between variables. However, it loses its legitimacy if it turns out that at least one linear combination between the components $I(1)$ of Y_t is stationary. This finding is all the more confirmed when we consider that the differentiation of non-stationary variables mask their long-term properties of particular interest. In addition, the Granger representation theorem tells us that in the presence of cointegration, VECM model should be specified. Add to this, are not the cointegration relationships in themselves restrictions on the dynamic relations of long run equilibrium for identifying permanent components of the model?

VECM representation of a VAR model is an intermediate representation between the VAR model in level, where all series are assumed stationary, and VAR model in first differences characterized by the absence of cointegration.

[5] a series is integrated of order d, denoted $I(d)$, if we must differentiate it d times to make it stationary. A stationary series is described as $I(0)$.

Economically, the usefulness of the VECM lies in its flexibility in modeling several phenomena especially as looking for and achieving economic equilibrium are often hampered by several factors[6]. Incorporating both short run and long run evolutions of variables, the VECM therefore is a dynamic representation for modeling adjustments that lead to a of long run equilibrium situation.

Cointegration theory introduced by Granger (1981, 1983), Granger and Weiss (1983) and Engle and Granger (1987), aims at analyzing the links between the non-stationary components of several series. This theory is based on the existence of some linear combinations of elements of a non-stationary vector which are integrated of a strictly smaller order[7].

Two series y_{1t} and y_{2t} are called cointegrated of order (d, b), denoted $CI(d, b)$ for $0 < b < d$, if: i) y_{1t} and y_{2t} are individually $I(d)$ and ii) there exists a vector $\beta' = (\beta_1, \beta_2) \neq 0$ such that $z_t = \beta_1 y_{1t} + \beta_2\ y_{2t} \backsim I(d-b)$, where $\beta' = (\beta_1, \beta_2)$ is called the cointedrating vector. In practice, the most frequent case studied in the econometric literature corresponds to $d = b = 1$.In this case, two series integrated of order one $I(1)$ are said to be cointegrated if there exists a stationary linear combination $(I(0))$ of these two series[8].

Let the reduced VAR representation described by (2), if we assume that the number of series constituting Y_t is $N = 2$ and that these two series are $I(1)$ and are cointegrated, then we can rewrite (2) as a VECM:

$$\Delta Y_t = \alpha z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (5)$$

$$= \alpha\beta' Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (6)$$

$$= \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (7)$$

where Δ is the first difference operator, $\Gamma_i = -(A_{i+1} + \ldots + A_p)$ for $i =$

[6] These factors include incomplete information and the presence of adjustment costs which are subject to economic operators and traders on the one hand, and the existence of internal and external shocks, on the other hand.

[7] In other words, cointegration states that the eventual existence of linear combinations between series $I(d)$ $(d > 0)$ of order strictly less than d reflects the fact that their non-stationary components are compensated in some way.

[8] The underlying reasoning on which this theory is based is that the evolution of series y_{1t} and y_{2t} can be divergent in the short-term because they are both non-stationary, but they can grow together in the long term. It is then said that there is a long run stability relationship called cointegration.

$1, \ldots, p-1$, the rank of $\Pi = -(I_N - A_1 - \ldots - A_p)$ is equal to $r < 2$ (which amounts to considering that $r = 1$ since the two series are cointegrated), $3b1$ (the weight matrix) and $3b2$ (matrix of cointegration) are of dimension $(2, 1)$ and rank equal to $r = 1$.

3.3. An alternative representation of a cointegrated system

Taking into account the cointegration relationships in the analysis is not a systematic procedure and may expose the modeler to additional difficulties. These difficulties arise when it comes to reversing the VECM in order to achieve a VMA representation of both reduced and structural form of the model necessary for studying the IRF (impulse response fonction) and the FEVD (forecast error variance decomposition). The VECM inversion procedure was the subject of several studies in the econometric literature, including those of King, Plosser, Stock and Watson (1987), Stock and Watson (1988), King et al. (1987, 1991), Warne (1991, 1993), Lütkepohl and Reimers (1992) and Johanson (1995)[9].

The second alternative representation of a cointegrated system is the common trend representation. This representation amounts to considering that if the rank of cointegration of the vector $Y_t \backsim CI(1.1)$ is r (equal to 1 for$N = 2$), then this implies that r stochastic trends are eliminated and that $k = N - r$ trends only remain and which become common to the N components of Y_t. The idea is that the long-term co-movement of cointegrated series is governed by a common trend, which implies reducing the number of stochastic trends.

According to the Granger representation theorem, the equation of the VECM given by (6)[10]can be written as follows:

$$Y_t = \Xi \sum_{i=1}^{t} \varepsilon_i + \Xi^*(L)\varepsilon_t + Y_0^* \tag{8}$$

where $\Xi = \beta_\perp \left[\alpha'_\perp \left(I_N - \sum_{i=1}^{p-1} \Gamma_i \right) \beta_\perp \right]^{-1} \alpha'_\perp$[11], $\Xi^*(L)\varepsilon_t = \sum_{j=0}^{\infty} \Xi_j^* \varepsilon_{t-j}$ is the stationary component of Y_t et Y_0^* contains initial values of the series.

[9]These studies have used an alternative representation of a cointegrated system derived from the Granger representation theorem to perform the VECM inversion procedure.

[10]respecting the following conditions:

a) The number of unit root of non-stationary series is exactly equal to $N - r$.

b) α and β are (N, r) matrices and $rank(\alpha) = rank(\beta) = r$.

[11]Let $P_\beta = \beta(\beta'\beta)^{-1}\beta'$ the projector on the cointegrating space which is of dimension r and $P_{\beta_\perp} = \beta_\perp(\beta'_\perp\beta_\perp)^{-1}\beta'_\perp$ the projector on the orthogonal space to the cointegrating space, of dimension k, such as $\beta'\beta_\perp = 0$ and $P_\beta + P_{\beta_\perp} = I_N$.

where $\beta_\perp$, of dimension (N, k), is a basis of k vectors orthogonal to β.

This representation is a multivariate version of the Beveridge-Nelson decomposition of Y_t. This decomposition is interesting because it breaks down the process Y_t into two parts $I(1)$ and $I(0)$. Thus, Y_t is governed by $k = N - r$ components $I(1)$ represented by $\Xi \sum_{i=1}^{t} \varepsilon_i$[12] and r components $I(0)$ represented by $\Xi^*(L)\varepsilon_t = \sum_{j=0}^{\infty} \Xi_j^* \varepsilon_{t-j}$[13]. The first k non-stationary components of Y_t, also called common trends, drive the system in its long run trajectory. The r transitory components that remain describe the short run behavior of the process. Then, if the N structural innovations w_t deduced from the expression (3) are identified, we may consider that only r of them would have short-term effects. Thus, substituting equation (3), describing the vector of canonical innovations ε_t as a linear combination of structural innovations w_t of the same date, in the expression of common trends gives $\Xi B_0^{-1} \sum_{i=1}^{t} w_i$. The long run impacts of structural innovations are given by the matrix ΞB_0^{-1}. The fact that the rank of the matrix ΞB_0^{-1} is equal to $N - r$ implies that it contains at most r columns of zeros. This amounts to considering that among the structural innovations of the model, only r innovations should have short run effects and the rest of them $(k = N - r)$ are expected to have long run effects.

Given the aforementioned information and the fact that the just identification of a structural model requires the imposition of $\frac{1}{2}N(N-1)$ additional restrictions, then we will need $\frac{1}{2}r(r-1)$ restrictions to identify transitory shocks and $\frac{1}{2}k(k-1)$ restrictions to identify permanent shocks. Identifying structural innovations associated with SVECM therefore requires a total number of restrictions equal to $\frac{1}{2}r(r-1) + \frac{1}{2}k(k-1) = \frac{1}{2}N(N-1) - rk$. The fewer restrictions compared to a SVAR model is due to the fact that in the framework of a SVECM cointegration properties of the variables lead to long-term restrictions provided by the data. This finding is all the more confirmed when considering the case of a bivariate model with one cointegrating relation $(r = 1)$, where the identification of short run and long run shocks occurs without recourse to additional restrictions . It is sufficient in this case to allow the first shock to have a permanent impact and the second one to have a transitory impact or vice versa.

[12] The non-stationary component of Y_t consists of N random walks multiplied by the matrix Ξ of rank $k = N - r$ capturing the long run effects.

[13] Stationarity of the r transitory components of Y_t implies absolute summability of matrices Ξ_j^* capturing the short run impact of shocks. This amounts to considering that these matrices converge to zero as j tends to ∞.

the scenario to be adapted in our paper to study the dynamic relationship between energy consumption and GDP in Tunisia is the one that allows the second shock to have a permanent effect on the variables of the model and the first one to have just a transitory impact. Restrictions will therefore take the following form:

$$\Xi B_0^{-1} = \begin{bmatrix} 0 & * \\ 0 & * \end{bmatrix} \text{ and } B_0^{-1} = \begin{bmatrix} * & * \\ * & * \end{bmatrix} \tag{9}$$

4. Data and results

The model adapted in our paper is a bivariate model containing energy consumption and GDP in Tunisia. Series of energy consumption (kg oil equivalent) and GDP per capita (constant 2000 U.S. $) are obtained from the World Bank. The data are annual and spread over the period 1971-2009.

Performing the usual unit root tests (Augmented Dickey-Fuller (ADF) and Phillips Perron (PP)), we conclude that the logarithms of energy consumption (ene_t) and GDP per capita (gdp_t) are individually $I(1)$ (see Table 1). In addition, the two series appear to exhibit an upward trend and move together in the same direction (see Figure 1). Then we suspect the eventual existence of a cointegrating relation between the two series. To test the eventual existence of cointegration, two approaches can be applied: Engle and Granger's approach (1987) and Johansen's approach (1988). Despite its simplicity of application, Engle and Granger's (1987) procedure suffers from a number of shortcomings. Indeed, in addition to the fact that it is only applicable on bivariate models, the estimated cointegrating relation suffers from a small sample bias[14]. Then we will use in our study the second multivariate approach of Johansen (1988) which is more general and robust. The application of the procedure of Johansen (1988) is intrinsically linked to the type of specification that we want to test depending on whether the cointegrating relation and VECM contain or not a constant and/or a trend. This choice has a direct influence on the Likelihood ratio tests (the trace statistic test and the maximum eigenvalue statistic test[15])

[14]The Monte Carlo simulations performed by Banerjee et al. (1986) and Stock (1987) have focused on this type of shortcoming of Engle and Granger's (1987) approach.

[15]- the trace statistic test allows to test the body of the following hypotheses: the null hypothesis reflects the existence of at most r cointegrating relations, $H_0 : rank(\Pi) \leq r$, against the alternative hypothesis $H_1 : rank(\Pi) \succ r$.

- the maximum eigenvalue statistic test allows to test the existence of r cointegrating relations, $H_0 : rank(\Pi) = r$, against the alternative hypothesis of $r + 1$ relations, $H_1 : rank(\Pi) = r + 1$.

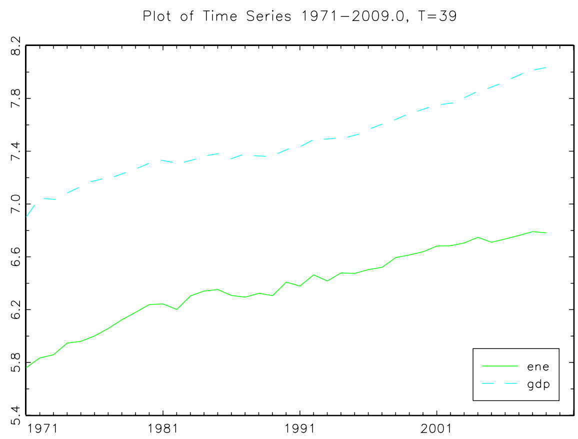

Figure 1: Evolution of logarithms of energy consumption and logarithms of GDP in TUNISIA over the periode 1971-2009.

and the critical values derived from these tests[16].

The specification employed in our model is the one that assumes the absence of a trend in the cointegrating relation and the presence of a constant in the VECM. This choice is motivated by two reasons. The first one is an economic argument which assumes that in a situation of long-term equilibrium, the relationship between consumption and revenue has no trend. The second reason associated with the presence of a constant in the VECM is based on the fact that the logarithms of our two series seem to be characterized by a linear upward trend.

The results of the trace statistic test given by the Johansen procedure is summarized in Table 2. The calculated value of the trace statistic 16.152 is greater than the critical value 15.494 at 5% significance level (see table 3). We therefore reject the null hypothesis of no cointegration. However, we accept the null hypothesis that there is at most one cointegrating relation ($3.013 < 3.841$) at 5% significance level. We therefore conclude with the existence of one cointegrating relation between the logarithms of energy consumption and the logarithms of GDP per capita in Tunisia ($r = 1$). It follows that the appropriate multivariate specification that should be used is the VECM. The lag order of our VECM is equal to 1. The choice of the order of the model is based on the AIC selection criterion.

[16]we will use in our study the trace statistic test which is much more used in the econometric literature.

Table 2: Results of ADF and PP tests

	ADF		PP	
Variables	level	First difference	level	First difference
ene	-2.352	-8.353	-3.268	-8.280
GDP	-0.524	-9.110	-0.512	-8.659
5% critical value	-2.943	-2.943	-2.941	-2.943

Table 3: Johansen cointegration test

Number of cointegrating vector	Eigenvalue	Trace statistic	5 % critical value	Rank r
none	0.298	16.152	15.494	0
at most 1	0.078	3.013	3.841	1

The estimation results of the reduced form of our VECM is given by:

$$\begin{bmatrix} ene_t \\ gdp_t \end{bmatrix} = \begin{bmatrix} 0.355 \\ -0.031 \end{bmatrix} + \begin{bmatrix} -0.081 \\ 0.016 \end{bmatrix} \begin{bmatrix} 1.000 & -0.330 \end{bmatrix} \begin{bmatrix} ene_{t-1} \\ gdp_{t-1} \end{bmatrix} + \begin{bmatrix} -0.346 & -0.077 \\ 0.059 & -0.224 \end{bmatrix} \begin{bmatrix} \Delta ene_{t-1} \\ \Delta gdp_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \quad (10)$$

The inference and the estimation of the structural form of our VECM requires the identification of ΞB_0^{-1}. Since our model is a bivariate model with one cointegrated relation, the just identification of the SVECM doesn't need any additional restrictions. We will just assume according to the neoclassical theory that energy is neutral to growth on the long-term. This assumption implies that we enable the second shock ε_{2t} to have a permanent impact on the variables of the model and ε_{1t} to have a transitory impact.

Estimates of the structural form is therefore as follows:

$$\widehat{B_0^{-1}} = \begin{bmatrix} 0.022 & 0.026 \\ -0.004 & 0.024 \end{bmatrix} \text{ and } \widehat{\Xi}\widehat{B_0^{-1}} = \begin{bmatrix} 0 & 0.007 \\ 0 & 0.022 \end{bmatrix}$$

4.1. Impulse response functions

The study of the responses to shocks through impulse response functions is based on the SVEC identification scheme. Indeed, according to our bivariate model specification and the neoclassical theory's dichotomous assumption, we expect that th first shock ε_{1t} will have a transitory impact, while the second shock ε_{2t} will have a permanent effect. However, this latter long run effect was not treated extensively by the literature. Previous studies have focused only either on causality or on short run shock impact (see M.Balloumi (2009), C.Park, M.Chung and S.Lee (2011), P.K.Narayan, S.Narayan and A.Parasad (2008)).

Our work is distinct from the above works in that it does not confine itself to studying only causality between energy consumption and GDP, but it rather investigates their interdependence by invoking the impact of shocks and repercussions of their propagation on these variables.

Figures 2 and 3[17] show respectively the responses of energy and the production of both types of shocks generated by SVEC modeling, namely short-term and long-term shocks. It is precisely the treatment of both types of shocks that distinguishes our paper from the few attempts that have analyzed our two variables through the SVAR models by investigating only the short-term dynamics. Our duel treatment will enable us to extract the trend and cycle components of the model.

Our model has two structural innovations which one of them should have a permanent impact on the variables since the cointegration rank is equal to one. The two graphs in Figure 3 show the response of the two variables to this long term shock. At this stage, the confidence intervals are constructed from the Hall's percentile method. It should be noted that none of the confidence intervals associated with the impulse response functions does contain zero. It follows then that the long-term effect of the permanent shock on both variables will be significant.

We note, for energy as well as for production, the response to a long-term shock is almost zero at time zero, which confirms the long- term identification scheme. This finding is all the more confirmed for two series since they begin to react from the first year. The estimated production response to the permanent shock is positive throughout the considered period. Furthermore, this response is widened over time, which is quite reasonable in economic terms. The same goes for energy, it reacts positively to the permanent shock in the long term. However, this positive effect is stabilized at the 20th period from which the response enters in a threshold effect phase.

Figure 2 shows the response of the two variables to the transitory shock. It is clear from these graphs that the response patterns of the two variables are very different. Indeed, the transitory shock has an instantaneous and negative impact on production which tends to decay over time to reach zero in the end of period. Meanwhile, Energy reacts positively to the transitory shock. Indeed, it

[17] the abscissa in these impulse response-graphics is the years and the ordinate indicates the response of the variables.

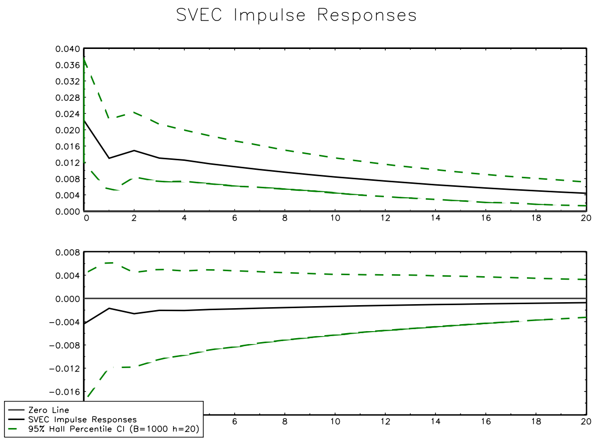

Figure 2: Responses of energy and GDP (top to bottom) to transitory shock (TUNISIA) with 95% Hall percentile bootstrap confidence interval based on 1000 bootstrap replications.

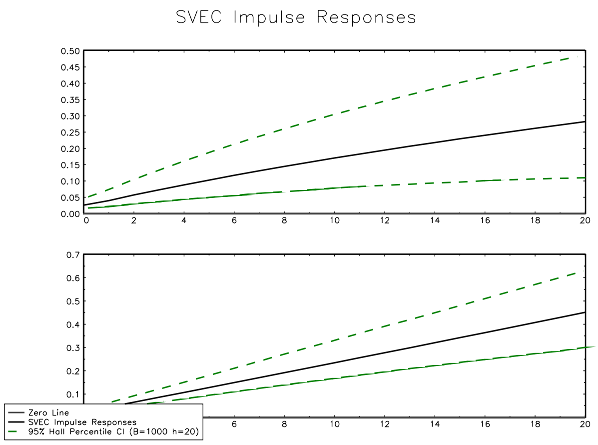

Figure 3: Responses of energy and GDP (top to bottom) to permanent shock (TUNISIA) with 95% Hall percentile bootstrap confidence interval based on 1000 bootstrap replications.

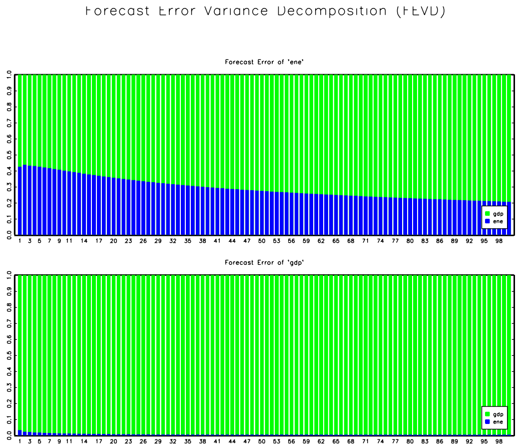

Figure 4: Forecast error variance decomposition of energy and GDP system (TUNISIA) with relative contribution of permanent shock (gdp) and transitory shock (ene).

has an instantaneous response which decreases slowly in the second period from which the shock continues to propagate slowly in an inconspicuous manner and tends to vanish at the end of the period. The fact that the short-term impact on both variables vanish at the end of the period is quite logical since it represents the stationary component of the model.

4.2. Forecast error variance decomposition

Decomposing the variance of the forecast error made in the context of our multivariate structural model is to highlight the contribution of each shock to the variation of a target variable. With regard to the SVEC model, the emphasis is on the proportions of the prediction error variance of two series due to permanent and transitory shocks.

Figure 4 shows respectively the prediction error decomposition of energy and production over a hundred periods. We note that both for production and energy, the impact of long-term (gdp) is increasing over the horizons. However, the importance of short-term shock (ene) declines for our two variables. In fact, production is governed almost in its entirety by a long-term shock and energy tends to be dominated less and less by the short-term shock over the horizons.

5. Economic implications

To properly analyze the empirical results, the following question should be answered to determine the short-term effect of the shock exerted on energy and production: how an oil price shock is transmitted to the public? Two regimes are possible. The first regime is that the shock is transmitted through the State which is supposed to withstand its effects for a period of time and then it starts to prepare the public to bear the costs. In this regime (Tunisia, Sweden), there will be a time lag between the onset of the effective shock, immediately supported by the State, and the individuals' perception of the shock effects occurring afterwards. In such a system, the public (consumers and producers) warned by the shock can take precautions and act in accordance with their interests even before the effective date from which the measures taken by the government (e.g. increase in energy prices) enter into force. However, in the second regime (USA), the market transmits the immediate shock and therefore the public should act accordingly.

5.1. Short run effects

Generally speaking, the shock effect on energy consumption will be positive and decreasing in the short term (see figures 5 and 8). Positivity is due to two main reasons. First, oil is weakly elastic with respect to prices since it is difficult to substitute. Second, the shock may change the behavior of applicants, encouraging them to consume more in the present to guard against a possible future shock. The decrease in quantity consumed is in turn explained by the fact that as economic agents are far away from the shock date, they make sure more of its transitory nature. In the case of Sweden and Tunisia, we see in the very short term the quantities consumed experiencing sharp declines. This reflects the speed of response expressed by different economic agents towards their energy demands. Indeed, as already mentioned, Tunisia shocks are not transmitted immediately to individuals but rather they will be entirely administered by the state. More precisely, the state announces ex-ante it will react on the price vector ex post. Warned, the public seems to respond to informational programs before the announced measures and policies become effective in sourcing the desired quantity to handle at least the immediate future. When the informational vector enters into force (the immediate term), the current energy consumption drops significantly simply because individuals have already taken precautions. However, in the case of the USA, energy consumption increases in the immediate future. Behind this, the immediate transmission of the shock by the market and therefore applicants instantly adjust their behavior to this new information. Increase in quantities consumed is the result of an anticipation elasticity turned upward and prompts more energy demand in the present to guard against possible continuums of future shocks. Obviously, the Swedish case is similar to the Tunisian one because the Swedish government shows its shock response strategy leaving room for individuals to take their steps a few days before the strategy is applied.

Beyond the immediate future, in these three countries, the effect of the shock on energy consumption (in the short term is positive, decreasing and it tends to weaken further). The rationale behind this behavior is explained by the fact that the post-shock pessimism / optimism, generated at the shock time, results in an increased awareness that the aforementioned shock is only transitory and that a return to equilibrium is obvious.

Finally, in the cases of the U.S. and SWEDEN, the reaction of economic shocks is more flexible. Indeed, the U.S. shock vanishes gradually over time. However, in Tunisia the shock effect on energy does not vanish despite its decline. Once again, the nature of the regime that wants to administer shocks in keeping with the government's interest ultimately causes these findings. More specifically, this reflects the reality of a small country (price taker) where individuals will be subject to externalities and constraints imposed on them. As for the short-term effect of the energy shock on production, we may say, with no doubt, it is a different ball of wax: negative in Tunisia but, on the contrary, it is both positive and decreasing in the U.S. and Sweden.

For the Tunisian case, the downward trend in quantities consumed has probably a negative effect on production and especially at shock time. Given that a small country is typically characterized by low-tech and low factor productivity, shock management in the immediate future will penalize production. All things being equal, the shock may raise the costs and expenses of companies (increase in raw material prices, increases in capital price and import prices) and consequently it forces them to reduce in the short term their production to readjust their budget to new spending. However, this does not persist because the negative shock effect on output continues to shrink proving that the productive systems in the short term will converge to their initial levels.

For USA and SWEDEN, the short-term effect exerted by the shock on output is positive and decreasing. The positivity feature is interpreted by an increase in the quantities consumed already resulting from the shock. Moreover, the positive and decreasing effect of the shock on energy seems to stimulate a similar effect on production in identical proportions and trends. A priori, developed countries have already acquired a long experience in the management of these shocks which, therefore, cannot have a negative effect on real variables. Indeed, facing shocks, the productive system automatically protects itself by supplying itself with more energy. This may lead us to ask the following question: can we expect post-shock prosperity?

In short, we can say that the short-term effect exerted by the shock on both energy and production (except in the case of Tunisia, whose production is negatively affected) seems to follow the same rhythm and trend: it is both positive and decreasing.

5.2. Long run effects

In the long term, the shock effect on energy is positive and increasing in Tunisia (see figure 3). However, the aforesaid effect is negative in the U.S. and SWEDEN (see figures 6 et 9). Its magnitude remarkably grows over time. To explain these changes, we note that in developing countries (i.e. Tunisia) production systems are largely dependent on oil. Indeed, almost all companies make use of oil or its substitutes, themselves largely dependent on oil (electricity). In addition, politicians seem to be passive because they do not deploy any energy diversification strategy. In this respect, the expenses incurred by the Tunisian government to search for new energy sources verge on 0%. The incentive scales put in place have not shown, so far, a significant change in the behavior of entrepreneurs who continue to use oil and other sources of oil users. For this, the Tunisian long-term policy will still rely on oil and any futuristic growth of the Tunisian economy is heavily dependent on this input. That is, such a result is worrying as the main problem that should be resolved: what will be the effect of a decision approved by the EU which prohibits the export of goods produced by polluting energy sources? In a global context unanimously advocating the reduction of polluting energy emissions, it should be prepared to undergo economic restrictions either quantitative or qualitative. While the automotive industry in China began to rethink its strategy to produce cars that are subject to the EU restriction in the pollution threshold allowed, no effort is made in Tunisia in this way, which may jeopardize future growth.

In the USA and Sweden, the long- term effect of the shock on energy is negative. This reflects a change in energy cycle, putting an end to oil era and ushering the era of renewable energy (new more efficient and cleaner sources). In this regard, the Swedish Government is planning to get rid of oil dependence by the year 2020.

Examining the graph, such passage is shy at the start and is taking magnitude (from the fifth period). Indeed, this seems to be logic because changing the production system can not be feasible overnight, requiring, of course, some time to take effect. The long-term effect exerted by the shock on output is positive and increasing in both countries. Thus, the shock does not appear to determine growth. This is jointly explained by two fundamental reasons. First, the shock neutrality in the long run, highlighting a return to classical and neoclassical assumptions stating that growth is the result of endogenous and real variables. Second, developed countries will succeed in their strategies of oil substitution by new sources (which explains decreases in energy consumption on the one hand and increases in production, on the other hand).

Examining the U.S. and Sweden FEVD graphs (see Figure 7 and 10) shows that energy is mainly governed by the short-term while production is governed by the long-term. However, this scheme is relatively refunded in the tunisian case (see Figure 4). A priori, in developed countries, energy remains a simple factor competing with other substitutable goods in the short term and long term. That's why the energy variation is much more explained by short term than by long term.

According to economic theory, production depends on the long run productive strategy. Therefore, it reacts weakly with cyclical fluctuations (always converges to the equilibrium growth path).

6. Conclusion

In conclusion, this paper has allowed us to reach several fundamental results both methodologically and empirically. On the methodological level, we have demonstrated, first, that the true dynamic of the relationship binding energy consumption to growth is not necessarily identifiable from the study of causality. Indeed, this dynamic may be better captured by the use of IRF and FEVD which need determining the structural VMA form of the model. Second, as we relied on a SVECM, we were able to identify both the cyclical component of the model and the one that characterizes the trend. Third, from the two previous results, we were able to highlight the response variables (ie energy consumption and growth) to a long run shock. This issue has not been, to the best of our knowledge, addressed in the literature.

Empirically, four results are reached; First, in the short term we noticed that the impact of the shock on energy consumption was generally positive and decreasing. This result may be explained on the one hand by the fact that in the immediate it would be difficult to substitute energy by other goods and, on the other hand, that the shock might encourage economic agents to build up precautions in order to guard themselves against further shocks. Second, the effect of the short run shock on production was positive and decreasing in the U.S. and Sweden and negative and decreasing in Tunisia. A priori, it seems that developed productive systems are not sanctioned by a shock whenever

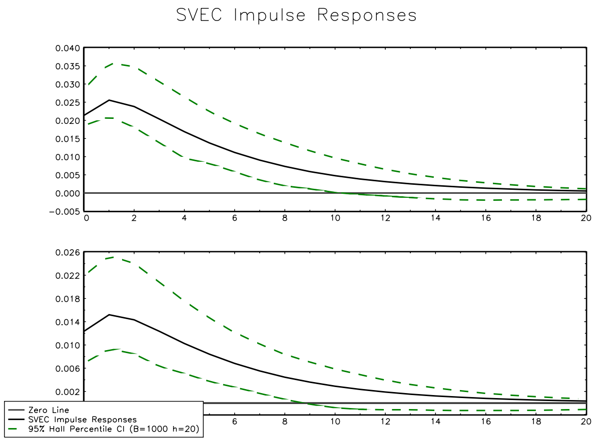

Figure 5: Responses of energy and GDP (top to bottom) to transitory shock (USA) with 95% Hall percentile bootstrap confidence interval based on 1000 bootstrap replications.

alternatives are possible for productivity gains. However, in a small country like Tunisia, the productive system is directly penalized because it would be difficult, in the short term, for the company to endure additional costs to maintain a constant level of production.

Third, the effect of a long run shock on energy consumption in Tunisia was positive and negative in the U.S.A and Sweden. This result is important as it reflects the willingness of developed countries to substitute current energy sources by promoting renewable and cleaner sources. Such a strategy is not approved in the Tunisian case which proves that the electricity era is still long and may be permanent. Quarto and as a consequence to the previous result, the effect of a long run shock on production in the U.S.A and Sweden seems to be positive and increasing. Indeed, the succession of short run shocks encourage decision makers to search for new more productive and effective energy sources. This allows in the long term and even in the very long term to converge to optimal energy which may lead, *ceteris paribus*, to maximizing growth.

Finally, the following question may be asked: does capitalism develop from shocks to which it is confronted? The answer to this question is a priori positive as losses caused by short run shocks will be counterbalanced by futuristic gains translated by increased opportunities for sustainable and more important economic growth.

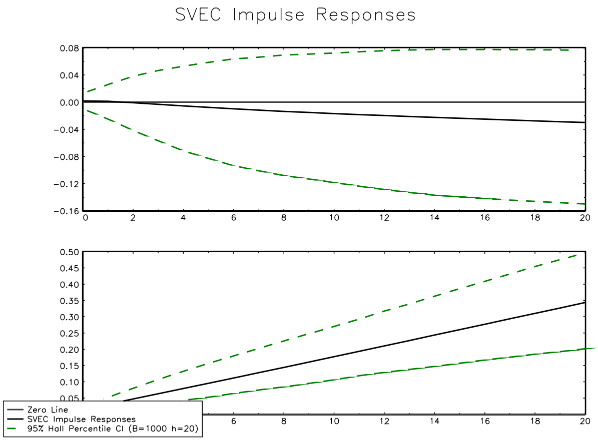

Figure 6: Responses of energy and GDP (top to bottom) to permanent shock (USA) with 95% Hall percentile bootstrap confidence interval based on 1000 bootstrap replications.

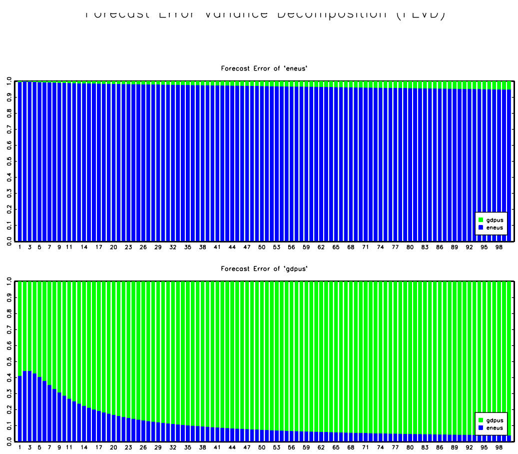

Figure 7: Forecast error variance decomposition of energy and GDP system (USA) with relative contribution of permanent shock (gdp) and transitory shock (ene).

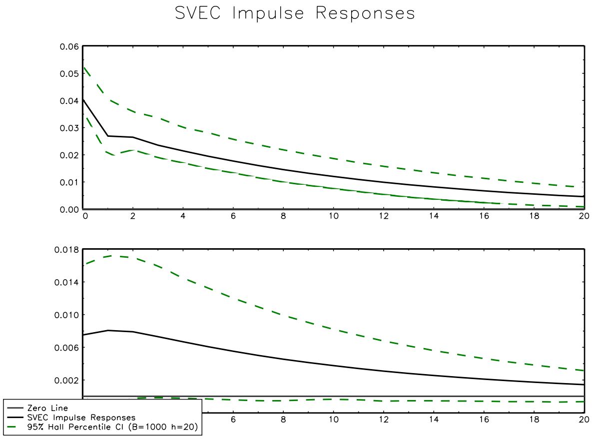

Figure 8: Responses of energy and GDP (top to bottom) to transitory shock (SWEDEN) with 95% Hall percentile bootstrap confidence interval based on 1000 bootstrap replications.

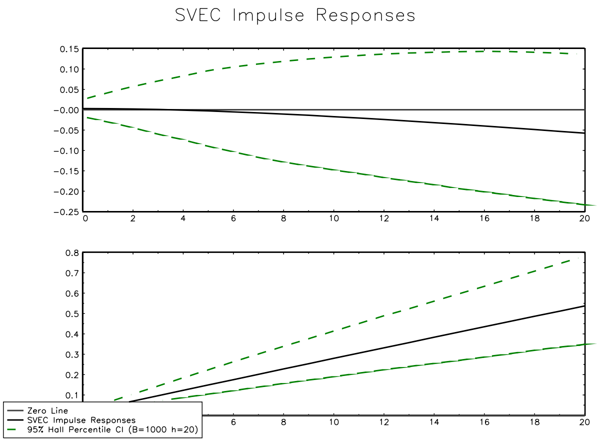

Figure 9: Responses of energy and GDP (top to bottom) to permanent shock (SWEDEN) with 95% Hall percentile bootstrap confidence interval based on 1000 bootstrap replications.

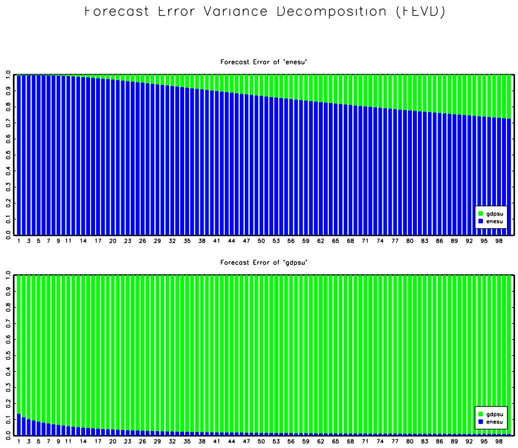

Figure 10: Forecast error variance decomposition of energy and GDP system (SWEDEN) with relative contribution of permanent shock (gdp) and transitory shock (ene).

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