Average price of natural gas increased 9.94 percent per annum within 1967 to 1997. It reached to 31.6 Rials per cubic meter in 1997, from 1.6 Rials per cubic meter in 1967. During recent years (1988 to 1997) the nominal price of natural gas has annually increased 24.4 percent.

Average price of electricityincreased 11.8 percent per annum within 1967 to 1997. This measure changed from 1.42 Rials per kWh in 1967 to 31.6 Rials per kWh in 1997.

Average nominal price of final energy was 1775.5 Rials per BOE in 1988. It expanded to 12429.5 Rials per BOE in 1997 with an annual growth rate of 21.6 percent. While the real price of energy reached to 667 Rials per BOE in 1997 from 664 Rials per BOE in 1988, with growth rate of 0.4 percent per annum.

Up-ward energy price has mainly been adjusting with the aims of controlling the growth rate of energy demand. In spite of policy makers' expectation, this policy has not been succeeded to achieve such goals. High population growth rate, inefficient used technologies, improper combination of private and public vehicles, and etc are the main reasons for high energy intensity that could not be resolved merely by price adjustments.

Final energy intensity would indicate the structural changes in demand side of energy sector. Decreasing the energy intensity is the main target of the Iranian energy policy. Energy pricing policy and other non-price policies affect the trend of energy intensity. Energy intensities for petroleum products, natural gas and electricity have been increasing up to 1989. Substituting petroleum products by natural gas caused decreasing trend of intensity for petroleum products and an increasing trend for natural gas. Also intensity based on electricity has an increasing trend. Final energy intensity was 12.74 BOE per million Rials of real GDP in 1967. It has reached to 41.65 BOE per million Rials of real GDP in 1997 with annual growth rate of 3.9 percent. Although in the period of 1988 to 1997 the annual growth of energy intensity has decreased to 1.6 percent, but it is still increasing.

The trend of demand of carriers has shown that petroleum products have been partially substituting by natural gas. Therefore, taking such a consideration into account drives the priors of our model.

SBVAR model is a robust, reliable rorecasting tool

Model specification for Iran

As we discussed earlier, because of the importance of policy variables e.g. real energy prices and energy intensity criterion, which is essential to be appeared in the specification of the model that non-structural BVAR models ignore them, we have suggested a new model called SBVAR. The specific form of the system 1 for Iran includes three equations for Petroleum products, natural gas, and electricity. The B(L) is a (3×3) matrix of coefficients for lagged dependent variables. The Γ is a (3×4) matrix of the coefficients for policy variables. The (4×1) vector Z then includes real GDP, average real price of petroleum products, natural gas, and electricity. Each prices appeared in its correspondent equation.

All the variables are in the level and in logarithmic values. In a logarithmic functional form of energy demand model the coefficient of real income gives the income elasticity of energy demand. If the coefficient be grater than unity (lower than unity), it means that intensity is increasing (decreasing), whereas the unit amount of elasticity means that energy intensity is constant. Applying Bayesian methodology makes it possible to bring the prior information of improving energy intensity in the future or vise versa. The proposed methodology could take ideas of both engineers and economists about energy intensity into account for more precisely forecasting of the energy demand in the future.

1. Energy Economist, corresponding author. Institute for International Energy Studies (IIES), E-mail: mo_mazraati@yahoo.com

2. University of Technology Sydney, rezafa@eng.uts.edu.au

continued

variable i and j, with the lag length (p). This ratio scales the variables to count for differences in units of measurement and thus enables specification of the prior without consideration of themagnitudes of the variables. The factors base1i and control2i are used to ascertain OT_i and the factors $base2_{ij}$ and control3i are used to determine matrix w_{ij}. The base1i measures the initial standard deviation of the first own lag of a univariate autoregresive equation of degree one. This initial value changes with factor control2i. According to Standard Symmetric Minnesota prior, the and control3i are set to 0.5 and unity respectively. Otherwise they would settle an asymmetric prior, which might be based on experiences of the researcher or "finding final model procedure" (next section).

The $S^{o}d(\gamma_{iz})$ is the prior standard deviation of variable z in equation i. The factor base3iz is the initial value that is determinable by a dynamic structural model. The control4iz is the factor in which changes the intial prior value

The parameters base1i, $base2_{ij}$, $base3_{ij}$, d, control1i, control2i, control3i, and control4ij are called hyper parameters. Given these small numbers of parameters a large number of prior standard deviations are effectively ascertained. Assuming the value of control factors to unity makes the standard Minnesota Priors.

2-3) Finding final model for Bayesian and UVAR Models

The hyper parameters are arbitrarily changed by researcher. Thus, many prior variances can be achieved for the coefficients. Evaluating the n period ahead forecasting, we could find out the best prior variances as well as the best-estimated model. Using Rolled-up regressions and calculating Mean Absolute Errors (MAE), Mean Absolute Percentage Errors (MAPE), Root Mean Squared Percentage Error (RMSPE), U-Theil or U criteria for one (n) year(s) ahead forecast, the model with least forecasting error is chosen. An alternative approach for evaluating the accuracy of the models is to count wins and losses of the models to give forecast errors. Each model will be ascribed a win when its absolute forecast error is lower than other model and vice versa.

Final estimation of the UVAR model is achieved by determining the optimal lag length. Optimal lag length is determined through some informative criteria like Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and likelihood ratio that in turn may not lead to a unique solution.

some policy variables have been added in the BVAR model as a new way of modeling.

Energy Demand in Iran and Extracting Prior Information

For specifying a suitable models and quantifying priors for estimating BVAR or SBVAR model for Iran, the structure of energy demand in Iran is analyzed. To this end, demand of energy carriers, energy intensity and prices are discussed.

In this study, energy carriers include petroleum products, natural gas and electricity, which cover 98.4 percent of total final energy demand in Iran. Petroleum product consumption has annually increased 7.3 percent, and it changed from 20.3 million liters per day in 1967 to 180.6 million liters per day in 1997. Whereas, the annual growth rate has amounted to 3.9 percent within 1988 to 1997 ũ, mainly due to natural gas substitution.

Natural gas consumption has increased annually 20 percent from 0.3 million cubic meters per day in 1967 to 120 million cubic meters per day in 1997. Although the annual growth of natural gas has decreased to 14.4 percent within 1988 to 1997, high level of consumption means that the substitution policy is under execution.

Electricity consumption has annually increased 13.2 percent. It has changed from 4 million kilowatt per hour (kWh) per day in 1967 to 207.4 million kWh per day in 1997. The annual growth rate of electricity demand has decreased to 8.3 percent within 1988 to 1997. It is mainly because of market saturation and relative completeness of the electricity grid.

Energy prices were almost unchanged for a long period of time. A continuos up-ward adjustment of nominal energy prices have been approved as an Act to be executing by energy authority for the second and third Iranian five-year Development Plan (1995-2004).

The weighted average prices of petroleum products was 2.5 Rials per liter (1$=70 Rial) in 1967. It has been increased 10.6 percent per annum and reached to 60.3 Rials per liter (1$=3007.5 Rialsب) in 1997. Annual growth rate of the price of petroleum products has been 20.3 percent within 1988 to 1997.

Where $(T\times1)$ vector E_{it} is series of dependent variable in equation I; X is a $[T\times(1+(I\times p)+H)]$ vector of all right hand variables in a typical equation; the $[(1+(I\times p)+H)\times1]$ vector λ contains all coefficients of a typical equation; and $(T\times1)$ vector ε_t is stochastic disturbance terms. In addition, the $[(1+(I\times p)+H)\times1]$ vector r contains prior means and $\{[(1+(I\times p)+H)]\times([(1+(I\times p)+H)]\}$ diagonal matrix R includes standard deviations of parameters of a representative equation of system (1); the $[(1+(I\times p)+H)\times T]$ vector U contains the stochastic part of restriction, given $var(U)=var(\varepsilon_t)=S^2$. The scalar is standard deviation of the equation; and $Sd^o(\lambda)$ is prior standard deviation of coefficients in the equation (For practical calculation, see equations 8 to 12). Then the estimators would be:

$$\hat{\lambda}_{Bayesian} = (X'X + R'R)^{-1}(X'E_{it} + R'r) \quad (3)$$

$$Var(\hat{\lambda}_{Bayesian}) = \hat{S}^2(X'X + R'R)^{-1} \quad (4)$$

Where S^2 is defined as follows:

Where $\hat{S}^2$ is defined as follows:

$$\hat{S}^2 = \frac{(E_{it} - X\lambda_{OLS})'(E_{it} - X\lambda_{OLS})}{T-k} \quad (5)$$

In relation (5) λ_{OLS} is the OLS estimation of λ and (T-k) is the degree of freedom with T observations and k parameters.

2-2) Prior Information Determination for Bayesian Method

Litterman (1981) introduced a simple but informative procedure for determining the prior means and variances of each representative VAR equation in the model (1). This is called "Minnesota priors" (Todd, 1990b). General idea for determining priors is that current lags are more informative and have higher explanatory powers. So according to "random walk with drift" hypothesis, the prior mean of the first own lag coefficient is set to unity and a prior mean of zero is assigned to all other coefficients indicating that these variables are viewed as less important in the model. According to intercept terms, the prior means is determined by OLS estimation of the intercept of a univariate equation of dependent variable over its first own lag ($c^\wedge_i$). In the case of SBVAR, the prior means of policy variables ($\gamma^\wedge_{iz}$, Third term of system 1) must also be determined. On the base of our suggestion, these prior means might be determined by a dynamic structural model, which contains some lagged dependent variables. These can be estimated by SUR or OLS methods, including an error correction term, if any. Technically, it is specified as follows:

Prior Means:

$$\beta^o_{ijk} = 1 \qquad \forall\ i=j \text{ if } k=1; \text{Otherwise} \qquad \beta^o_{ijk} = 0 \quad (5)$$

$$\overset{o}{C}_i = \hat{c}_i \quad (6)$$

$$\overset{o}{\gamma}_{iz} = \hat{\gamma}_{iz} \quad (7)$$

The prior variances which specifying uncertainties on prior means decrease through lag lengths. In other words, with increase of lag length, researcher precisely accepts zero means for coefficients (β_{ijk}) . This is the general rule for determining the standard deviation of the parameters. Since the model contains huge number of parameters, Litterman (1980) suggested a formula to generate the standard deviations as a function of a small number of hyperparameters. For the intercept terms the preliminary prior standard deviation is set sufficiently large to let the data determines its quantity, i.e. the prior distribution of coefficient is highly flat (Racette, et al, 1994). In the case of SBVAR, the prior standard deviations of policy variables ($\gamma^\wedge_{iz}$, Third term of system 1) must also be determined. On the base of our suggestion, the initial prior standard deviations might be determined by a dynamic structural model, which contains some lagged dependent variables. These can be estimated by SUR or OLS methods, including an error correction term, if any. Technically, it is specified as follows:

Prior standard deviations:

$$\overset{o}{S}d(C_i) = OT_i * \hat{S}^p_i * control_{1i} \qquad \forall\ i \quad (8)$$

$$\overset{o}{S}d(\beta_{ijk}) = OT_i * W_{ij} * K^{-d} * \frac{\hat{S}^p_i}{\hat{S}^p_j} \qquad \forall\ i,j,k \quad (9)$$

$$OT_i = base_{1i} * control_{2i} \quad (10)$$

$$W_{ij} = base_{2ij} * control_{3i} \quad \text{if } i \neq j \qquad \text{otherwise } W_{ij} = 1 \quad (11)$$

$$\overset{o}{S}d(\gamma_{iz}) = base_{3iz} * control_{4iz} \qquad \forall\ i,z \quad (12)$$

Where $S^od(C_i)$ stands for the standard error of intercept of equation i. The term OT_i describes the overall tightness of the distribution of the coefficients. A tighter prior evolves as the value of the OT_i decreases. The term $S^\wedge{}^p_i$ is standard errors of a univariate autoregressions for dependent variable of equation i, with the same lag length (p). The variables control1i is a factors for changing prior standard deviation of intercept parameters of equation i.

The $S^od(\beta_{ijk})$ is the prior standard deviation of variable j, equation i, at lag k. The prior tightens on increasing lags by using a larger value of d. The parameters W_{ij} are relative tightness or namely matrix weights. This matrix makes differences between own and cross lags in each equation. So it captures the tightness of variable j in equation i as compared with variable i. Lower values of W_{ij} decreases the interaction between cross variables. The K^{-d} is the lag decay with decay factor d that has a harmonic shape (d=1). The term $\frac{S^\wedge{}^p_i}{S^\wedge{}^p_j}$ is scaling factor, where $S^\wedge{}^p_i$ and $S^\wedge{}^p_j (i\neq j)$ are standard errors of each univariate autoregressions for

Theil-Goldberger as an approximation of Bayesian method is used for estimation of a BVAR model. It is believed that the BVAR models have better forecasting performance (Todd, 1990b). So the present paper is comparing the forecasting performance of VAR and BVAR model to accept or reject the above mentioned judgments in the context of Iranian energy demand model. Another class of modeling, which is a hybrid of UVAR and classical structural models and in this study is called SVAR models, is also discussed. As a new class of modeling that is a hybrid model of BVAR and classical structural models, which we have named it as "Structural Bayesian VAR (SBVAR)" model are also analyzed in this paper. The SBVAR is the paper's contribution in the literature of Classical and Bayesian econometric modeling.

The rest of the paper is organized as follows: Section 2 discusses the model specification, which gives a general form of spesification for UVAR, SVAR, BVAR, and SBVAR. Classical vs. bayesian estimation technique, prior information determination for bayesian method, and finding final model for bayesian and/or UVAR models are theoriticaly discussed in this section. Section 3 presents the energy demand in Iran and extracting prior information for Iran. Section 4 analyzes model specification for Iran. Section 5 presents Estimation and comparisons. Section 6 offers policy implication of the SBVAR model. Finally section 7 contains conclusion.

Due to the importance of real energy prices and the energy intensity criterion or generally policy variables, the methods of structural and non-structural modeling has been combined

Model Specification and Estimation

We introduce a general from, which represent the UVAR and SVAR models. The UVAR is a linear combination of all lagged variables, presented in the model including intercept terms in each equation, where a SVAR model also includes some policy variables. The general form is as follows:

$$E_t = C + B(L)^* E_t + \Gamma^* Z_t + \varepsilon_t \quad (1)$$

Where, the model parameters B(L) is a vector of (I×J) and takes the form, $B_{ij}(L) = \sum_{k=1}^{p} L^k \beta_{ijk}$, where L the lag operator is defined by , $L^k E_t = E_{t-k}$ is the lag length, and i and j are the counter of the equation and endogenous variables respectively. Also E_t is a (I×1) vector of endogenous variables while Z is a matrix of (H×1) and stands for exogenous or policy variables, also Γ is a matrix of (I×H) size indicating the coefficient of policy variables. Furthermore, ε_t is stochastic disturbances term, which is assumed to be white noise. Right-hand-side variables of the model (1) are predetermined variables. So the OLS method can be used for estimation of coefficients and SUR method has no more advantage (Pindyck et. al., 1991). Optimal lag length (p) is experimentally determined by some Information Criteria. A model that just includes the first and second terms of the system (1) is a typical UVAR model while the whole system (1) is a typical form of a SVAR model. Applying the Bayesian technique of estimation, instead of classical techniques, for the former and latter cases, one could addresses the systems as BVAR and our proposed SBVAR models, respectively. The SBVAR model is our paper's contribution to the former models of UVAR, SVAR, and BVAR. It is practically proved that SBVAR outperform the other models, in the context of Iran's energy demand.

2-1) Classical vs. Bayesian Estimation Technique

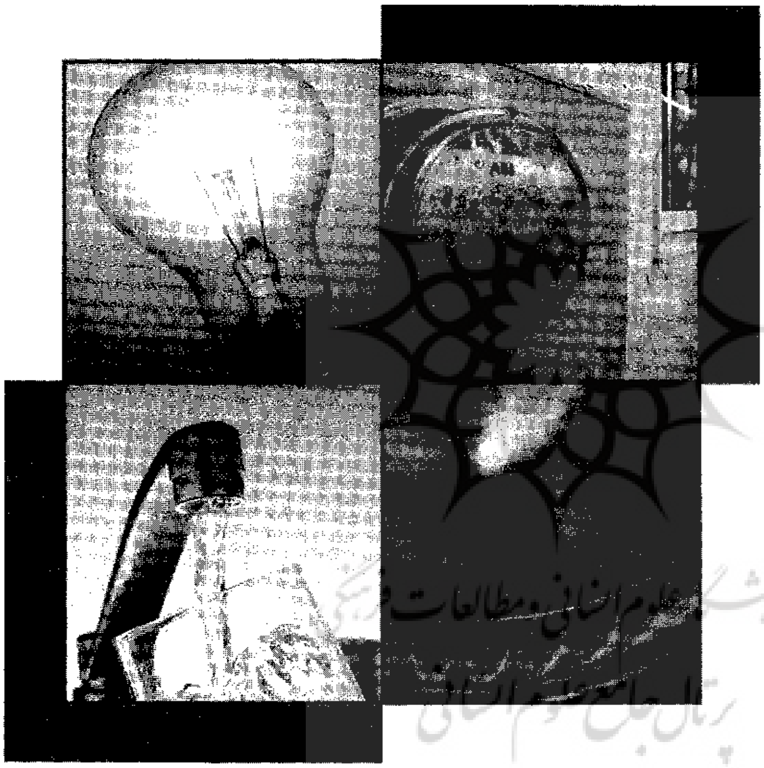
Classical approach is based on a hypothetical repeated sample, using statistical inferences. In the Bayesian analysis, instead of producing a point estimator, it produces a density function of a parameter as its prime piece of output, called posterior density function. The Bayesian method is based on the Bayes theorem named after Tomas Bayes that is based on inductive reasoning. (Gower, 1997). Bayesian estimation of coefficients needs prior information in the form of means and variances (Kennedy, 1999). The stochastic restriction method of Theil-Goldberger, or so-called mixed estimation method is used for Bayesian estimation of VAR models (Borissov, 1992 & Kirvelyova, 1992). In a special case, the mean of posterior distribution is a point Bayesian estimator (Green, 1993; Zellner, 1996).

A practical method for combining prior information and the information of time series is the stochastic restriction method of Theil-Goldberger (Borissov, 1992 & Kirvelyova, 1992). That is,

$$\begin{cases} E_H = X\lambda + \varepsilon_H \\ \text{S.t.}: r = R\lambda + U \quad r = \left(\dfrac{S}{\overset{0}{Sd(\lambda)}} \otimes I \right)^* \lambda + U \end{cases} \quad (2)$$

Improved Forecasting and Policy Analysis of Energy Demand in Iran

Mohammad Mazraati (Ph.D.)[1]
Reza Fathollahzadeh Aghdam (MSc.)[2]



ABSTRACT

This paper has modeled demand of major energy carriers including petroleum products, natural gas and electricity by VAR and BVAR models. Also knowing the current and future changes in Iranian energy sector, the energy intensity and actual prices have been added to the BVAR model as a new way of modeling. This approach combines Structural and Non-Structural econometric modeling method and introduces a Hybrid model of SBVAR. Using General and Symmetric Minnesota priors, Theil-Goldberger technique and the Rolled-up regressions, it is shown that SBVAR model has better forecasting performance. Also forecasting the energy demand shows that because of considering natural gas substitution in the model, the sub-hypothesis "Iran will become a net oil importer up to 2011" is rejected. Further more as an advantage of SBVAR model, policy analysis is possible and it shows that Non-price policies have better effects on conservation of energy and reduction of energy intensity.

Key Words: Energy demand, Iran, Bayesian, Vector Autoregressions, Structural, forecasting performance.
JEL Classification: C, Q

Introduction

Classical econometrics is based on statistical inference. Basically it has been used for empirical testing of some economic theories. These models are based on specific theories (formally or informally) or specifying economic structure. Therefore, they are called as structural models. Sims (1980) is one of the critics of this kind of modeling. According to Sims' criticisms for specifying a model, the modelers may impose incredible restrictions. Also in many cases, economic theories may not be sufficient to determine the right specifications. Sims offered an alternative method of modeling as "Unrestricted Vector Autoregressions" (UVAR) that is not based on a specific economic theory.

The UVAR is called non-structural model (Adams et. al., 1995; Enders, 1995). Although UVAR model has been criticized by many researchers but it has been used in different economic contexts (Todd, 1990a). On the other hand, Non-classical (Bayesian) branch of econometrics has developed based on Bayes theorem and statistical analysis (Kennedy, 1990 and Zellner, 1994,1996). Litterman (1981) applied Bayesian method for estimating coefficients of the VAR models, named as BVAR models. Litterman (1981) and others in Federal Reserve Bank of Minneapolis and Minnesota offered a simple but informative method of quantifying prior information for coefficients of a VAR model (karlsson, 1989,1993). This is namely called Standard Minnesota Priors or simply Minnesota priors. Other researchers have adjusted the Minnesota idea and quantified the prior information (Raccette, 1994; Borissov, 1997; Francisco, 1995 and Dua, 1995, 1996).

Knowing the prior information, the mixed estimation method of