

ENERGY CONSUMPTION AND ECONOMIC GROWTH IN SWEDEN: A LEVERAGED BOOTSTRAP APPROACH, (1965-2000)

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Abstract

The causal interaction between energy consumption, real activity and the prices in the Swedish economy is investigated over the period 1965-2000. The leveraged bootstrap simulation technique is used to generate more reliable critical values for tests of Granger causality between integrated variables. The estimation results reveal that energy consumption does not cause economic activity but rather it is caused by economic activity. Also we find that prices cause both economic activity and energy consumption without feedback causal relationship from these variables. The policy implications of these causal findings are explained.

JEL Classification: C32, Q43

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1. Introduction

The role of energy in economic growth is not without controversies in the empirical studies since energy promotes the productivity of capital, labor, and other productions factors. In the past two decades, several studies have examined the causality between energy consumption and economic growth in industrialized countries. To date, the empirical results have been mixed and conflicting. Kraft and Kraft (1978) find unidirectional causality running from output to energy consumption in the US. Akarca and Long (1979) find

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evidence in favor of causality running from energy consumption to employment (output) in the US. Akarca and Long (1980), Yu and Hwang (1984), Erol and Yu (1987a, 1987b), and Yu and Jin (1992) find no causal relationships between output (or employment) and energy consumption in industrialized countries.

However, the bulk of the literature has so far produced inconsistent and elusive results concerning the causal relationship between energy consumption and economic growth. This may stem from (i) different institutional, structural frameworks and the policies followed of the countries under consideration, (ii) the time period chosen, and (iii) the methodological differences.

The direction of causation between energy consumption and economic growth has important policy implications. A unidirectional causality running from output to energy consumption may imply that energy conservation policies have little adverse or no effects on economic growth. For example, in the case of negative causality running from output to energy consumption, implementing energy conservation policies could lead to a rise in total output (or employment). On the other hand, a unidirectional causality running from energy consumption to income may imply that energy consumption affects economic growth. For example, reducing energy consumption could create a fall in income or employment. The finding of bi-directional causality or feedback between energy consumption and output implies that a high level of economic growth leads to high level of energy demand and vice-versa.

Energy conservation policies aimed at declining energy use must look for some channels to reduce consumer demand in order to impede unfavorable effects on economic growth. Such an attempt could be achieved through an appropriate combination of energy taxes and subsidies. Policy-makers should also encourage industries to adopt technology that reduces pollution. Finally, the finding of no causality in either direction, the so called “neutrality hypothesis”, would mean that energy conservation policies do not affect economic growth.

The purpose of this paper is to examine the energy-income relationship for Sweden. Annual time series data over the period 1965-2000 were utilized in this study. The choice of the time period was constrained by availability of data on energy consumption and the choice of Sweden is justified by the fact that it is a market-oriented economy with relatively unregulated capital accounts, and the sample period does include boom period with improved government finances, external net borrowing, and full employment and a bust period with rapidly increasing unemployment and deteriorating government finances. Thus, the sample is not tranquil in a way that could favor any hypothesis mentioned above.

The departure from earlier studies of the causality between energy consumption and economic growth is in the methodology used to examine the interaction between variables. We apply a leveraged bootstrap approach recently developed in the literature (Davidson and Hinkley, 1999; Hacker and Hatemi-J, 2006). The method adopted here differs from previous studies in the following aspects: it is not sensitive to the assumption of normality; it works well for non-stationary data; it has better small sample properties compared to standard tests; and the empirical analysis includes price developments in the specification because they play a crucial role in affecting energy consumption and most importantly, as a proxy for the degree of the efficient functioning of the economy. In other words, an improvement in economic efficiency through structural means is expressed by price developments and economic growth.

The paper proceeds as follows: Section 2 deals with methodological issues and the data used in the empirical analysis, while in Section 3 the empirical evidence is presented. Finally, Section 4 offers conclusions and policy implications.

2. Data and Methodology

The sample period is 1965-2000, and the definitions and sources of variables are as follows:

EC: total commercial energy use in tons of oil equivalent, data was obtained from British Petroleum, various issues.

RY: real income, defined as GDP in constant 1995 prices (deflated by consumer price index) in terms of SEK, data was collected from International Financial Statistics, various issues.

CPI: consumer price index, data was taken from International Financial Statistics, various issues.

Figure 1. Energy and Gross Domestic Product in Sweden

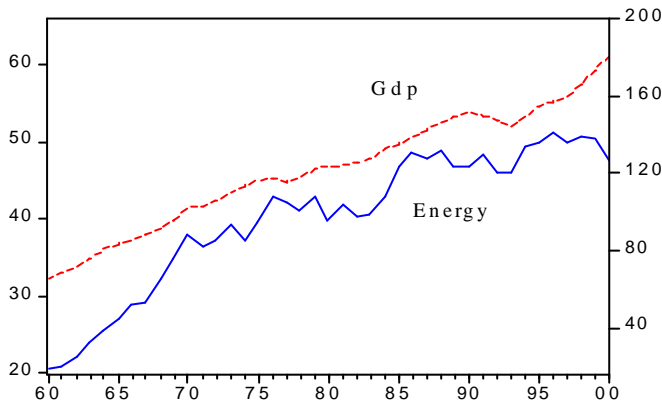


Figure 1 presents the evolution of the Energy Consumption (thousand kt of oil equivalent) and real Gdp (billion of dollars at 1995 prices and exchange rates) of Sweden. Since the data generating process for many time series is characterized by unit roots (non-stationarity) special attention should be paid to the time series properties of the data in order to avoid spurious and misleading inference. It is well known that the standard ADF tests for unit root have low power if structural breaks are present. To account for the oil shock when tests for unit roots are conducted we make use of the Perron (1989) test. This test is based on the following regression:

$$y_t = c_1 + c_2 D_t + d_1 t + d_2 D_t t + g J_t + r y_{t-1} + \sum_{i=1}^n b_i D y_{t-i} + j_t, \quad (1)$$

where t = the time period (the linear trend term), D_t is equal to zero if $t \leq 1973$ and it takes value one if $t > 1973$, J_t is equal to one if the time period t is the first period after that of the structural break, and is 0 otherwise, Δ denotes the first difference, j_t represents a white noise error term, and y denotes the variable that is tested for unit root. Regression (1) allows for a structural break in both the mean value and the deterministic trend of the variable under investigation. The null hypothesis is of a unit root is $\alpha = 1$. The optimal number of lagged differences (n) is chosen by including more lags until the null hypothesis of no serial autocorrelation for j_t is not rejected by the Ljung-Box test at the 5% significance level.

To test for causal effects between energy consumption, economic activity and prices we utilize the following vector autoregressive model of order p , VAR(p):

$$y_t = \alpha + A_1 y_{t-1} + \dots + A_p y_{t-p} + e_t, \quad (2)$$

where y_t is 3×1 vector of our variables, α , is a 3×1 vector of intercepts and e_t is a 3×1 vector of error terms. A denotes the matrix of parameters.

In this paper, we check whether each of these variables is Granger caused by either of the other two variables. Before conducting tests for causality, there are several other issues that deserve mentioning. The choice of the optimal lag order is important because all inference in the VAR model is based on the chosen lag order. To this end, we make use of a new information criterion introduced by Hatemi-J (2003). This new information criterion performs well especially for non-stationary data and it is described below:

$$HJC = \ln(\det \hat{W}_j) + j \left(\frac{n^2 \ln T + 2n^2 \ln(\ln T)}{2T} \right) \quad j = 0, \dots, p, \quad (3)$$

here \ln signifies the natural logarithm, $\det \hat{\Omega}_j$ is the determinant of the estimated variance and covariance matrix of the error terms in equation (2) for lag order j , n stands for the number of variables (three in this case), and T is the sample size used to estimate the VAR model. The lag order that minimizes equation (3) is the optimal lag order.

According to Sims et. al. (1990) standard distributions usually do not apply for testing Granger causality if the variables are integrated. To remedy this shortcoming Toda and Yamamoto (1995) suggest an augmented VAR($p+d$) model to be used for tests of causality between integrated variables. The authors suggest augmenting the VAR model by extra lags, d , which is equal to the integration order of the variables. Consider the following augmented VAR ($p+d$) model:

$$y_t = \mathbf{n} + A_I y_{t-1} + \dots + A_p y_{t-p} + \dots + A_{p+d} y_{t-p-d} + \mathbf{e}_t. \quad (4)$$

The null hypothesis on non-Granger causality is defined as:

$$H_0: \text{the row } j, \text{ column } k \text{ element in } A_r \text{ equals zero for } r=1, \dots, p \quad (5)$$

Let us to make use of the following denotations in order to describe the Toda-Yamamoto test statistic in a compact way:

$$Y := (y_1, \dots, y_T) \quad (n \times T) \text{ matrix,}$$

$$D := (y, A_I, \dots, A_p, \dots, A_{p+d}) \quad (n \times (1 + n(p+d))) \text{ matrix,}$$

$$Z_t := \begin{bmatrix} 1 \\ y_t \\ y_{t-1} \\ \vdots \\ y_{t-p-d+1} \end{bmatrix} \quad ((1 + n(p+d)) \times 1) \text{ matrix, for } t = 1, \dots, T,$$

$Z := (Z_0, \dots, Z_{T-1}) \quad ((1+n(p+d)) \times T) \text{ matrix, and}$

$d := (e_1, \dots, e_T) \quad (n \times T) \text{ matrix.}$

By means of this notation, the estimated VAR($p+d$) model can be represented compactly as:

$$Y = DZ + d. \quad (6)$$

We continue by estimating \hat{d}_U , the $(n \times T)$ matrix of estimated residuals from the regression (6) without imposing the null hypothesis of no causality. Then the matrix of cross-products of these residuals are computed as $S_U = \hat{d}_U' \hat{d}_U$. We define $b = \text{vec}(D)$, where vec means the column-stacking operator. The modified Wald (MWALD) test statistic, introduced by Toda-Yamamoto, for testing non-Granger causality is then written as

$$MWALD = (C\hat{b})' [C(Z'Z)^{-1} \otimes S_U]^{-1} (C\hat{b}) \sim \chi_p^2, \quad (7)$$

where \otimes is the Kronecker product, and C is a $p \times n(1+n(p+d))$ matrix. Each of the p rows of C is associated with the restriction to zero of one parameter in b . The elements in each row of C acquire the value of one if the related parameter in b is zero under the null hypothesis, and they get the value of zero if there is no such restriction under the null. Using these notations, the null hypothesis of non-Granger causality can be expressed as the following:

$$H_0 : Cb = 0.$$

The MWALD test statistic is asymptotic χ^2 distributed with the number of degrees of freedom equal to p , the number of restrictions to be tested. However, Hacker and Hatemi-J (2006) demonstrate that the inference based on the Toda-Yamamoto test statistic becomes

more precise if bootstrap distributions are utilized instead of asymptotic chi-square distributions. For this reason, we will make use of the bootstrap simulation techniques to produce our own critical values in causality tests. It should be mentioned this technique is based on the empirical distribution of the underlying data set and it is not sensitive to assumption of normality. Another issue that is important to take into account is the presence of autoregressive conditional heteroscedasticity (ARCH). In order to guarantee that the presence of ARCH effects does not render bias in estimated results we use the leveraged bootstrap as suggested by Davison and Hinkley (1999) and Hacker and Hatemi-J (2006). The bootstrap technique, introduced by Efron (1979), is based on resampling the data set to estimate the distribution of a test statistic. Using this distribution can decrease bias in inference by providing more precise critical values.¹ The simulations are conducted by programming in Gauss.²

3. Empirical Results

The estimation results for unit root tests are presented in Table 1. Based on these results we can conclude that each variable is integrated of order one.

Prior to tests for causality the lag order was set to three because this lag order minimized the information criterion presented in equation (3). The results of leveraged bootstrap tests are presented in Table 2.

¹ The bootstrap technique is not described here to save space. The interested reader is referred to Efron (1979) for introduction of the technique and Hacker and Hatemi-J (2006) for discussion of this technique regarding the Toda-Yamamoto test.

² A program procedure written in Gauss to conduct the leveraged bootstrap simulations is available on request from the authors.

Table 1. Unit Root Test Results Based on Perron Test.

VARIABLE						99%	95%
EC_t	ΔEC_t	CPI_t	ΔCPI_t	RY_t	ΔRY_t	CV	CV
-2.40	-5.75	-1.45	-4.41	-1.03	-3.85	-	-3.80
(0)	(0)	(1)	(0)	(0)	(0)	4.41	

Notes: CV=Critical Value. The numbers in the parentheses indicate the number of lags required to remove potential autocorrelation in the Perron regression (equation 1) at the 5% significance level using the Ljung-Box test. D is the first difference operator.

Table 2: Results of Causality Test Based on Bootstrap Simulation Techniques.

The null hypothesis	The estimated test value (mwald)	1% bootstrap critical value	5% bootstrap critical value	10% bootstrap critical value
$CPI \neq RY$	17.643***	17.386	11.340	8.260
$CPI \neq EC$	10.543**	15.705	8.612	7.014
$EC \neq CPI$	0.617	12.270	9.140	6.814
$EC \neq RY$	2.515	13.270	8.553	6.798
$RY \neq CPI$	3.272	13.370	8.961	7.326
$RY \neq EC$	12.055**	16.131	8.710	6.886

Notes: MWALD is the modified Wald test, which described in equation 6. The notation \neq implies non-Granger causality. The notation ***, **, and * means that the null hypothesis on Non-Granger causality is rejected at the 1%, 5% and 10% significance level, respectively. The lag order of the VAR model, p , was set to three. Also the augmentation lag, d , was set to one since each variable contains one unit root.

The estimation results reveal that energy consumption does not cause economic activity but rather it is caused by economic activity. Also we find that prices cause both economic activity and energy consumption without feedback causal relationship from these variables. Generally speaking, improvements in economic efficiency, resulting from productivity increases by promoting endogenous growth mechanisms would enhance economic growth and consequently favorably affect energy consumption. This also implies

that there is scope for energy conservation measures without serve impacts on economic growth. Furthermore, economic efficiency as reflected in price developments, is a determining factor of both energy consumption and output behavior.

4. Summary and Conclusions

The causal interaction between energy consumption, real activity and the prices in the Swedish economy is investigated over the period 1965-2000. Prior to conducting tests for causality, the time series properties of the underlying data are checked through a Perron test.

The results show that each variable is integrated of the first degree. We have also paid extra attention to capturing the appropriate dynamics of the model by applying a new information criterion that works well for choosing the optimal lag order in the VAR model containing integrated variables. The leveraged bootstrap simulation technique is used to generate more reliable critical values for tests of Granger causality between integrated variables. This method is not sensitive to the non-normal distribution of the error terms and it is robust to the presence of autoregressive conditional heteroscedasticity. Also this simulation technique seems to have better small sample properties.

The estimation results reveal that energy consumption does not cause economic activity but rather it is caused by economic activity. Also we find that prices cause both economic activity and energy consumption without feedback causal relationship from these variables. The established unidirectional causality running from income to energy, may imply that energy conservation policies may be implemented with little adverse or no effects on economic growth. Moreover, economic efficiency, as reflected in price developments, is a determining factor of both energy consumption and output behavior.

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