Structural breaks and energy efficiency in Fiji

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Abstract

This paper examines how energy-output ratios in Fiji have responded to the energy crises and in particular if they have declined after the shocks. The expectation is that energy efficiency should improve after the oil shocks. For this purpose we used at first a few simpler procedures and then the recently developed tests for structural breaks by Bai and Perron (1998 and 2003).

Keywords: Energy Output Ratios, Energy efficiency, Structural Breaks, Deterministic and Stochastic trends and Bai and Perron tests.

JEL Classification: O30, O13, Q32, Q40, Q43.

1. Introduction

Energy is an important input into the production of total output. Policies to improve its efficiency have become important due to the four energy crises and also to reduce emission of the green house gases. The four energy crises have been due to the 1973-1974 OPEC embargo, 1979-1980 Iranian revolution, 1990-1991 Gulf war and more recently due to a variety of reasons like the Iraq war since 2003, increased demand for energy by the rapidly growing economies of China and India, nuclear tests by North Korea and a potential threat due to Iran becoming a nuclear country. Therefore, it is useful to analyze if energy is used more efficiently by various countries. Two important factors that might have encouraged energy saving are the general rise in the relative price of energy caused by the shortages and various government incentives to encourage energy saving. The latter is more important because generally firms pass on to consumers increases in the unit costs of production and therefore increases in energy prices may not bring sufficient changes in their relative prices. Therefore, it is necessary to understand how energy-output ratios responded to energy crises and environmental needs. If the energy ratios did not decrease adequately, it is necessary to reduce them with appropriate policy measures.

The objective of this paper is to examine how energy-output ratios (EYRs hereafter) have responded to the oil shocks and in particular if they have declined after the shocks. For this purpose we shall use at first a few simpler procedures and then the recently developed tests for structural breaks by Bai and Perron (1998 and 2003).[1] This paper is structured as follows. Section 2 presents a few summary statistics on various EYRs in Fiji. In Section 3 we briefly formulate two measures of energy efficiency and examine if there have been structural breaks in these measures—first with a few simple techniques and then with the Bai and Perron tests. Finally in Section 4 conclusions and limitations of

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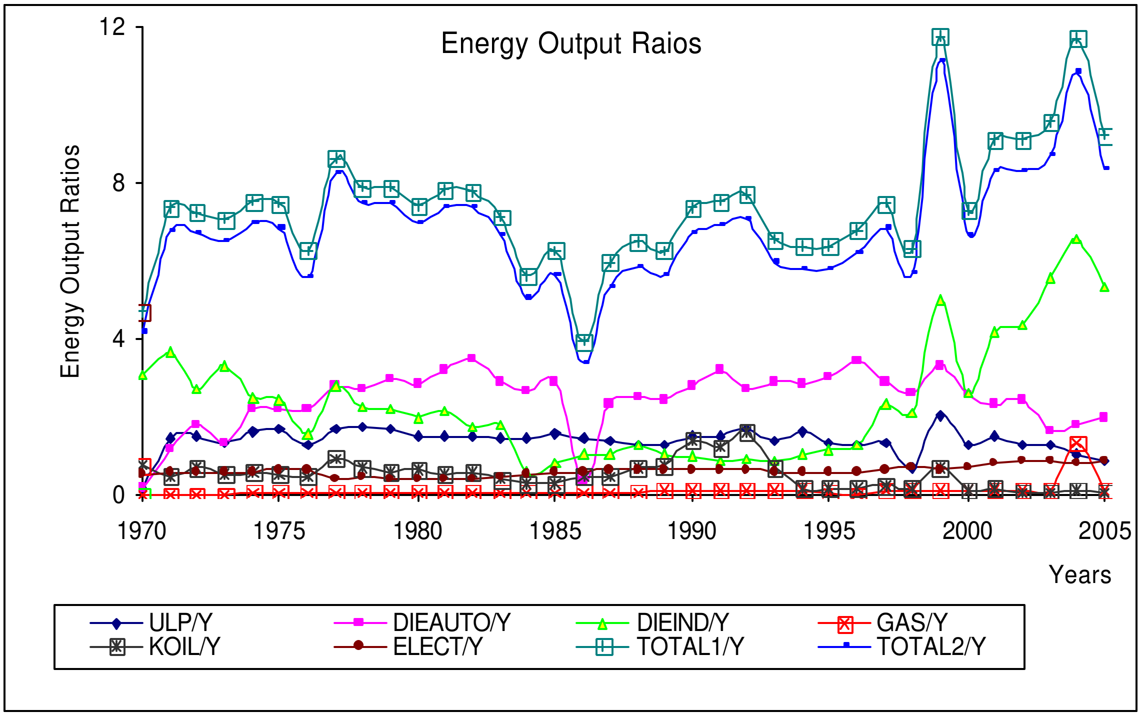
[1] Perron and Qu (2003 and 2006) have developed tests similar to the Bai-Perron tests, which are claimed to be more efficient in finite samples when partial structural break procedures are used. However, both types of tests have similar efficiency in pure structural break tests. Perron and Qu tests are computationally more demanding. Furthermore, in our subsequent estimates, partial structural break models did not perform well. Therefore, we ignore the Perron and Qu tests in this paper.

our paper are stated. A limitation of this study is that its scope is restricted to technical issues. These techniques are demanding and therefore, we have ignored the discussion on the policies to improve EYRs or estimate cointegrating equations.

2. Energy-Output Ratios and their Trends in Fiji

The main sources of energy for Fiji are: unleaded gasoline (ULP), automotive diesel (DIE1), industrial diesel (DIE2), gas (GAS), kerosene (KOIL) and electricity (ELECT). Industrial diesel is the main input into electricity generation. However, electricity is also generated through a few hydro based systems[2]. The ratios of these energy sources to output are given in Figure 1. Table 1 provides a few summary measures of the energy-output ratios.

Figure 1: Energy Output Ratios



Data Source: Calculated from energy data available from Key Statistics and Overseas Trade Reports, Bureau of Statistics, Suva, Fiji. Total1 includes electricity and Total2 excludes electricity. Energy from an energy source is measured in mega joules (MJ). Total output is GDP (millions of dollars) in 1995 prices.

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[2] 80 MW Wailoa hydro project was commissioned in 1983, 6 MW Wainikasou hydro power station in 2004 and 2.8 MW Vaturu power station in 2005.

Table 1: Summary Measures for Energy Output Ratios

	ULP/Y	DIE1/Y	DIE2/Y	GAS/Y	KOIL/Y	ELECT/Y	TOTAL1/Y
MEAN	1.3947182	2.430471557	2.3630982	0.1103401	0.5104213	0.6094183	7.4184676
STD	0.3114912	0.768809763	1.4489944	0.2196164	0.3664444	0.1176443	1.5753738
MAX	2.0171122	3.461096013	6.5503846	1.3532769	1.6496861	0.872744	11.794426
MIN	0.1641972	0.185321992	0.6014329	0.0153928	0.0333959	0.4137774	3.9447558

Calculated from Energy Output Ratios given in Figure 1.

Generally energy output ratios show a slight increase from 1970 to 2005 with the exception of ULP/Y which shows an almost constant trend for this period and KOIL/Y which shows a declining trend for this period.

The variation in energy output is the greatest for the auto diesel and the industrial diesel. The industrial energy output ratio shows the highest positive correlation with the total output ratio. Each of the other categories of energy output ratio shows a positive correlation with the total output ratio with the exception of the kerosene output ratio which shows a negative correlation for this period.

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3. Energy Efficiency and Structural Breaks

At the aggregate level a quick method to examine energy efficiency is to compute and plot the ratio of energy to GDP, or a similar output variable e.g., sectoral outputs like the industrial output, and examine how this ratio and its trend behaved before and after major oil shocks. This can be examined by regressing the log of energy-output ratio on a constant and a constant and time (*T*) as follows.

$$\ln(E_t/Y_t) = \alpha + \varepsilon_t \qquad (1)$$

$$\ln(E_t/Y_t) = \alpha + \beta T + \nu_t \qquad (2)$$

where E is energy, Y is output and e and ? are errors. Equation (1) assumes that there is no trend in EYR. If energy efficiency has improved after the oil shocks *a* in (1) should decrease. This is similar to the tests in the example of Bai and Perron (1998, 2003) where they have tested if the real rate of interest has remained constant in the United States of

America. In equation (2) we added the time trend and this can be justified as follows. For example, when the EYR of kerosene is examined, it may be expected that β could be negative because some households and firms have been switching, over a period, from kerosene to gas or electricity. Even in the aggregate EYR, the coefficient of trend may be positive and significant. This would be so because when new technologies are adopted, which are generally more capital intensive, EYR may increase.

It may be objected that a deterministic trend is inappropriate for capturing the effects of technical improvements which generally are somewhat random in occurrence. However, while this may be valid for explaining the number of patents, it is unlikely that firms will use the latest technology immediately. In fact they may adopt these technologies gradually over time. Therefore, a deterministic trend may work well in explaining how technology improves efficiency. In addition energy saving is also affected by the behaviour of households and firms and they may learn to save energy and replace high energy consuming appliances and equipment only slowly with time without the need for new inventions and technologies. Smaller and fuel efficient cars already exist but consumers may buy them gradually over time. Or that firms and households may switch off equipment and appliances to save energy and they cultivate this habit over time. Nevertheless it is important to understand the differences between these two ways of modelling and their use. A stochastic trend needs a re-specification of (2), for example, as follows:

$$\ln(E_t / Y_t) = \ln(E_{t-1} / Y_{t-1}) + \varsigma_t \qquad (3)$$

where ς is an error. This implies that the rate of growth of energy efficiency is a random walk i.e., $\Delta \ln(E_t / Y_t) = \varsigma_t$. If this is correct, β in (2) should be insignificant. However, in practice there may be both stochastic and deterministic trends in technology. Therefore, equation (2) which ignores deterministic trend may overestimate β. Kaufman (2004) has an enlightening discussion of this issue.[3] His approach is also useful to analyse the

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[3] The methodological controversy on whether deterministic or stochastic trends are appropriate in the time series models is an interesting but difficult to resolve issue. Harvey (1997) in an influential paper makes a

determinants of the energy-output ratio and decompose their effects. If the trends in technology have both deterministic and stochastic components, (2) can be expressed as:

$$\begin{aligned}\ln(E_t / Y_t) &= \lambda[\ln(E_{t-1} / Y_{t-1}) + \varsigma_t] + (1-\lambda)(\alpha + \beta T + \nu) \\ &= (1-\lambda)\alpha + (1-\lambda)\beta T + \lambda[\ln(E_{t-1} / Y_{t-1}) + \upsilon_t] \qquad (4)\end{aligned}$$

where ? is the weight given to the specification with a stochastic trend. We have estimated (4) with the exact maximum likelihood, after correcting for the second order serial correlation, and found that both ? and ß are insignificant. However, ? was also negative and insignificant in the Wald test with ?^{2}(1) = 0.22646 [p< 0.634]. Therefore, we have opted to retain a deterministic trend in our specification with the realisation that its coefficient may be slightly overestimated. Furthermore, since any non-linear curve can be seen as consisting of a number of straight lines, with varying slopes, if there are stochastic trends, that would be reflected in a large number of structural breaks in a liner trend. Therefore, we believe that our procedure is a pragmatic option for determining structural breaks with a deterministic trend.[4]

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strong case for stochastic trends because models with deterministic trends are a limiting case with stochastic trends when the hyper-parameters (which allow for the level and slope of the trend to change) are equal to zero. Estimation with stochastic trends and tests for the convergence to zero of the variances of the relevant equations etc., calls for an entirely different approach and this is beyond the scope of the present paper. The method we have used to nest stochastic and deterministic trends is simple and similar to an approach used by Campbell and Mankiw (1989) to evaluate the Keynesian and permanent income hypotheses of consumption. Dimitropoulos, Hunt and Judge (2004) are one of the earliest to estimate energy models with stochastic trends. Several other models with stochastic trends are estimated by Hunt and his colleagues at the Surrey Energy Economics Center. However, in spite of Harvey's forceful arguments, time series models with deterministic trends are still widely used. This may be due to a valid belief that the effects of technological progress are unlikely to follow the smooth but non-linear trends estimated with stochastic trends.

[4] Another option is to make ß a function of past accumulated values of (E/Y). A similar approach is used in some endogenous growth models based on learning by doing where the rate of technical progress is made a function of an autonomous and an induced component. Rao (2007) has used this approach to estimate the steady state growth rates in some newly industrialising Asian countries. Nevertheless, we do not claim that the deterministic versus stochastic trends issue is resolved with our arguments.

Having offered a justification for our approach, we proceed to examine the structural stability of equations (1) and (2) with a few alternative methods. For example the Chow test and the CUSUM tests etc., can be used for this purpose but they do not satisfactorily indicate the break dates and in which direction the structural changes have taken place. The stability of the parameters can also be examined by estimating with the recursive and/or rolling least squares. These two simple methods provide some preliminary but not rigorous insights into the stability of the equations. Therefore, it is necessary to use more formal techniques such as the Gregory and Hansen (1996) cointegration technique with a single structural break or the Bai and Perron (1998, 2003) tests with multiple structural breaks. The Gregory and Hansen test is actually a cointegration test with a single structural break at an unknown date and it is desirable to use it when equations (1) and (2) are augmented with some additional determinants of EYRs. Kaufman has developed a useful approach to estimate the cointegrating equations, but he did not test for structural breaks. In contrast our main purpose in this paper is to estimate the break dates and how these structural changes affected the parameters in equations (1) and (2) due to the energy shocks. Cointegrating vectors can be estimated later after understanding the structural breaks, but this is beyond the scope of our present paper.[5] In what follows we only apply the Bai and Perron tests for structural breaks in equations (1) and (2).[6]

We define two energy-output ratios. (*E1/Y*) includes electricity and (*E2/Y*) excludes electricity because a significant proportion of electricity is generated by diesel generators and including Diesel2 and electricity leads to some double counting. However, the trends in both measures are similar; see Figure 2. We first select (*E2/Y*) to develop our methodology and then apply to other energy-output ratios. The plots of *(E1/Y)* and *(E2/Y)* showing a very similar pattern are given in Figure 2. It can be seen that perhaps there are many structural breaks, some minor and some dominant, in both (E1/Y) and (E2/Y)

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[5] Johansen, Masconi and Nielson (2000) have developed a method to estimate cointegrating equations with known structural breaks.

[6] In estimating the cointegrating equations, after the Bai and Perron break tests, it is necessary to use some discretion because it may not be possible to get meaningful cointegrating equations for all the regimes. Furthermore, various evaluation test statistics in the Bai and Perron tests may also give different break dates.

around the same dates. Equations (1) and (2) have been estimated for (E2/Y) with the recursive and rolling least squares, but the latter estimates gave a better picture of the likely structural changes in the parameters. The plot of the estimates of a from equation (1) and a and ß from (2) are in Figures 3, 4 and 5 respectively. Figures 4 and 5 imply that perhaps the intercept term in equation (2) has fewer breaks than in equation (1). However, there seem to be four to five distinctive breaks in the slope coefficient of equation (2). Since these observations are arbitrary and the possible number of breaks in the parameters are not formally tested, the Bai-Perron structural break tests are useful. In their tests there are alternative tests to determine the break dates. These are (a) the Sup F_T (k:q) test for the null hypothesis of no structural break against the alternative of a fixed number of breaks (b) the UDmax test, a double maximum test of the null hypothesis of no structural break against the alternative of an unknown number of breaks given some upper bound on the number of breaks, (c) the SupF_T $(l \mid l+i)$ test, which is a sequential test of the null hypothesis of l breaks against the alternative of $l+1$ breaks. In addition there is also the usual SBIC test based on the standard errors.[7] Generally it is to be expected that results with these test may not tally with each other. Therefore, instead of presenting all the test results on equations (1) and (2) for the ten energy-output ratios, we shall only use the SBIC test to determine the number of breaks and report the results based on the other tests only if they are significant.[8]

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[7] These procedures can be implemented with the codes written by Bai and Perron and they can be downloaded from their homepages. RATS can be used if only the SBIC test is used. We have used GAUSS because it also gives the F-test results. We are grateful to Tom Maycock of Estima and Jon Breslaw of GAUSSX for help with these tests. We also acknowledge Professors Bai, Perron for the excellent GAUSS codes.

[8] Readers interested in understand the application of these tests may also refer to a very useful paper by Esteve and Martýnez-Zahonero (2007).

FIGURE 2

Ratios of Total Energy to Output

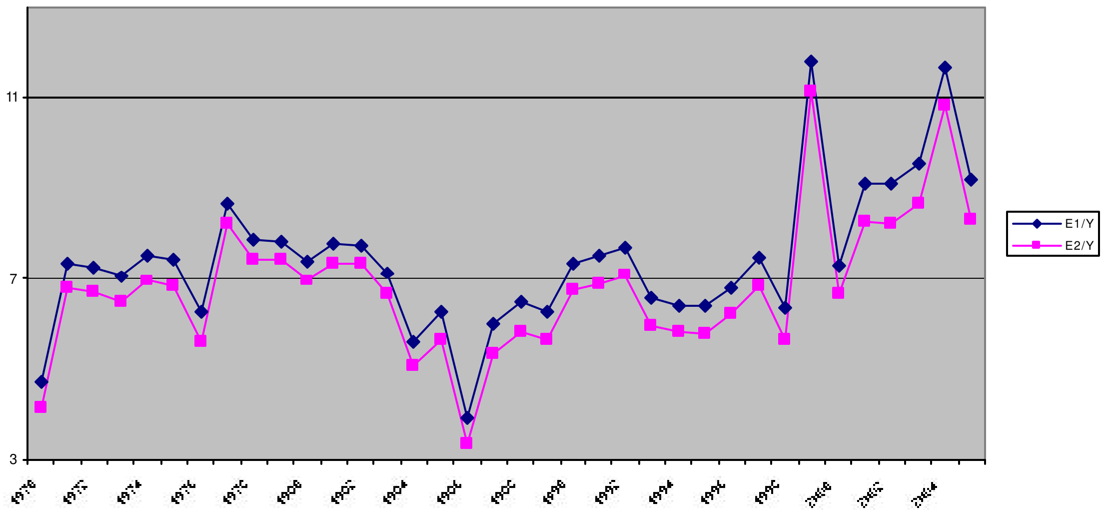


Figure 3

Plot of a in Equation 1 with Rolling least Squares with the Bands of 2 SEs

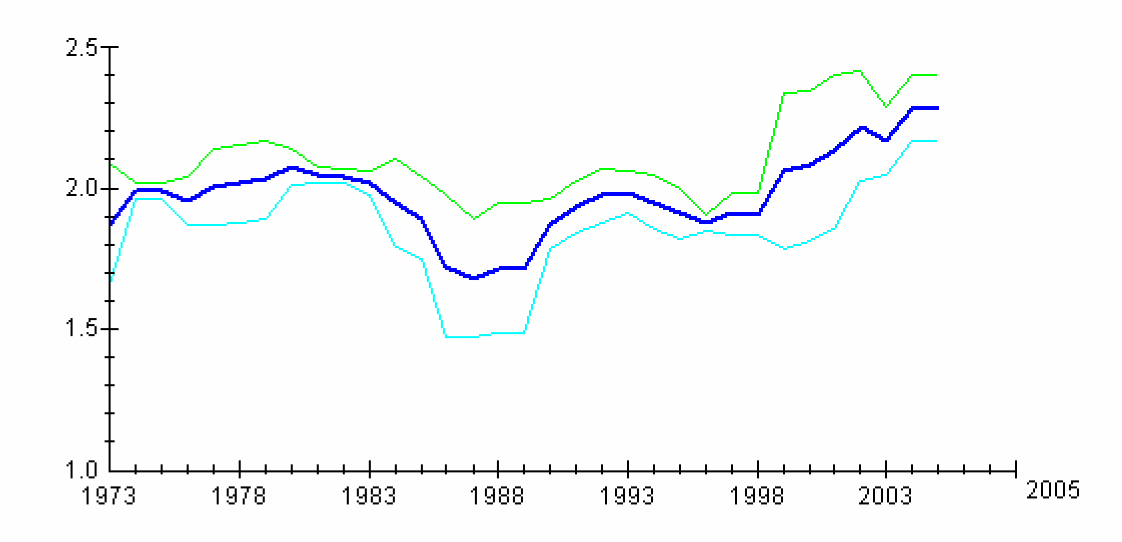


Figure 4

Plot of a in Equation 2 with Rolling Least Squares with the Bands of 2 SEs

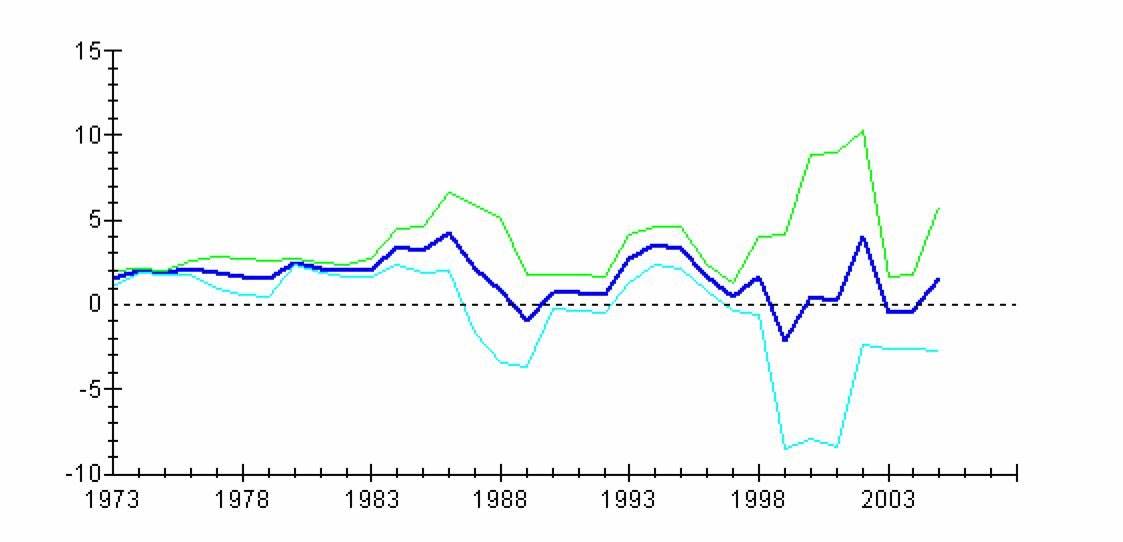
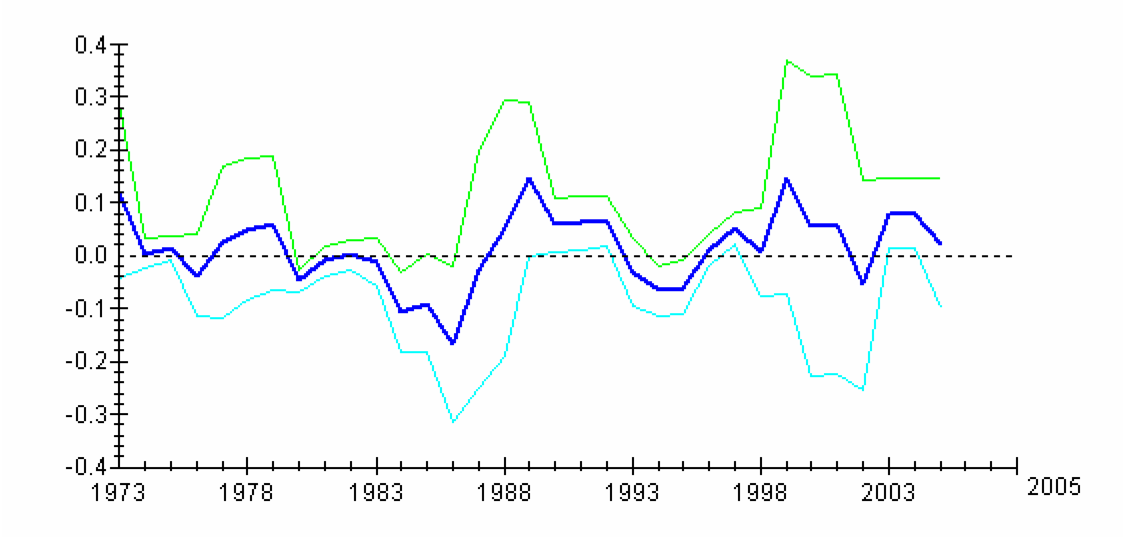


Figure 5

Plot of ß in Equation 2 with Rolling Least Squares with the Bands of 2 SEs



Results based on the application of the Bai and Perron method to equations (1) and (2) with (E2/Y) as the dependent variable, are in Table 2 (A, B, C and D) below. In Table 2A, estimates of equation (1) are given. In Tables 2B to Table 2D estimates of equation (2) without any constraints, followed by the restriction that the intercept is constant and then the slope is constant are reported. In all these tables the number of possible breaks has been restricted to 3 so that there are 4 regimes so that each regime has a reasonable number of observations. The break date is selected on the basis of SBIC, except in Table 2D, where the Sup F_T (i+1|i) test result is used**.** The reason for this is that this test statistic was insignificant in all other estimates and therefore the SBIC is used. Although the SBIC criteria found only one break in Table 2D, the estimated parameters (not reported) are similar in magnitude to those reported in this table.

Table 2A
Estimates of Structural Breaks
Equation 1

Number of breaks selected by SBIC	1
Break Dates	1998
Estimates of intercept for each regime (unrestricted)	1.915632 (1970-1998) [p-value 0.000] 2.258596 (1999-2005) [p-value 0.000]
R-Bar Square	**0.405**

Table 2B
Estimates of Structural Breaks
Equation 2 (Unrestricted)

Number of breaks selected by SBIC	1
Break Date	**1983**
Estimates of intercept for each regime (unrestricted)	1.750648 (1970-1983) [p-value: 0.000] 1.094285 (1984-2005) [p-value 0.000]
Estimates of the coefficient of Trend for each regime (unrestricted)	0.020458 (1970-1983) [p-value 0.070] 0.031078 (1984-2005) [p-value 0.000]
R-Bar Square	**0.478**

Table 2C
Estimates of Structural Breaks
Equation 2 (Intercept held constant)

Number of breaks selected by SBIC	**2**
Break Dates (Based on SBIC)	**1981 and 1986**
Restricted Estimate of intercept (intercept held constant)	1.678519 (1970-2005) [p-value 0.000] Restricted
Restricted Estimate for each regime of the coefficient of Trend (intercept held constant)	0.030895 (1970-1980) [p-value 0.009] 0.004330 (1981-1986) [p-value 0.318]* 0.014885 (1987-2005) [p-value 0.000]
R-Bar Square	**0.481**

Asterisk indicates insignificance at 5% level

Table 2D
Estimates of Structural Breaks
Equation 2 (Slope held constant)

Number of breaks selected by SBIC	**1**
Umber of breaks selected by Sup F test	**2** **Sup F_T(2|1):17.78** **(95% CV = 12.95)**
Break Dates (Based on Sup F test)	1983 (14) and 1992 (21)
Intercept for each regime	1.645239 (1970-1983) [p-value 0.000] 1.069712 (1984-1992) [p-value 0.000] 0.963060 (1993-2005) [p-value 0.000]
Trend (held constant)	0.034513 (1970-2005) [p-value 0.000]
R-Bar Square	0.481

Estimates of equation (1) in Table 2A imply that the intercept shifted up in 1999 and this does not correspond to any energy shocks and implementation of energy saving policy measures. This upward shift seems to be due to the cumulative effects of trend which is ignored in equation (1).

In Tables 2B to 2D, the break dates and the shifts in the parameters seem to be more plausible. All the 3 alternative estimates imply that the first break occurred during 1981-1983 which is after the second oil shock due to the Iranian revolution. Unrestricted estimates in Table 2B imply that while the intercept shifted down by about 47%, the trend has increased by 42%. These shifts imply that the log of energy-output ratio (LEYR), at the end of the first break in 1983, was 2.037060 which has immediately declined substantially, presumably due to the second oil crisis, to 1.125363 in 1984. However, LEYR has slowly increased since 1984 and reached a value of 1.778001 by 2005. This is about 26% energy saving since 1983 and Fiji seems has done well in saving energy.

In Tables 2C and 2D, constrained estimates of equation (2) are given. In Table 2C it is assumed that the intercept remains invariant but the slope may change between the regimes. The limitation of this assumption is partly reflected in an insignificant estimate of the coefficient of trend in the second regime covering the period 1981-1986. Nevertheless, when the estimates of the coefficients of the first and third regimes are compared, there is evidence that there has been saving of energy since 1970-1980.
The energy-output ratio, implied for 1980 is 2.018364 which has declined by a modest 7% to 1.946449 by 2005. Qualitatively this is consistent with the findings based on Table 2B.

Results in Table 2D assume that trend remains constant but the intercept may change. It is difficult to say if this is a reasonable assumption prior to testing if the estimates of the intercepts and coefficients of trend in the unconstrained estimates of Table 2B are significantly different. However, it is the only estimate in which the Sup F test, based on the sequential estimates, is significant and we have used this test to select the break dates. The first and second break dates in 1983 and 1991 correspond to the second (Iran revolution) and third (Gulf war) energy shocks. The reduction in the energy-output ratio is quite significant after the first break but seems to have increased by 2005 to almost its value in 1983. By the end of the first break in 1983 the log of energy-output ratio was 2.093908 and this has decreased by 23% to 1.863511 by the end of 1992. However, since then it has increased to 2.205528, a 34% increase, by the end of 2005. These results indicate that somehow the gains made in saving energy have disappeared after some time.

Since the conclusions from the unrestricted estimates in Table 2B imply that the energy output ratio has shown a decline, it is necessary to test if the estimated coefficients significantly differ in both regimes. Therefore, we have re-estimated equation (2) with the appropriate dummy variables. When the Wald test is used to test if the intercepts are significantly different, the null is rejected. The computed $?^2$ (1) test statistic, with p-value in the square brackets, is 59.0316 [0.000]. The computed $?^2$ (1) test statistic for the differences in the coefficients of trend is 3.1218 [0.077] and the null can be rejected at the 10% level. It may be said that the assumptions underlying the two constrained equations are somewhat inappropriate and the estimates and conclusion based the estimates in Table 2B should be preferred. For this reason we conclude that the efficiency with which energy is used in Fiji has increased by 26% since the second energy shock in 1983.

To conserve space detailed estimates of trend breaks in the other energy-output ratios are not reported. In Table 3 below only unconstrained estimates of equation (2) for the energy-output ratio where the measure of total energy includes electricity *(E1/Y)* and the ratios for the major components of energy are reported. The energy components selected are unleaded petrol *(ULP/Y),* auto-diesel (DIE1/Y) and industrial diesel (DIE2/Y).

The break dates selected by SBIC and the first break occurred after the first energy shock of 1974 for the two automobile fuels viz., of ULP and DIE1 in columns 2 and 3. For total energy and industrial diesel (DIE2) the first break was due to the 1983 the second energy crisis caused by the Iran revolution. Two other breaks due to the Iranian and Gulf crises seem to have shifted the energy-output ratio for DIE1. After the first break in 1983 there has been a break in 1996 for DIE2 perhaps due to the increases in crude oil prices. Continued tensions between USA and Iraq during the year created uncertainty in the oil market. Cold weather in USA increased demand for heating fuel. Industrial action by Norwegian oil workers resulted in decline in crude oil exports, bombing of military facility in Dhahram in Saudi Arabia exacerbated speculative demand for oil. The total output of the existing hydro electric power stations in Fiji increased due to improved water / plant availability.

In row 4 the respective energy-output ratios are computed for the year of the first break and then for the year 2005 to indicate how this ratio has evolved during these years. The total energy ratio *(E1/Y)* behaved very similar to *(E2/Y)* in Table 2B with a downward shift in the intercept and an upward shift in the coefficient of trend. While the energy-output ratio *(E2/Y)* declined by 26%, *(E1/Y)* declined by only 18% perhaps due the less flexible and increasing demand for electricity due to the rural and urban electrification programmes. The electricity-output has increased by 23% from 1976 to 2005.

Table 3
Estimates of Structural Breaks
Equation 2 (Unrestricted)

	log(E1/Y)	log(ULP/Y)	log(DIE1/Y)	log(DIE2/Y)
Number of breaks Selected by SBIC	1	1	3	2
Break Date	1983	1974	1974, 1985 and 1990	1983 and 1996
Implied log energy-output ratio	1983: 2.0885 2005: 1.9099 change = -18%	1974: 0.8498 2005:0.2215 change = -63%	1974: 1.0323 2005: 0.8728 change = -16%	1983: 0.5626 2005: 0 .1144 change = -45%
Intercepts	1.852668 [p-value 0.000] 1.224103 [p-value 0.000]	-1.388958 [p-value 0.000] 0.569292 [p-value 0.000]	-1.492368 [p-value 0.000] 0.748976 [p-value 0.049] -7.469160 [p-value 0.000] 2.056904 [p-value 0.001]	1.209401 [p-value 0.000] -0.602396 [p-value 0.057] -2.643368 [p-value 0.002]
Trend	0.016845 [p-value 0.100] 0.029817 [p-value 0.000]	0.447742 [p-value 0.070] -0.011220 [p-value 0.071]	0.504937 [p-value 0.000] 0.024892 [p-value 0.440] 0.420779 [0.000] -0.038197 [p-value 0.065]	-0.046198 [p-value 0.001] 0.027644 [p-value 0.063] 0.125351 [p-value 0.000]
R-Bar Square	**0.499**	**0.460**	**0.681**	**0.906**

The energy shocks have improved the efficiency of ULP by a massive 63% mainly due the substitution of more energy efficient smaller cars and perhaps due to reductions in recreational trips. Improvement of energy efficiency in the transport industry is more modest at 18%. This is mainly because most of the goods are transported by road in Fiji and alternatives are virtually nil. The energy efficiency in the use of industrial diesel is substantial at 45%. This was mainly due to the decreased demand for diesel by the FEA because of good rain falls in the Wailoa basin hydro plant catchment areas. The output from this hydro plant has increased substantially since 1996 (with the exception of 2000) by 10% in 1997.[9]

4. Conclusions and Limitations

This paper attempted to determine energy efficiency in Fiji Islands using data from 1970 to 2005. The period contains four major oil shocks. Using energy output ratios at the aggregate levels and the specific category energy use, we were able to establish that Fiji made significant energy efficiency gains in response to energy crises.

We have used the Bai-Perron structural break tests to find the break dates and estimate the intercept and slope parameters to determine efficiency gains. Our results show that in all cases energy output ratios declined by 2005 compared to the earlier periods. The total energy output ratios declined by 26%. The energy shocks have improved the efficiency of ULP use by a massive 63%. The energy efficiency in the use of industrial diesel is substantial at 45%.

However, we need to mention two limitations of this paper. Firstly, the paper has dwelled on the technical aspects of estimation of structural breaks. Second, we have ignored the discussion on the policies to improve EYRs and/or estimate the cointegrating equations.

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[9] The increase in power generation due to good rain falls are as follows:

1997	10.1%
1998	3.4%
1999	7.4%
2000	-7.6%
2001	9.9%

The fall in 2000 was due to the political coup and the shutdown of the plant for two months.

However, cointegrating vectors can be estimated after understanding the structural breaks, but this is beyond the scope of our present paper.

DATA APPENDIX

MJ = Energy measured in mega joules.
ULP = Gasoline in MJ
DIE1= Auto motive diesel in MJ
DIE2= Industrial diesel in MJ
GAS = LPG gas in MJ
KOIL= Kerosene in MJ
ELECT= Electricity in MJ
TOTAL1= Total energy in MJ.
TOTAL2/Y= Total energy excluding electricity in MJ.
Y = GDP.

(ULP/Y) = Gasoline to output ratio. Data Source: Overseas Trade Reports, Bureau of Statistics, Suva, various issues.

(DIE1/Y)= Auto motive diesel to output ratio. Data Source: Overseas Trade Reports, Bureau of Statistics, Suva, various issues.

(DIE2/Y) = Industrial diesel to output ratio. Data Source: Overseas Trade Reports, Bureau of Statistics, Suva, various issues.

(GAS/Y) = LPG gas to output ratio. Data Source: Overseas Trade Reports, Bureau of Statistics, Suva, various issues.

(KOIL/Y) = Kerosene to output ratio. Data Source: Overseas Trade Reports, Bureau of Statistics, Suva, various issues.

(ELECT/Y) = Electricity to output ratio. Data Source: Fiji Electricity Annual Reports, 1980 – 2005, Suva.

(TOTAL1/Y) = (*E1/Y*) = Total Energy to output ratio.

(TOTAL2/Y) = (*E2/Y*) = Total Energy to output ratio.

Y = Output is GDP (millions of dollars) in 1995 prices. Data Source: Key Statistics, Bureau of Statistics, Suva.

Data Conversion Methodology:

All different energy units have been converted to a common measure of Mega joules by the following methodology:

Electricity 1kW hour is 3,600,000 Joules or 3.6 MJ.
Gasoline is 34.2 MJ per Liter
Diesel is 38.5 MJ per Liter
Reference: http://en.wikipedia.org/wiki/Fuel_efficiency; http://www.greenfleet.com.au/transport/technical.asp.

Natural Gas is 37 MJ per cubic metre. 0.8 kg gas is 1 cubic metre i.e. the Fiji Gas Tank is approximately 13kg so contains about 16.25 cubic metres.
Reference: http://hypertextbook.com/facts/2002/JanyTran.shtml

Kerosene is 44MJ per kg. The link below has the UN report with official values.
Reference: http://www.humanitarianinfo.org/darfur/uploads/idp/Cooking%20fuel%20-%20helpdoc%20by%20UNJLC.pdf

REFERENCES

Bai J, and Perron P. (1998), Estimating and testing linear models with multiple structural changes. *Econometrica,* **66:** pp. 47–78.

Bai, Jushan and Perron, Pierre (2003), Computation and analysis of multiple structural change models, *Journal of Applied Econometrics,* **18:** pp. 1-22.

_____________ (2003), Critical values for multiple structural change tests, *Econometrics Journal*, **6:** pp. 72–78.

Campbell, J.Y. and Mankiw, N.G. (1989) Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence Working Paper No.2924, National Bureau of Economic Research, Cambridge, MA.

Dimitropoulos, John; Hunt, Lester C and Judge, Guy (2004), Estimating Underlying Energy Demand Trends using UK Annual Data, *Surrey Energy Economics Center*, Discussion Paper Series No. 108.

Esteve Vicente and Martínez-Zahonero, José. L, (2007) Testing the long-run relationship between health expenditures and GDP in the presence of structural change: the case of Spain, *Applied Economics Letters*, **14:** Issue 4 - 6 May, pp 271 - 276

Fiji Electricity Authority, (1980 – 2005), Annual Reports, Fiji Electricity Authority, Suva, Fiji.

Gregory, A.W. and Hansen, B.E. (1996) "Residual based tests for cointegration in model with regimes shifts, "*Journal of Econometrics,* **70**: 99-126.

Harvey, A. (1997), Trends, Cycles and Autoregression, *The Economic Journal*, **107:** pp.192-201.

Kaufmann, K. R. (2004), The mechanisms for autonomous energy efficiency increases: A cointegration approach. *The Energy Journal,* **25**: pp. 63-86.

Perron, Pierre and Qu, Zhongjun (2006), Estimating Restricted Structural Change Models, *Journal of Econometrics*, **134**: pp. 373-399.

Rao, B. B (2007), Estimates of the Steady State Growth Rates for Selected Asian Countries with an Endogenous Growth Framework, Mimeo, unpublished.

Søren Johansen, Rocco Mosconi and Bent Nielsen (2000), Cointegration analysis in the presence of structural breaks in the deterministic trend, *Econometrics Journal*, **3:** pp. 216–249.