SEEDS
Surrey **E**nergy **E**conomics
Discussion paper **S**eries

SURREY
ENERGY
ECONOMICS
CENTRE

An Empirical Analysis of Energy Demand in Namibia

Glauco De Vita, Klaus Endresen
and Lester C. Hunt

July 2005

SEEDS 110
ISSN 1749-8384

Department of Economics
University of Surrey

The **Surrey Energy Economics Centre (SEEC)** consists of members of the Department of Economics who work on energy economics, environmental economics and regulation. The Department of Economics has a long-standing tradition of energy economics research from its early origins under the leadership of Professor Colin Robinson. This was consolidated in 1983 when the University established SEEC, with Colin as the Director; to study the economics of energy and energy markets.

SEEC undertakes original energy economics research and since being established it has conducted research across the whole spectrum of energy economics, including the international oil market, North Sea oil & gas, UK & international coal, gas privatisation & regulation, electricity privatisation & regulation, measurement of efficiency in energy industries, energy & development, energy demand modelling & forecasting, and energy & the environment. SEEC also encompasses the theoretical research on regulation previously housed in the department's Regulation & Competition Research Group (RCPG) that existed from 1998 to 2004.

SEEC research output includes **SEEDS** - **S**urrey **E**nergy **E**conomic **D**iscussion paper **S**eries (details at www.seec.surrey.ac.uk/Research/SEEDS.htm) as well as a range of other academic papers, books and monographs. SEEC also runs workshops and conferences that bring together academics and practitioners to explore and discuss the important energy issues of the day.

SEEC also attracts a large proportion of the department's PhD students and oversees the MSc in Energy Economics & Policy. Many students have successfully completed their MSc and/or PhD in energy economics and gone on to very interesting and rewarding careers, both in academia and the energy industry.

Enquiries:

***Director of SEEC and Editor of SEEDS*:**
Lester C Hunt
SEEC,
Department of Economics,
University of Surrey,
Guildford GU2 7XH,
UK.

Tel: +44 (0)1483 686956
Fax: +44 (0)1483 689548
Email: L.Hunt@surrey.ac.uk

www.seec.surrey.ac.uk

University of Surrey

Surrey Energy Economics Centre (SEEC)
Department of Economics

SEEDS 110
ISSN 1749-8384

AN EMPIRICAL ANALYSIS OF ENERGY DEMAND IN NAMIBIA

Glauco De Vita, Klaus Endresen
and Lester C. Hunt

July 2005

ABSTRACT

Using a unique database of end-user local energy data and the recently developed Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration, we estimate the long-run elasticities of the Namibian energy demand function at both aggregated level and by type of energy (electricity, petrol and diesel) for the period 1980 to 2002. Our main results show that energy consumption responds positively to changes in GDP and negatively to changes in energy price and air temperature. The differences in price elasticities across fuels uncovered by this study have significant implications for energy taxation by Namibian policy makers. We do not find any significant cross-price elasticities between different fuel types.

JEL Classification: Q41; Q42; Q48.

Key Words: Energy demand; ARDL; Cointegration

An Empirical Analysis of Energy Demand in Namibia

G. De Vita*, K. Endresen and L. C. Hunt*****

**Oxford Brookes University Business School, Wheatley Campus, Oxford OX33 1HX, UK.*

***Independent Energy Consultant. Private Bag 13303, Windhoek, Namibia*.

***Surrey Energy Economics Centre (SEEC), Department of Economics, *University of Surrey, Guildford, Surrey GU2 7XH, UK.*

1. Introduction

There are compelling reasons underlying the importance of research on energy demand in developing countries. Although developing countries currently consume a limited share of the world's commercial energy, the faster income growth of their economies suggests that they may soon come to consume the majority of the world's energy (Dahl, 1994). The International Energy Agency (IEA) predicts that developing countries will increase their share of global oil consumption from 20.5% in 1999 to 35.8% in 2020 (IEA, 2002). Various authors (see, for example, Levine *et al*., 1995) also point to the extensive investments required in new generation capacity to meet the growing demand for electricity in developing countries. For regions such as sub-Saharan Africa the investments necessary to produce the required increase in all forms of commercial energy are major compared to traditional gross capital formation in society and net capital inflows. Over-investments in energy infrastructure and investments made long before they are needed, represent costly drains on scarce resources. Under-investments, or investments made too late, can also carry significant economic costs. With a significant potential for energy demand growth in the developing world, but an equally great uncertainty over the time and magnitude of this growth, providing information that may decrease this uncertainty should prove valuable to policy makers.

Despite the above, there is still a paucity of research on energy demand in the developing world and, of the scarce literature that exists, only a small proportion presents formal econometric studies of the response of energy consumption to changes in income, prices and other relevant regressors. Moreover, most of these studies focus on Asia (see, for example, Brenton, 1997; Pesaran *et al*., 1998; Pourgerami and von Hirschhaussen, 1991) and Latin America (Balabanoff, 1994; Hunt *et al.*, 2000; Ibrahim and Hurst, 1990; Edmonds and Reilly, 1985) leaving a glaring gap for sub-Saharan Africa, and Namibia in particular (see Table 1 for a summary of main empirical studies on energy demand in developing countries).

TABLE 1 HERE

Stage and Fleermuys (2001) examined energy use in Namibia for the period from 1995 to 1998, using annual data. The authors emphasise the lack of reliable energy statistics. Their study is mainly a brief, descriptive overview of the structure of sectoral energy use. Lundmark (2001), using annual data from 1980 to 1996, found no statistically significant relationship between economic growth and consumption of electricity in Namibia. He did not include other energies in his study. Stage (2002) attempted to carry out an input-output analysis of the Namibian economy for the period 1980-1998. He was not able to obtain continous long-run time series data, and instead picked two years for which annual data were available. Nearly all the increased use of primary energy over his sample period was attributed to the increase in households' energy use. We assume that his household data are based on estimates as there are no time series data on household energy usage in Namibia.

As evidenced above, the unavailability of good quality data is a constraint in the analysis of the energy sector in African countries. In this paper we begin to fill this gap by undertaking what is, to our knowledge, the first econometric study of the Namibian energy demand function at aggregated level and by energy type, that uses high quality, quarterly end-user data covering a relatively long period (1980 to 2002). This contribution adds to what has gone before in several ways.

Previous econometric studies have in the main based their regressions only on the price and income variables, and typically only for aggregate energy consumption or a single form of energy. Here, we control for most of the variables that can be expected to influence energy consumption, including air temperature, the HIV/AIDS incidence rate and, in the individual energy type equations, the price of alternative fuels. Additionally, we are able to examine the behaviour of energy consumption over the post-independence period (1990 to 2002), thus controlling for the effect on energy demand of the Namibian transition from war to peace.

Several researchers use international prices rather than local prices when estimating energy consumption in developing countries (see, for example, Gately and Huntington, 2002). This may lead to misleading results since due to local import duties, consumer taxation, subsidy and cross-subsidy schemes, most consumers may not experience the level of, or changes in, world market prices (see also Griffin and Schulman, 2005). An equally important weakness in many energy studies is the use of average rather than marginal prices (Woodland, 1993). Where electricity is sold with an energy component (marginal price) and a capacity component (fixed price component), the average price is in fact a function of consumption. We use marginal prices.

Finally, many previous studies estimating income and price elasticities of energy demand for developing countries have either ignored the need for testing the time-series properties of the variables entering the energy demand function or have used the Engle and Granger (1987) or Johansen (1988, 1991) cointegration methods, both of which presuppose that all the series contain a unit root. A merit of the ARDL bounds testing approach (Pesaran and Shin, 1999; Pesaran *et al.*, 2001) that we employ, is that it allows testing for cointegration when it is not known with certainty whether the regressors are purely I(0), I(1) or cointegrated.

The remainder of this paper is set out as follows. In Section 2, an overview of the Namibian energy sector is presented. In Section 3, the model and data used are discussed. Section 4 illustrates the ARDL bounds testing approach to cointegration that we employ. Section 5 reports the empirical results while Section 6 offers a discussion of the main findings and their policy implications. The final section draws some conclusions.

2. The Namibian energy sector

Namibia has a well-established institutional framework for the energy sector. The Ministry of Mines and Energy (MME) is responsible for national energy policy. Their mission is to regulate the responsible development and sustainable utilization of Namibia's (mineral and) energy resources for the benefit of all Namibians. Nampower is the State-owned power utility and has traditionally held a monopoly in electricity generation, import and transmission. Although government policies allow for the establishment of independent power producers, no such companies have yet been formed. The Electricity Control Board (ECB) was established in 2000, and is the statutory regulatory body for generation, transmission, distribution, supply, import and export of electricity (MME, 2000). The ECB issues licenses. Local Authorities buy the electricity from Nampower, and perform the role of electricity distributors to final consumers in municipal areas.

Energy Policy

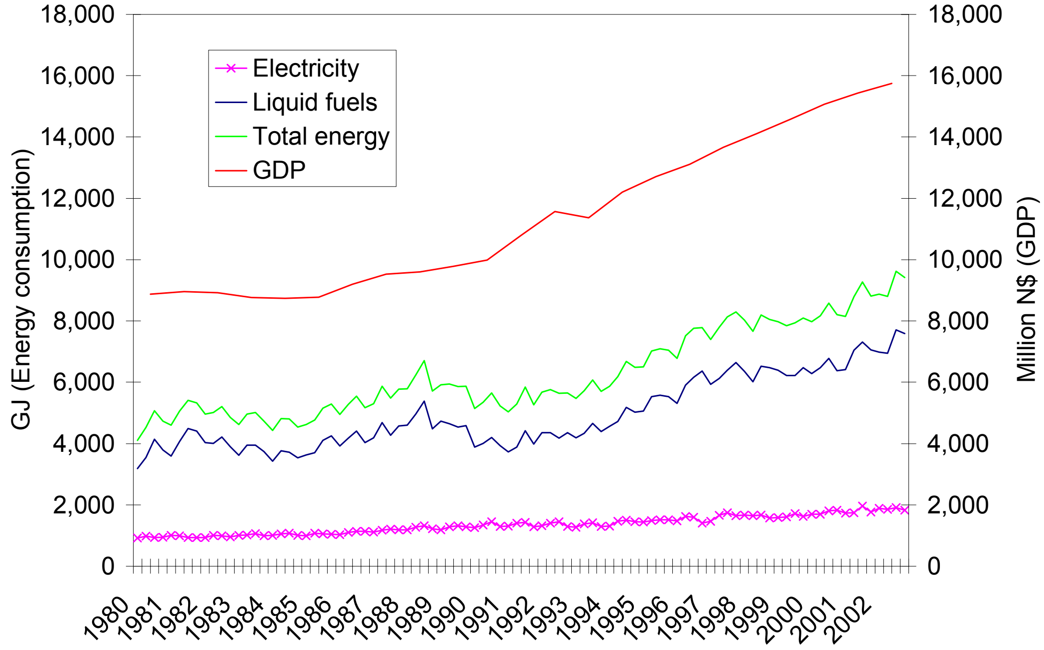
Two processes relevant to the formulation of energy policy in Namibia took place between 1980 and 2002. Firstly, Namibia was transformed from being a colony to an independent nation in 1990. Secondly, SWAPO changed from an independence movement in exile, to the governing party of the new republic.

Prior to independence the energy policies of the colonial South African government were supply orientated. The government of independent Namibia has, on the other hand, pursued a more balanced energy policy, which also includes demand-orientated initiatives such as an active rural electrification program. The new Government opened up Namibia's interaction with the outside world, and has been successful in attracting significant foreign investments in oil and gas exploration. The two main energy policy objectives of the NDP1 were selfsufficiency in electricity, and the completion of the rural electrification programme, both by 2010. The latter objective is critical to increase consumption of electricity since many Namibians still do not have access to the grid. In 2001, the government's Rural Electricty Distribution Master Plan (REDMP) identified 2855 rural localities in Namibia. 87.1% of them were not electrified. On the other hand, it is estimated that 75% of the urban population has access to the grid (MME, 2001).

MME's White Paper (WP) on Energy Policy in 1998 (MME, 1998) was a continuation of the policy framework launched in the First National Development Plan (NDP1) in 1995 (NPC, 1995). Some of the goals in the WP are to establish effective governance systems to provide a stable policy framework for the energy industry. In order to support social upliftment, households shall have access to appropriate and affordable energy supplies. Government's target is that by 2010, 25% of all rural households shall be connected to the national grid (as compared to a survey based estimate of 8% in 1997).

The most recent energy policy document is the energy chapter in the National Development Plan 2 (NDP2) (covering the period 2001/2 – 2005/6), which reaffirms the WP's objectives. Investments will be made in generating plants, transmission lines, fuel depots and retail outlets in order to improve socio-economic conditions in Namibia. Rural areas, where people rely on traditional forms of energy, are to be the focus of this effort. NDP2 supports greater use of alternative forms of energy, particularly where conventional energy services prove to be too costly (NPC, 2002a).

Figure 1: Consumption of commercial energy



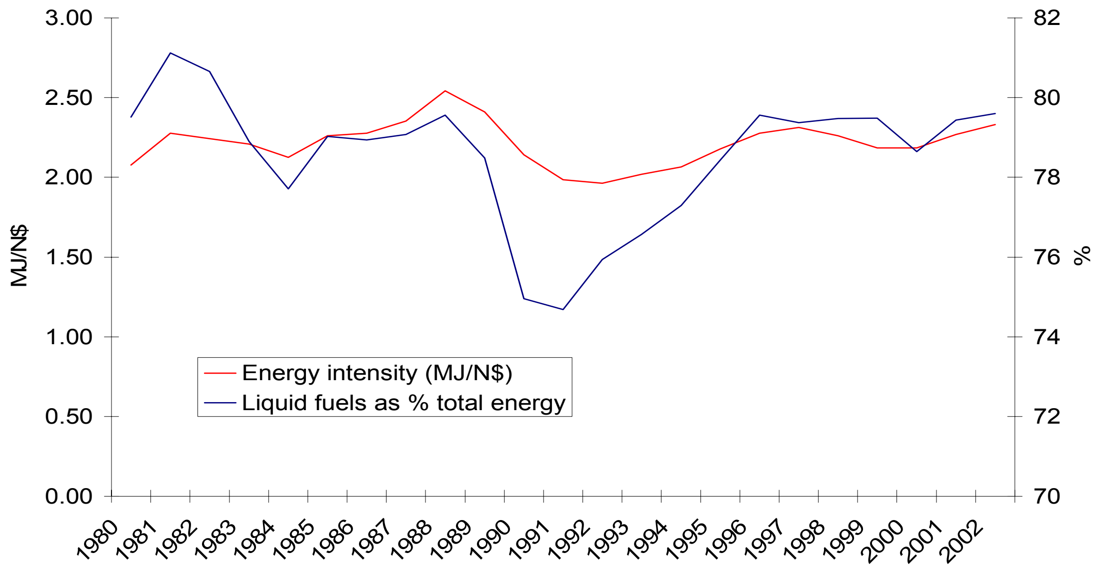
Source: Nampower (2003), Caltex (2003), NPC (2002b; 2003). Note: 1995=100

Energy Consumption

The total consumption of commercial energy in Namibia was fairly stable in the 1980s, but increased since around independence in 1990 (Figure 1), with liquid fuels dominating consumption of commercial fuels. Since 1990 the consumption of liquid fuels has grown relatively more than GDP and the consumption of electricity. All the liquid fuels and approximately 50% of the electrical energy consumed are imported. Traditional (or non-commercial) energy represents about a quarter of the country's total energy consumption.

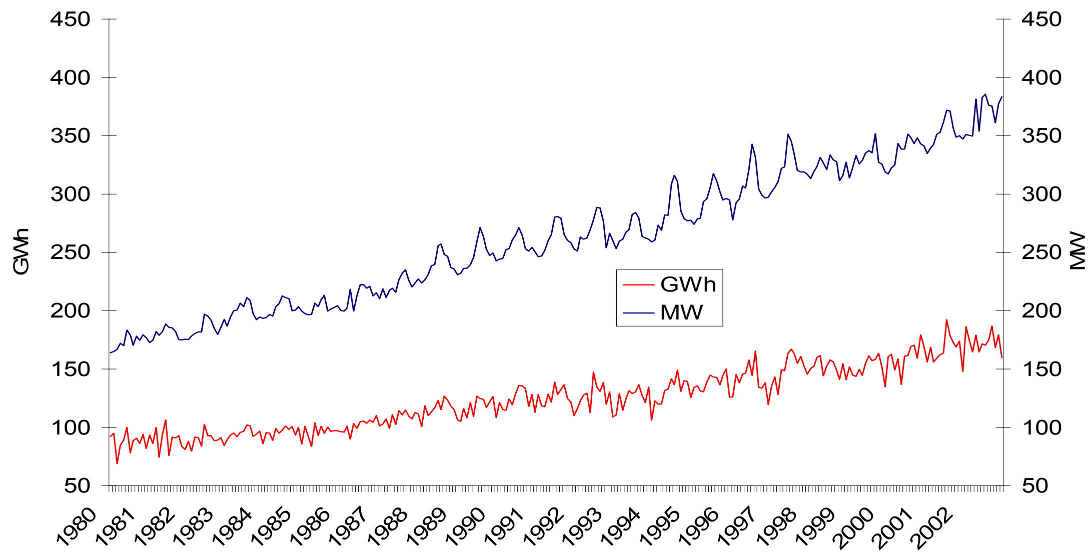
The energy consumption per capita, the weighted constant price of energy as well as energy intensity (energy consumption divided by GDP) varied prior to independence, but have mainly increased in the 1990s. Energy intensity and the fuel structure (liquid fuels' share of total commercial energy) appear well aligned for most of the study period (Figure 2).

Figure 2: Energy intensity and fuel structure



Source: NPC (various editions) and Caltex (2003).

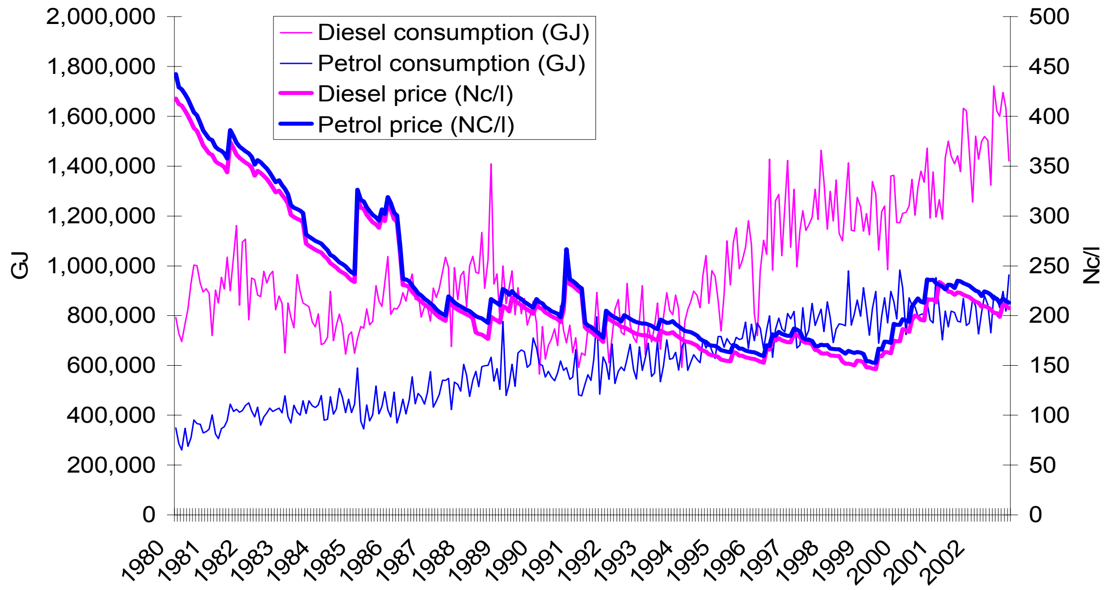
Figure 3: Consumption of electricity and maximum demand capacity



Source:Nampower(2003).

Consumption of electrical energy has grown less than the maximum demand capacity, implying a decrease in the average load factor in Namibia (Figure 3). The consumption of electrical energy has grown much in line with the national GDP and contrary to the decrease in the marginal price for electrical energy.

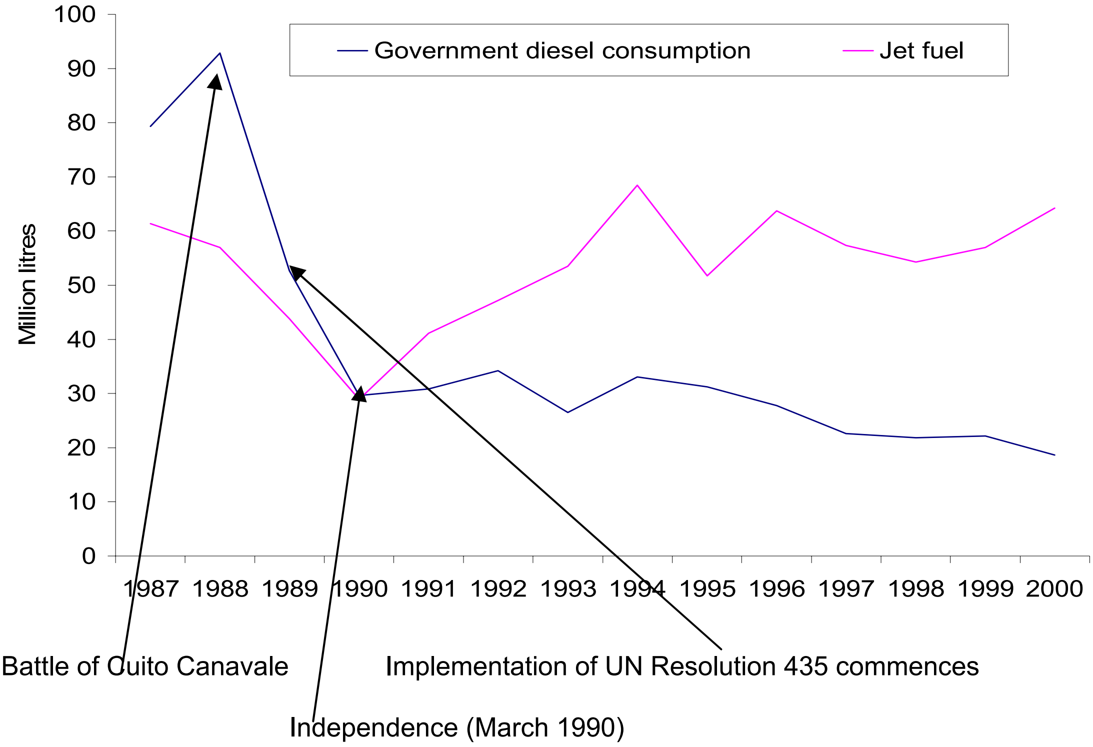
Figure 4: Diesel and petrol consumption and prices



Source: Caltex (2003), Engen (2002), MME (2002).

The consumption of liquid fuels per capita has increased since independence, and more so than GDP per capita. The real cost of liquid energy has generally fallen during the study period. Diesel, followed by petrol, is the dominant liquid fuel in Namibia. The volumes of kerosene and LPG are relatively negligible. Petrol and diesel consumption are generally growing, but at different paces. This is possibly a result of differences in use. Petrol is only an on-shore transport fuel. Diesel is used for automotive purposes (private vehicles, rail and all types of trucks), offshore vessels and stationary motive power. The real prices of petrol and diesel are closely related. When in 1999 prices started to rise, diesel consumption continued to grow while the growth in petrol consumption levelled off (Figure 4).

Figure 5: Fuel consumption in peace and war



Source: Caltex (2003). Note: Data on jet fuel are not available before 1987. Data on government consumption shows that their use of diesel increased steadily from the late seventies until an all-time high in 1988. The battle of Cuito Canavale was a military turning point in the war.

Government's consumption of diesel, and the overall use of jet fuel, dropped sharply after a peace accord was reached for Namibia (Figure 5), implying that much of the previous government's fuel consumption was related to the war. By independence, energy consumption reflected, for the first time in many years, the energy demand of a country at peace and without extensive military activities.

3. Model and data

Our aggregated, long-run energy demand function is specified as follows:

$$ed_t = \alpha + \beta_1 y_t + \beta_2 p_t + \beta_3 x_t + \mu_t \qquad (1)$$

where ed_t is the consumption of energy, y_t is GDP and p_t is the price of energy. Lower case letters denote log values. We estimate (1) for total national energy consumption and for the consumption of each type of energy (electricity, petrol and diesel) using non seasonally adjusted quarterly data for the entire 1980q1 to 2002q4 period as well as for the post-independence sub-period 1990q1 to 2002q4. In addition to GDP and the price variable, all our estimated regressions test for the significance of additional regressors (x_t), namely, air temperature, the HIV/AIDS incidence rate and, in the individual energy type equations, also the price of alternative forms of energy.

Volume data of different energy forms are aggregated using heating values according to the conversion factors reported in DUKES (UK Digest of Energy Statistics, 2001). When the consumption of a combination of energy forms is estimated, the relative amount of energy (expressed in Joules) is multiplied by the marginal price for that energy form in order to arrive at the weighted marginal energy price.

Nampower's internal accounting records are the source of data for aggregated consumption of electricity as well as for marginal and average prices. Nampower's sales to Local Authorities are distributed to end-users at prices traditionally set by the individual Local Authority. We obtained good quality end-user data from the large municipalities. These data have been extracted from unpublished printed records held by the Municipalities of Swakopmund, Walvis Bay, Windhoek and Tsumeb. These data represent about 50% of all electricity consumed in Namibia. To track changes in energy tariffs charged by the Local Authorities, we have retrieved most of the relevant copies of the Government Gazette from libraries in Windhoek and Cape Town since the mid 1970s (Government Gazette, 1975 – 2002). The published tariffs include both energy tariffs (marginal prices) and demand charges. We calculated the weighted marginal cost of electricity for *all* end-users in Namibia by combining the tariffs for consumers located in Local Authorities and the weighted Nampower tariffs for end-user consumer groups.

Various petrol companies supply liquid fuels to the Namibian market. Caltex in South Africa serves as a secretariat for the petrol companies in Namibia and has generously made the combined sales volumes statistics available to us (Caltex, 2003). The pump-price for a certain liquid fuel is the same for all consumer groups in the same geographical area. But diesel consumers in the fisheries, mining, agricultural and construction sectors can apply for a sector-specific refund (rebate) for part of the road tax component of the pump price. The *marginal* price for liquid fuels equals the 'pump price', and where applicable, the *rebated* pump price for *diesel*. Post-independence price data were obtained from MME (2002), who controls the prices for diesel and petrol. BP Namibia (2002) provided LPG price data while Shell Namibia (2003) provided kerosene prices. The compilation of pre-independence diesel and petrol prices, and most of the kerosene and LPG prices, was done by going through a variety of records kept with the South African Petroleum Industry Association (SAPIA, 2002) and petrol companies in Cape Town (Engen, 2002). Caltex' volume data do not differentiate between the different grades of petrol. The prices for the different grades are closely linked. The correlation coefficient for changes in the prices for Super and Premium grade petrol was 99.66% for the period from 1971 to 1999, and 99.93% for Premium and Regular grade petrol. We use price data for Premium grade petrol as representative of all octanes of petrol.

Namibia's GDP per capita is one of the highest in Africa, and its Gini coefficient is one of the highest in the world. Energy analysis based on consumption per capita when the Gini coefficient is extreme is of limited relevance at the national level, unless the skew in income (and energy consumption) distribution is either constant or if the pattern of change is known. We therefore use total GDP rather than per capita. Quarterly GDP data are only available for the period from 1993 to the end of 2002 (NPC, 2003). Given the high correlation (95%) between annual GDP and the Consumer Price Index (CPI) for the period 1980 to 2002, we used the Friedman (1962) interpolation technique to estimate the quarterly GDP data for the period 1980 to 1993 based on CPI data for the same quarters. The official CPI is published monthly on the website of the Bank of Namibia.

The HIV/AIDS epidemic is still in its infancy in Namibia but has the potential for devastating demographic effects. There are no continuous time-series data for the HIV incidence rate in Namibia. Observations have been recorded by ante-natal clinics, at bi-annual frequencies. The available time series is short. We have interpolated the existing data (MHSS, 1999; 2000; 2001), and extrapolated back to the time the first incidence was recorded.

The Namibia Meteorological Services (2003) provided daily (mean minimum, mean and mean maximum) temperature data for certain locations in Namibia. We use temperature data from Windhoek as a proxy for national weighted average temperature. Windhoek, physically located in the middle of the country, is also the economic centre of Namibia (about 30% of the national electrical energy is consumed in Windhoek).

4. Methodology

Before cointegration methods were introduced, the ARDL framework was seen as the most attractive approach for modeling energy demand relationships since it reflected the pattern often seen in energy consumption, where sluggish adjustments in demand take time to fully materialize. However, the advent of cointegration analysis, with its emphasis on retaining the long-run information in the data by exploiting a cointegrating relationship (if found) among variables in levels, has come to signify the overt dismissal of the traditional ARDL approach (Bentzen and Engsted, 2001).

Although the Johansen (1988) method is by no means the only approach to cointegration, it has enjoyed widespread adoption since its inception. The most obvious advantage of the Johansen method is that it allows estimation of multiple cointegrating vectors where they exist. Far too often, however, practitioners fail to recognize that the application of the

Johansen technique presupposes that the underlying regressors are all integrated of order one (Pesaran *et al*., 2001). This is necessary because in the presence of a mixture of stationary series and series containing a unit root, standard statistical inference based on conventional likelihood ratio tests is no longer valid. Harris (1995), for example, notes that the trace and maximum eigenvalue tests from the Johansen procedure may lead to erroneous inferences when *I*(0) variables are present in the system since stationary series are likely to generate spurious cointegrating relations with other variables in the model.

Significantly, Pesaran and Shin (1999) and Pesaran *et al*. (2001) developed a new ARDL bounds testing approach for testing the existence of a cointegration relationship that is applicable irrespective of whether the underlying series are *I*(0), *I*(1). This approach, therefore, rehabilitates the ARDL framework while overcoming the problems associated with the presence of a mixture of *I*(0) and *I*(1) regressors in a Johansen-type framework.

To implement this technique, we start by modelling equation (1) as a conditional ARDL-ECM:

$$\begin{aligned}\Delta edt &= c_0 + c_1 t + \sum_{i=1}^{m}\alpha_i \Delta x_{t-i} + \sum_{j=0}^{n}\beta_j \Delta y_{t-j} + \sum_{k=0}^{p}\delta_k \Delta p_{t-k} + \sum_{r=0}^{q}\phi_r \Delta x_{t-r} \\ &+ \varphi D_t + \pi_1 ed_{t-1} + \pi_2 y_{t-1} + \pi_3 p_{t-1} + \pi_4 x_{t-1} + \xi_t \end{aligned} \quad (2)$$

where c_0 and c_1 t are the intercept and time trend components. Despite its restrictive nature, the latter is included to capture the effect of technical progress and other exogenous impacts that are not measurable directly (see Hunt *et al.*, 2003, for further discussion). D_t is a vector of dummy variables included to allow for significant trend or level breaks (due to shocks in prices or impacts related to the transition to independence) or pulses in the series (due to outlier observations). The different types of dummies are explained through their notations, and their significance reported in Tables 3 to 8. The dummy notation starts with the letter 'D' and is followed by three digits (XXX) referring to the year and the quarter. The last letter of the dummy shows whether it refers to a trend break (TB), shift of level (L) or a pulse (P). T_c

represents the quarter when the trend break, level shift or pulse took place. t is the time axis. DXXXL = 1 if $t \geq T_c$ and = 0 if $t < T_c$; DXXXTB = $t - T_{c-1}$ if $t \geq T_c$ and = 0 if $t < T_c$; DXXXP = 1 if $t = T_c$, and = 0 otherwise.

ξ_t are assumed to be white noise error processes. The lag structure of the first difference regressors is set to ensure an absence of serial correlation in the estimated residuals. We report the order of the chosen ARDL process guided by the Schwarz Criterion (SC) for each estimated equation in Tables 3 to 8.

Following Pesaran *et al*., (2001), we regard y_t, p_t and x_t as 'long-run forcing' variables for ed_t, in the sense that there is no feedback from the level of ed_t in (2). This assumption implies weak exogeneity of the regressors, i.e. that the explanatory variables are not cointegrated among themselves and that, therefore, the cointegrating rank (i.e. the number of cointegrating vectors) is restricted to unity.

It should be emphasised at this point that in implementing this methodology, OLS estimation of the ARDL-ECM (run using the Microfit 4 software package, see Pesaran and Pesaran, 1997) is merely an intermediate step necessary to undertake the bounds tests for cointegration. Equation (2), therefore, is not aimed at the estimation of short-run elasticities, which go beyond the scope of this paper.

The null hypothesis of 'no cointegration' is tested using an F-statistic for the joint significance of the coefficients of the lagged levels in (2). Pesaran *et al.* (2001) prove that, under the null hypothesis, the asymptotic distribution of the F-statistic is non standard irrespective of whether the regressors are I(0) or I(1), and provide two adjusted critical values that constitute upper and lower bounds of significance. If the F statistic exceeds the upper critical value we can conclude that a long-run relationship exists. If the F statistic falls below the lower critical value we cannot reject the null hypothesis of 'no cointegration'. If the statistic lies within the respective bounds, inference would be inconclusive. Critical values are also made available to encompass a range of different drift and trend components.

Should a cointegrating relationship be found, the next step in implementing this methodology is to estimate the conditional long-run model for ed_t, which can be obtained from the reduced form solution of (2), when $\Delta ed=\Delta y=\Delta p=\Delta x=0$:

$$edt = \Theta_1 + \Theta_2\, t + \Theta_3\ y_t + \Theta_4\ p_t\ + \Theta_5\, x_t + \nu_t \tag{3}$$

where Θ_1= $-c_0/\pi_1$, Θ_2= $-c_1/\pi_1$, Θ_3= $-\pi_2/\pi_1$, Θ_4= $-\pi_3/\pi_1$, Θ_5= $-\pi_4/\pi_1$, and ν_t is an IID $(0,\sigma^2)$ error process. These long-run coefficients, which form the focus of our empirical analysis, are those reported in Tables 3 to 8.

6. Estimation results

While the ARDL bounds testing approach to cointegration allows regressors to be either I(0) or I(1), it is still necessary to ensure that the dependent variable is I(1) in levels and that none of the regressors is I(2) or higher. Accordingly, all variables were tested for unit root (UR). UR testing was performed using Dickey-Fuller (DF) or Augmented Dickey-Fuller (ADF) tests for series that did not display any apparent structural breaks. Since Perron (1989) demonstrated that the ADF tests cannot reject the null hypothesis of a unit root against trend stationary alternatives if the data generating process is one of stationary fluctuations around a trend function with a one-time break, when visual inspection of the time series indicated a single break point we employed the Perron (1989) UR test. Perron (1989) calculated critical values for the autoregressive coefficient $\tilde{\alpha}$ in equation (4), for each of three cases which allow for an exogenous break, at time t, in level, in rate of growth and in both level and rate of growth. The critical values also account for alternative λs (with 10% intervals), where λ is a measure of how far into the sample the break took place.

$$y_t = \tilde{\mu} + \tilde{\beta} t + \tilde{\alpha} y_{t-1} + \tilde{\varepsilon}_t \tag{4}$$

The detailing of Perron's (1989) test is beyond our scope, suffice to say that if the estimated $\tilde{\alpha}$ in our UR testing of variables where one break is suspected is less than Perron's critical value (in absolute terms), the null hypothesis of a unit root is not rejected.

In the case of two structural break points, we employed the Lumdsaine and Papell (1997) UR model given in (5):

$$\Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \qquad (5)$$

where $DU1_t$ and $DU2_t$ are dummies for a mean shift occuring at times $TB1$ and $TB2$. $DT1_t$ and $DT2_t$ are dummies for the corresponding trend-shifts. $DU1_t = 1$ if $t > TB1$, $DU2_t = 1$ if $t > TB2$, $DT1_t = (t-TB1)1$ if $t > TB1$, and $DT2_t = (t-TB2)1$ if $t > TB2$. $t = 1,\ldots..,T$. UR testing is done by comparing the relevant estimated values from (5) with the relevant critical values provided by Lumsdaine and Papell (1997).

The results of our UR testing are shown in Table 2. As a matter of interest, Table 2 also reports the standard (A)DF test statistics and associated critical values in the cases in which the UR test was done according to the Perron (P) or Lumsdaine and Papell (LP) tests. We found that all dependent variables used in our estimations were I(1). With respect to the regressors, GDP and air temperature were found to be I(0) while all other regressors contained a unit root in levels. The finding of a mixture of I(1) and I(0) regressors is particularly important to appreciate the merit of this methodology in that it confirms the use of the ARDL bounds testing approach to cointegration as the most appropriate and reliable estimation technique given the time series properties of our data.

TABLE 2 HERE

The results of the bounds testing (and the order of the ARDL processes) are reported for each estimated regression in Tables 3 to 8. Since in all cases the computed bounds (F) statistic is greater than the upper critical value, these tests confirm the existence of a cointegrating relationship between the dependent variable and the regressors within each of the estimated equations. Armed with this finding, we next proceed to build on it by estimating the long-run models. Tables 3 to 8 also report several diagnostic tests, all of which suggest an adequate model specification and high goodness of fit of the individual equations (for more details see the Note at the bottom of Table 3).

TABLE 3 HERE

Table 3 reports the results of the estimation of the national consumption of all commercial energies as a function of weighted total energy price, GDP, temperature and the dummy D884L. All regressors are highly significant. National energy consumption appears to be income elastic, price inelastic and sensitive to mean minimum temperature. Energy consumption increases (or decreases) when temperature decreases (or increases). The trend and level of the weighted marginal national energy price changed various times during the sample period. Only the break in 2001q2 is significant, and then only in the bounds test for the post-independence period. The HIV incidence rate was insignificant as an explanatory variable and was therefore omitted from the preferred equation. The long-run elasticities for price, GDP and temperature for the 1990q1 to 2002q4 period and the period 1980q1 to 2002q4 are similar. This implies that D884L sufficiently captures structural changes around the time of independence.

TABLE 4 HERE

Table 4 shows that the significant explanatory variables for the total consumption of grid electricity in Namibia are the price of electricity, GDP and mean minimum temperature. When a low temperature gets even lower (or higher), more (or less) electrical energy is consumed in Namibia. Changes in high temperatures do not normally have the same effect. The long-run GDP elasticity is about twice the absolute value of the long-run price elasticity. Diesel and kerosene prices were found to be insignificant. There are in other words no cross-price elasticities between electricity, diesel and kerosene.

Electricity from the public grid could, in principle, be regarded as a potential alternative to diesel and kerosene for the provision of various energy services. A consumer can, in principle, choose to run a diesel auto-generator instead of drawing electricity from the grid. Similarly, a household can choose to use kerosene lamps rather than electric bulbs. The absence of significant cross-price elasticities between diesel and electricity is probably due to the fact that the opportunity to switch between grid electricity and auto-generators is limited in areas outside the municipalities. Where grid electricity is made available outside municipal areas, farmers and companies do connect as they find grid power more reliable than operating auto-generators. Auto-generators might then be kept for fall-back purposes, if the grid supply were to be interrupted, but would in general not be used in an on/off fashion depending on variations in the relative price between diesel and public electricity.

The amount of energy relevant for switching between grid electricity and kerosene for lighting purposes as a result of variations in relative prices can only be marginal. The amount of kerosene sold in Namibia during the last five years (litres converted to Joules = heating values) is only 6.26% of the electricity consumed in the country (KWh converted to Joules).

The government of independent Namibia has pursued an active policy of making electricity available in rural areas and to consumers that were deprived of this energy form during the colonial dispensation. One might intuitively expect the implementation of this policy to be reflected in a positive and significant time-trend in the estimation of the national consumption of electricity. This is in fact not the case. The amount of electricity sold to rural areas, although growing strongly, is small compared to consumption in urban areas. Hence, the growth in rural electricity consumption does not have a major impact on national consumption. The associated time-trend is not significant. The dummy reflecting independence (INDDUM) was not significant.

As noted earlier in the paper, one can estimate national energy consumption per capita, or include the size of the population as a regressor. We found that the high correlation (96.1) between total population and national GDP caused multicollinearity problems. For the sake of completeness, therefore, we also estimated a model of electricity consumption per capita and found that the long-run elasticities were lower in the per capita case. This points to the possible role of the growing size of the population as an explanatory variable for the increased electricity consumption over time. But this cannot be proven without better data on the rate of electrification (the proportion of the population actually connected to the electricity grid) and the rate of change (if any) in income distribution. In Namibia, with so many people living in subsistence economies, electricity or energy consumption per capita is possibly nothing but a statistical concept with little relevance for meaningful demand analysis at the national level. The $\overline{R}^2$ for the estimate of the electricity consumption per capita was much lower (0.55) than the $\overline{R}^2$ for the aggregated electricity consumption (0.97). The regressors were also less significant in the *per capita* model. For these reasons, the model for aggregated national electricity consumption (Table 4) is our preferred model.

TABLE 5 HERE

As shown in Table 5, the consumption of petrol is found to be price and GDP elastic, but less sensitive to temperature fluctuations. Comparing estimations for the entire period with the post-independence period shows that the significant regressors are the same, with only minor differences in their values. This supports that INDDUM picks up the effect on petrol consumption of the transition from pre- to post-independence.

The high correlation between petrol and diesel prices creates problems of multicollinearity. It is not possible to distinguish any effect on petrol consumption as a result of changes in diesel prices. The same holds for the consumption of transport diesel as a function of petrol prices. Unfortunately, sufficient data were not available for other potentially important variables, such as the price indices for petrol and diesel vehicles, or the extent of the tarred roads network. However, the good diagnostic results imply that the model adequately estimates the demand for petrol in Namibia. Petrol is a transport fuel, and is not a substitute to (or from), or complementary with, electricity and kerosene. The estimations found that the prices for electricity and kerosene were not significant for the consumption of petrol.

Diesel was a major fuel for the war machine prior to independence, and we expected this to influence the estimation of the diesel consumption for the entire period 1980q1 to 2002q4. As shown in Table 6, the estimate for the diesel price elasticity has the expected sign but is not significant. The mean maximum temperature variable was more significant than the mean minimum temperature. When the low and the high temperatures were combined in the same equation the mean minimum temperature was insignificant.

TABLES 6 & 7 HERE

As discussed earlier, a government policy is to refund part of the fuel tax to certain consumers when their diesel consumption is related to non-transport purposes. We modelled diesel consumption using the calculated weighted *rebated* diesel price, and, as an alternative, the non-rebated pump price (Table 6). The resulting estimates were almost identical and the price elasticity was insignificant in either case. The national weighted rebated diesel price includes a large amount of non-rebated diesel (two thirds of total consumption). The fact that neither the rebated nor the pump price is statistically significant does not say anything about the effect of the rebate in the respective economic sectors. Whether the rebate is important or not must be analyzed at the sectoral level. Table 7 shows the estimated regression after the price variable was dropped.

Petrol is exclusively a transport fuel, while diesel is a multi-purpose fuel. Transport diesel is used in all sectors, and is the dominant fuel for heavy goods and commodity transport in addition to buses and trains. Petrol is the main fuel for private cars and smaller vans. The national demand for petrol and diesel therefore respond differently to changes in price, GDP and temperature variables.

TABLE 8 HERE

In Table 8 we limit estimation of diesel consumption to the post-independence period. The value of the long-run GDP elasticity changes marginally, diesel price is still insignificant, and the long-run elasticity for temperature is reduced. The peaceful post-independence situation presents a different consumption pattern for diesel but despite this, the GDP elasticity does not change much when the 1990q1-2002q4 period is estimated.

6. Discussion

The difference in elasticities for the various energies reflects the difference in services provided by the various fuels. There are no significant cross-price elasticities for the various energy forms. The lower $\overline{R}^2$ for diesel consumption probably reflects the fact that diesel has a more diverse utilization than other fuels.

Our focus in this paper was on long-run elasticities. Our estimates of aggregated energy consumption compare well with those *per capita* figures reported by Pesaran *et al.* (1998), who also employed the ARDL bounds testing approach to cointegration. They found a mean long-run income elasticity of 1.23 and a mean long-run price elasticity of –0.261. Our figures for *total* energy consumption are 1.27 and –0.34 but we were able to control for temperature as an exogenous variable. There are major variations among the 10 Asian countries studied by Pesaran *et al.* (1998). Our income and price elasticities are closest to those of Thailand; 1.17 and –0.34 respectively. Both Namibia and Thailand are low middle income countries.

In her survey Dahl (1994) reports income elasticities of 0.69 to 1.68, and price elasticities of -0.30 to –0.96 for the sub-Saharan region for alternative periods from 1960 to 1975. For the period from 1970 to 1980 she reports an intermediate income elasticity of 1.28 and price elasticity of –0.94 for Botswana, and 1.33 and -0.97, respectively, for Nigeria.

We found different price, GDP and temperature elasticities for the consumption of various energy forms. Diesel has the highest long-run GDP and temperature elasticities (in absolute values) (1.96 and –1.12 respectively). Petroleum has the highest long-run price elasticity (-0.86), while electricity's is lower (-0.30). Electricity has the lowest long-run GDP elasticity (0.59), while petroleum's (1.08) is between those of diesel and electricity.

Balabanoff (1994) reports income and price elasticities for electricity from South America from the 1970s to the early 1990s. The estimates for Brazil were 1.73 and –0.43, and for Columbia 1.88 and –0.18 respectively. Brenton (1997) found an expenditure elasticity for electricity of 1 for middle income countries, and a price elasticity of –0.69. Electricity prices in Namibia were for many years the lowest in the world. This could hinder the relevance of a direct comparison of Namibian electricity elasticities with those from other continents.

Our estimated results for the consumption of electricity are in direct contradiction to those of Lundmark (2001), who applied simple OLS in regressing Namibian electricity demand on electricity and coal prices, and on GDP. He used annual data for the period 1980 to 1996. None of his coefficients were significant, and the regression's $\overline{R}^2$ was 0.789. The comparison acts as a reminder of the need to apply appropriate data (he did not compile end-user prices), to use a correct model (his coal prices are not relevant for the end-use of electricity in Namibia), to employ a large sample (his estimation was only based on 17 observations), and a suitable methodology (Lundmark did not deal with the time-series properties of the series).

A number of researchers (Sailor and Munoz, 1996; Al-Faris and Ghali, 1998; etc.) have found that climatic variables play a significant role in the demand for energy. None of these studies, however, relate to energy consumption in Africa. Low temperatures are in general significant in our models for Namibia, while the significance of high temperatures is limited to diesel consumption. This confirms that much of the commercial energy in Namibia is used for producing heating rather than cooling services. Heating services are cheaper and more accessible. Variations in low temperatures affect energy demand more than variations in high temperatures. The lack of symmetry between the heating and cooling services also highlights the difference between the energy demand function of Namibia vis-à-vis that of an OECD country, where there is also high saturation of cooling appliances.

Our findings appear to have significant policy implications, particularly with respect to the way in which taxation could help the Namibian government increase fiscal revenues and regulate the level and/or structure of energy consumption. For example, if government needed to increase its tax revenues, comparatively more tax could be charged on diesel than on petrol since we found the price elasticity for diesel to be much lower than for petrol. It is in practice difficult to have different energy taxes for all consumer groups as government may not be able to control their sourcing of liquid fuels. One method used in certain European countries is to mix different coloring agents into the diesel to be sold at different taxation levels. This method has not been tried in Namibia and could prove useful for more selective energy taxation and pricing. Additionally, the differences in price elasticities across fuels uncovered by our empirical analysis provide valuable evidence for informing environmentally motivated energy taxation, should the Namibian government wish to pursue this as a policy objective.

7. Conclusions

In this paper we presented the first econometric study of Namibian energy demand at aggregated level and by energy type, that uses high quality, quarterly end-user data covering a relatively long period (1980-2002). Our results have shown that energy demand in Namibia conforms to a priori expectations of a negative price elasticity and a positive GDP elasticity. In most cases we also find a negative temperature elasticity.

Diesel has the highest GDP and temperature elasticities (in absolute terms). The price elasticity for the consumption of petrol is much higher than that of electricity (in absolute terms), while diesel does not display any significant price elasticity. The differences in price elasticities across fuel types have clear implications for energy taxation by Namibian policy makers. The consumption of electricity has the lowest GDP elasticity, while the GDP elasticity for the consumption of petrol is between that of electricity and diesel.

We did not find any significant cross price elasticities between different energy forms. Consumers appear to retain their fuel mix and consumption level. They seem to get ‘locked’ into a set of appliances and equipment for the provision of the energy services they require, and do not easily break away from that pattern even if prices and income change. Additionally, our results have also shown that the relatively recent but very high HIV incidence rate in Namibia has not yet made its mark on energy consumption.

Notwithstanding the value of our findings, it should be borne in mind that energy demand might assume different connotations in different economic sectors. Sectoral consumers do not make optimal demand decisions under the same constraints and do not necessarily demand the same services from the various energy forms. A sectoral analysis of the Namibian demand for energy, therefore, offers a profitable avenue for future research.

References

Al-Faris, A.F. and Ghali, K.H., 1998. Environment-based forecasting of peak-load profiles for electricity consumption in the western United Arab Emirates. *The Journal of Energy and Development* **24** 1, 1-15.

Balabanoff, S., 1994. The dynamics of energy demand in Latin America. *OPEC Review* **Winter**, 467-488.

Bentzen, J. and Engsted, T., 2001. A revival of the autoregressive distributed lag model in estimating energy demand relationships. *Energy* **26**, 45-55.

BP Namibia (2002). Namibian LPG prices. Unpublished database. BP Namibia. Windhoek.

Brenton, P., 1997. Estimates of the demand for energy using cross-country consumption data. *Applied Economics* **29**, 851-859.

Caltex, 2003. Sales volumes of liquid fuels in Namibia 1979-2002. Unpublished database. Caltex, Cape Town.

Dahl, C., 1994. A survey of energy demand elasticities for the developing world. *The Journal of Energy and Development* **17** 1, 1- 47.

DUKES (2001) UK Digest of Energy Statistics 2001. DTI, London.

Edmonds, J. and Reilly, J.M., 1985. Global Energy: Assessing the Future. Oxford University Press, Oxford.

Engen, 2002. Various sales data for petroleum, diesel and kerosene. *Unpublished company records*. Engen, Cape Town.

Engle, R. and Granger, C., 1987. Co-integration and error correction: representation, estimation and testing. *Econometrica* **55** 2, 251-276.

Friedman, M., 1962. The interpolation of time series by related series. *Journal of the American Statistical Association* **57** December, 729-757.

Gately, D. and Huntington, H.G., 2002. The asymmetric effects of change in price and income on energy and oil demand. *Energy Journal* **23** 1, 19-55.

Government Gazette (1975-2002). Government of the Republic of Namibia, Windhoek.

Griffin, J.M. and Schulman, C.T., 2005. Price asymmetry in energy demand models: A proxy for energy-saving technical change? *The Energy Journal* **26** 2, 1-21.

Harris, R., 1995. Using Cointegration Analysis in Econometric Modelling. Prentice Hall, London.

Hunt, L.C., Salgado, C. and Thorpe, A., 2000. The policy of power and the power of policy: Energy policy in Honduras. *The Journal of Energy and Development* **25** 1, 1-36.

Hunt, L.C., Judge, G. and Ninomiya, Y., 2003. 'Modelling underlying energy demand trends'. Chapter 9 in L.C. Hunt (Ed.) Energy in a Competitive Market: Essays in Honour of Colin Robinson, Edward Elgar, May, pp. 140-174.

IEA, 2002. Key World Energy Statistics (2001 Edition). IEA, Paris.
Ibrahim, I.B. and Hurst, C., 1990. Estimating energy and oil demand functions – A study of thirteen developing countries. *Energy Economics* **12**, 93-101.

Johansen, S., 1988. Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* **12**, 231 –254.

Johansen, S., 1991. Estimating and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica* **59** 6, 1551-1580.

Levine, M.D., Koomey, J.G., Price, L., Geller, G. and Nadel, S., 1995. Electricity end-use efficiencies: Experience with technologies, markets, and policies throughout the world. *Energy* **20** 1, 37-61.

Lumsdaine, R. and Papell, D., 1997. Multiple trend breaks and the unit-root hypothesis. *Review of Economics and Statistics* **19**, 212-218.

Lundmark, R., 2001. Changes in Namibia's energy market. *Scandinavian Journal of Development Alternatives and Area Studies* **20** 1-2, 103-112.

MHSS, 1999. Report of the HIV Sentinel Sero Survey. Ministry of Health and Social Services, Windhoek.

MHSS, 2000. Projecting the impact of HIV/AIDS in Namibia. Ministry of Health and Social Services, Windhoek.

MHSS, 2001. Report of the HIV Sentinel Sero Survey. Ministry of Health and Social Services, Windhoek.
MME, 1998. White Paper on Energy Policy. Ministry of Mines and Energy, Windhoek.
MME, 2000. Electricity Act. Act 2 of 2000. Ministry of Mines and Energy, Windhoek.

MME (2002) Controlled prices for Petrol and Diesel 1989-2002. Unpublished data files from the Ministry of Mines and Energy, Windhoek.

Namibia Meteorological Services, 2003. Monthly temperature data for selected locations in Namibia. Unpublished. Ministry of Works, Transport and Communication, Windhoek.

Nampower, 2003. Various internal sales and accounting data. Nampower, Windhoek.

NPC, 1995. *First National Development Plan (NDP 1) – Volume 1 – 1995/1996-1999/2000.* National Planning Commission, Windhoek.

NPC, 2002a. Volume 1: Macroeconomic, sectoral and cross-sectoral policies. Second National Development Plan – (NDP2). National Planning Commission, Windhoek.

NPC, 2002b. National accounts 1980 – 2001. National Planning Commission, Windhoek.

NPC, 2003. National Accounts 1994 – 2002. National Planning Commission, Windhoek.

Perron, P., 1989. The great crash, the oil price shock, and the unit root hypothesis. *Econometrica* **57**, 1361-1401.

Pesaran, M.H. and Pesaran, B., 1997. Microfit 4.0. Oxford University Press, Oxford.

Pesaran, M.H., and Shin, Y., 1999. An autoregressive distributed-lag modelling approach to cointegration analysis, in: Strøm, S. (Ed.) Econometrics and Economic Theory in the 20th Century. Cambridge University Press, Cambridge.

Pesaran, M.H., Smith, R. and Akiyama, T., 1998. Energy demand in Asian economies. Oxford University Press, Oxford.

Pesaran, M.H., Shin, Y. and Smith, R.J., 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* **16**, 289-326.

Pourgerami, A. and von Hirschhausen, C.R., 1991. Aggregate demand for energy and dynamics of energy elasticities in non-oil developing countries. *The Journal of Energy and Development* **14** 2, 237-252.

Sailor, D. and Munoz, R.J., 1996. Sensitivity of electricity and natural gas consumption to climate in the USA - methodology and results for eight states. *Energy* **22** 10, 987-998.

SAPIA, 2002. Price increases for petrol, diesel and kerosene. Unpublished data files. The South African Petroleum Industry Association, Cape Town.

Shell Namibia, 2003. Paraffin prices in Grootfontein, Windhoek and Walvis Bay 1999-2002. Shell Namibia, Windhoek.

Stage, J., 2002. Structural shifts in Namibian Energy Use: An input-output approach. *The South African Journal of Economics* **70** 6, 1103-1125.

Stage, J. and Fleermuys, F., 2001. Energy use in the Namibian economy from 1995 to 1998. *Development Southern Africa* **18** 5, 423-441.

Woodland, A.D., 1993. A micro-econometric analysis of the industrial demand for energy in New South Wales. *Energy Journal* **14** 2, 57-89.

Table 1: Summary of elasticities from main studies on developing countries

Country	Period	Dependent variable (demand for:)	Long-run GDP (Income)	Long-run Price	Long-run Other	Short-run GDP (Income)	Short-run Price	Source
Bangladesh	1973-1990	Energy	1.98	0.04				Pesaran *et al.* (1998)
India			1.01	-0.07				
Indonesia			1.56	-0.49				
Korea			1.07	-0.14				
Malaysia			2.21	-1.16				
Pakistan			1.32	0.05				
Philippines			0.84	-0.43				
Sri Lanka			0.22	0.06				
Taiwan			0.90	-0.13				
Thailand			1.17	-0.34				
Mean			1.23	.-0.26				
Bangladesh	1973-1990	Transport sector energy	1.625	0.000				
India			0.436	-0.033				
Indonesia			1.286	-0.324				
Korea			1.387	-0.203				
Malaysia			3.318	-1.753				
Pakistan			1.425	0.165				
Philippines			1.187	-1.324				
Sri Lanka			0.578	0.101				
Taiwan			1.038	-0.005				
Thailand			1.474	-0.375				
Mean group estimate			1.375	-0.375				
Bangladesh	1973-1990	Residential energy	1.252	-0.043				
India			1.643	-0.005				
Indonesia			1.187	-0.569				
Korea			0.624	0.203				
Malaysia			1.004	-0.286				
Pakistan			2.947	-0.334				
Philippines			1.654	-0.347				
Sri Lanka			0.376	-0.363				
Taiwan			0.811	-0.191				
Thailand			1.629	-0.114				
Mean group estimate			1.312	-0.135				
Argentina	1970-1990	Oil	1.98	-0.25				Balabanoff (1994)
Argentina		Electricity	1.00	n/a				
Brazil			1.73	-0.43				
Chile			1.65	n/a				
Colombia			1.88	-0.18				
Equador			1.95	n/a				
Peru			0.70	n/a				
Brazil	1970s – early 1980s	Energy				1.16	-0.15	Ibrahim and Hurst (1990)
India						1.56	n/a	
Morocco						1.03	n/a	
Phillipines						1.14	-0.17	
Taiwan						1.24	-0.24	
Algeria						0.89	-0.89	
Egypt						0.85	-0.27	
Indonesia						1.19	n/a	

Mexico						1.27	-0.12	
Saudi Arabia						1.23	-0.24	
Poor countries	Data collected in 1980, for 5 year intervals	Electricity		-0.073	0.919 (i)			Brenton (1997)(ii)
Middle-income countries				-0.695	1.007 (i)			
Rich countries				-0.704	0.877 (i)			
sub-Saharan Africa	1960-1975	Energy	1.67 (iii)	-0.58 (iii)		1.67	-0.06	Dahl (1994)
Botswana	1970-1980		1.28 (iii)	-0.94 (iii)				
Nigeria			1.33 (iii)	-0.97 (iii)				
Average of 50 developing countries			1.27	-0.33		0.53	-0.33	
Brazil	1970-1973	Energy	1.0					Edmonds and Reilly (1985)
Colombia			0.8					
Mexico			1.2					
Venezuela			1.6					
All LDCs			1.2					
Brazil	1973-1978		1.1					
Colombia			0.7					
Mexico			2.0					
Venezuela			0.5					
All LDCs			1.4					
Namibia	1980-1996	Electricity	-0.512 (iv)	-0.863				Lundmark (2001)
Honduras	1973-1995	Electricity	0.786					Hunt *et al.* (2000)
		Petroleum	1.578					

Note: (i) Expenditure elasticity for electricity. (ii) Using cross country data. (iii) From dynamic and static models. (iv) Not significant.

Note: The findings of Pesaran *et al.* (1998) are the most comparable to ours since we have used the same ARDL methodology. However, Pesaran *et al.'s* estimates refer to the share of energy in total expenditure, and are on a *per capita* basis. The other contributions to the literature quoted in Table 1 have used various methodologies; for example, Brenton (1997) employed cross-country data while Dahl's (1994) offers a survey of empirical results drawn from several studies employing a variety of methodologies. Generally, the time series analyses are log-linear OLS/GLS. Some of the data cover periods with major shocks in oil prices (1973), and this tends to affect the results. Few, if any, of the data used involve end-user prices. Some of the estimates of the income elasticity, omit the price variable, and the results are then in many cases prone to exaggerate the value of the GDP elasticity.

Table 2: Summary of UR testing

Variable	Level			Conclusion
	Test(*)	Statistic	Critical Value	
National electricity consumption	ADF	-3.326	-3.465	The variable is I(1)
National petrol consumption	ADF P	-2.398 2.823	-3.463 -4.04	The variable is I(1)
National diesel consumption	ADF P	-1.956 0.639	-3.460 -3.96	The variable is I(1)
National energy consumption	P ADF	3.6 -2.787	3.74 -3.464	The variable is I(1)
National marginal (weighted) electricity price	P ADF	-2.964 -2.862	-4.17 -3.467	The variable is I(1)
Diesel price	P ADF	-2.065 1.177	-3.99 -3.482	The variable is I(1)
Rebated, national diesel price	ADF P	-1.822 0.049	-3.461 -3.8	The variable is I(1)
Petrol price	LP ADF	-6.294 0.803	-6.65 -3.48	The variable is I(1)
Weighted national energy price	DF P	-2.131 3.405	-3.467 -4.04	The variable is I(1)
Rebated, national *weighted energy* price	DF	-1.915	-3.461	The variable is I(1)
GDP	P ADF	-5.083 -3.545	-4.22 -3.467	The variable is I(0)
Mean minimum temperature	ADF	-4.048	-3.502[a]	The variable is I(0)
Mean maximum temperature	ADF	-1.805	-2.895	The variable is I(1)

Note: Unless otherwise stated, the critical values refer to the 95% significance level. Superscript [a] refers to the 99% level.
(*) DF = Dickey-Fuller test. ADF = Augmented Dickey Fuller test. P = Perron's test. LP = Lumsdaine and Papell's test.

Table 3: National consumption of commercial energy

Dependent variable: National energy consumption					
		1980Q1 – 2002Q4		1990Q1 – 2002Q4	
	Regressors:	**Estimate:**	**T-ratio (Prob):**	**Estimate:**	**T-ratio (Prob):**
Long-run elasticities	Weighted national energy price	-0.344	-1.992 (0.050)	-0.297	-1.985 (0.054)
	Total GDP	1.266	5.596 (0.000)	1.286	9.228 (0.000)
	Mean minimum temperature	-0.676	-2.696 (0.009)	-0.240	-2.205 (0.034)
	D012L			0.065	0.921 (0.363)
	Intercept	8.802	3.580 (0.001)	6.739	3.148 (0.003)
	D884L	-0.307	-2.614 (0.011)		
Tests and diagnostics	SEE	0.039		0.036	
	$\overline{R}^2$	0.962		0.956	
	DW-statistic	2.267		2.289	
	Serial correlation(χ4)	7.475 (0.130)		2.329 (0.675)	
	Functional form(χ1)	1.020 (0.313)		0.857 (0.355)	
	Normality(χ2)	1.425 (0.490)		0.259 (0.879)	
	Heteroscedasticity (χ1)	0.598 (0.439)		1.874 (0.171)	
Order of the ARDL process		(2,0,0,0)		(1,0,0,0)	
Bounds F statistic vs upper critical value		F 6.218 > 4.855		F 6.353 > 6.309[a]	

Note: For Tables 3 to 8, the critical values of the bounds tests are taken from Pesaran and Pesaran (1997), Table F, p.478. Unless otherwise stated, all critical values refer to the 95% significance level. Where present, the superscript [a] denotes significance at the 99% level.

Note: For Tables 3 to 8, we also report the following statistics and diagnostic tests. *SEE* refers to the Standard Error while $\overline{R}^2$ expresses the ratio of the explained sum of squares to the total sum of squares (adjusted for degrees of freedom). Both are 'goodness of fit' measures, where SEE should be as small as possible and the $\overline{R}^2$ as close to unity as possible. The *DW statistic* refers to the Durbin Watson 0<*d>4* test for serial correlation. As rule of thumb, if the statistic *d* is found to be around 2, one may assume that there is no first-order autocorrelation. *Serial correlation* refers to the Lagrange multiplier statistic, which specifically tests whether the disturbances are autocorrelated up to order 4. *Functional form* shows the result of Ramsey's RESET test using the square of the fitted values. *Normality* shows the results of the testing of skewness and kurtosis of the residuals while *Heteroscedasticity* refers to the regression of squared residuals on squared fitted values to establish whether the disturbances have a constant variance. A 'chi-square' (χ^2) statistic is shown for each of the test statistics and the comparison with the critical values decides whether the regression passes the tests. The order is given in the notation *p* of χp . At the 95% level of significance, the critical value is 3.84 for *p* = 1; 5.99 for *p* = 2, and 9.49 for *p* = 4. The number in brackets next to the individual chi-square statistic shows within what percentage of the distribution the individual statistic is found.

Table 4: National electricity consumption

Dependent variable: National electricity consumption (1980q1-2002q4)			
	Regressors:	**Estimate:**	**T-ratio (Prob):**
Long-run elasticities	Weighted national marginal electricity price	-0.298	-3.042 (0.003)
	Total GDP	0.589	5.160 (0.000)
	Mean minimum temperature	-0.356	-1.966 (0.053)
	Intercept	12.031	6.295 (0.000)
Tests and diagnostics	SEE	0.034	
	$\overline{R}^2$	0.971	
	DW-statistic	1.784	
	Serial correlation(χ4)	4.493 (0.343)	
	Functional form(χ1)	0.920 (0.338)	
	Normality(χ2)	0.008 (0.996)	
	Heteroscedasticity(χ1)	2.191 (0.139)	
Order of the ARDL process		(4,0,1,0)	
Bounds F statistic vs upper critical value		F 5.881 > 4.855	

Table 5: National consumption of petrol

Dependent variable: National petrol consumption					
		1980q1 – 2002q4		1990q1 -2002q4	
Long-run elasticities	**Regressors:**	**Estimate:**	**T-ratio (Prob):**	**Estimate:**	**T-ratio (Prob)**
	Petrol price	-0.858	-3.803 (0.000)	-0.794	-2.441 (0.019)
	Total GDP	1.081	5.786 (0.000)	0.957	7.474 (0.000)
	Mean minimum temperature	-0.272	-1.909 (0.061)	-0.199	-1.650 (0.107)
	Intercept	12.846	4.630 (0.000)	12.933	3.890 (0.000)
	INDDUM	-0.311	-2.718 (0.008)		
Tests and diagnostics	SEE	0.035		0.030	
	$\bar{R}^2$	0.978		0.952	
	DW-statistic	2.192		2.562	
	Serial correlation(χ4)	8.936 (0.063)		9.755 (0.045)	
	Functional form(χ1)	0.338 (0.561)		0.262 (0.609)	
	Normality(χ2)	1.249 (0.535)		1.386 (0.500)	
	Heteroscedasticity(χ1)	0.477 (0.490)		6.270 (0.012)	
Order of the ARDL process		(8,2,1,0)			
Bounds F statistic vs upper critical value		F 7.189 > 6.309[a]			

Note: INDDUM = 1 for the period from 1980q1 to 1989q4, and = 0 otherwise.

Table 6: National consumption of diesel

Dependent variable: National diesel consumption (1980q1-2002q4)					
		Rebated price		Pump price	
	Regressors:	**Estimate:**	**T-ratio (Prob):**	**Estimate:**	**T-ratio (Prob):**
Long-run elasticities	Rebated, weighted price	-0.109	-0.458 (0.648)		
	Pump price			-0.138	-0.565 (0.574)
	Total GDP	2.075	4.992 (0.000)	2.077	4.957 (0.000)
	Mean maximum temperature	-1.240	-2.306 (0.024)	-1.246	-2.294 (0.025)
	Intercept	0.961	0.252 (0.802)	1.232	0.321 (0.749)
	D884L	-0.560	-3.308 (0.001)	-0.573	-3.249 (0.002)
	D851861L	0.305	1.465 (0.147)	0.309	1.475 (0.144)
Tests and diagnostics	SEE	0.066		0.066	
	$\bar{R}^2$	0.904		0.905	
	DW-statistic	2.258		2.259	
	Serial correlation(χ4)	7.195 (0.126)		7.115 (0.130)	
	Functional form(χ1)	2.519 (0.112)		2.395 (0.122)	
	Normality(χ2)	0.948 (0.623)		0.926 (0.629)	
	Heteroscedasticity(χ1)	1.315 (0.252)		1.291 (0.256)	
Order of the ARDL process		(3,0,0,0)		(3,0,0,0)	
Bounds F statistic vs upper critical value		F 8.225 > 6.309[a]		F 8.225 > 6.309[a]	

Table 7: National consumption of diesel – without the price regressor

	Dependent variable: National diesel consumption (1980q1-2002q4)		
Long-run elasticities	**Regressors:**	**Estimate:**	**T-ratio (Prob):**
	Total GDP	1.961	5.536 (0.000)
	Mean maximum temperature	-1.124	-2.412 (0.018)
	Intercept	0.707	0.247 (0.806)
	D884L	-0.534	-3.904 (0.000)
	SEE	0.067	
	$\overline{R}^2$	0.903	
	DW-statistic	2.185	
	Serial correlation(χ4)	6.487 (0.166)	
	Functional form(χ1)	0.966 (0.326)	
	Normality(χ2)	0.871 (0.647)	
	Heteroscedasticity(χ1)	2.678 (0.102)	
Order of the ARDL process		(3,0,0)	
Bounds F statistic vs upper critical value		F 9.786 > 7.815[a]	

Table 8: Post-independence consumption of diesel

Dependent variable: National diesel consumption (1990q1-2002q4)			
Long-run elasticities	**Regressors:**	**Estimate:**	**T-ratio (Prob):**
	GDP	1.856	11.562 (0.000)
	Mean maximum temperature	-0.493	-2.076 (0.044)
	Intercept	-0.987	-0.635 (0.529)
Tests and diagnostics	SEE	0.065	
	$\overline{R}^2$	0.933	
	DW-statistic	2.186	
	Serial correlation(χ4)	1.388 (0.846)	
	Functional form(χ1)	0.071 (0.790)	
	Normality(χ2)	0.122 (0.941)	
	Heteroscedasticity(χ1)	2.507 (0.113)	
Order of the ARDL process	(1,0,0)		
Bounds F statistic vs upper critical value	F 9.786 > 7.815[a]		

Note:

This paper may not be quoted or reproduced without permission

Surrey Energy Economics Centre (SEEC)

Department of Economics

University of Surrey

Guildford

Surrey GU2 7XH

SURREY

ENERGY

ECONOMICS

DISCUSSION PAPER

SERIES

For further information about SEEC please go to:

www.seec.surrey.ac.uk