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Estimating the demand for gasoline in developing countries: Senegal

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ABSTRACT

This paper estimates the aggregate demand for gasoline in Senegal from 1970 to 2008. The long-term and short-term elasticities of demand with respect to gasoline prices and income are of paramount interest in this study. In Senegal, rising food prices, unemployment and shortage of electric supply are always associated with the spiking cost of world oil prices. To understand the external shocks of world oil price and demand for gasoline in Senegal, this study tested a log linear model against the linear model of the demand-for-oil function with lagged dependent variables as an explanatory variable. Here, the linear specification of the demand for oil is rejected in this study in favor of the log linear. The natural log transformation is typical when using high frequency data and significantly reduces skewness and kurtosis. Generally in this study, I found that short run elasticity is smaller than long-run elasticity and gasoline demand is inelastic with respect to both price and income for both the short and long runs in Senegal. This is why researcher like Moosa posits that "this assertion can be rationalised on the grounds that oil is such an important commodity that does not have close substitutes at least for its uses" (1998, p. 3).

1. Introduction

As the financial crisis continues to evolve globally, infinite number of questions emerge about how the crisis developed that will impact industrialized countries. Meanwhile, research and analysis have demonstrated that developing countries will be even more severely impacted (World Bank, 2009). For instance, countries such as Senegal (non-oil producer), with less sophisticated economies, are much less capable of adjusting to the price shocks associated with oil price increases since the 1970s and most recently in 2008. On one hand the quasi totality of energy available in Senegal (petrol, gas fuel, and electricity) are produced from imported oil which represents 35% (oil fuels) and 5% thermal power of the energy balance (UNDP, 2008). On the other hand since Senegal serves its domestic market as well as those of Gambia, Guinea Bissau, Sierra Leone, Liberia, Mauritania, and Mali, I think that it would be interesting to start looking at the case of Senegal and SAR (African Society of Refinery) first, and then draw preliminary lessons from there, for the sub region. Therefore, the wide range of projections of future Least Developed Countries (LDC) energy demand suggests a need for better information about energy-economy in the LDCs.

In Senegal, investigating how sensitive is gasoline demand with respect to change in income and prices at the pump has critical implications for public policies analysis regarding climate change in developing area, food security, "optimal taxation", subsidies, exposure to financial and macroeconomics exogenous shocks and generally national security issues. While a great deal of attention has been paid to the empirical investigation of price and income elasticity of gasoline demand (see, for example, Archibald and Gillingham, 1980; Puller and Greening, 1999), only a few studies have attempted to estimate the elasticity beyond 2000, especially in developing countries and particularly in Senegal.

The objective of this paper is to present an alternative specification of the long-run and short-run demands for oil functions in Senegal, to demonstrate the proposition that oil demand is price-inelastic in the long-run. Another objective is to investigate the log-linear specification by using some model specification error test.

2. Background

The Republic of Senegal (République du Senegal) (French), Sounougal (Wolof) with its Capital city Dakar (1,641,358 inhabitants,

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1994) covers 196,722 km². The total population of 12.04 million leads to a population density of 46 inhabitants per km² with the share of 46%, living in urban regions (World Bank, 2008). Senegal was granted independence from France on April 4, 1960. Senegal, like the Cape Verdian Peninsula, geographically stretches along the West African coast along the Atlantic Ocean (Ministry of Environment and Nature Protection, Department of Environment, 2001). Moreover, Senegal is a flat country which does not exceed 130 masl and the climat is subject to both geographical factors and atmospheric influences(Ministry of Environment, 2001). The Ministry's research papers series states that "the presence of seashore extending over 700km and its location on the west-end side of the African continent, result in climate variations between the coastal zone and the hinterland" (p.1).

In the early 1990s, Senegal undertook strong and ambitious economic reform initiatives as a result of some economic challenges and fiscal imbalances(Lamnet, 2002). According to a Lamnet study (2002), the reforms started with a devaluation of 50% of Senegal's currency, the CFA franc pegged to the French Franc with a fixed exchange rate regime since its inception. The same study also highlighted that Senegalese Government's attempt to control the situation led to an increase of gasoline prices at the pump. Such interventions, however gave a boost to the Senegalese economy with an increase of its GDP growth of 2.1% in 1993 to 13.8% in 1997 which was amounted to 4.37 billion U.S dollar in 2000(Lamnet, 2002). Most importantly, even though inflation remained high compared to many developing countries, the rate of inflation was decreased to less than 2% (World Bank, 2008). Investment then increased from 13.8% of GDP in 1993 to 16.5% in 1997. According to World Bank forecast, the GDP is expected to be constant at 2% (as cited in Lamnet, 2002). Senegal as member of the current Economic Monetary Union (UEMOA) created in 1994 favored regional integration and economic cooperation in the region by unifying external tariff barriers (Lamnet, 2002).

Even if it seems, that Senegal's economy is remarkable in the region, its performance is highly and heavily dependent on oil import and relatively challenged by the variation and uncontrolled world oil prices. According to Lamnet (2002), in 2000, the Senegalese electricity consumption exceeded 1 million MWH and was entirely supplied by fossil fuels. In addition the Senegalese government 's shares in the national electric company (SENELEC) felt to 41% in March 1999, leading others multinational companies such as Hydro Quebec and Elyo to hold 34% of the total shares both from Canada and France respectively (Lamnet, 2002). The increase in the urban population estimated at 3.5% (World Bank, 2008) led to an increase of electricity. To response to increase demand of electricity Senegal tried various options including augmenting "the generating capacity and ..expand[ing] the access to electricity up to now maintaining by oil import" (Lamnet, 2002, p. 1). In the same framework, in 1999, Hydro-Quebec, Chagnon International (Canada) and one of the local consortium "Keur Khadim" together implemented a 37.4 MW oil-fired plant (Lamnet, 2002). Even though natural gas is not yet exploited in the country, Lamnet argues that this plant possesses the properties to generate natural gas once significant quantity of the product become available in the site.

The natural gas consumption of Senegal totaled 42.3 million cm^3 in 2003 and is covered by exploiting the country's reserves of 3.17 milliard cm^3 (World Bank 2005). According to EIA, (2002), " in Senegal, the overall oil consumption estimated at 9.12 millions barrels is entirely supplied by imports (as cited in Lamnet, 2002). This is to highlight the fact that in Senegal, compared to some countries in West Africa like Nigeria and Ghana, there are no proven potential oil resources. In addition, " there are no proven coal reserves and there is no contribution to the country's energy mix" (Lamnet, 2002). According to Energy in Africa group, Senegal has undertaken a construction of an independent power producer (IPP) which consists of a 56MWH oil-fired plant implemented in the suburb of Dakar(Cap de Biches) about 20 kilometers from the capital city (as cited in Lamnet, 2002). According to Lamnet sources, "The project is financed by the General Electric's Structured Finance Group, the World Bank's International Finance Corporation and the Italian service provider Sondel" (p. 1).

Today, one sixth of the world's greenhouse gas emissions are contributed by automobiles or passenger cars (Potoglou and Kanaroglou, 2007). Consequently, in 2001 the government of Senegal enacted a new regulation stating that cars cannot be imported into the country if they are over 5 years old. In 2004, "the Senegalese government (i) increased electricity rates by 15% in September (2003) to ease an energy crisis that caused widespread blackouts between 2006 and 2008 and initiated a gradual phase-out of butane subsidies; (ii) revised the price-setting formula for petroleum products to reflect market conditions; and (iii) created a new discretionary margin in the price structure, which would allow them to limit the pass-through of declining international prices" (IMF, 2006). Therefore, there are a number of arguments to conjecture that current demand elasticities differ substantially from those in the 70s and 90s as the transportation analysis and investigations have hypothesized that "behavioral and structural parameters of the past decades have changed the responsiveness of many OECD countries" (Hughes et al, 2006, p.1a). Many researchers like myself argues that this information could be used to understand and exploit past trends and the determinants of future demand with respects to different assumptions.

3. Literature review

Empirical studies of the demand for gasoline have received considerable attention in both developed and developing countries (see Drollas, 1984; Graham and Glaister, 2004). There are several empirical studies that have examined the determinants of gasoline demand in a number of countries (see Elsevier.com/energy economics). Meta-analysis (Brons et al., 2006) is also used to determine if there are factors that systematically affect price and income elasticity estimates in studies of gasoline demand in most developed countries. In the literature a number of studies have applied co-integration analysis to the modeling of gasoline demand (see Alves and Bueno, 2003; Bentzen, 1994; De Vita et al., 2006; Eltony and Al-Mutairi, 1995; Polemis, 2006; Ramanathan, 1999; Samini, 1995). In their study investigating "the demand for gasoline in South Africa, Akinboade et al., (2008) have looked at several studies in which various "determinants for gasoline or energy demand have been considered (p.3223). They found out that in the literature review, "In it simplest form, the demand for gasoline has been model as a function of real income and gasoline price"(Eltony and Al-Mutairi, 1995; Birol and Guerer, 1993; Ramanathan, 1999, as cited in Akinboade, et al.,2008, p.3223). To investigate the implications of changing fuel efficiency, another study by Bentzen, (1994), in Danmark "specify gasoline demand as a function of time trend, gasoline price and per capita vehicle stock" (as cited in Akinboade, et al., 2008, p.3223). As a result, Bentzen further found out that "In such specifications income only influences gasoline demand through the stock of vehicles" (as cited in Akinboade, et al., 2008, p.3223). Akinboade, et al's study reveals that a whole range of determinants factors have been deployed to model gasoline demand. Such determinants include "a function of real gasoline price, and per capita stock and prices indexes (Eltony, (1993); income and price (Birol and Guerer, (1993); real per capita income, real gasoline price and real alcohol price(Alves and Bueno, (2003); time trend per capita income(GDP), real prices of gasoline and diesel as well as per capita vehicle fleet (Polemis, 2006)" (2008, p. 3223).

In addition, Hughes et al. argue that "the short-run price and income elasticities of gasoline demand have also been studied extensively in the literature. Dahl and Sterner (1991) and more recently, Espey (1996) provide thorough reviews based on hundreds of gasoline demand studies especially in developing country. Dahl argues that technically, any elasticity value is both imprecise" and uncertain. To begin with, elasticities vary across economic sector, fuels, type of economy, and time according to Dahl and Sterner. Consequently, Dahl (2004) states that small homogenous samples cannot perfectly represent the larger population and sometimes lead to impossible results. Heterogeneity also tends to creep into large samples, and aggregating heterogeneous data tends to bias elasticity estimates upward, due to demand changes in response to factors correlated with, but not related to, price changes. These include income, capital stocks, and demand for the goods and services the energy was consumed to provide (Dahl, 2004).

The literature on models specification of gasoline demand reveals that "most of the models developed in the early 1970s were one-equation models, estimating the fuel consumption simply in dependence on gasoline prices, disposable income, and gasoline consumption in the previous period (e.g., Houthaker et al., 1974 as cited in Storchman, 2005, p. 26). Storchman's study titled " Long run gasoline demand for passenger car: the role of income distribution" found that few studies have incorporated " variables such as railway prices or population density (e.g Ramsey et al., 1975 as cited in p. 26). The same study by Storchman also highlighted Nordhaus (1977) and Sweeney (1978) which developed a "complex dynamic approach in order to evaluate elasticity of sectoral energy demand. In another study, by Pindyck (1979), applied this approach in a pooled cross section time series model for 16 countries including a subsample of a few developing countries. As pointed out by many authors (e.g., Baltagi et al., 2002; Drollas, 1984; Griffin and Gregory, 1976; Nordhaus, 1977;), they argue that cross sectional data shows much less multicollinearity than time series data. However, it is shown that the price of oil has a significant effect on demand in the short run but not in the long run. It is also shown that economic activity, as proxied by output or income, is the most important determinant of the demand for oil and that the elasticity of substitution vis-à-vis coal is extremely low. Generally, the literature review reveals that the demand for oil by developing countries is conventionally modeled as a log-linear function, in which demand depends on income, the price of oil and perhaps a deterministic time-trend and macroeconomics aggregate that reflect the state of technology. On one hand, the reviewed literature also reveals that the demand for gasoline has been modeled in a variety of ways. The lagged endogenous model has been used extensively in the literature. That formulation of the gasoline demand model does not recognize the non-stationary nature of the time series data. However, it is now widely recognized that most economic data time series tend to be non-stationary (Asche, 1997: 229). Ignoring the non-stationary nature of the economic data series could result in spurious relationships (Stanley, 2000). The most common variables that have been included in the estimation of gasoline demand models include real income, real price of gasoline, price of substitute energy source and per capita vehicle fleet.

On the other hand however, Moosa (1998) argues that "the log-linear demand function has been criticized even by those economists who actually use it. The most important criticism is that it implies constant elasticities for any range of values in the explanatory variables." (p. 3). Balanoff (1994) further argues that the log-linear function " imposes severe restrictions involving assumptions about the elasticity of substitution" (as cited in Moosa, 1998, p. 3). Moosa (1998) in his study on "Long-run and Short-run demand for oil by developing countries: an empirical analysis" identified that others researchers such as Clarke (1983) and Kouris (1981) are also very critical of the log-linear specification due to its lack of consistency with "neoclassical theories of behaviour" and its "temporal stability" features respectively (p. 23). As Moosa (1998) suggests: "The prediction of the model that the long-run price elasticity is greater than the short run elasticity does not seems to be consistent with casual empiricism. For example, following the first oil price adjustment of 1973-74, the rate of growth of oil demand by developing countries declined to 1.3 per cent per anum, from 8.4 per cent in the period 1950-73. This decline however, was only temporary as oil demand grew an annual compound rate of 6.7 per cent in the period of 1976-79, although there was no reversal in oil prices. If anything, this observation indicates that short -run elasticity is greater than long-run elasticity". (p. 3) In other words, as Moosa argues, the importance of oil as a key commodity makes it difficult if not impossible to substitute due to its unique and various functions. In addition, to argue in the same line as Moosa, the slow adoption and development of technological progress in countries like Senegal makes it reasonable to conjecture that " oil demand in the long run is determined primarily by the pace of economic activity, proxies by a measure of aggregate output or income" (1998, p. 3).

4. The model

Given data constraints in developing countries mostly in Senegal, I estimate the demand for gasoline using a linear model and a log-linear model first. I specify gasoline demand Yt (quantity demanded of gasoline) as a function of total population in thousands (*Pop*), the real price index for gasoline (*Gas Price*), per capita income (I, Income), *Price* index for public transportation (*Ppt*), *the lagged dependent variable* Y_{t-1} and ε_t a random error which is assumed to be white noise normally and identically distributed. In order to differentiate between short-run and long-run price and income elasticities, a stock adjustment mechanism is incorporated in this study allowing for "a lagged dependent variable" to appear in the specification. Following the specifications of Bentzen (1994), Alves and Bueno (2003), Ramanathan (1999), and Polemis (2006), I specified the linear model of gasoline demand and the log-linear model form as follow:

$$\mathrm{Y}(t) = \beta_0 + \beta_1(Pop) + \beta_2(gas\ Price) + \beta_3(Inc) + \beta_4(Ppt) + \beta_5\mathrm{Y}_{t-1} + \varepsilon_t \tag{M1}$$

$$\mathrm{LogY}(t) = \gamma_0 + \gamma_1\ Log(Pop) + \gamma_2 Log(gas\ Price) + \gamma_3\ Log(Inc) + \gamma_4 Log(Ppt) + \gamma_5 LogY_{t-1} + \varepsilon_t. \tag{M2}$$

According to economic theory the coefficients in these models are expected to be either positive or negative respectively. Therefore, I assume that if income increases purchases of motor vehicles increase and gasoline demand will increase as well. Therefore I expect β_3 or γ_3 the coefficients for income to be positive and β_2 or γ_2 the coefficients for gas price to be negative. Because as gas prices increase demand Y(t) will decrease. As population increases, demand for gasoline increases then I expect to see the coefficients β_4 or γ_4 for public transportation to be negative and the coefficients β_1 or γ_1 for population to be positive as well. Because when gas price is increasing index for public transportation is also increasing and consequently the cost of transport becomes high. Consequently, people tend to travel less because of transportation cost. Finally, if the equation is dynamically stable, I expect that the coefficient β_5 or γ_5 to be less than unity, and that gives the often obtained result that long-run elasticity is greater than short-run elasticity (Balabanoff, 1994). I also expect to see that in the long run Y_{t-1} and Y_t will tend toward a point of being equal and coefficients in the short run are β_1 or γ_1; β_2 or γ_2; β_3 or γ_3; β_4 or γ_4 and β_5 or γ_5 and in the long run coefficients are as follows: $\frac{\gamma_1}{1-\gamma_5}$ or $\frac{\beta_1}{1-\beta_5}$, $\frac{\gamma_2}{1-\gamma_5}$ or $\frac{\beta_2}{1-\beta_5}$, $\frac{\gamma_3}{1-\gamma_5}$ or $\frac{\beta_3}{1-\beta_5}$, $\frac{\gamma_4}{1-\gamma_5}$ or $\frac{\beta_4}{1-\beta_5}$.

5. The data

Because unseasonalized quarterly data were unavailable I use annual time series data for the period 1970–2008 to estimate the demand for gasoline in Senegal. The main reason for not using an extended period is that the Senegalese National Energy Agency (ANSD) and the Statistical, Economic and Social Research for Islamic Countries (SESRIC), provide statistical data for gasoline prices in Senegal from 1970 onwards. I found that data for income and public transportation index were missing for the periods of 1978 and 1979 as well as of 1981 and 1983. To fill the gap that existed between two periods I made little adjustments in the time series by taking the average between two periods. The per capita Income (Inc) is measured in Millions in the national currency (CFA) as well as the population total (*Pop*). These data are also available from the International Energy Agency (IEA). The energy prices index for gasoline (GasP) are taken from “Energy prices and Taxes” (ANSD) and have been deflated by the consumer price index (2000 = 100). The data for Income (*Inc*) and population total (*Pop*) were obtained from the ANSD and SESRIC, and African reserve bank (ARB). Finally, *Price* index for public transportation (*Ppt*) came from the International Energy Agency (IEA).

6. Specification error tests

In this study, in order to determine the most appropriate basic functional form I approached the study by conducting a model specification error test to decide whether to choose the linear or log-linear model. An equation that specifies a linear relationship among the variables gives an approximate description of some economic behavior according to many economic theories. In addition, the parameters of the linear model have an interpretation as marginal effects. However; the benefit of the log-linear is that coefficients can easily be translated into elasticities. For instance, in the log form presented in the above equation, the coefficient γ_2 for gas price (GasP) can be interpreted as price elasticity of demand, while the coefficient for Income (*Inc*) can be interpreted as the income elasticity of demand.

First I discuss the linear model versus log linear model using *Box–Cox* test for linearity, and/or P_E tests to make sure that the model is correctly specified. As we know that Shazam (software) will use iterative methods to estimate *Box–Cox* regressions for λ and the "ALL" options is used to allow Shazam (software) to transform all the variables by the same λ. A value of $\lambda = 1$ gives a linear model and a value of $\lambda \neq 1$ gives a double log model (Table 1).

I computed a Box–Cox likelihood ratio test statistics $2[L(\lambda) - L(\lambda = 1)]$ which is $[-21.8535 + 64.2562] = 42.4027$. To perform the test statistic, I compared this value (42.4027) with χ^2_1 distribution with 1 degree of freedom which is equal to 3.84. Since the value of the test (42.4027) is greater than the critical value 3.84 at the 5% level of significance, therefore I reject the null hypothesis (H_0) of linearity which is H_0:$\lambda = 1$ against H_A:$\lambda \neq 1$. Hence in what follows in this paper I use the log linear model.

Second to confirm the correctness of the model specification, I test the log-linear using the RESET (Regression Specification Error Test), the Rainbow test, and the CUSUM (Cumulative Sum of recursive residuals) for two reasons: to detect incorrect functional form with the log linear model and also test check if no relevant explanatory variables have been omitted from the regression equation form. Moreover, all the tests in this study are conducted at the 5% level of significance. Here the test is an F test that tests whether the coefficients on the new regressors are zero for the log linear model and how well the model fits a set of observations. The computed value for the *Reset* test is 82.23401 and, the critical value from the F table given by $F_{0.05,4}$, $(N - K - M) = F_{0.05,4,33}$ is 2.61, then I reject the null hypothesis of linearity and specification error due to incorrect functional form. I also perform the rainbow test (Utts, 1982). The computed value for the Rainbow test is 8.402944, the critical value from the $F_{(19,\ 14)}$ distribution table is 2.39, and again I reject the null hypothesis of linearity and specification error due to incorrect functional form.

In addition, the CUSUM test is performed to test for incorrect functional form leading to parameter instability because; parameter instability may also come from omitted variables or structural changes. These tests can also detect some of the systematic changes in the model and some of the hap hazards in the model as well. Since CUSUM does not have one constant critical value I compute recursive residuals and statistical boundaries. From there, I checked if the CUSUM value crosses the boundary. As can be seen from the graph (below Fig. 1), the computed value is within the boundaries and therefore the null hypothesis of no specification error is not rejected. The model passes the test.

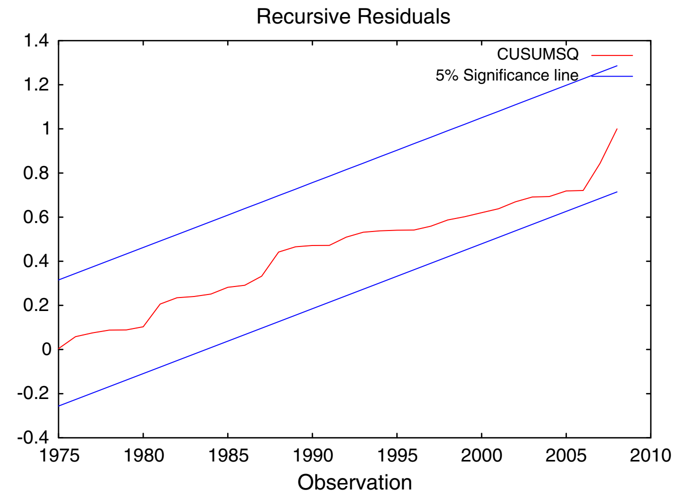

Fig. 1. The cumulative sum of recursive residuals.

Finally, this paper also used Durbin–Watson (*DW*) test statistic to detect the presence of autocorrelation in the residuals from the regression analysis. If (4-d)$<d_{l,\alpha}$ then there is a statistical evidence that the error term are negatively correlated. If (4-d)$>d_{u,\alpha}$ then there is a statistical evidence that the error term is not negatively correlated. To perform the test for autocorrelation under $H_0: \rho = 0$ and $H_A: \rho > 0$ hypothesis where $H_0: \rho = 0$ is the null hypothesis. The output result gave a Durbin–Watson test value of 0.5985 close to 2 at 5% level and here I used a two sided test. I find from the Durbin–Watson statistic 2, 5% table (D-5A kmenta, p. 765) that the critical value [4–0.5985] = 3.4015 is greater than $d_{u,\alpha}$ (1.626). Therefore there is statistical evidence that the error terms are not negatively correlated. Then I accept the null hypothesis (H_0) and the model passes the test of autocorrelation.

To discuss heteroscedasticity I used Goldfeld–Quandt Test to ensure that the estimators are unbiased (Table 2). I tested under the hypothesis $H_0: \gamma_1^2 = \gamma_2^2 = \gamma_3^2 = \gamma_4^2 = \gamma_5^2$ and H_A are not true. And the Goldfeld–Quandt [1972] (G–Q) statistic provides tests for different error variances between two subsets of observations and is calculated as $GQ = \frac{SSE_2^2}{SSE_1^2}$. I divided the 39 observations in to two groups with low values of X and one with high omitting some central observations. And then I ran two separate regressions and the GQ test is found to be 0.1488 and the critical value is obtained from the $F_{(28,\ 28)}$ degree of freedom table under 5% level of significance. The critical value which I found to be equal to 1.8687 is greater than 0.1488 therefore I rejected the alternative hypothesis for heteroscedasticity. The tables below summarize the results of the tests performed for misspecification error test.

7. Estimation results and interpretation

In this paper I used time series data covering the years 1970 to 2008 to estimate the demand for gasoline in Senegal. The first step was to discuss the linear model versus the log linear using *BOX–COX* test to make sure that the model is correctly specified. All the test statistics are distributed as F, such that a significant test statistic for M1 (linear) versus M2 (log-linear) implies the rejection of the former (*linear*) in favor of the latter (*log-linear*). The results presented show an overwhelming rejection (by

Table 1
Test for linearity against log-linearity (one sided test and significance level of 0.05%).

Hypothesis	Box Cox ratio	$\chi^2_{(1\,;\,0.051)}$	Critical value	Degree of freedom	R^2	R^2 adjusted
$H_0 \lambda = 1$(linear model) $H_0: \lambda < 1$(non-linear model)	42.4027	1.686	(3.841)	1	0.9978	0.9975

Table 2
Goldfeld–Quandt statistic.

Hypothesis	Significance level	$F_{(28;28)}$	Critical value	G–Q test
$H_0\gamma=0$ (null hypothesis)	5%	1.686	(1.8687)	0.1488E

NB: f for alpha = 0.05%.

all tests and criteria) of the linear model. Hence I used the log linear model to estimate the demand for gasoline in Senegal. The log-linear regression model is a standard approach in the fuel consumption literature, and it is becoming increasingly common in the traffic literature (Pagá and Birol (2007). Many studies have identified income and fuel price as the major parameters to determine energy consumption (Sammi, 1995; Wohlgemuth, 1997; Banaszak et al., 1999, De Vita et al., 2006). This finding supports the theoretical arguments against the use of the linear specification. The second step was to use tests for misspecification error and to confirm the correctness of the model specification using the log-linear model. For this purpose, the Ramsey (1969) RESET test, the CUSUM test and the Rainbow test are initiated to test the incorrect functional form and also test that no relevant explanatory variables have been omitted from the regression equation. Consequently we have the estimated coefficient for each variable, their T score and standard errors under 5% significance level in the table below Table 3.

$$Y(t) = 1849.36 + 0.19598\ln(Pop) + (-)\,0.121249\ln(gas\ Price) + 0.5967\ lnY_{t-1} + 0.4581\ln(Inc) + -1.0138ln\ (Ppt) + \varepsilon_t.$$

Looking at the output of the results it might be possible to demonstrate the importance of income changes relative to price changes by conducting simulation experiments to examine the effect (on demand) of a once-and-for-all 10% rise in income and the oil price in Senegal. The results of the estimation presented with the tables, showing a substantially greater effect for the rise in income and population growth. The model provides a good fit of the data with $R^2=0.9978$ and adjusted $R^2=0.9975$. As expected, the coefficients were constant with expectations showing particularly a greater effect of income on gasoline demand. Moosa's findings in his paper when he argues that: " the behavior of the ratio of the demand for oil under the base (no change) scenario to its value under alternative scenarios encompassing an income or a price shock" (p. 9). The results also show that the change in the demand for oil is larger with respect to income compare to the change in price. Similar to Moosa's arguments," it is obvious, not only that the immediate change in the demand for oil is greater in the case of an increase in income than an increase in price, but also that it takes longer to absorb the effect of the shock in the case of a rise in income" (p. 9) particularly in Senegal and many developing countries (see also Kraft and Rodekohr, 1978 and Baltagi et al., 2002). These findings highlight the fact that, changes in oil prices are most likely to be once-and-for-all scenario unlike income changes which can be sustained through the overall growth of an entire economy (Mossa 1998, p. 9). This is why one can argues that the variations of oil price is the major determinant of gasoline demand in the long-run in developing countries like Senegal (Moosa, 1998). The implications is that if gasoline price increases, then demand for gasoline declines and that if income is held constant(ceteris paribis) and gas price increases there is a tendency for consumer (household, firms, governments…)

Table 3
Estimation results.

Variables	Coefficient estimate	Standard errors	T-statistics	Significance level
Population (*Pop*)	0.19598	0.23557	8.3192	5%
Gasoline price (*Gas price*)	−0.121249	0.4440	0.27303	5%
Lagged dep variable (Y_{t-1})	0.5967	0.2463	2.4014	5%
Income (*Inc*)	0.4581	0.30962	1.4798	5%
Public transportation (*Ppt*)	−1.0138	0.30952	327.55	5%

preferences to shift from driving their own car or buying new or used car and use public transportation especially in Senegal.

In the long-run, the estimated coefficients are $\frac{\gamma_1}{1-\gamma_5}=0.4859459$; $\frac{\gamma_2}{1-\gamma_5}=-0.3006422$; $\frac{\gamma_3}{1-\gamma_5}=1.13587899$; $\frac{\gamma_4}{1-\gamma_5}=-2.5137614$. The long-run income elasticity (1.13587899) and the elasticity of substitution at the means, as calculated from the estimated equation, is (0.76487E-03).This implies the dominant role played by income in the demand for gasoline in Senegal. In addition, this illustrates Moosa findings when he argues " the extremely low value of the elasticity of substitution confirms the earlier proposition on the unavailability of close substitutes for oil and technological constraints faced by developing countries when trying to switch from oil to coal" (Moosa 1998, p. 7). Moosa further suggests that " when the price of oil is included in the cointegrating regression analysis, the results are robust and do not display significant changes" (p. 7). This implies that the price of oil can be technically removed without much impact in the cointegrating regression (Moosa, 1998).

In the short run the coefficients estimated are: $\gamma_1=0.19598(Pop)$; $\gamma_2=-0.121249(Gas\ price)$; $\gamma_3=0.4581(Inc)$; $\gamma_4=-1.0138(Ppt)$ *and the lagged dependent variable* $\gamma_5=0.5967(Y_{t-1})$, which in fact is less than unity as predicted and confirm that long-run elasticity is greater than short-run elasticity for gasoline demand in Senegal (Balabanoff, 1994). These results, and observations in this paper are consistent with Moosa's findings. As he point out that the long-run elasticity is greater than the short-run elasticity in many developing countries. This study found out the same is true for Senegal. In Senegal, like in many developing countries, "This assertion can be rationalized on the grounds that oil demand in the long-run is determined primarily by the pace of economic activity, proxies by a measure of aggregate output or income and population growth" (Moosa, 1998, p. 3). The findings in this study present an alternative specification of the long-run and short-run demands for oil functions in developing countries such as Senegal, by demonstrating the proposition that oil demand is price-inelastic in the long-run. Note that the period of high gasoline price from 1973 to 1980 and 2007 to 2009 coincided with an external shock of world oil prices and a global financial crisis extended by factors such as high unemployment rate and inflation contributed to changes in gasoline demand and consumption. Consequently, in Senegal and many developing countries, these findings reveal greater implications for historical macroeconomics circumstances in these elasticity estimates in this paper.

The log-linear model specified here in this study seems to be well determined, passing the diagnostics for serial correlation (*SC*), functional form (*FF*), normality (*NO*) and heteroscedasticity (*HS*) as highlighted earlier by Moosa in his paper. Moosa claims that "the estimated value of the coefficient on the error-correction parameter indicate that 37 percent of the deviation from the equilibrium long-run value of the demand for gasoline is corrected each year" (p. 9). Furthermore, the model in this paper seems to be structurally stable as found in Moosa's study. The following figure(Fig. 1) shows that the model passes the CUSUM and CUSUMQ tests as shown in Fig. 1 respectively.

8. Conclusion

In this paper, an attempt has been made to estimate the demand for oil in developing countries particularly in Senegal. First, the linear specification of the demand for oil is rejected in favor of the log-linear specification with $\lambda=1$ tested against $\lambda=0$. This indicates that the elasticity of demand is not constant over the sample of study with respect to all variables included in this study. Secondly, what is really important here is that economic productivity is a major determinant of the demand for gasoline. As Moosa (1998) indicates" what matter in the long-run as the major determinant of the demand for oil, is economic activity as proxy by GDP or Income" (p. 9) . Finally, the variations of oil price play an important role for the determinant of the demand for gasoline in the short run only. " [The] long-run effect [of demand gasoline] is limited to it being conducive to switching to other forms or energy" (p. 9) such as natural gas, fossil fuel etc. However, to investigate policy implications based on these findings, one should exercise caution. First overall, the negative value for gasoline price does not indicate that gasoline price is not crucial in Senegal. Many researchers on the subject argue that, it " rather implies that gasoline prices operates technically almost and entirely via the choice of cars (used cars in Senegal and in many developing countries) and that the past fluctuations in gasoline price have not been considerable to reduce gasoline usage in the sector of transport generally. Moreover, the negative impacts of gasoline price on public transportation in Senegal implies a long-run impact on gasoline demand and its use. Variations in the price of gasoline however, are found to have negative impact on the demand and use of gasoline in Senegal.

Consequently the price index for public transportation will tend to increase mostly in developing countries where regulation and law enforcement is very critical. Population growth is also very important (0.19598) because if population increases, demand for gasoline increases and prices for gasoline might increase as well. In this particular study however, public transportation index and coefficient estimated (−1.0138) express the behavioral changes of spiking gasoline prices in Senegal. Therefore, the short run elasticity is a measure of change in driving behavior as a result of a change in the world oil prices since Senegal a major importer of crude oil around the world. Then a driver's response to higher price is largely composed of a reduction in the amount of driving (vehicle miles traveled) and an increase in the fuel efficiency of driving. To keep oil product prices uniform across the country I think that the government of Senegal has to put in place a systemic price adjustment mechanism to balance the cost of transport in remote areas. Certainly, this could generate a very strong incentive for malpractice, especially on the transport segment of the downstream oil sector in the country. However, this might not necessarily affect the quality of the products traded on the market, but it could have a significant financial impact on the gasoline industry. The findings of this paper confirms various empirical studies regarding gasoline demand in developing countries. Yet it reaffirms the skepticism addressed by many researcher on the subject regarding the log-linear specification or formulation of the demand for oil or gasoline function as highlighted in Moosa' study (1998).

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