InternationalJournal of Energy Economics and Policy
Vol. 4, No. 1, 2014, pp.76-82
ISSN: 2146-4553
www.econjournals.com

Modelling Gasoline Demand in Ghana: A Structural Time Series Approach

Ishmael Ackah
Department of Economics, Portsmouth Business School,
University of Portsmouth, UK. Email: Ackish85@yahoo.com

Frank Adu
Department of Economics, KNUST, Ghana.
Email: frankadau64@gmail.com

ABSTRACT: Concerns about the role of energy consumption in global warming have led to policy designs that seek to reduce fossil fuel consumption or find a less polluting alternative especiallyfor the transport sector. This study seeks to estimate the elasticities of price, income, education and technology on transport gasoline demand sector inGhana. The Structural Time Series Model reports a short-run price and income elasticities of -0.0088 and 0.713. Total factor productivity is -0.408 whilstthe elasticity for education is 2.33. In the long run, the reported price and income elasticities are -0.065 and 5.129 respectively. The long run elasticityfor productivity is -2.935. The study recommends that in order to enhanceefficiency in gasoline consumption in the transport sector, there should beinvestment in productivity.

Keywords: UEDT; Total Factor Productivity (TFP); Gasoline Demand
JEL Classifications: Q31; Q32; Q43

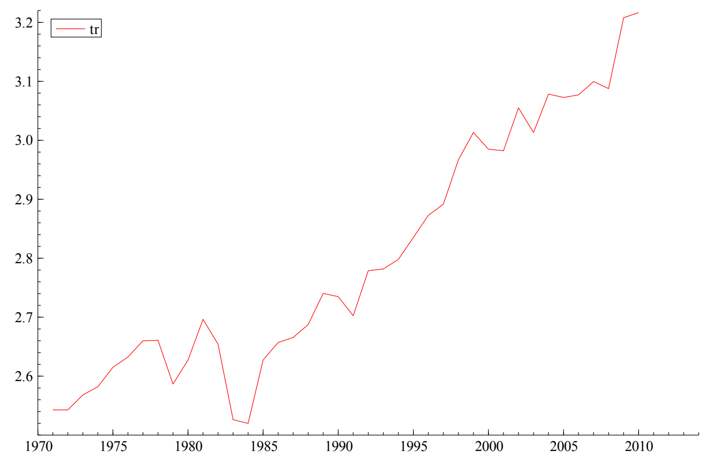
1. Introduction

The development of modern societies thrives on mobility. The ability of people, goods and services to move to places where they can command optimum value is vital for development. This is because; such exchanges increase employability and economic wellbeing on nations. Gasoline consumption has been found to be one of the engines that facilitate private and economic mobility (Pock, 2010). Due to this, gasoline is considered a vital import commodity for many countries and therefore estimates of elasticities for gasoline demand helps to forecast gasoline consumption, design appropriate policies to curb gasoline demand and determine the responsiveness of price, income and other relevant factors to a fuel disruption (Dahl, 2012). In addition, estimating the gasoline demand elasticities help to forecast demand and determine taxes to reduce energy consumption if necessary (Rao and Rao, 2009). Again, the value of gasoline imports in many countries makes it a key determinant of balance of payment deficit, fiscal deficit and economic growth (Alves and Bueno, 2003). For instance, according to Kwakwa (2012), Ghana spent about $1.72 billion to import crude oil, gas and oil products between January and July 2011 resulting in a 45.4% annual growth of merchandise imports of the country within the period to an amount of $8.6 billion.

Though an important source of energy, the use of gasoline and diesel leads to emission of greenhouse gases such as carbon dioxide, lead, monoxide and nitrogen oxide. According to Fuglestvedt et al., (2008), the use of motor fuels contributes 21% of global carbon emissions, 37% of nitrogen oxide and 18% of carbon monoxide. Due to this, the importance of road transport pollution on public health and environment has been a policy concern since the passage of the Clean Air Act in the US in 1970 (Johnson, 2003). According to Johnson (2003), the effect of inhaling the exhaust fumes from diesel and gasoline usage can lead to asthma and other health related issues and calls for the use of LPG in transportation. Beer et al. (2000) argues that harmful particle emissions from diesel cars are 100 times lower than LPG.

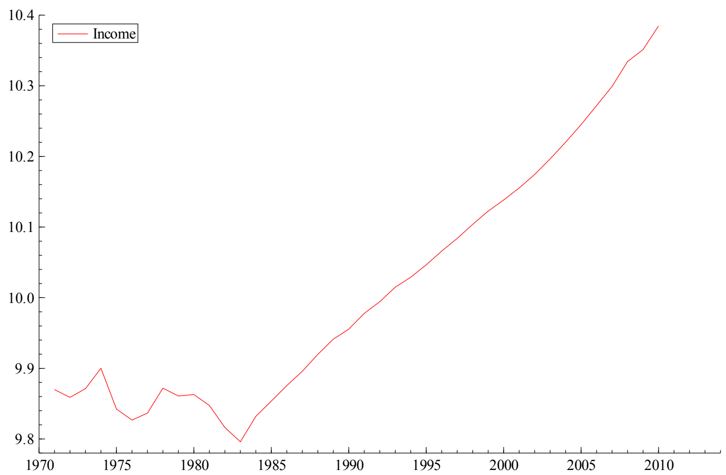
Data available from the Driver and Vehicle Authority (2010) estimates that registered vehicles in Ghana increased from 767,067 in 2000 to 1, 128,138 representing 47.07% change. This increase is a result of high demand for road transport and the quest for individuals to have their own cars (EPA, 2011).

Figure 1. Gasoline demand in Ghana from 1971 to 2010



As can be seen in Figure 1, gasoline consumption shows an upward trend from 1984 growing at 9.53% per annum over the estimated period. This is similar to the trend of the income over the same period as shown in figure 2.

Figure 2. Growth in income from 1971 to 2010



Though these estimates of elasticities for gasoline demand are important, there are few studies on gasoline demand in Ghana and Africa as a whole. Studies on factors influencing gasoline demand have received attention since the oil price hikes in the 70's and 2008 in the developed economies. Cloete and Smith (1988) estimate the price and income elasticities for gasoline demand in South Africa. They report price and income elasticities of -0.37 and 0.40 respectively. The gasoline demand literature is surveyed by Dahl and Sterner (1991).They report average short run price and income elasticities of -0.26 and 0.48 respectively. Belhaj (2002) studies gasoline demand in Morocco from 1970 to 1996 and report price elasticity of -0.30 and income elasticity of 0.50. Alves and Bueno (2003) employ the two-step Engle and Granger (1987) to estimate cross price elasticity between gasoline and alcohol and the income and price elasticities for gasoline demand. Their findings indicate that gasoline and alcohol are not perfect substitutes and found long run income elasticity to be 0.12. The Autoregressive Distributed Lag method (ARDL) is employed to motor gasoline consumption in South Africa by Akinboade et al (2008). The study reports long run price and income elasticities of -0.47 and 0.36Ziramba (2010) examines the demand for imported crude oil in South Africa as a function of real income and the price of crude oil over the period 1980–2006. The estimated long-run price and income elasticities of −0.147 and 0.429 suggest that import demand for crude oil is price and income inelastic. The few energy demand studies on Ghana often concentrate on electricity. For instance, Adom et al. (2012) estimates the factors responsible for the historical growth trends in aggregate domestic electricity demand quantifying their effects both in the short-run and long-run periods using the ARDL Bounds cointegration approach and the sample period 1975 to 2005. In the long-run, real per capita GDP, industry efficiency, structural changes in the economy, and degree of urbanisation are identified as the main driving force behind the historical growth trend in aggregate domestic electricity demand. However, in the short-run, real per capita GDP, industry efficiency, and degree of urbanisation are the main drivers of aggregate domestic electricity demand. Industry efficiency is the only factor that drives aggregate domestic electricity demand downwards. Dahl (2012) uses both static and dynamic equations to measure global gasoline and diesel price and income elasticities. He reports price and income elasticities of -0.26 and 1.27 for Ghana.

Given the importance of non-economic factors to energy demand and the derived nature of the demand for gasoline, it is needed to estimate other factors that influence gasoline consumption apart from price and income. It is therefore important to understand factors such as the behavioral focused interventions on gasoline demand such as educational scheme (Broadstock and Hunt, 2010). Again, recent calls for the DVLA to implement laws and regulations on the 'road worthiness' of vehicles appears to buttress the point that technology is important for gasoline consumption. This is because, apart from accident prevention, road worthy vehicles may consume less fuel.Sterner (2007) argues that the income and price elasticities are even affected by technological progress. Productivity has been found to be essential for energy consumption (Boyd and Pang, 2010). This is because when productivity is high, less inputs is required to produce the same output and therefore less energy.

Following the works of Harvey (1997), Hunt et al (2003) and Broadstock and Hunt (2010), this study estimates the elasticities of factors that influence gasoline demand in Ghana. Specifically, this study therefore seeks to:

- Examine the effect of technological advances on gasoline demand in Ghana
- Ascertain the impact of exogenous non-economic factors such as lifestyle, culture etc on gasoline demand
- Estimate income and price elasticities for aggregate level and the transport sector

2. Methodology and Data

2.1. Methodology

According to Broadstock and Hunt (2010), times series modelling has been dominated by cointegration techniques since the 1980's.Harvey (1997) posits that the cointegration method has poor statistical properties and could lead to misleading estimates. Another shortfall of the earlier gasoline demand estimation methods is that, technological progress and other exogenous factors are either ignored or approximated by a deterministic time trend (Hunt et al., 2003).

Additionally, Hunt et al., (2000) argues that that technical progress is not the only exogenous factor that influences energy demand. Therefore, factors such as consumer tastes, change in regulations, change in economic structure, change in lifestyles and values, might all play an important role in driving natural gas demand. In the absence of appropriate data to capture all the different exogenous effects, a stochastic UEDT is included in the natural gas demand specification estimated in line with recent research (Harvey and Koopman, 1993, Hunt et al., 2000; Hunt and Ninomiya, 2003). To achieve this, the STSM is utilized given it allows for the impact of unobserved components in a time series model to be a captured by a stochastic trend (Harvey et al., 1986).

The STSM decomposes time series into explanatory variables, a stochastic trend and an irregular component. Since additional observations are included, the parameters and unobserved components of the model are estimated by using recursive filtering smoothing process (Kalman, 1960) and maximum likelihood.

A framework similar to the methodology of Dilaver and Hunt (2011) is used.

$$eo_{tt} = \theta_y^o y_{tt} + \theta_p^o po_{tt} + \theta_w^o w_{tt} + \theta_h^o h_{tt} + \mu_{tt}^o + \varepsilon_{tt} \qquad 1$$

Where eo_{tt} is the natural log of non-renewable energy demand, y_{tt} is the natural log of income, po_{tt} is the natural log of energy prices, h_{tt} is the natural log of human capital, w_{tt} is the natural log of technical efficiency, and ε_t is the error term $\theta_y^o, \theta_p^o, \theta_w^o, \theta_h^o$ are the elasticities of income, price, technical efficiency and human capital respectively

$$\mu_{tt}^{o} = \mu_{tt-1}^{o} + \gamma_{tt-1}^{o} + \eta_{tt}^{o} \qquad 2$$

$$\gamma_{tt}^{o} = \gamma_{tt-1}^{o} + \xi_{tt}^{o} \qquad 3$$

Where $\varepsilon_{tt} \sim NID(0,\sigma_{eo}^{2})$, $\eta_{tt}^{o} \sim NID(0,\sigma_{\eta^{o}}^{2})$ and $\xi_{tt}^{o} \sim NID(0,\sigma_{\xi^{o}}^{2})$. Equation (2) and (3) represent the UEDT for energy demand. μ_{tt}^{o} is made up of level and slope components. This is a stochastic trend dependent on $\sigma_{\xi^{o}}^{2}$ and $\sigma_{\eta^{o}}^{2}$.

Following the work of Broadstock and Hunt (2010), the initial model is estimated as Autoregressive Distribution Lag version with 4 lags. Statistical insignificant variables are eliminated and normality, auxiliary residuals and diagnostic test are carried out to obtain the preferred equation. Equations (1) to (3) are estimated with the software package STAMP (Koopman et al., 2000).

2.2. Data

Annual data from 1971 to 2010 on transport was obtained from the IEA. Consumer price index obtained from the World Bank is used as proxy for gasoline prices. GPD and government expenditure on education (proxy for human capital) in constant US dollars is obtained World Development Indicators whilst data on total factor are obtained from the UNIDO.

3. Results

The purpose of the study is to examine the effect of productivity, non-economic factors and economic factors on transport gasoline demand in Ghana. Given that Ghana has been achieving a consistent growth of more than 5% over the last decade. The African Economic Outlook (2012) estimates that Ghana achieved the highest growth in the world in 2011 at 14.4% which has led to high increase in rural-urban migration since many people leave the rural areas to the cities for greener pastures. Data available at the World Bank indicates that the urban population has increased by 10.20% annually between 1971 and 2011. This comes with it demand for transportation and hence gasoline. Another growth factor has been the increased access of workers to car loans which has led to growth in the number of private car ownership.

The estimates of the Structural Time Series Model report a short and long- run income elasticity of 0.713 and 5.129 (table 1). This means that in the short-run, demand for gasoline becomes a necessity since substitutes are not readily available. However, in the long run, consumers find alternatives such as using a bicycle, gasoil or even walking when income reduces but travel more and drive more when income increases. The reported long –run elasticity is similar to Wadud et al. (2011) for the power sector in Bangladesh. He reported a long-run income elasticity of 6.3 for natural gas demand. The price elasticity for the short-run is -0.0088 implying that any 1% increase in price leads to a 0.0088% reduction in gasoline demand. The price elasticity for the long-run is -0.065. Demand for gasoline is price inelastic in both the short and the long run. The government should therefore remove the subsidies since changes in price leads to less than proportionate change in demand.

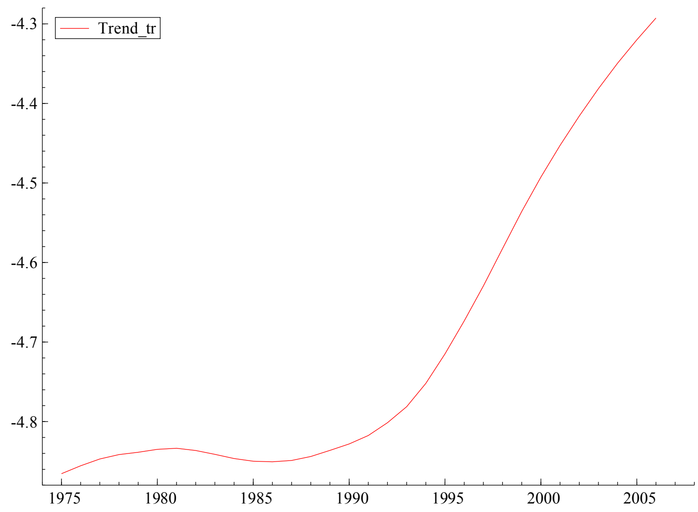
According to Boyd and Pang (2010), energy efficiency improvements rely on the growth of productivity. This means that as productivity increases, less energy should be required to perform the same task. The estimated short and long-run elasticities are -0.408 and -2.935 respectively which confirms Boyd and Pang's assertion. This implies that investment in productivity can be a means of curbing energy related carbon emissions. Human capital represented by government expenditure on education has a positive and significant influence on gasoline demand. This is because education influences a person chance of gaining employment and earning higher income. Xia-hai and Qian (2011) posits that education has significant and positive effect on total income and off-farm income. Education also enhances mobility and the need for leisure which have gasoline usage implications. The elasticity for human capital is 2.3397.

The shape estimated UEDT is smooth trend with fixed level and a stochastic slope. It rises steadily after the early 1990's (figure 3). This may suggest that 'taste' preferences do not have much impact on gasoline demand in Ghana. The UEDT is similar to the one reported in Dilaver and Hunt (2011).

Table 1. Ghana Gasoline Demand in the Transport –elasticities and tests

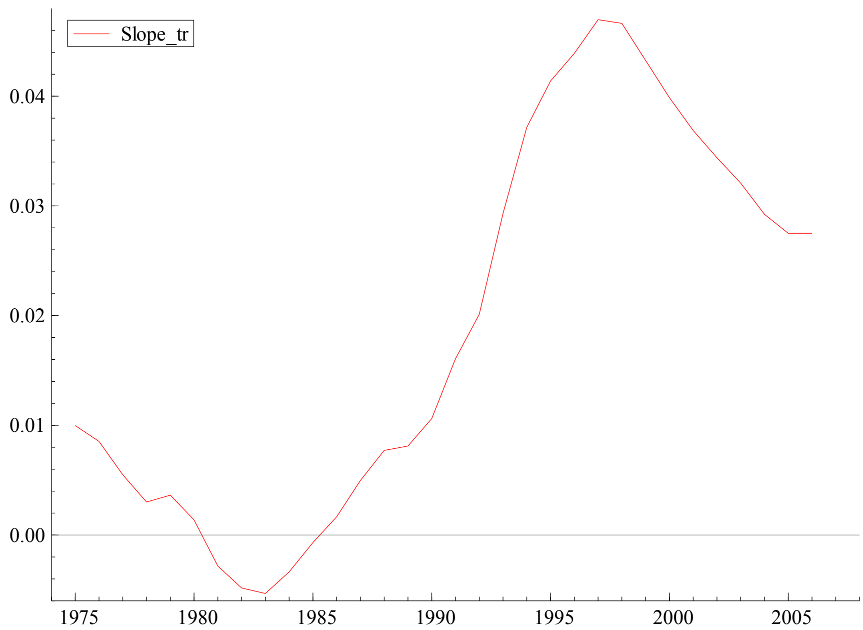
Estimated coefficients			
Oil_1	**0.266****	**Goodness of fit**	
Oil_2	**-0.595*****	**p.e.v**	**0.000750**
Income	**0.713****	**p.e.v/m.d**	**1.346**
Price	**-0.0088****	**R^2**	**0.975**
Education	**2.337*****	**RD2**	**0.671**
TFP	**-0.408*****		
Long-run Elasticities			
Price	**-0.065**		
Income	**5.129**		
TFP	**-2.935**		
Summary Statistics			
Hyperparameters		**Std.error**	**0.00274**
Irregular	**0.020620**	**Normality**	**0.531**
Slope	**0.0088536**	**H (10)**	**0.544**
Level	**0**	**DW**	**2.150**
Predictive Test		**Q (8, 6)**	**6.886**
Failure	**23.30**		
Cusum t (4)	**0.310**		
Auxiliary Residuals			
Irregular		**Slope**	
Normality	**0.128**	**Normality**	**1.382**
Skewness	**0.120**	**Skewness**	**1.048**
Kutosis	**0.008**	**Kutosis**	**0.334**
** represents 5% significance level *** is 1% significance level			

Figure 3. UEDT



The estimated UEDT especially from 1992 to 2010 can be classified as 'gasoline using' (figure 4). The trend may be driven by gasoline price subsidies and access to car loans which allow consumers to drive more. The quest for the government to withdraw petroleum price subsidies has been met by opposition from many angles. However, the trend shows that the policy encourages the excessive use of gasoline which prevents the government to meet its carbon emission targets.

Figure 4. Slope of the UEDT



4. Conclusion

Energy is not demand for its sake. It is the service energy provides such as heating, transport and lighting that is demanded. This implies that there are factors that influence energy demand apart from the price of energy and income. In addition, there have been calls to curb carbon emissions from energy usage. For this to be effective, factors that influence the demand for energy need to be estimated for appropriate policies to be designed. Unfortunately, most of these studies are carried out in developed economies.

The purpose of this study is to examine the effect of both economic and non-economic factors on transport gasoline demand in Ghana. The results indicate that transport gasoline demand is price inelastic implying that continual gasoline price subsidy is economically inefficient. In addition, productivity is found to have an inverse relationship with gasoline consumption. This means that investment in productivity can help curb carbon emissions in the energy sector. Gasoline demand is income inelastic in the short-run but elastic in the long- run.

The study recommends that efforts should be made to investment in avenues that will lead to productivity growth. Again, government should take gradual but transparent steps to remove gasoline price subsidies.

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