

Fuel Efficiency Vehicle Adoption and Carbon Emissions in a Country Context

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Abstract

The paper aimed at establishing the relationship between age, engine capacity, fuel type and fuel efficiency and carbon emissions. The relationship was obtained using panel data on newly imported registered vehicle stock obtained from Uganda Revenue Authority. This involved collecting data on imported vehicle inventory into Uganda for the period from 2013 to 2017 which was later analysed using the stata software. The findings indicated a positive relationship between a vehicles age, engine capacity, vehicle category (Light Duty Vehicles, Medium Duty Vehicles and Heavy Duty Vehicles) and fuel efficiency and carbon emissions.

A comparison with the global fuel efficiency targets indicated that more fuel was being consumed in Uganda compared to non-OECD countries. A reduction in fuel consumption and emissions was observed in petrol vehicles while diesel vehicles had increased carbon emissions and fuel consumptions due to an increase in engine capacities. The findings imply that government should develop policy options that promote vehicle fuel efficiency, transport system operators may undergo training in fuel efficiency issues that will result in an attitudinal change while academicians need to carry out more research comparing the effect of transport systems operators ages, level education and income on carbon emissions and fuel efficiency. The majority of research on fuel efficiency and carbon emissions uses survey data rather than panel data. Further, previous research is focused on vehicles that are already on the road rather than focusing on the effect of age, engine capacity, fuel type on fuel efficiency and carbon emissions.

Keywords: Fuel efficiency, Vehicles, Carbon emissions, Energy

1. Introduction

Fuel efficiency of vehicles is a subject that has attracted attention of many researchers. Much of the research and emphasis on fuel efficiency is in developed nations and in varied topical areas that include fuel efficiency and motor vehicle travel (Small & Van Dender, 2007); determinants of consumer interest in fuel economy (Popp, Van de Velde, Vickery, Van Huylenbroeck, Verbeke, & Dixon, 2009); determinants of changes in car fuel efficiency in Great Britain (Kwon, 2006); fuel economy standards and automobile safety (Crandall & Graham, 1989) and modelling the effects of transport policy levers on fuel efficiency and national fuel consumption (Kirby, Hutton, McQuaid, Raeside, & Zhang, 2000). Much of the emphasis is placed on fuel efficiency rather than carbon emissions.

Carbon emissions are increasing, particularly in the developing world, where the use of vehicles is on the rise. The global vehicle fleet is set to increase rapidly from about 850 million today to as much as 2.5 to 3 billion by 2050 (Global Fuel Economy Initiative (GFEI), 2016). Ninety percent of this growth is set to take place in developing and transitional countries (Global Fuel Efficiency initiative -State-of-the-World-report, 2016). As the average vehicle fuel economy in these countries is stagnant, it is predicted that greenhouse gas emissions of the global fleet are set to triple. According to the International Energy Agency (IEA)(2013), the transport sector has the highest growth of CO₂ emission of any sector. In the same perspective, Song et al. (2013) also indicate that road transportation is a major fuel consumer and greenhouse gas emitter. It's contribution to energy related CO₂ emissions are estimated to go from one quarter today to one-third by 2050. Black carbon and pollutant emissions are also set to increase similarly with major health and short-term climate impacts.

Fuel economy standards have mostly been implemented in the developed (OECD) countries such as the US, Canada, Japan the EU, the BRICS (Brazil, Russia, India, China and South Africa), and a few other emerging economies. Only Mauritius has developed and implemented the first fuel economy / CO₂ based fee-bate system in the developing world (Global Fuel Efficiency Initiative (GFEI), 2014). However, through the GFEI, more countries are acknowledging the need for strong policies on fuel efficiency (GFEI, 2014).

Mixed research exists on carbon emissions and fuel efficiency. The majority of these studies

are scattered, characterised with conflicting findings and conducted in the developed world (see Musti & Kockelman, 2011; Fingerman, Sheppard, & Harris, 2018) and different industrial sectors such as the fishery industry (Parker et al., 2018). Existing research focuses on tax reforms (Parker et al., 2018); use of hybrid and electric vehicles (Fernández, 2018); blending hydrogen with natural gas to vehicles with fuel cells (Ogden, Jaffe, Scheitrum, McDonald, & Miller, 2018) and a dearth of research on policy. Further, existing research on policy is characterised by conflicting findings. For example, Shaw, Hales, Edwards, Howden-Chapman & Stanley (2018) found no relation between fuel tax and a reduction in gas emissions while Sterner (2007), Samaras & Meisterling (2008) and Morrow, Gallagher, Collantes & Lee(2010) found a positive relationship between the two aspects. Also Shaw et al. (2018) saw an increase in fuel prices as a short term solution to reducing carbon emissions.

Whereas the majority of the research has been carried out in the road transport sector (see Alam, Hyde, Duffy, & McNabola, 2018; Fingerman et al., 2018), emphasis was placed on light duty passenger vehicles and electric vehicles (see Ahn, Rakha, Trani, & Van Aerde, 2002; DeMelo et al., 2018). Although recent studies advise that electric vehicles may solve emission problems, Fernández (2018) found out that electric cars pollute the environment during their production at power plant level and during the generation of electricity to be stored in the batteries of these electric cars. However, transport emissions may be reduced through generating electricity using renewable energy sources such as wind, solar, geothermal and a change in social habits.

Over 50% of oil use around the world is for transport and nearly all the recent and future expected growth in oil use comes from increased transport activities. Globally, the transport sector is rising faster than any other sector and the number of vehicles on the planet is set to triple by 2050 (GFEI, 2012, 2014 and 2015a, b). Due to the rapid growth in vehicle population, especially private passenger vehicles, controlling the fuel energy demand and greenhouse gas (GHG) emissions has become a global concern (Feng et al., 2011). Thus, promoting fuel efficiency and reducing carbon dioxide (CO₂) emissions is a key global development agenda.

In Uganda, vehicle emissions are a major contributor to poor air quality particularly in urban and rural areas due to increased importation of used vehicles (Mutenyo et al., 2015), the number of hours spent in traffic, and the nature of fuel consumed among others. Given these trends, solutions are needed to reduce emissions and energy consumption from the transportation sector since it is widely believed to be a major contributor to climatic change. Good climatic change is one of the pre-requisites for poverty eradication and increased agricultural production (Hertel & Rosch, 2010; Sanchez, 2000). In developing countries such as Uganda, agriculture is a major occupational sector and primary source of income for the poor where 70% of the population depends on agriculture. The productivity of this sector highly depends on good climate (Afedraru, 2015). Hence implementing the GFEI is a civil obligation as well as a development concern. Given the above, the paper aims at establishing the relationship between age, engine capacity, fuel type and fuel efficiency and carbon emissions using panel data of newly imported registered vehicle stock.

2. Literature Review

This section provides a review of both the conceptual and empirical literature on vehicle fuel

efficiency and environmental emissions, the relationship between the age of a vehicle, engine capacity and fuel efficiency and the relationship between age of the vehicle, engine capacity, fuel type and carbon emissions.

2.1 Vehicle Fuel Efficiency and Environmental Emissions

Road transportation is a major fuel consumer and greenhouse gas emitter (Song, Zhang, Sekimoto, Horanont, Ueyama, & Shibasaki, 2013). Sustaining a clean environment has become an important issue in society. Environmental emissions caused by automobiles and motorcycles are some of the relevant environmental problems to be tackled (Hsieha et al., 2002). Thus reducing pollution from motor vehicles is of great importance to mitigating climate change. Environmental emissions are considered to be proportional to the fuel consumed during vehicle's operations (Fontaras, Zacharof, & Ciuffo, 2017). Fuel consumption is the reciprocal of fuel Efficiency and may be defined as the amount of fuel used per unit distance (Mathew, 2014). The lower the value of fuel consumption, the more economical the vehicle is said to be. Although a substantial amount of research exists on environmental emissions produced by transport systems, factors such as driving behaviour, vehicle configuration and traffic conditions are reconfirmed as highly influential (Van Mierlo, Maggetto, Van de Burgwal, & Gense, 2004; Rakha & Ding, 2003; Fontaras et al., 2017). Neglected factors such as side winds, rain and road grade may have significant contributions in fuel consumption in real world driving (see Fontaras et al., 2017). Fuel efficiency of a vehicle is determined by a number of factors that include vehicle characteristics, environmental and traffic conditions, and driver and user related factors.

Vehicle characteristics identified include an increase in mass weight of a vehicle (Pagerit, Sharer & Rousseau, 2006; Wohlecker, Johannaber, & Espig, 2007; Bishop, Martin, & Boies, 2014); a vehicle's aerodynamic resistance(see Hucho & Sovran,1993; Wohlecker et al., 2007); rolling resistance of a tyre (Crolla, 2009); and auxiliary systems of a vehicle for example, the air conditioning system and lights(Tong et al., 2000; Schipper, 2008; Weilenmann, Alvarez & Keller, 2010). Environmental and traffic conditions include weather conditions (Karlsson & Ellen, 2012); ambient temperature (Alvarez & Weilenmann, 2012; Fontaras & Dilara, 2012); cold start of a vehicle(Mock, German, Bandivadekar, & Riemersma, 2012; Joumard, Andre, Laurikko, Le Anh, Geivanidis, & Samaras, 2006; Dardiotis, Martini, Marotta, & Manfredi 2013); road morphology, road surface and road shape (Boriboonsomsin & Barth, 2009; Ardekani & Sumitsawan, 2010); and traffic conditions and congestion (Burgess & Choi, 2003; Spalding, 2008; Smit et al., 2008). Driver and user related factors involve driving behaviour of the drivers (Ericsson, 2001; Brundell-Freij & Ericsson, 2005); aggressive driving (André & Pronello,1997; Ericsson, 2001; Rakha & Ding, 2003); driver training (Beusen et al., 2009; Barkenbus, 2009); eco-driving (European Environmental Agency, 2016; Joumard et al., 2006; Haworth, 2001); four-wheel drive (Fontaras, et al., 2017); and occupancy rates (Fontaras et al., 2017).

Whereas the literature may indicate the existence of the link between vehicle fuel efficiency and environmental emissions, the influence of vehicle fuel efficiency on environmental emissions has not been given significant attention in the literature. However, a reduction in environmental emissions may be achieved as a result of promoting the adoption of fuel

efficiency vehicles among motorist owners. Although studies on vehicle fuel efficiency exist, the majority of the studies are carried in developed nations and a few developing nations with limited emphasis on African countries.

2.2 Age of a Vehicle, Engine Capacity and Fuel Efficiency

Fuel efficiency is a measure of how far a vehicle will travel with a gallon of fuel; it is expressed in miles per gallon while fuel consumption is the inverse of fuel economy (Greene, 2008). It is the amount of fuel consumed in driving a given distance and is measured in gallons per 100 miles, and in liters per 100 kilometers. The amount of fuel consumed depends on the engine, the type of fuel used, and the efficiency with which the output of the engine is transmitted to the wheels.

Research on vehicle's age shows that older vehicles may consume much fuel compared to new vehicles. Further, people who drive older vehicles cannot afford newer vehicles and accept lower fuel economy as a tradeoff. Other people, instead, may value lowering their fuel costs via increased new-vehicle fuel economy at the potential cost of higher vehicle investment (Popp et al., 2009). However, an improvement in fuel efficiency in a country's economy may improve when newer vehicles are bought and older vehicles are scrapped. Although fuel efficiency may improve with the purchase of new vehicles, the improvement will be more quickly observed if the average engine size is also reduced (Wang, McGlinchy, Badger & Wheaton, 2015). A car's engine size, also known as the engine capacity or simply CC, is the size of the volume swept by each of the cylinders, which inside combine and burn air and fuel to generate energy. The larger the engine size, the more fuel your vehicle consumes (Leduc, Dubar, Ranini, & Monnier, 2003), the more power it produces, and the more your car accelerates. Further, the decrease of engine capacity and the increase of the specific performance helps to reduce fuel consumption by limiting pumping, friction and heat energy losses (Salamon, McAllister, Robinson, Richardson, Martinez-Botas, Romagnoli, Colin Copeland, & Turner, 2012). However, in some cases a large sized engine may not consume more in fuel than a small sized engine, but not all the time. There are many factors that go into a vehicles' design that can have negative or positive impacts on this specific cost. For example: Engine efficiencies may be improved due to better fuels, and if refineries are able to provide the fuels demanded by modern engines at a lower cost. Thus, the potential for fuel efficiency improvement may depend on fuel attributes as well as on engine technology. Implementing certain engine technologies may require changes in fuel properties, and vice versa (Greene, 2008).

2.3 Age of the Vehicle, Engine Capacity, Fuel Type and Carbon Emissions

Older vehicles produce substantially more pollution than new ones and the effects become more stronger with the vehicles age (Harrington, 1997). But conflicting research findings exist whether new vehicles produce carbon emissions or not. For example, research conducted by European Environment Agency (EEA) (2018) on new vehicles shows that the average carbon dioxide (CO₂) emissions from new passenger cars and vans registered in the European Union (EU) in 2018 increased for the second consecutive year, reaching 120.4 grammes of CO₂ per kilometre.

Older vehicles are being driven by poor people in developed nations and by arrange of people

in developing countries. An older vehicle fleet in conjunction with poor maintenance practices and limited vehicle testing can mean that the impacts of motorisation on developing nations are many times worse than an equal level of motorisation in a developed nation (Wright, 2004; Fomunung, Washington, & Guensler, 1999). Further, carbon emissions are high in older technology or tampered vehicles (Fomunung et al., 1999). However, emissions from older vehicles can be reduced through strengthening the existing inspection and maintenance programs, which require periodic emission control tests before vehicles can be reregistered. Although important, many developing countries lack inspection and maintenance program policies. Thus a reason for higher levels of carbon emissions arising from the transport industry. Also Chiang, Tsai, Yao & Ho's (2008) findings show that emission tests before and after repair and maintenance on older vehicles fail to reduce emissions because of deterioration of the three-way catalyst over time. Besides, the age of the vehicles, carbon emissions may arise from the type of fuel used.

Fuel is not equal to fuel when carbon dioxide emissions for each are considered. Given that the majority of vehicles either use petroleum or diesel, vehicles that use diesel are found to be higher environmental emitters. Although diesel contains more carbon than petrol, carbon dioxide (CO₂) emissions of diesels tend to be lower. However, diesel cars emit significantly higher levels of other air pollutants, especially nitrogen oxides (NO_x) and particulates thus affecting their environmental soundness (Organisation for Economic Co-operation and Development (OECD), 2014). Whereas petrol is seen to produce more carbondioxide than diesiel, emissions from petrol cars have been dramatically reduced by the introduction of catalytic converters, which oxidise pollutants such as CO to less harmful gases such as carbon monoxide (May, 2017; Bromberg, Cohn, Rabinovich, & Heywood, 2001; Rajesh, Sundaram, Sivaganesan, Nagarajan, & Harikishore, 2019). When compared to petrol cars without catalysts, catalyst cars have much lower CO, HC and NO_x emissions, at the expense of CO₂ emissions, which increase due to the oxidation of carbon monoxide to CO₂. As a consequence of this, a catalyst car will also use slightly more fuel and become less efficient. However, despite these improvements, petrol cars with catalysts still produce more CO and HC than diesel cars, although exhaust emissions of NO_x and particulates are much lower than diesel cars. In fact particulate emissions from petrol cars are so low that they are not routinely measured. Although alternative fuels such as compressed natural gas (CNG); liquefied petroleum gas (LPG); city diesel; hydrogen; alcohol fuels; and battery operated vehicles have been developed to replace petrol and diesel, it is cheaper to improve conventional fuels(petrol and diesel) than to use many of the alternatives as no investment is needed for new storage tanks and service stations (Demirbas, 2003; Niculescu, Clenci, & Iorga-Siman, 2019).

All in all and despite the much debate over which car, petrol or diesel, is cleaner, weighing up the advantages and disadvantages is not easy. For example, diesel cars have been promoted, as they produce less CO and HC on average when compared to petrol cars, and they have greater fuel economy producing less CO₂ per km. However, recent health concerns about particulate matter have given diesels a less environmentally-friendly image, as have the higher emissions of nitrogen oxides compared with petrol cars. As a comparison, petrol cars produce virtually no particulate matter, take longer to warm up, produce more carbon dioxide per mile on average, and emissions of the regulated pollutants are higher.

3. Research Methodology

Panel Data on imported vehicle inventory into Uganda for the period from 2013 to 2017 was obtained from Uganda Revenue Authority. Average fuel consumption per one kilometer, average fuel efficiency (estimated in Liters per 100 Kilometers) and CO₂ emission grams of carbon dioxide emissions per kilometer (gCO₂/Km) were computed for vehicles registered in 2013-2017.

Fuel efficiency and carbon-dioxide emissions computations were calculated as follows: Average fuel efficiency was estimated in liters per hundred kilometers (L/100 Km). Vehicle fuel economy was expressed in terms of liters of gasoline per 100 kilometers of travel (L/100km). The vehicle fuel economy ratios were computed by fuel type and engine capacity. The vehicle database reports data on engine capacity in cubic centimeter (CC), therefore we used CC displacement for analysis. The engine capacity were categorized into 5 sub-groups <1000, 1001-1500, 1501-2000, 2001-2500 and SUV (luxury cars). This was guided by an analysis made on the data. Observations from the data showed that with the exception of SUVs, the majority of the vehicles had engine capacities ranging between 1000CC and 2500CCs. Vehicles within the same engine capacity ranges were assumed to exhibit similar fuel efficiency and CO₂ emission rates and therefore comparable for the required computations. CO₂ emission grams of carbon dioxide emissions per kilometre (gCO₂/Km) were computed for vehicles registered in 2013-2017.

Estimates to compute CO₂ emission for particular vehicle categories (gCO₂/km) were derived from fuel efficiency (FE) i.e. for petrol fleet CO₂ = 23.2* FE of the petrol fleet while for diesel fleet CO₂ = 26.5*FE for diesel fleet¹ FE was derived from the manufacturers' websites and vehicle characteristics web portals². Comparisons of the results on fuel efficiency with the global fuel efficiency targets were made to tell the levels of fuel consumption in Uganda in relation to the non-OECD countries.

After deriving the estimates for fuel efficiency and carbon emissions, data was analysed using the Stata software. The data on excel worksheets was imported into Stata 13 statistical software. The name Stata is a syllabic abbreviation of the words statistics and data (Jimenez-Valdivia, Malpartida-Carrillo, Rodríguez-Cárdenas, Dias-Da Silveira, & Arriola-Guillén, 2019). Stata is a general-purpose statistical software package created in 1985 by Stata Corp. It's mostly used in research, especially in the field of economics, sociology, political science, biomedicine and epidemiology. Stata's capabilities include data management, statistical analysis, graphics, simulations, regression, and custom programming (Jimenez-Valdivia et al., 2019; Buchmann & Downs, 2018).

4. Results

This section provides findings on carbon emissions and fuel efficiency. Results include the types and age of registered vehicles based on vehicle weights; Age, Engine Capacity, Fleet fuel type and Fuel efficiency; LDVs Fuel type, Engine capacities and Fuel Efficiency; and Fleet fuel type and Carbon emissions.

¹ Source: <https://www.unitjuggler.com/convert-fuelconsumption-from-gperkmgasoline-to-lper100km.html>

² <http://carfueldata.direct.gov.uk/>; <https://www.greenvehicleguide.gov.au/>;
<http://www.nextgreencar.com/>; <https://car-emissions.com>

4.1 Types of Registered Vehicles Based on Vehicle Weights

Findings show that between 2013 and 2017, about 201732 vehicles were registered; 8.4% fell in the category of HDVs (heavy duty vehicles), 80.1% fell in the category of LDVs (low duty vehicles) while 11.5% fell in the category of MDVs (medium duty vehicles). Analysis of the trend of vehicle registrations on average except for MDVs which registered 5541 showed that registrations were highest in 2014 for all vehicle categories (See Table 1).

Table 1. Vehicle Inventory by weight category at Registration: 2013-2017

Weight category							
Years	HDV		LDV		MDV	Total	
2013	4523	11.1%	31977	78.8%	4066	10.0%	40566
2014	6615	11.9%	43909	79.0%	5083	9.1%	55607
2015	2193	5.9%	31336	83.6%	3943	10.5%	37472
2016	2146	6.3%	27317	80.5%	4491	13.2%	33954
2017	1462	4.3%	27130	79.5%	5541	16.2%	34133
Total	16939	8.4%	161669	80.1%	23124	11.5%	201732

Source: Computations based on vehicle registration data for the period 2013-2017.

4.2 Age of Registered Vehicles Based on Vehicle Weights

Findings show that the average age of imported vehicles has been increasing over time. However, HDVs dominate the oldest fleet registered in Uganda at registration followed by MDVs and then the LDVs. LDV fleet registered averaged at 15 years at registration unlike HDV and MDV which ranged in over 20 years. The weighted average relatively increased from 15 years to 17 years between 2013 and 2017 (see Table 2). New vehicle registrations comprised the smallest proportion across vehicle weights, 5.2%, 2.8% and 1% for HDV, LDV and MDV fleet respectively (see Table 3). The results indicate that Uganda imports older vehicles than new vehicles. The implication is that older vehicles were brought into the country and this signifies an increase in emission levels.

Whereas the government emphasizes the importation of new vehicles, the technology that curbs emissions in vehicles has not drastically changed with fundamentals such as how catalytic converters work for 2005, 2012 and 2018 vehicles Models (Ziraba, 2018). This is contrary to findings by Harrington (1997) and the Uganda Baseline fuel efficiency survey (2015) that show that age of a vehicle affects fuel efficiency. Thus placing more emphasis on proper maintenance, use of genuine fuels and oils and avoidance of bad driving habits may promote fuel efficiency and reduce carbon emissions.

Table 2. Age and vehicle weight category

Year	HDV	LDV	MDV	Overall average
2013	20	14	18	15
2014	22	15	20	16
2015	23	14	22	16
2016	24	15	23	16
2017	25	15	23	17

Source: Computations based on vehicle registration data for the period 2013-2017.

Table 3. New versus old fleet

Year of Registration	Vehicle Weights								
	HDV			LDV			MDV		
	New	Old	% of new	New	Old	% of new	New	Old	% of new
2013	354	4169	7.8	1407	30570	4.4	111	3955	2.7
2014	429	6186	6.5	1615	42294	3.7	73	5010	1.4
2015	93	2100	4.2	768	30568	2.5	31	3912	0.8
2016		2146	0.0	463	26854	1.7	17	4474	0.4
2017		1462	0.0	275	26855	1.0	5	5536	0.1
Total	876	16063	5.2	4528	157141	2.8	237	22887	1.0

Source: Computations based on vehicle registration data for the period 2013-2017.

4.3 Comparison Criteria for the New and Old Vehicles

The comparison for the vehicles whether new or old were based on the year of manufacture for the vehicles. After the year of manufacture, the year of registration of the vehicle by Uganda Revenue Authority was also considered. The time lag between the year of manufacture and the year of registration was used to tell whether the vehicle was old or new. Whereas the government emphasizes the importation of new vehicles, the technology that curbs emissions in vehicles has not drastically changed with fundamentals such as how catalytic converters work for 2005, 2012 and 2018 vehicles Models (Ziraba, 2018). This is contrary to findings by Harrington (1997) and Mutenyo, Banga, Matovu, Kimera & Lawrence (2015) that show that age of a vehicle affects fuel efficiency. Thus placing more emphasis on proper maintenance, use of genuine fuels and oils and avoidance of bad driving habits may promote fuel efficiency and reduce carbon emissions.

4.4 Age, Engine Capacity, Fleet Fuel Type and Fuel Efficiency

Findings show that diesel vehicles below 1001CC were imported while very old and the number of imported vehicles increased from 17.8-20.7 years (see Figure 1). Diesel vehicles in the categories 2001-2500CC and SUVs were relatively newer at registration compared to

other categories. The average ages for the SUVs ranged from 9.4 years to 13.8 years while vehicles with engine capacities of 2001CC-2500CC had their average ages ranging from 12 years to 15.4 years between 2013 and 2017. The average age of the diesel fleet was below 15 years. Similarly for Petrol fleet, vehicles with engine capacities of 2001CC-2500CC and SUV categories were registered newer than other fleet categories. And vehicle fleet of less than 1001 CC were oldest at registration over the period 2013-2017 (see Figure 2).

Further, Diesel registered fleet and SUVs were fuel guzzlers whose fuel consumption increased from 9.7L/100km in 2013 to 10.7 L/100km implying a 9.3% in fuel demand to cover same distance(see Figure 3) while in the case of the petrol fleet, for the petrol fleet, SUVs average fuel consumption increased from 12.1L/100km in 2013 to 13L/100km implying a 6.9% in demand for gasoline (petrol) between fleet registered in 2013 and 2017 (see Figure 4).

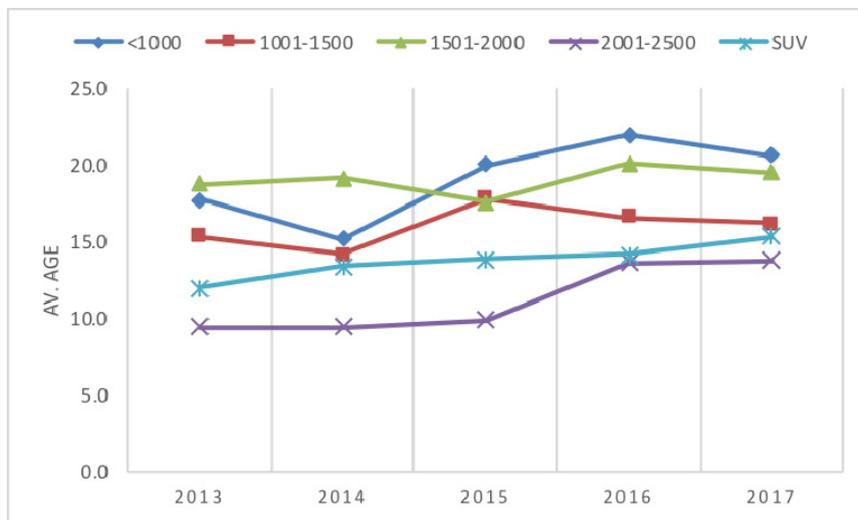


Figure 1. Age and engine capacity category for the diesel fleet

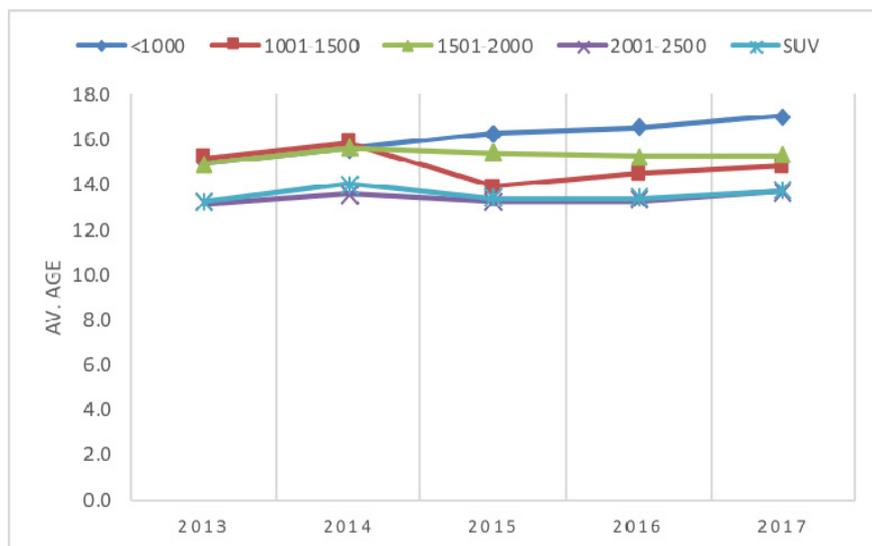


Figure 2. Age and engine capacity category, petrol fleet

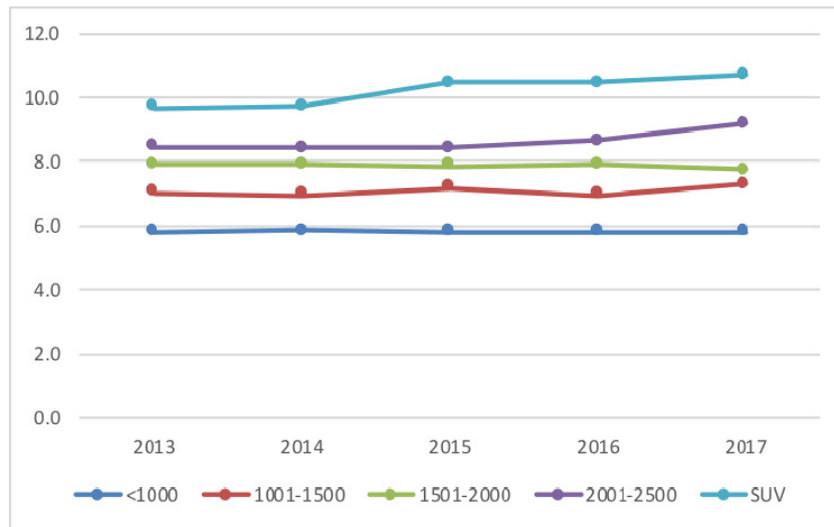


Figure 3. Engine capacity and fuel efficiency diesel fleet

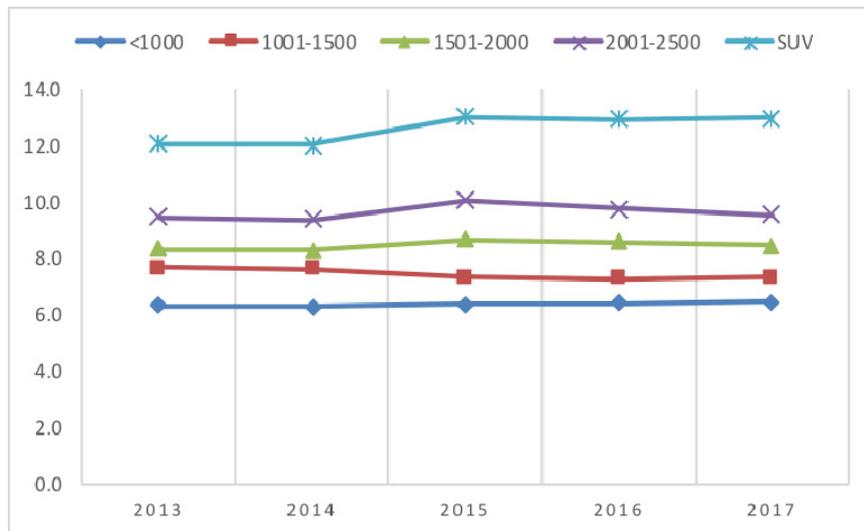


Figure 4. Engine capacity and fuel efficiency petrol fleet

Compared to the global and regional fuel efficiency targets for OECD (Organisation for Economic Co-operation and Development) and non-OECD country averages, Uganda’s fleet relatively consumed more petrol. The average fuel estimate for the OECD and Non-OECD countries in addition to the global average is 9.02L/100km in 2015 while Uganda’s fuel consumption is estimated at 8.9L/100km in 2017. The fuel efficiency levels deviate by 52.8% from the GFEI target of 4.2L/100km in 2030. Uganda may reduce the fuel consumption levels by benchmarking what other countries have done in terms of fuel efficiency and pollution standards for passenger vehicles as it seems to be performing already badly.

4.5 LDVs Fuel type, Engine Capacities and Fuel Efficiency

The age and fuel efficiency of LDV fleet was assessed to provide insights into the implications of a regulatory policy on age of vehicles imported into the country given that they are the most widely used in Uganda. Findings show that for diesel LDV fleet, the

average age of registered vehicles increased from 11.6-15.3 years between 2013 and 2017. Similarly, fuel efficiency increased by 1 unit, implying an increase of 10.9% of the fuel required to travel a similar distance for vehicles imported in 2017 relative to those of 2013(see Table 4). Notably, the average engine capacity was 2864.9CC in 2013 and 2920 CC in 2017 and these are branded as SUVs. The results imply that fuel efficiency (FE) increases with age.

For the Petrol fleet, the average age remained approximately 15 years between the same period but increased from 14.7years to 14.8 years over the same period. This implies that the relatively high age of vehicles at registration is of concern to promoting fuel economy national policy, since older cars for any engine capacity and vehicle technology consume more fuel and hence emit more CO₂ per kilometre. The average age has been worsening for all categories of engine capacity despite the imposition of the environmental tax by URA in 2008. This is a deviation from the global target of 4.2.

Also the average fuel efficiency increased slightly from 8.7L/100km to 8.9L/100km, implying a slight increase in fuel demanded of 2.3% to cover similar distance for fleet registered in 2017 relative to those registered in 2013. Overall, the average fuel efficiency of LDVs increased from 8.8 L/100km in 2013 to 9.1 L/100km in 2017 implying a 3.3% increase in the demand of fuel for vehicles imported between 2013 and 2017. Besides fuel efficiency, the average engine capacity increased relatively to 2023.5 CC (2017) from 1946.3 CC in 2013. However, engine capacities have been declining for all categories and fuel types (see [错误!未找到引用源。](#)). Similarly, registrations of brand-new vehicles has steadily declined in all vehicle categories, implying more used cars are being imported into the country.

From the analysis of age and engine capacities of LDV's, the results showed that on average, the age of the fleet across all categories increased, except for engine capacities ranging from 1001-1500 and 1501-2000 categories which averaged at 15 years. Significant increases were registered in vehicle registrations less than 1001CC and SUVs which increased from 15.1-17.1 and 12.6-14.5 years respectively between 2013 and 2017. The results also showed that SUVs consumed more fuel for 100km under the LDV category. Fuel efficiency of vehicles in all categories except 1001-1500CC increased between 2013 and 2017(see Table 6). The worrying situation is that SUVs which are fuel guzzlers had an estimated increase in average fuel consumption of 8.4% from 2013-2017. This could be attributed to the increased demand of SUVs and relatively older versions, that do not make use of the recent technology that is cognizant of the environment.

Increases in fuel consumption may be due to there being a lack of understanding of fuel efficiency policies and their benefit. For example policies that would be used as solutions to fuel efficiency such as high fuel prices and fuel tax are used for generating government revenue in Uganda. Whereas vehicles older than eight years are hit by a 50 percent environmental tax compared to vehicles between five and eight years old that require a tax rate of 35 percent, there is still a concern of whether the differentiation in taxation will promote a reduction in fuel efficiency. There is also lack of institutional coordination and cooperation between the Energy, Environment, Transport and Finance Ministries that would serve as a deterrent to develop comprehensive fuel economy policies.

Further, there is little documentation about the current policy interventions being

implemented to promote fuel efficiency economy in Uganda. This is largely because there is no national vehicle fuel economy policy in place currently. Nonetheless, the non-motorized transport policy 2012, and the draft Urban Transport policy (2014), contain a number of proposals for traffic management and safety, road quality and promotion of public transport, all of which if fully implemented would contribute to the vehicle fuel efficiency, particularly for motor vehicles within the capital city and other major towns. For instance, according to the Uganda Vision- 2040, at least 80% of Uganda's freight transport will be carried by rail and the standard gauge rail will transport at least 10% of all persons for inter-urban and international trips by year 2040 (National Planning Authority (NPA), 2010). The review of documents and consultations held with stakeholders revealed that there were a few interventions directly related to fuel efficiency.

Table 4. Age and fuel efficiency of LDV fleet

Fuel type	Diesel Fleet			Petrol Fleet		
	Year	Av age	Av FE	Av power (CC)	Av age	Av FE
2013	11.6	9.2	2864.9	14.7	8.7	1946.3
2014	12.7	9.2	2849.2	15.3	8.6	1947.2
2015	13.0	9.8	2867.6	14.7	9.0	1976.9
2016	14.5	10.0	2895.3	14.6	9.1	2040.2
2017	15.3	10.2	2920.0	14.8	8.9	2023.5

Source: Computations based on vehicle registration data for the period 2013-2017.

Table 5. LDV vehicle inventory by engine capacity at registration

Engine Capacity	DIESEL					PETROL					Total
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	
<1000	13	18	2	3	3	944	1249	672	542	339	3785
1001-1500	30	39	15	15	24	4242	5680	5691	3574	4214	23524
1501-2000	248	429	222	230	178	16813	23105	14780	12877	12759	81641
2001-2500	1429	1918	1135	688	548	2043	2996	2356	3219	3947	20279
SUV	3192	4291	2997	2973	2423	3023	4184	3466	3196	2695	32440
Total	4912	6695	4371	3909	3176	27065	37214	26965	23408	23954	161669

Source: Computations based on vehicle registration data for the period 2013-2017.

Table 6. Age, Engine capacities and Fuel efficiency (Power CC) categories by year of registration

LDV Engine capacity	2013		2014		2015		2016		2017	
	Av age	Av FE								
<1000	15.1	6.3	15.6	6.3	16.3	6.4	16.6	6.4	17.1	6.4
1001-1500	15.2	7.7	15.9	7.6	13.9	7.3	14.5	7.3	14.8	7.3
1501-2000	15.0	8.3	15.7	8.3	15.5	8.7	15.3	8.6	15.4	8.4
2001-2500	11.6	9.1	12.0	9.0	12.2	9.6	13.4	9.6	13.7	9.5
SUV	12.6	10.9	13.7	10.9	13.6	11.8	13.8	11.8	14.5	11.9
Total	14.2	8.8	14.9	8.7	14.5	9.1	14.6	9.2	14.9	9.1

Source: Computations based on vehicle registration data for the period 2013-2017.

4.6 Fleet Fuel Type, Engine Capacity and Carbon Emissions

Findings show that on average CO₂ emissions have remained high with some categories increasing relatively across fuel types. The overall CO₂ emissions for diesel fleet increased from 244.2gCO₂/km to 271.1gCO₂/km while for petrol it increased slightly from 201.2gCO₂/Km to 207.1gCO₂/Km between 2013-2017 (see Table 7). The average CO₂ emission of new diesel fleet was estimated at 217.5gCO₂/km in 2013. This increased to 263.2gCO₂/Km in 2017. Similarly for petrol fleet it was estimated to have declined from 252.8gCO₂/Km in 2013 to 226.8gCO₂/km in 2017. The increase in CO₂ for diesel fleet between 2013 and 2017 may be attributed to the importation of bigger vehicles (higher engine capacities) and absence of policies that would be used as solutions to transport environmental emissions such as high fuel prices and fuel tax as fuel prices and tax are used for generating government revenue in Uganda. Whereas vehicles older than eight years are hit by a 50 percent environmental tax compared to vehicles between five and eight years old that require a tax rate of 35 percent, there is still a concern of whether the differentiation in taxation will promote a reduction in carbon emissions. Even vehicles of five or eight years may produce higher carbon emissions and consume more fuel due to factors related to drivers' attitude towards the two aspects. However, findings indicated that between 2013 and 2017, average power for diesel fleet increased from 2886.6CC to 2960.3CC while the average power for petrol fleet declined relatively from 2879.8CC in 2013 to 2567.7CC in 2017 which translates into reduced emissions.

Table 7. CO₂ (gCO₂/Km) emissions by engine capacity categories and Fuel type

Engine capacity	<i>CO₂ Emissions Diesel Fleet</i>					<i>CO₂ Emissions Petrol Fleet</i>				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
<1000	155.1	155.3	155.1	155.1	155.1	146.8	146.2	147.6	148.7	149.6
1001-1500	186.0	184.7	190.2	184.5	193.5	178.7	177.1	169.8	169.5	169.8
1501-2000	209.7	209.6	207.9	209.6	205.6	193.4	192.8	201.2	199.2	196.3
2001-2500	224.7	223.1	223.5	229.1	243.6	219.5	218.2	234.1	227.0	222.2
SUV	256.4	257.4	277.1	277.6	283.0	280.9	279.4	302.8	301.2	301.8
Total	244.2	243.8	259.3	264.6	271.1	201.2	200.6	209.2	211.3	207.1

Source: Computations based on vehicle registration data for the period 2013-2017.

5. Conclusion

The paper aimed at establishing the relationship between age, engine capacity, fuel type and fuel efficiency and carbon emissions using newly imported registered vehicle stock. The findings indicate a positive relationship between a vehicle's age, engine capacity, fuel type, vehicle category (LDV, MDV and HDV) and fuel efficiency and carbon emissions. Fuel efficiency estimates increased for the imported vehicles implying an increase in fuel consumption regardless of their age, fuel type and engine capacity. SUVs were found to be the highest fuel guzzlers compared to LDVs. While carbon emissions for both the diesel and petrol fleet increased, a slight increase was observed in the petrol fleet. Further, the average age for the engine capacity categories was worsening meaning that vehicles with older technology were still being imported into the country. A reduction in fuel consumption was observed in petrol vehicles while diesel vehicles had increased fuel consumption due to an increase in engine capacities. An improvement in fuel efficiency results in a reduction in carbon emissions and a reduction in emissions results in improvements in climate change problems.

6. Research Implications

The research has implications to transport system operators, academicians and policy makers. The transport policy makers will be able to devise better ways of improving efficiency of transport systems such as driver training on fuel efficiency issues and also strengthening rules on vehicle importation and clearance. Policy options available for Uganda to promote vehicle fuel efficiency include: regulatory policies, fiscal-related incentives/disincentives and traffic control measures. Regulatory policies that may be considered include encouraging importation of vehicles with up to date technologies, charging varied registration fees depending on the age of the vehicle in addition to the environmental levy and encouraging and providing more secure environments for non-motorised transport. Charging varied registration fees means that vehicles beyond eight years will be charged higher registration fees. However, implementation of policies depends on the level of technology, the level of road infrastructure and institutional capacity for enforcement of the policies. More effective policies that promote interactions between the policy makers and transport system operators

may be developed. To academicians, the research contributes to the body of knowledge through examining the effect of age, engine capacity, vehicle category and fuel type on carbon emissions and fuel efficiency.

Whereas much of the focus is placed on policy options, attitudinal and behavioural aspects are ignored. Both an attitudinal and behavioural change of the motor vehicle operators may have an impact on fuel efficiency and gas emissions. Therefore, research examining the impact of attitudes and behavioural aspects of motorists on fuel efficiency and carbon emissions is vital. Also more research is required on the impact of vehicle technologies inherent in different vehicle models on fuel efficiency and carbon emissions. This is an area where researchers have been silent.

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