Electric Vehicle Deployment in China and the Associated Implications on the Electricity Grid and Carbon Footprint: Lessons for South Africa

Fourth Industrial Revolution

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***Abstract*—Currently, there is a global acceptance of transforming the transport industry by replacing conventional vehicles by Electric Vehicles (EVs) as a means of reducing greenhouse gas and mitigating carbon emissions problems associated with conventional vehicles. The year 2017 was a milestone for sustainable automobile production, with electric vehicles deployments going above 100 million units globally. Much of the deployment occurred in China. China has the highest number of electric vehicles per capita in the world. The deployment approach has been very aggressive causing serious strain in its electricity grid and the environment as a result of a large amount of electricity demanded by this fleet of Chinese electric vehicles, and also as deploying electric vehicles in China is highly associated with the carbon emissions from electricity generated from coal. The South Africa automobile industry is preparing for a similar deployment model, in which 50% of all vehicles will be electric by 2050. Noting that South Africa currently suffers from endemic electricity supply inconsistency and as over 90% of its electricity is generated from coal, it is important to have an informed policy on the cost and benefits of the deployment model from lessons learned from China.**

Keywords - electric vehicles; policy approach; policy implication.

I. INTRODUCTION

The United Nation's Sustainable Development Goals (UNSDG) in general have an ambitious and transformational vision for the globe- striving for a world where the environment of humans and other species is safe, resilient and sustainable [1]. The Fourth Industrial Revolution builds on the digital and technological revolution and leads to unprecedented paradigm shifts in the grid warranting a transformation of entire systems. The automobile and transport industry is a significant influence of this shift through the introduction of EVs [2]. Most economies have generally supported that conventional vehicles should be replaced with EVs as EVs have the potentials to significantly reduce gas emissions from the transport sector. Viewing EVs deployment as an effective measure to reduce the climate impact of the transport sector, governments around the world have initiated strategies and frameworks to encourage producers and consumers to drive electric vehicles [3]. This study will be assessing China's policy implications as a road map for the South African deployment policy. China deployment strategy caused strain on its electric grid and increased its carbon footprint. Bearing in mind South Africa's weak electricity grid with typical periodic shortfalls and its significant electricity generation capacity from fossil fuel resources, more knowledge about the challenges ahead will be beneficial.

The rest of the paper is structured as follows. In Section II, we go over related literature review. Section III presents the methodology and Section IV is the results and analysis. The conclusion and future work are listed in Section V.

II. LITERATURE REVIEW

This section presents an overview of the developments to China's EV market and compares trends related to South Africa.

The Electric Vehicles Initiative (EVI) is a multi-government policy designed under the Clean Energy Ministerial (CEM) in 2009 [4]. The primary goal is "dedicated to conducting collaborative activities that support the design and implementation of EV policies and programs" [4]. The EVI currently has 16 member states as partners. The United States, Canada, and China are currently co-leading the EVI.

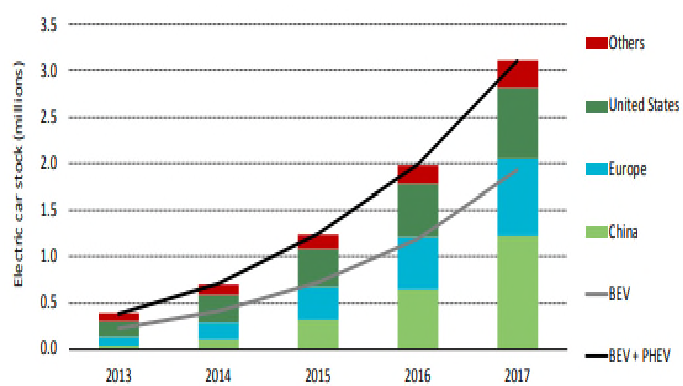

Figure 1. Evolution of the global electric car stock, 2013-2017, IEA [5]

According to [3], China is currently the largest electric car market in the world, accounting for more than 40% of all-electric car sales in the world as of 2016. "In 2016,

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China became the country with the largest electric car stock, with about a third of the global total with more than 200 million electric two-wheelers, 3 to 4 million Low-Speed Electric Vehicles (LSEVs) and more than 300 thousand electric buses" [3]. An increase in EV demand has also led to an increase in public and private charging infrastructure. "In 2016, the annual growth rate of publicly available charging (72%) was higher, but of a similar magnitude, than the electric car stock growth rate in the same year (60%)" [3]. Through the New Energy Vehicle (NEV) program, China aimed at an EV market stock of about 80 million by 2030. The aggressive deployment strategy has some associated implications on the grid and the carbon footprint of the country. South Africa Green Transport Strategy (GTS), with a goal aimed at transforming the transport sector to 50% EV by 2050, seems to be on this same path.

The International Energy Agency (IEA) [6] conducted an extensive research investigating different scenarios for EV deployment in China and the associated implications thereof with regard to energy portfolio, economics, and the environment. It identified that the impact of EVs in terms of CO2 emissions and on-grid capacity at the national level largely depends on the charging strategy and EV design. As a result, the analysis conducted in this paper utilized this important outcome as a basis for assessing the EV impact, by evaluating the effect of two commonly deployed EV designs (PHEV and BEV) in the Chinese market on independent variables.

III. METHODOLOGY

The Ordinary Least Square (OLS) was used to show evidence of a relationship between the independent and dependent variables. The following tests were performed:

- Unit root test
- OLS estimation test
- Serial correlation
- Normality
- Heteroscedasticity

A. Data Sourcing and Limitations

The dependent variables (total grid capacity, electricity generated from coal and emission from coal) were sourced from the World Bank. The independent variable (EV demand) was sourced from EV Volumes [8]. The analysis only considered 10 years of yearly data (2009 to 2019) due to a lack of data. The lack of accurate and reliable data has been identified as a significant problem hindering the development of useful EV-grid models and strategies [7].

B. Model specification

The Ordinary Least Square (OLS) model was employed in performing multiple linear regressions. A multiple OLS model is denoted as follows:

$$Y_t = \beta_o + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \varepsilon_t \qquad (1)$$

With reference to equation (1) indications represented are as follows:

Y_t = Dependent variable

β_o = The intercept of the equation.

β_{1-3} = The slope coefficient of the independent variables.

X_{1t-3t} = The independent variable that is used to predict the dependent variable.

ε_t = The error term.

The model specification (causality between the dependent variable to independent variables) of this paper was then equated as:

$$BEV\ /\ PHEV_t = \beta_0 + \beta_1 GC_t \beta_2 EGC_t \beta_3 EC_t + \varepsilon_t \qquad (2)$$

With reference to formula (2) indications represented are as follows:

PHEV = Plug-in Hybrid Electric Vehicles
BEV = Battery Electric Vehicles
GC = Grid Capacity
EGC = Electricity Generated from Coal
EC = Emissions from Coal

IV. RESULTS AND ANALYSIS

Traditionally, the OLS requires that a cointegration and error term be determined between the independent and the dependent variables through the Engle-Granger analytical technique. However, the technique was not utilized due to limited observations and also because the aim of the paper was mainly to show evidence of a relationship between the independent and dependent variables.

TABLE I. UNIT ROOT TESTS

Variables	ADF P-Values	PP P-Values
PHEV	0.0011	0.0532
BEV	0.0433	0.0633
GC	0.0534	0.0045
EC	0.0061	0.0550
EGC	0.0514	0.0007

TABLE II. ORDINARY LEAST SQUARE ESTIMATIONS FOR VARIABLES

OLS estimation for PHEV		
Variables	**t-statistics**	**P-value**
GC	-545.8878	0.0012
EC	187.2888	0.0034
EGC	-35.95261	0.0177
OLS estimation for BEV		
GC	-1345.742	0.0501
EC	3063.620	0.0034
EGC	-80.49225	0.0079

All conducted unit root tests (Table I) produced a stationary outcome at 1st difference. The p values from all series were below 0.05.

The OLS estimation (Table II) detects if a relationship exists between the independent variables (*PHEV & BEV*) and dependent variables (*GC, EGC & EC*). Outcomes from estimation tests produced a *p-value* of results <0.05. The regression analysis further confirmed reliability by obtaining an R-squared of 94% for PHEV and 60% for BEV.

Table III presents the results of the diagnostic tests. Here, the errors were normally distributed. Serial correlation was not detected. The White's test and the Arch test reflect that the series are homoscedastic.

TABLE III. DIAGNOSTIC TESTS

Test	Measurement	P-values
Normality	Jarque-Bera	0.8762
Serial correlation	Correllogram test at (1st difference)	0.134
Heteroscedasticity	White's test	0.0940
	Arch test	0.1450

V. CONCLUSION AND FUTURE WORK

Replacing conventional vehicles with EV's deployment is a delicate transformation that requires extensive research that would guide policy towards reliable and applicable strategies. Instead of the current ongoing excitement concerning deploying EVs in South Africa as soon as possible, an effective cost-benefit analysis should be conducted on the currently planned deployment goals.

Important topics gathered from this study as lessons for South Africa are as follows:

- It is important to re-evaluate the deployment model to determine the percentage and grid network tolerance. It will be very aggressive to radically transform the transport industry such as 50% of all vehicles should be electric by 2050. South Africa does not have the potential for such a fast pace transformation, but rather a slower transformation with realistic periodic targets.
- End-user efficiency and consumption policing will be fundamental for ensuring consistency between the grid capacity and end-users demand. EVs penetration level of 50 % can cause serious low-voltage levels and grid supply shortfalls in the long-run to end-users.
- Other things to consider include: will the EVs market boom? Is complete automation an option, such as EVs with solar panels? Will the supply from renewable energy sustain the predicted demand?

The reflected evidence from China's case gives information on the importance of developing sustainable automated systems that can precisely monitor the demand of EVs to grid capacity periodically and also assess charging strategies and EV models to grid capacity. This study also aimed at achieving this objective.

In future work, the study will further asses the environmental and economic benefits of EVs technology in China to established evidence on the role of EV deployment to environmental wellness in the case of China.

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