

DIRECT, INDIRECT AND INDUCED IMPACT OF ELECTRIC VEHICLES IN NORWAY: A LEARNING EXPERIENCE FOR VIKSIT BHARAT 2047

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Abstract

With the emerging concerns of Climate change, Norway has recently expanded the Electric vehicle market, providing multiple economic incentives. In this context, the paper evaluates the relationship and impact of the electric vehicle market expansion on other sectors, such as electronic goods, the energy sector, and the transport sector, as well as the implications for other macroeconomic variables such as Gross Domestic Product, investment, and household consumption expenditure. The paper adopts the principal component technique to construct indices that capture the growth of electric vehicles, the electronic market, energy and transport sectors. A correlation technique is deployed to assess the relationship between the electric vehicle and the other sectors, as well as macroeconomic variables. The results reveal that there is a consistent rise in the output of electric vehicles, the electronics market, and the transport sector. A significant linear correlation between household consumption expenditure and national income, while a moderately positive correlation with the electronic index, is concluded from the analysis. However, a moderately negative correlation between household consumption expenditure and energy use. The electric vehicle index exhibits an increasing trend in the forecasted values for forty years, with both household consumption expenditure and Gross Domestic Product showing a consistent rise. The paper concludes that there is a minimal possibility of a rise in energy use as the increase in demand for electricity created by the rise in charging stations is offset by the reduction in the use of conventional energy in the transport sector. Thus, the findings from direct-indirect and induced impact provide a holistic roadmap for the electric vehicle adoption in Viksit Bharat 2047.

Keywords: Electric Vehicles, Norway, Principal Component Analysis, Gross Domestic Product, Household Consumption Expenditure, Correlation

1. Introduction

With the advent of Climate change as an inevitable challenge, Electric vehicles and hybrid electric vehicles are becoming increasingly commercially viable. This shift of the regime of internal combustion engines to electric mobility requires various strategies and forward-looking policies. The forecasts of ING Bank indicate that all new cars sold in Europe will be electric owing to the declining costs and economies of scale. Further, it was also pointed out that European drivers will become more competitive compared to internal combustion counterparts. The use of PEVs saved approximately hundreds of dollars in annual fuel costs, ranging from \$ 100 to \$ 1800 per vehicle, as examined in various regions of the United States. Chan highlights

the importance of integration of various technologies such as automobile, electric power utilities, electronics, energy storage and transportation authorities. The paper provides the significant challenges faced by electric vehicle commercialisation.

It is successfully pointed out that the costs of Li-ion battery packs continue to decline, and the costs among market leaders are consistently declining and are lower than the previous figures. Gruber et al. concluded that with the rapid adoption of electric vehicles powered by lithium-ion batteries, the lithium resources are sufficient enough to support demand until the end of the century. Bessa and Matos highlighted the role of intermediate entities, the aggregator and the role of business model and EV management. Diamond

examined the impact of government incentive policies to promote hybrid-electric vehicles. The study suggests a strong relationship between gasoline prices and hybrid adoption. Several economic incentives are provided in case of EV usage in the form of exemption from value-added tax (VAT) and permission to transit lanes. Various regions throughout United States have demonstrated the potential benefits from economic impacts of large scale deployment of electric vehicles. There is a shift in the spending on electric vehicles, which in turn results in macroeconomic impacts such as increased output and increase in employment.

Norway is characterised as one of the best countries to live in terms of air quality exhibiting the highest GDP per capita economically supported by petroleum reserves. However, the electricity production is largely due to the hydropower plants amounting to approximately 98% (Statistics Norway). There are several co-benefits associated with EV users, such as they can receive a charge from any electricity outlet, from workplaces, home garage, fuel station, etc. The EV market in Norway has rapidly expanded from 2010 supported substantially by the exemption from registration tax. The registration taxes mainly depend on the emissions in form of CO₂ and NO_x. Torper asserts that in Norway there are high taxes on high – emission cars and lowertaxes on low and zero emission cars. The electric vehicles had complete exemption from the annual license fee between the period 1996-2004. Electric vehicles are also exempted from toll roads in Norway along with free public parking access since 1999. A substantial share of government support and financial support is attributed to charging stations by municipalities.

It is therefore extremely crucial to examine the relationship between electric vehicle and its impact on various macroeconomic variables such as electronic and transport sector along with the variables such as Gross domestic product, investment and household government expenditure. The paper attempts to

visualize the overall growth of electric vehicle market along with electronic and transport market by computing the indices of each using the principal component index and forecast the values of these indices for next forty years to comprehend the future growth and scenario of this significant sector. The paper also attempts to examine the linear relationship between the electric vehicles and other sectors such as electronic and transport sector and visualize the inter linkages between these sectors and macroeconomic variables such as income, investment and household consumption expenditure.

In order to establish the relationship and linkages of electric vehicle and macroeconomic variables, the paper constructs a theoretical model to justify the effect of electric vehicles on various other sectors and macroeconomic variables. The inter linkages and impact on various macroeconomic variables has been explained by the theoretical model discussed in the following section.

2. Theoretical Background

There are several benefits both direct, indirect and induced benefits. Several studies have estimated macroeconomic benefits of PEVs. The studies have mainly estimated the cost savings on the account of shift from vehicles using conventional source of energy to electric vehicles. There are studies that have also evaluated macroeconomic impact in terms of increased gross domestic product and impact on employment. On one hand, the use of electric vehicles reduces the consumption of petroleum and diesel fuel, saving the fuel cost of use of conventional transportation. This cost saving gets reflected in more spending by households on better quality of living, furniture, healthcare, education, and other goods. This creates the demand in other sectors, boosting up the economy. In the transport sector, the use of electric vehicles leads to an incremental increase. Further, the use of electric vehicles is an increase in demand for electricity in the

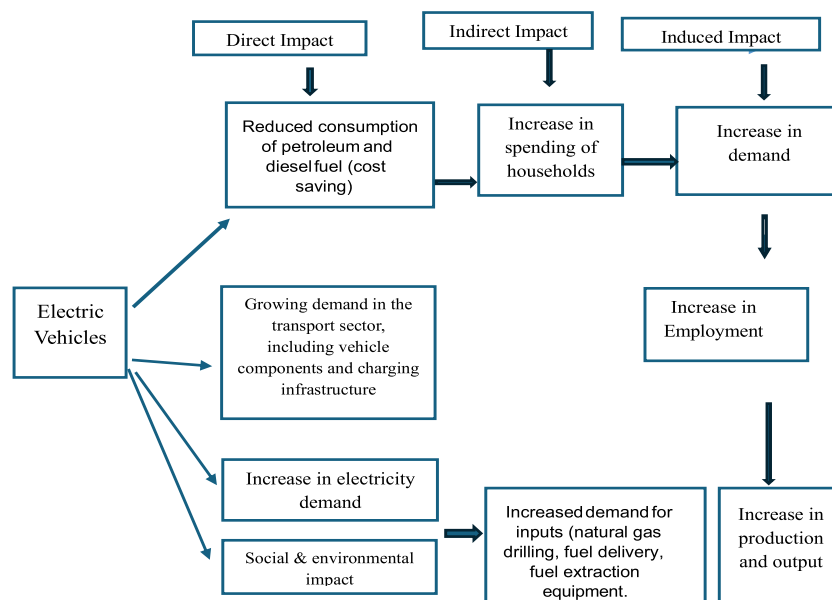


Fig 1: A Schematic Representation of the Direct, Indirect and Induced Impact of Electric Vehicles

transport sector. This will enhance production in the transmission and distribution section of the electricity sector. This implies more employment and jobs in the electricity sector leading to more spending in the form of increase in disposable income. Increase in disposable income creates more demand for other goods and services which is termed as induces demand. Induced demand gets reflected in form of increase in demand for clothing, vegetables and vehicles.

The overall impact of increased use of electric vehicles can be characterised as direct, indirect, and induced impacts. The first direct impact of increased use of electric vehicles is a substantial reduction in the consumption of petroleum and diesel fuel, leading to cost savings on the account of reduced use of fuel. There is a subsequent rise in demand in the transport sector, consisting of vehicle components and charging station infrastructure. The need for charging stations will create further demand for electricity, and there are other social and environmental impacts related to reduced emissions, leading to better air quality and, in turn, better health and living conditions.

The cost savings on account of reduced expenditure on petroleum and diesel fuel have an indirect impact on household consumption expenditure, as it boosts the consumption spending of households. This in turn has multiple induced macroeconomic impact which increases the aggregate demand of the entire economy, excess demand leading to more output and production. More output implies more employment generation in the economy. An increase in demand for electricity owing to an increase in the demand of charging stations, corresponding to an increase in the use of electric vehicles, creates electricity demand. More electricity demand exerts pressure on the electricity sector in terms of increased demand for inputs such as natural gas drilling, fuel drilling, and fuel extraction equipment.

There are various economic benefits associated with the displacement of petroleum-fueled vehicles. Apart from economic benefits, there are bound to be other environmental and social benefits in the form of reduced pollution. There is a substantial reduction in petroleum consumption, lowering the fuel costs, thus increasing the disposable income of households. The savings from petroleum fuel expenditure create new jobs in the economy, contributing to growth and development. An increase in spending on electric vehicles affects the market for vehicles in terms of production, employment and costs. Moreover, electric vehicles have the potential to even reduce electricity rates. Increased use of electric vehicles is expected to increase the electricity demand, raising the electricity revenue.

The direct, indirect, and induced impact of the use of electric vehicles can be broadly clubbed as the impact

on some significant sectors and some crucial macroeconomic variables. There is a large impact on the electronic industry comprising electronic products and electrical equipment, the energy sector consisting of electricity, gas, and air conditioning, and the transport industry, along with the macroeconomic variables such as Gross Domestic Product, household consumption expenditure, and investment. The data relating to the selected variables is obtained from the input-output table for various years given by Statistics Norway, and the indicators are appropriately computed and analysed using the methodology discussed in the following section.

3. Data and Methodology

To achieve the two-fold objectives, firstly, to examine the impact of the use of vehicles on various sectors and macroeconomic variables, the study deploys the input-output table, available on Statistics Norway for the years 2008 to 2020. The study deploys Principal Component Analysis (PCA) to compute the required indices.

3.1 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a dimension-reduction tool that can reduce a large set of variables to a small set that still contains most of the information in the large set. The main objective behind the PCA methodology is to reduce the dimensionality associated with data and later convert interdependent coordinates to independent ones.

3.2 Correlation

The statistical concept of correlation measures the degree and strength of the linear relationship between two variables. The relationship is presented as a correlation coefficient.

3.3 Model Formulation

The perceived impact of increased use of electric vehicles can be captured by the selected variables that provide a comprehensive picture. The indices of various sectors, such as the electric vehicle index, electronic index, and transport index, are computed using a principal component technique using the appropriate indicators so that the indices depict a comprehensive scenario. The data is obtained from the input-output tables from Statistics Norway. To visualise the impact on the total output of the economy, Gross Domestic Product is selected as an indicator, for observing the impact on consumption expenditure of households, household final consumption expenditure serves as a good indicator, and for visualising the impact on investment, gross fixed capital formation is selected as an indicator. A detailed account of selected variables is listed in Table 1.

4. Results and Discussion

The trends in the market share of electric vehicles reveal that the share occupied by electric vehicles in the market is consistently rising. This indicates the rising

share of electric vehicles in Norway between the period 2008 to 2016. There is a steep rise in the market share of electric vehicles after 2014, as depicted in the Appendix Figure A1. Along with the rising share of electric vehicles in the market, there is an increasing trend in the number of charging positions across Norway. The charging stations also exhibit a steep rise after 2013, as observed in figure 2. Both market share and the number of charging stations have drastically increased after 2013.

4.1 Trends and patterns of computed Principal

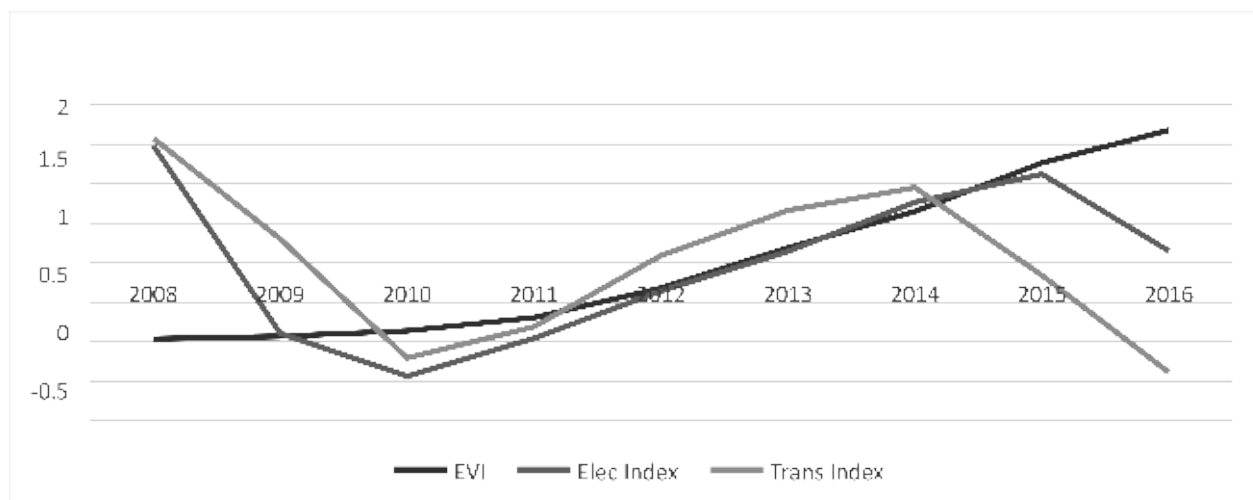


Fig 2: Trend in Principal Component index of Electric Vehicles, Electronic Appliances or Equipment, and he Transport Sector.

The electric vehicle index, which is constituted by indicators such as the total number of electric vehicles, the market share of electric vehicles, and the number of charging stations, indicates a consistently rising trend in Figure 2. There is a consistent rise in the Electric vehicle index, indicating a steep rise in market share and number of charging stations on account of the increasing use of electric vehicles in Norway. The electronic index is composed of electronic products and electrical equipment. The electronic index declines in the initial years from 2008 to 2010. However, as the electric vehicles index picks up at a faster rate from 2010, the electronic index also exhibits a sharp increase, but later in 2015, it shows a steep decline. Similarly, the transport index, which comprises vehicles, transport equipment, and repair services, also exhibited an initial decline till 2010 but rose steeply after 2010 till 2015, after which the index experienced a drastic decline. These computed indices are expected to be interrelated, which can be examined using the linear correlation coefficients.

All the selected macroeconomic variables have shown a similar trend in the selected time period. Gross domestic product and household final consumption expenditure show a consistent increasing trend, while the energy consumption in the form of electricity, gas stream and air conditioning, as reflected by the variable energy use, indicates a small incremental rise in the values from 2008 to 2020. There is a sharp kink in the

Component Indices and macroeconomic variables

The increasing use of electric vehicles in Norway as indicated by the data above, is expected to affect the electronic, electricity, and the transport sector. The paper constructs the indices for significant variables such as electric vehicles, electronic equipment, and the transport sector by deploying the Principal component analysis. These indices are plotted in figure 2 to evaluate the pattern or trends observed in the use of electric vehicles, electronic appliances or equipment, and the transport sector.

values of investment expenditure between 2009 to 2020. Any expected linear relationship can be examined using the correlation technique in the following section.

4.2 Correlation results

To comprehend the overall impact of increased use of electric vehicles, all direct, indirect and induced, it is crucial to examine the interrelationship between the various sectors and macroeconomic variables to comprehend the plausible impact on the economy. The plausible impact in the form of the linear relationship between the computed indices and selected macroeconomic variables is visualised by the correlation table compiled in Appendix Table A2.

The correlation coefficients explicitly reveal the linear relationship between the selected variables, essential to comprehend the plausible impact of the increased use of electric vehicles in Norway. It is evident from the above correlation coefficients that the electric vehicle index is significantly positively correlated with household consumption expenditure and national income or GDP (Gross Domestic Product). It is observed that there prevails a moderate positive correlation between electric vehicles and electronic appliances, suggesting that with an increase in the use of electric vehicles, the electronic and electric equipment also increases. A moderate negative correlation is witnessed between the use of electric

vehicles and energy use. An increase in electric vehicles, the use of electricity, gas and air conditioning reduces moderately. Therefore, it is evident that the use of electric vehicles is significantly linearly correlated with an increase in household consumption expenditure and national income, while moderately positively correlated with the electronic index. However, energy use exhibits a moderate negative linear relationship with electric vehicles.

5. Conclusion

With climate change emerging as one of the serious challenges, Norway is committed to reaching the targets of carbon neutrality by 2030. A substantial share of government support and financial support is attributed to charging stations by municipalities. It is therefore extremely crucial to examine the relationship between electric vehicles and their impact on various macroeconomic variables. The paper also attempts to examine the linear relationship between electric vehicles and other sectors, such as the electronic and transport sectors, and visualise the interlinkages

between these sectors and macroeconomic variables such as income, investment, and household consumption expenditure. It is observed that there prevails a moderate positive correlation between electric vehicles and electronic appliances, suggesting that with an increase in the use of electric vehicles, the electronic and electric equipment also increases.

A moderate negative correlation is witnessed between the use of electric vehicles and energy use. An increase in electric vehicles, the use of electricity, gas and air conditioning reduces moderately. Therefore, it is evident that the use of electric vehicles is significantly linearly correlated with an increase in household consumption expenditure and national income, while moderately positively correlated with the electronic index. However, energy use exhibits a moderate negative linear relationship with electric vehicles. The paper provides a significant learning for the electric vehicle adoption in Viksit Bharat 2047, by signifying the interplay of other sectors that result in direct,

Appendix:

Table A1: Description of Variable and Indicators

Sno.	Indices Symbols	Symbols	Attributes	Indicators	Units
1.	Electric Vehicle Index	EVI	Electric Vehicle Population	Total number of Electric Vehicles	Number
			Electric Vehicle Market share	EV market share	% percentage
			Charging stations	Total number of charging stations.	Number
2.	Electronic Index	Elec Index	Electronic Products	Computer, electronic and optical products	
			Electrical equipment	Electrical equipment	
			Vehicle	Motor vehicles, trailers and semi-trailers	
			Transport equipment	Other transport equipment	
			Repair Services	Wholesale and retail trade and repair services of motor vehicles and motorcycles	
3.	Energy use	Ener use	Energy consumption	Electricity, gas, steam and air-conditioning	
4.	Household Consumption	HFCE	Consumption expenditure by Households	Final consumption expenditure by households	
5.	Investment Expenditure	GFCE	Investment Expenditure	Gross Fixed Capital Expenditure	
6.	Total Output	GDP	Total income or output produced	Gross Domestic Product	

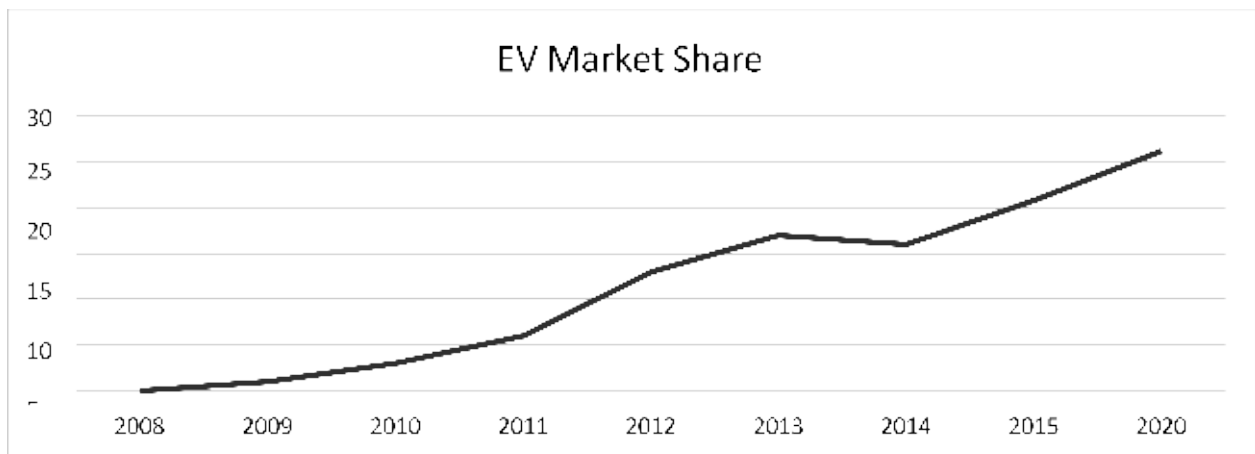


Fig. A1 : The Trend in Market Share of EVs in Norway

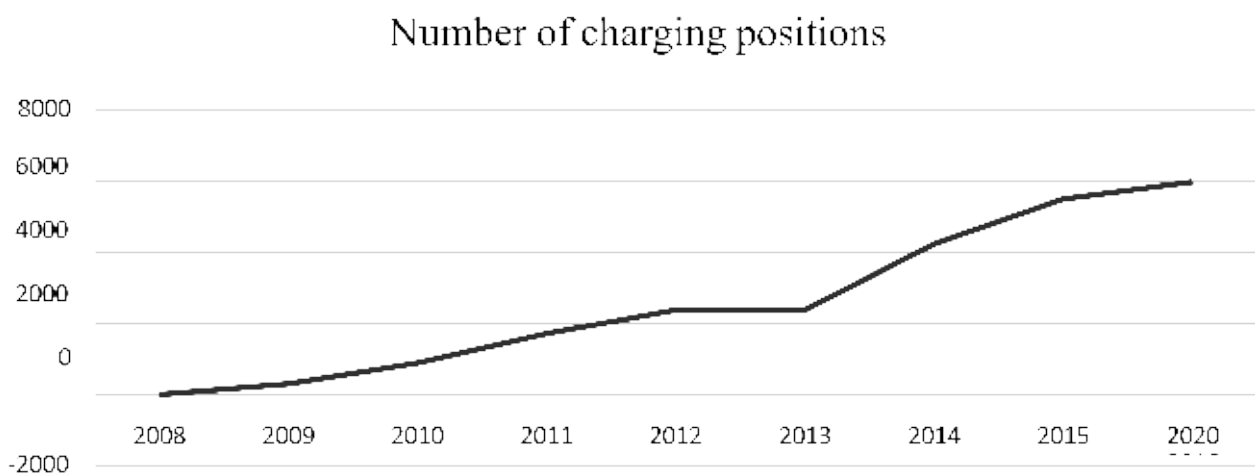


Fig. A2 : Trends in the Number of Charging Positions

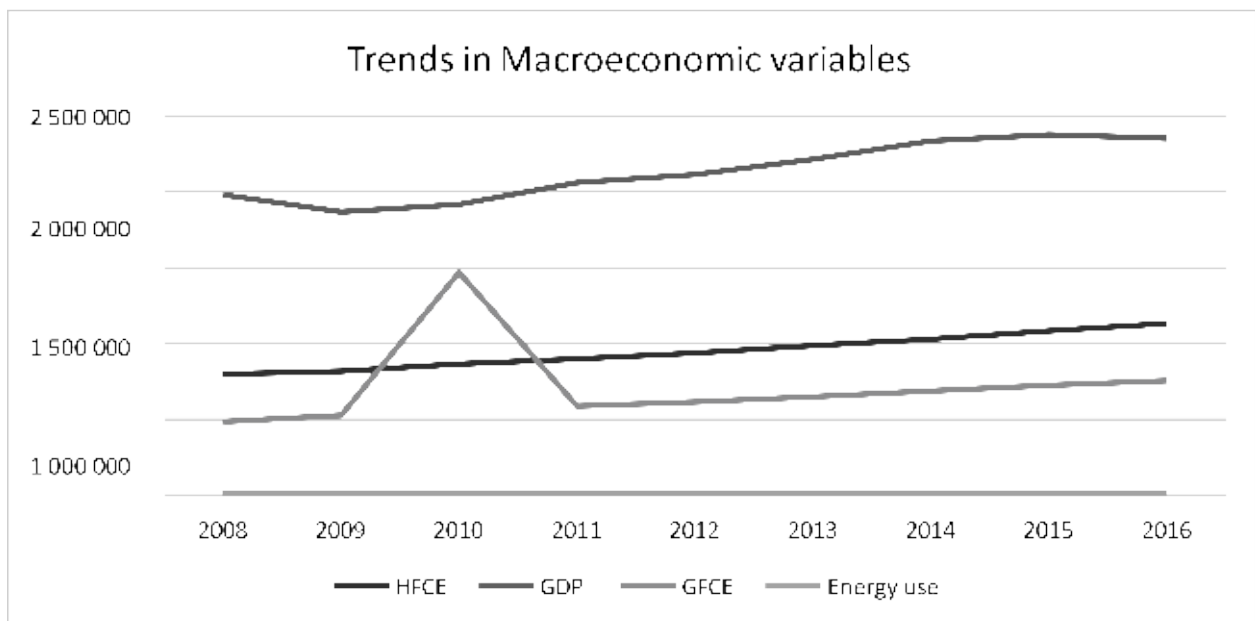


Fig. A3 : Trends in Macroeconomic Variables (Household Consumption, GDP, Investment, Energy Use)

Table A2 : Correlation Table

	<i>HFCE</i>	<i>GDP</i>	<i>GFCE</i>	<i>EVI</i>	<i>Elec Index</i>	<i>Trans Index</i>	<i>Ener use</i>
HFCE	1.0000						
GDP	0.9490	1.0000					
GFCE	0.0283	-0.1466	1.0000				
EVI	0.9152	0.8408	-0.0018	1.0000			
Elec Index	0.3345	0.5608	-0.4743	0.4199	1.0000		
Trans Index	-0.3353	-0.0652	-0.5801	-0.3501	0.6230	1.0000	
Ener use	-0.6120	-0.7732	0.5024	-0.4397	-0.6361	-0.3678	1.0000

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