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Discussion Paper

Introduction of Electric Vehicles in Saudi Arabia:

Impacts on Oil Consumption, CO_2 Emissions, and Electricity Demand



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Abstract

In this study, we project the number of internal combustion engine (ICE) vehicles in Saudi Arabia up to 2050. The projected number of vehicles is then used to project the oil demand and CO_2 emissions associated with the road transport sector by 2050. On the basis of the projected number of ICE vehicles, we design three scenarios for developing electric vehicles (EVs) (high-, moderate-, and low-growth scenarios) to determine the impact of the expansion of EVs on future oil demand, CO_2 emissions, and electricity demand.

Our projections show that by 2050, the total number of ICE vehicles in Saudi Arabia could reach 29.6 million, approximately 2.5 times the 2023 level. Scenario projections for EVs show that by 2050, the number of EVs could reach 14.8 million in the low-growth scenario, 17.8 million in the moderate-growth scenario, and 20.7 million in the high-growth scenario. By 2050, the electricity demand for EVs in Saudi Arabia is projected to reach 47.7 TWh per year in the high-growth scenario, 38.2 TWh per year in the moderate-growth scenario, and 28.6 TWh per year in the low-growth scenario.

The projected results of vehicle electrification show that the deployment of EVs can improve environmental quality by reducing CO_2 emissions and oil consumption in the road transport sector if sufficient renewable electricity generation capacity is added to meet electricity demand.

Keywords: Gompertz Function, GDP Per Capita, ICE Vehicles, EVs

1. Introduction

The transport sector plays a crucial role in a country's economic and social development. However, the growth in the number of internal combustion engine (ICE) vehicles is directly linked to the increase in CO_2 emissions and oil consumption, which poses significant environmental and economic challenges. Oil demand in the road transport sector accounts for approximately 45% of global oil demand, which is far more than in any other sector, driven primarily by the need for gasoline and diesel in road transport (IEA 2023a). Owing to strong economic development, urbanization, low fuel prices, and the lack of availability of public transport, the demand for vehicles has increased significantly in Saudi Arabia. The road transport sector is one of the primary consumers of oil in Saudi Arabia (Atalla, Gasim, and Hunt 2018). In 2021, Saudi Arabia's transport oil consumption was 42.78 MTOE, representing 42% of total oil consumption and 2.6 times the 1990 level. The average annual growth rate of oil consumption in the transport sector between 1990 and 2021 was 5.2% (IEA 2024). Transport oil demand in Saudi Arabia peaked in 2015 and then declined, due mainly to domestic fuel price adjustments aimed at reducing subsidies and optimizing energy consumption; however, we can expect a rebound in the next few years. Economic development has led to large cities with extensive road infrastructure and an extensive highway network connecting Saudi Arabia's various cities (Atalla, Gasim, and Hunt 2018), which has led to an increase in the demand for vehicles.

Saudi Arabia relies on fossil fuels to meet its transportation fuel requirements and consumes significant amounts of oil in its transport sector. According to Sheldon and Dua (2021), Saudi Arabia is the ninth-largest consumer of motor gasoline and the fourth-largest per capita consumer of on-road motor gasoline. The rapid increase in demand for oil in the road transport sector and the ever-increasing number of vehicles on the road have raised concerns about future oil exports, future energy consumption, and greenhouse gas emissions. The transition from oil-dependent transport to EVs represents a critical pathway through which to reduce global CO_2 emissions (Briceno-Garmendia, Foster, and Qiao 2022). The electrification of the vehicle fleet is central to addressing key environmental, transport, and energy policy challenges (Briceno-Garmendia, Foster, and Qiao 2022; Vega-Perkins, Newell, and Keoleian 2023; De Carvalho, Brasil Junior, and de Mendonça Brasil 2023). Countries worldwide have set ambitious long-term targets for moving away from ICE vehicles, with goals for the large-scale adoption of EVs or timetables for the complete elimination of ICE vehicles.

With the rapid economic growth of Saudi Arabia, road transport is becoming one of the country's most significant and fastest-growing oil-consuming sectors. Major development projects in Saudi Arabia, such as the NEOM, Red Sea Project, Qiddiya, and Diriyah Gate, are expected to significantly impact the country's vehicle and

oil demand in the road transport sector. These projects are part of the Saudi Vision 2030 initiative, which aims to diversify the economy, reduce dependence on oil, and promote tourism and investment. Mega-development projects in Saudi Arabia are expected to impact vehicle demand in the short and long terms. In the short term, the demand for vehicles for construction and logistics will increase, whereas in the long term, the demand for vehicles for passenger and commercial purposes will increase.

Given the critical role of the road transport sector in energy security and environmental quality, a comprehensive analysis of the transport sector in terms of the number of vehicles on the road, oil consumption in the road transport sector, and associated CO_2 emissions is essential for planning and future investment in road infrastructure. Furthermore, the analysis is critical for policy-making in the context of Saudi Vision 2030, which seeks to diversify the economy, reduce the country's dependence on oil revenue, and achieve its net-zero targets. However, the existing studies on Saudi Arabia have focused primarily on estimating the income and price elasticities of demand for diesel and gasoline in the transport sector in Saudi Arabia and have focused less on estimating or projecting the number of vehicles on the road; therefore, these studies do not assess the potential effects of fleet electrification policies. Against this backdrop, this study seeks to fill a gap in the literature by analyzing ICE vehicles; the prospects for EV adoption; and the related impacts on oil demand, electricity consumption, and CO_2 emissions in Saudi Arabia. ICE vehicle projection and scenario analysis for EVs are important for countries such as Saudi Arabia because they provide support for urban planning, renewable energy planning, road transport system planning and management, and countries' commitment to reducing greenhouse gas emissions. This study has two main objectives. The first objective is to estimate and project the following:

- The number of ICE vehicles until 2050
- The demand for oil in the transport sector
- CO_2 emissions associated with oil consumption in the transport sector

The second objective is to develop different scenarios for EVs in Saudi Arabia to determine the following:

- The effect of EV penetration on future oil demand in the transport sector
- The impact of EV adoption on CO_2 emissions
- The impact of EV adoption on electricity demand by the transport sector

This study makes several contributions to the literature. To our knowledge, this is the first study to project the number of ICE vehicles in Saudi Arabia using a state-of-the-art methodology. We use the Gompertz function to project the number of ICE vehicles due to the nonlinear nature of the relationship between vehicle ownership and gross domestic product (GDP) per capita (Dargay and Gately 1999; 2001). Second, we estimate and project the level of oil consumption in the road transport sector considering the fuel efficiency regulations introduced by the Saudi Arabian government. Importantly, this study is the first to include fuel efficiency standards for a more accurate estimation of oil demand in the road transport sector in Saudi Arabia. Third, on the basis of the projections of the number of ICE vehicles by 2050, we propose various scenarios for the development of EVs and estimate the corresponding electricity requirements for the projected EV adoption strategy.

The rest of the paper is organized as follows: Section 2 reviews existing studies, Section 3 provides the methodological framework and data definitions, and Section 4 presents the model estimation, projection of the number of ICE vehicles, and scenarios designed for EVs. The road transport oil demand model estimation and results are presented in Section 5. The oil demand projection – which considers the penetration of EVs, CO_2 emission projection, and electricity demand projection for EVs – are presented in Section 6. Section 7 concludes the paper with policy insights.

2. Literature Review

Despite the importance of the road transport sector in Saudi Arabia from an environmental perspective, it has received limited attention in the literature. The available literature, for example (Atalla, Gasim, and Hunt 2018; Gasim et al. 2023 and Hasanov et al. 2023), focuses mainly on income and price elasticities in the transport sector. Other studies have investigated the effect of oil consumption in the transport sector on CO_2 emissions (Alkhathlan and Javid 2015; Shannak, Mikayilov, and Dua 2024).

Atalla, Gasim, and Hunt (2018) analyzed the gasoline demand function in the transport sector of Saudi Arabia via a structural time series model (STSM) and reported that gasoline demand is price inelastic. Gasim et al. (2023) estimated the income and price elasticity of diesel and gasoline in Saudi Arabia's transport sector by also employing the STSM methodology and reported that both diesel and gasoline demand is price inelastic. The long-run price elasticities are estimated to be -0.16 for gasoline and -0.29 for diesel. The inelastic price elasticity in the transport sector can be explained by the fact that the price of oil in Saudi Arabia has historically been low due to subsidies, although this situation may change as Saudi Arabia implements economic reforms under Saudi Vision 2030. Alkhathlan and Javid (2015) investigated the effects of total and transport oil consumption on environmental quality in Saudi Arabia via the STSM methodology from 1971 to 2013. Their findings show that the elasticity of carbon emissions with respect to total oil consumption and transport oil consumption is positive and significant. A study by Shannak, Mikayilov, and Rubal Dua (2024) on Saudi Arabia examined the effects of domestic fuel price, population, and economic activity on transport CO_2 emissions. The results suggest that transport CO_2 emissions are less responsive to changes in fuel price. Mikayilov, Petite, and Dua (2024) investigated the effect of EV penetration on electricity demand in the capital city of Riyadh.

The vehicle demand function has not been investigated in Saudi Arabia because of the nonavailability of data on the number of active vehicles on the road. Algadhi, Mufti, and Malick (2002) addressed the vehicle data issue and devised a comprehensive approach to accurately estimate the total number of vehicles active on Saudi Arabian roads by addressing the various ways in which vehicles exit the operational fleet. The above authors incorporated three submodels – exports, accident-destroyed, and decay – into their overall model. These submodels were integrated into a larger mathematical framework that used the number of new vehicle registrations (from traffic directorate data) as the baseline input each year. The model then adjusted this number by subtracting the estimated number of vehicles exported, destroyed in accidents, and retired due to age and wear each year. Their comprehensive empirical analysis revealed that the average age of vehicles in Saudi Arabia is 11 years. This study estimated the number of vehicles on the road in Saudi Arabia until 1999.

There is no study available on Saudi Arabia regarding the vehicle demand function; therefore, we consider studies that have examined vehicle demand functions in other countries. These studies provide insights into the methodology and factors affecting vehicle ownership and demand. Torok (2022) employed the Gompertz growth function to model the market penetration rate of passenger vehicles in Hungary, focusing on its correlation with per capita GDP growth, highlighting the nonlinear, S-shaped curve typical of vehicle ownership growth as income levels rise. The above study meticulously calculated future growth via historical data on human-driven vehicles, projecting that similar patterns would likely apply to autonomous vehicles (AVs) as technological advancements continue (Torok 2022). Therefore, the above article explored the potential impact of AVs on future mobility, explicitly focusing on the projected growth of passenger vehicles in Hungary.

Dargay and Gately (1999) explored the impact of rising incomes on car and vehicle ownership via the Gomertz model for 26 countries from 1960 to 1992 and emphasized the significant role of the transportation sector in global oil consumption and energy usage, highlighting its rapid growth, particularly in non-Organisation for Economic Co-operation and Development (OECD) countries. The above study concluded that the ongoing increase in global vehicle ownership would continue to drive up oil demand and carbon emissions unless alternative energy sources are developed.

Dargay and Gately (2001) expanded the scope of their analysis in terms of the number of countries studied and the depth of the econometric analysis, particularly with respect to demographic adjustments and the exploration of response asymmetry to income changes. The vehicle projections in the above study were based on a dynamic econometric model that used the Gompertz function to estimate the relationship between GDP per capita and vehicle ownership per capita; the study concluded that the Gompertz function provides a statistically valid expression of the relationship between the number of vehicles per capita and GDP per capita. Moreover, the study revealed an asymmetric relationship between the number of vehicles and per capita income in the short run.

Dargay, Gately, and Sommer (2007) estimated vehicle saturation levels for a cross-section of 45 countries as a function of observable country characteristics, such as urbanization, population density, and GDP per capita. According to their forecast, the global vehicle population will increase from over 800 million in 2002 to over 2 billion units in 2030, with non-OECD nations accounting for 56% of all vehicle ownership.

Briceno-Garmendia, Qiao, and Foster (2022) examined how the transition to EVs represents a significant shift toward sustainable transport, driven by the potential for substantial environmental, economic, and social impacts. The study delved into the dual challenge of reducing local air pollution and global greenhouse emission levels while fostering technological innovations such as improved battery efficiency and electric motors. The economic implications of adopting electric mobility are multifaceted, ranging from vehicle and infrastructure costs to broader economic impacts on fuel markets and automotive industries.

From the available literature review, we can conclude that the rate of expansion of ICE vehicle ownership in emerging markets and developing countries has important implications for transport and environmental policy as well as for the global oil market (Dargay and Gately 1999; Vega-Perkins, Newell, and Keoleian 2023; Briceno-Garmendia, Foster, and Qiao 2022). Another important conclusion from the literature is that EVs are a key part of the global strategy to combat climate change. EVs can potentially reduce greenhouse gas emissions, reduce the degree of dependence on fossil fuels, and improve urban air quality (Briceno-Garmendia, Foster, and Qiao 2022; Vega-Perkins, Newell, and Keoleian 2023; De Carvalho, Brasil Junior, and de Mendonça Brasil 2023, among others).

3. Methodology and Data

3.1 Gompertz Model

The market's demand-side factors drive vehicle ownership expansion in developed and developing countries. Consumer income is the main driving factor in terms of the demand for vehicles. Economic development is directly linked with transport mobility. There are many explanations for why transport mobility or vehicle demand is related to economic growth and development. The mobility of labor and capital increases with rapid economic growth in different regions and cities (Wu, Zhao, and Ou 2014). Economic growth also increases urbanization levels, which in turn increases the demand for transport. Most previous studies have used per capita income as the driving factor of demand for vehicles (Dargay and Gately, 1999, 2001; Dargay, Gately, and Sommer 2007; Wu, Zhao, and Ou 2014). However, the relationship between vehicle ownership and GDP per capita is not linear. Previous empirical studies have shown that the relationship between vehicle ownership and economic growth takes an S-shaped form, with the following three different phases: a low-growth phase, a rapid-growth phase, and a saturation phase when growth approaches a steady-state level. The Gompertz model has been used in many studies to estimate and project the number of ICE vehicles. This model is useful for vehicle estimation because it typically follows an S-shaped curve due to factors such as market saturation, income, technological advances, infrastructure development, consumer awareness, and economic incentives. Dargay and Gately (1999) argued that the S-shaped curve best explains the relationship between per capita income and vehicle ownership. At the lowest income level, vehicle demand or ownership is low; as income increases, vehicle ownership accelerates and then slows or remains constant as it approaches the saturation level (Dargay and Gately, 1999; Huo and Wang, 2012).

The Gompertz function is widely used to study the relationship between vehicle ownership and income level (Dargay and Gately 1999; 2001; Dargay, Gately, and Sommer 2007; Hou et al. 2007; Huo and Wang 2012; Wu, Zhao, and Ou 2014). The Gompertz function is also used in the International Energy Association (IEA) global climate-energy model (2023). The Gompertz model is more flexible than is a logistic model, as it allows for the curvature to vary at low- and high-income levels (Dargay and Gately 1999). Huo and Wand (2012) demonstrated that the Gompertz model outperforms the logistic function in fitting historical data. The Gompertz equation can be written as follows:

$$V_t = \gamma\, e^{\alpha e^{\beta GDP_t}} \quad (1)$$

where V_t represents the level of vehicle ownership per 1000 people, γ denotes the saturation level of vehicle ownership per 1000 people, GDP denotes per capita GDP, and α and β represent negative parameters.

3.2 Transport Oil Demand Model

To project the level of oil consumption in Saudi Arabia's road transport sector, we assume that oil consumption is a function of oil price, number of vehicles, and oil efficiency in the transport sector. The transport oil consumption function describes how the amount of oil consumed for road transportation varies with changes in oil price, number of vehicles, and fuel efficiency. Instead of income, we use the estimated and projected values of vehicle demand from equation (1) as an explanatory variable in the oil demand equation to estimate and project oil demand for the road transport sector. This approach takes into account the direct relationship between the number of active vehicles on the road and oil consumption. Following (Aklilu 2020), the model of oil in road transport as a function of oil price, number of vehicles and efficiency can be written as follows:

$$oil_t = \delta_0 + \delta_1 p_t + \delta_2 veh_t + \delta_3 eff_t + \varepsilon_t \quad (2)$$

where *oil* is the level of oil consumption in Saudi Arabia's transport sector. The sum of diesel and gasoline consumption has been used as the total oil consumption of the road transport sector. *p* is the weighted average price of oil in the road transport sector, *veh* is the total number of vehicles on the road, and *eff* is the fuel efficiency in the transport sector. Lowercase letters indicate that the variable is used in its natural logarithmic form. We expect a negative relationship between oil demand and oil price (i.e., $\delta_1 < 0$). We also expect a negative relationship between oil demand and oil use efficiency (i.e., δ_3<) and a positive relationship between the number of vehicles and oil demand (i.e., $\delta_2 > 0$).

Our model specification differs from that of previous studies for Saudi Arabia in two ways. First, these studies have not considered the fuel efficiency measure in their empirical analysis. Fuel efficiency is a critical factor influencing oil demand in the road transport sector. Improved fuel efficiency leads to a significant reduction in fuel consumption, which in turn reduces oil demand. The government of Saudi Arabia has introduced fuel efficiency regulations such as the Corporate Average Fuel Economy (CAFE) standard and energy price reform in the transport sector. Second, unlike previous studies, we use the number of vehicles as an explanatory variable, instead of the income variable, in our model specification. We believe that the total number of vehicles on the road is a fundamental factor in the function of transport oil demand. Its growth directly influences fuel consumption through increased vehicle use and travel distance. Finally, we include dummy variables for different years to address the issue of structural breaks in the data. We expect outliers and breaks in Saudi Arabia's transport oil demand data because of various policy initiatives, such as energy price reform. Therefore, ignoring these facets can lead to a potentially misspecified empirical model with forecast failure and misleading policy implications (see, for example, Castle, Doornik, and Hendry 2021; Hendry, 2020).

3.3 Data

Regarding vehicle estimation, precise assessments and projections of the number of vehicles owned have significant policy implications for environmental regulations, transportation planning and management, and the world energy market.

Official statistics on exported vehicles, vehicles destroyed in accidents, and depreciation due to wear and tear over time are unavailable (Algadhi, Mufti, and Malick 2002), except for those from 1983 and 1999, when official estimates were made on the basis of mandatory reregistration and license plate changes. Therefore, data on the number of active vehicles on the road are

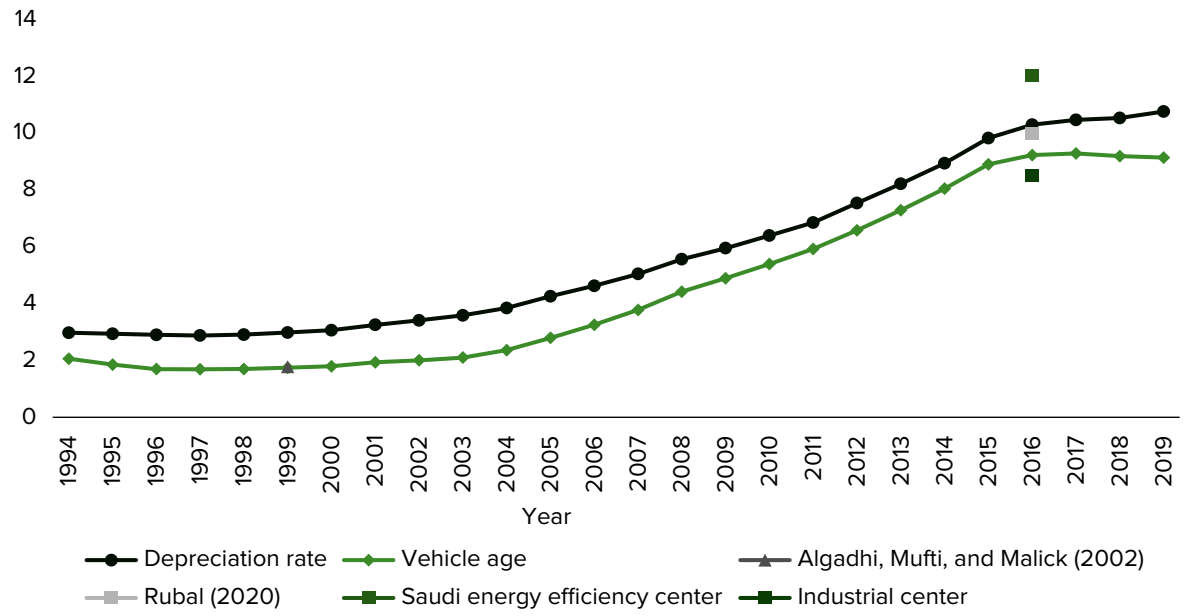
not available. In the literature, two basic approaches are used to estimate the number of vehicles on the road in Saudi Arabia. (i) Average age of vehicles approach: this method is useful in countries such as Saudi Arabia, where climatic and economic conditions can affect vehicle lifespans. According to Algadhi, Mufti, and Malick (2002), the average maximum vehicle age in the KSA is 11 years, considering the number of vehicles exported, destroyed in an accident, or depreciated by wear and tear. (ii) Constant attrition rate approach: this method assumes a constant rate of vehicle retirement or attrition, meaning that a certain percentage of vehicles are removed from the fleet each year due to factors such as wear and tear and accidents. Dua (2020) used a constant attrition rate of 4.35% to estimate the active number of vehicles on the road in Saudi Arabia.

Using these two approaches, we estimate the number of vehicles on the road in Saudi Arabia. Our estimate is based on the available vehicle data for 1983. We assume that the number of imported vehicles represents the number of additional vehicles, as no historical data on new vehicle sales are available. The vehicles estimated in this study are within the range of the estimates provided by various previous studies and reports from different Saudi agencies (see Figure 1). Vehicle estimates obtained via the depreciation method are slightly greater than those obtained via the vehicle age-based approach. Algadhi, Mufti, and Malick's (2002) projection of vehicles for 1999 closely matched the number of license plates issued to all vehicles in the KSA. Our estimates in this study, which are based on the average age estimation approach for 1999, are in line with the projections of Algadhi, Mufti, and Malick (2002).

The green line in Figure 1 shows the significant increase in the number of active vehicles on the road between 2000 and 2016 due to economic expansion, population growth, and urbanization. This growth has led to an increase in the number of vehicles on the road from 1.8 million in 2000 to 9.2 million in 2016, representing 10.4% annual average growth. However, after 2016, the growth rate of the number of vehicles has declined slightly due to domestic pricing reform and CAFE initiatives.

GDP per capita is calculated by dividing GDP (constant 2018 SAR million) by population data. The GDP data are from the General Authority of Statistics (GaStat 2024), and the population data are taken from the United Nations Population Division, Department of Economic and Social

Figure 1. Number of vehicles in Saudi Arabia from 1994 to 2019 (in millions).



Sources: Authors' estimation; Algadhi, Mufti, and Malick (2002); Dua (2020); SEEC (2018); and Industrial Clusters (2018).

Affairs. Oxford economic forecast growth rates are used to project the GDP data until 2050.

Data on oil consumption in MTOE are taken from the IEA. Oil consumption data for transport from the IEA are available for diesel and gasoline consumption. The sum of diesel and gasoline consumption is used as the total oil consumption in the road transport sector.

The price of diesel and gasoline (in SAR/TOE) is calculated via royal decrees and ECRA (Saudi Electricity Regulatory Authority) reports. For more detailed sources of diesel and gasoline prices in Saudi Arabia's transport sector, see Hasanov et al. (2023). Gasoline and diesel weighted average prices are used as proxies for oil prices in the road transport sector. We assume that the values of oil prices in 2023 will remain constant until 2050.

The fuel efficiency variable (Eff) is the ratio of gross value added in the transportation sector to oil consumption in the transportation sector. The CAFE standard was implemented in 2016 in Saudi Arabia to improve vehicle fuel efficiency by an average of 4% per year. This initiative is part of the country's broader Saudi Vision 2030 reforms, aiming to reduce fuel consumption, lower carbon emissions, and encourage the adoption of more fuel-efficient vehicles. With respect to the projection of efficiency, we use 2% growth until 2050 instead of 4% per year.

4. Gompertz Model Estimation

The model described in Equation (1) is estimated for annual time series data from 1994 to 2019. A critical factor in estimating the total number of vehicles is the saturation of vehicle ownership per 1,000 people. Dargay and Gately (1999) assumed a saturation level of 850 total vehicles per 1,000 people for 26 countries. The saturation level of Saudi Arabian vehicle ownership γ per 1,000 people is assumed to be 700. The assumption is based on the country's rapid economic development under Saudi Vision 2030. Megadevelopment projects in Saudi Arabia are expected to significantly impact the demand for vehicles in various segments. These projects will lead to urban expansion and potentially attract new residents, and the demand for passenger vehicles is expected to grow. The estimation results of the Gompertz model are presented in Table 1. Following Dargay and Gately (1999), we use maximum likelihood methods to estimate the Gompertz model given in Equation (1) because of its nonlinear nature.

The estimated parameters α and β are significant with correct signs and reasonable magnitudes. We find that our estimated values of α are similar to those of Wu, Zhao, and Ou (2014) for the OECD and Europe. However, the estimated value for β is smaller than the abovementioned estimates. Our estimated values of α and β (in absolute terms) are smaller than those of Dargay, Gately, and Sommer (2007) and Dargay and Gately (2001). The difference in the estimated values of α and β may be due to the geographical location, economic structure, and sample period.

Table 1. Parameter estimation in the Gompertz function.

Regression in the Gompertz function			Parameter estimation	
Parameter	**Coefficient**	**t Stat.**		
$\ln(-\alpha)$	1.32	9.42	α	-3.758
β	-0.00005	3.27	β	-0.00005

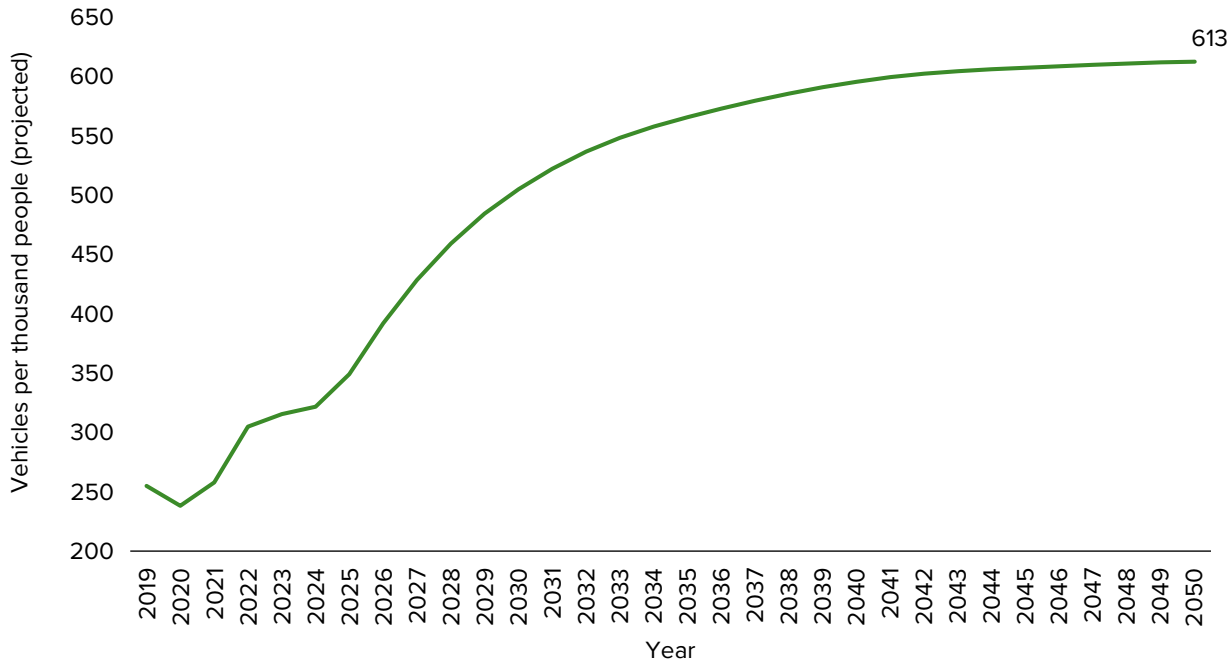
4.1 Projection of Vehicles Until 2050

Using the Gompertz model, we project the number of ICE vehicles in Saudi Arabia. Figure 2 shows the projected number of ICE vehicles per 1,000 people by 2050. The number of ICE vehicles in Saudi Arabia is estimated to be 613 per 1,000 population by 2050. The Industry Center has stated that approximately 11 million vehicles are currently operating in the KSA, which is close to our forecast of 11.65 million vehicles for 2023[1]. Figure 2 shows that the number of vehicles will sharply increase between 2024 and 2035, with an average increase of 6.3%. The vehicle growth rate will slow to 1.4% between 2036 and 2050. However, by 2050, the number of ICE vehicles per 1,000 people in Saudi Arabia will not reach the saturation level as assumed in the estimation of the Gompertz model, meaning that the vehicle stock still has the potential to increase after 2050. The high-level growth in the number of vehicles up to 2035 and the low-level growth after 2035 can be justified in two ways. First, the vehicle projection depends on GDP per capita, as explained in Section 2, which, in Saudi Arabia, is influenced by various factors, including economic diversification efforts under Saudi Vision 2030 and the global economic environment. Saudi Vision 2030 is the cornerstone of Saudi Arabia's economic strategy to diversify its economy away from oil dependence. The successful and effective implementation of the Saudi Vision 2030 initiative is expected to lead to sustained economic growth in Saudi Arabia until 2035. After reaching a stable level, economic growth will slow. The second reason is a characteristic of the Gomertz model. This model is characterized by an S-shaped curve, which represents slow initial growth, followed by rapid growth and then slowing growth approaching an asymptotic maximum.

4.2 Scenarios Designed for EVs

EV adoption in Saudi Arabia is likely to depend on various factors, such as government policies, infrastructure development, and consumer demand. We design three different EV adoption scenarios for Saudi Arabia. The first is a low-growth scenario, in which we assume that Saudi Arabia has an EV adoption potential of 1% by 2025 and will reach 30% by 2050. We assume that the

Figure 2. Projected number of vehicles per thousand people.



Source: Authors' projections based on the model specified in Equation (1).

uptake of EVs is likely to be slow due to inadequate infrastructure, low consumer demand due to limited public awareness, and continued subsidies for oil prices. The key assumption of the low-growth scenario is that Saudi Arabia's authorities do not set ambitious targets for EV deployment and infrastructure development.

The second is a moderate-growth scenario; Saudi Arabia is assumed to have an EV adoption potential of 1% by 2025, which will reach 40% by 2050. To achieve the target of EVs accounting for 40% of all vehicles on the road by 2050, the government can introduce incentives and measures such as tax breaks, subsidies, and the expansion of charging infrastructure in major cities through public-private partnerships and the integration of renewable energy sources.

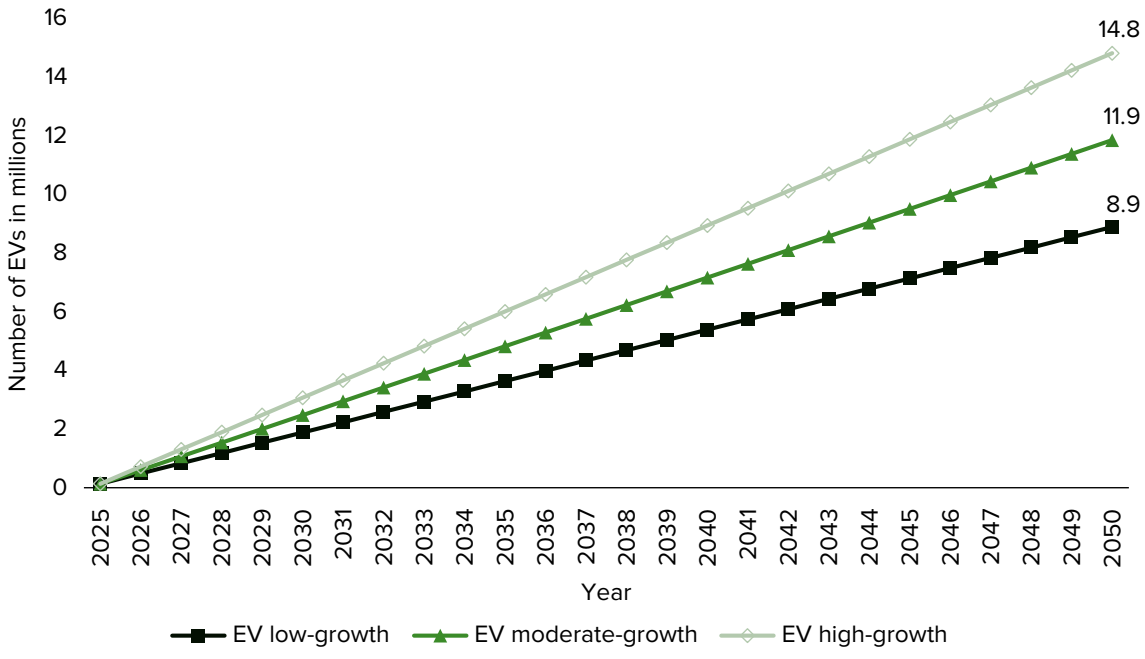
The third is a high-growth scenario; in this scenario, it is assumed that Saudi Arabia's potential for EVs will be 1% in 2025 and 50% in 2050 (Trieb et al. 2015). To achieve high growth, the government could take numerous initiatives in line with Saudi Vision 2030. These initiatives include setting targets for EVs, investing in the local production of EVs, electrifying public transport, integrating with renewable energy, and banning the sale of new ICE vehicles by a specific year to accelerate the EV transition.

With respect to the domestic production of EVs, the agreement between the Saudi Public Investment Fund (PIF) and Lucid Motors is a critical strategic move (Espey n.d.). The PIF, a major shareholder of Lucid Motors, has signified Saudi Arabia's intent to become a significant player in the EV market. The collaboration includes plans to manufacture Lucid EVs in Saudi Arabia, which could boost local production, create jobs, and reduce import dependency. According to media reports, Saudi Arabia has set a target to achieve a 30% share of EVs in Riyadh Capita by 2030, which is a significant step toward reducing carbon emissions, improving air quality, and decreasing the reliance on fossil fuels (Espey n.d.; Mena Show n.d.; Astute Analytica 2024).

Figure 3 shows the projected number of EVs under each of the three scenarios (low-, moderate-, and high-growth scenarios), and the corresponding number of ICE vehicles is shown in Figure 4. According to our projections, the number of EVs will be 14.8, 11.9, and 8.9 million in 2050 under the high-, moderate-, and low-growth scenarios, respectively (Figure 3).

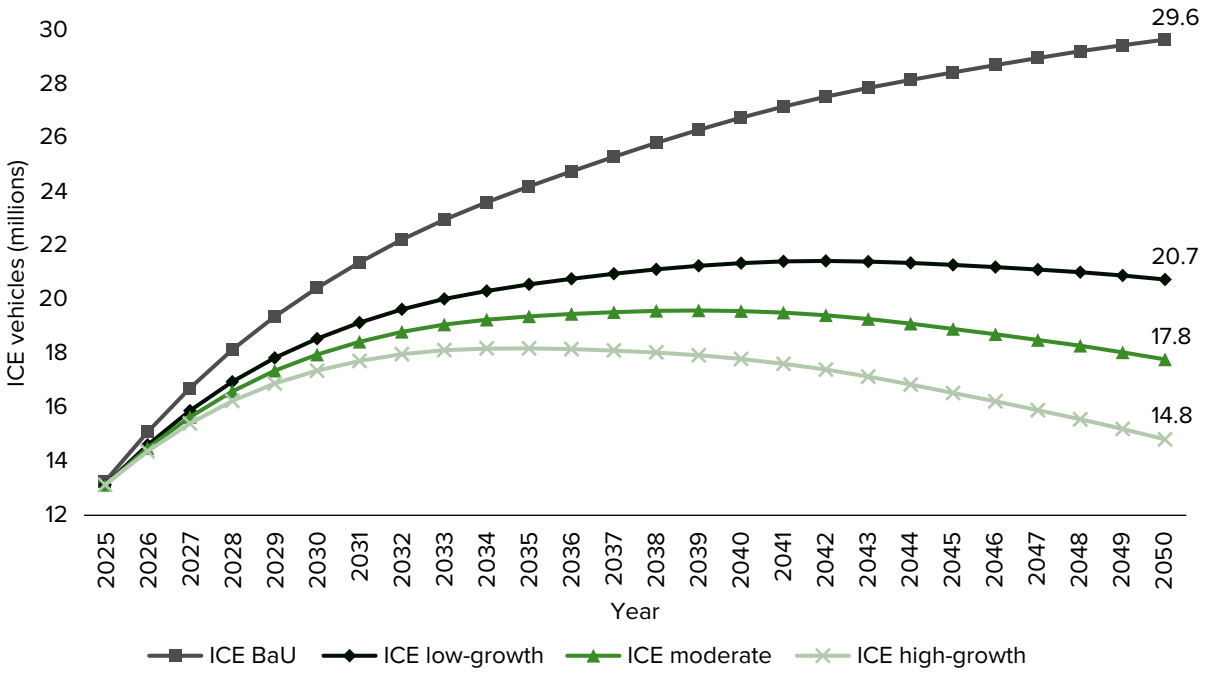
The corresponding numbers of ICE vehicles will reach 20.7, 17.8, and 14.8 million in 2050 under the low-, moderate-, and high-growth scenarios, respectively (Figure 4).

Figure 3. Different scenarios for EVs in Saudi Arabia (2025-2050).



Source: Authors' projections.

Figure 4. Number of ICE vehicles (in millions).



Source: Authors' projections.

5. Oil Demand Model Estimation and Empirical Results

5.1 Unit Root Test Results

To determine the order of integration of the variables included in our analysis, we use the augmented Dickey-Fuller (ADF) test (Dickey-Fuller 1979) and the Phillip-Perron (PP) (1988) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Kwiatkowski et al. 1992) tests. All three-unit root tests are performed at the level and first difference of the variables. Table 2 presents the findings of the ADF, PP, and KPSS unit root tests. From the ADF and PP test results, we can infer that all of the variables in our analysis follow a unit root process at a given level and stationarity at their first difference, except for *vehicle*. Therefore, we can conclude that all the variables are integrated of the order one, i.e., I(1). For the *vehicle* variable, both the ADF and PP tests do not reject the null hypothesis of the unit root at the first difference.

The KPSS unit root test is used to determine the unit root process for the vehicle variable. The null hypothesis of the KPSS unit root test is that the variable is stationary at the level. Panel C of Table 2 reports the vehicle's KPSS unit root test results. The KPSS t statistic is greater than the critical value at the 10% significance level, and thus, the results demonstrate that the null hypothesis of stationarity is rejected at this level. The intercept and the trend are included in the unit root test equation at the level, and the intercept is included in the first-difference equation. However, at the first difference, the KPSS t statistic is less than the critical values, and thus, we cannot reject the null hypothesis of stationarity. This situation leads us to conclude that all the variables are nonstationary at their logarithmic level and are stationary at their first-difference level. In other words, they can be considered I(1) series.

5.2 Long-Run Estimation Results of the Oil Demand Equation

Following Pesaran et al. (2001), an autoregressive distributed lag (ARDL) approach to cointegration is used to estimate the long-run relationship between transport oil consumption and its determinants. The estimated oil demand equation passes all residual diagnostic tests, such as autocorrelation, heteroscedasticity, autoregressive conditional heteroskedasticity (ARCH)

Table 2. Unit root test.

ADF unit root test						
	Level			First difference		
Variable	t Stat	DC	K	t Stat	DC	K
Oil_t	-1.322	c	1	-4.730***	c	0
P_t	-1.613	c	2	-6.349***	c	0
$Vehicle_t$	-1.762	c, t	1	-2.590	c	0
Eff_t	-2.117	c, t	0	-3.530**	c	0
PP unit root test						
	Level			First difference		
Variable	t Stat	DC	K	t Stat	DC	K
Oil_t	-2.490	c	0	-4.612***	c	0
P_t	-2.583	c	2	-6.034***	c	0
$Vehicle_t$	-2.684	c, t	2	-2.560		0
Eff_t	-2.192	c, t	0	-3.485**	c	0
KPSS unit root test						
$Vehicle_t$	0.131*	c, t		0.253	c	

*Note: The maximum lag order is set to two, and the optimal lag order (K) is selected based on the Schwarz criterion. ***, **, and * indicate the rejection of the null hypothesis of the unit root at the 1%, 5%, and 10% significance levels, respectively. The critical values for the KPSS test are taken from Kwiatkowski-Phillips-Schmidt-Shin (1992). In Table 1, DC indicates a deterministic component; C and T indicate the constant and trend, respectively; and K represents the number of lags in the final unit root test equation.*

effect, and normality tests, as well as the Ramsey Regression Equation Specification Error Test (RESET), for parameter stability. The residual diagnostic test results are reported in Panel B of Table 3. We introduce dummy variables in the ARDL general specification for the period 2017-2019 to capture the effect of the energy price reform period and CAFE standard initiative, for 2008 to capture the effect of the global financial crisis, and for 1998 to capture the effect of the Asian currency crisis.

To examine the long-run relationships among the variables included in our model, we apply the bound cointegration test, and the results are reported in Panel C of Table 3. The calculated value of the F statistic of 50.35 is greater than the upper-bound critical values reported by Pesaran et al. (2001) and Narayan (2005) at the 1% significance level.

Therefore, the cointegration test confirms the existence of long-run relationships among the variables. The long-run estimation results of the ARDL method are reported in Panel A of Table 3. The long-run estimation results have theoretically and statistically expected signs. The estimated elasticity of the oil price and fuel efficiency

Table 3. Estimation results.

A: Long-run estimated coefficient		
Variable	**Coefficient**	**Std. error**
P_t	-0.169***	0.017
$Vehicle_t$	0.344***	0.033
Eff_t	-0.281***	0.043
C	1.836***	0.473
B: Residual diagnostics		
Statistic	**t Value**	**Prob.**
F_{LM}	2.546	0.139
F_{White}	1.287	0.350
F_{ARCH}	4.109	0.056
X^2_{JB}	0.231	0.891
F_{RESET}	0.771	0.403
C: Cointegration tests result		
F-statistic	50.35***	

*Note: F_{LM}, F_{White}, F_{ARCH}, and X^2_{JB} denote F statistics to test the null hypothesis of no autocorrelation, no heteroscedasticity in the residual, no autoregressive conditional heteroscedasticity, and no function form misspecification, respectively; X2JB indicates the chi-square statistic to test the null hypothesis of the normal distribution of the residual. ***, **, and * indicate the rejection of the null hypothesis at the 1%, 5% and 10% significance levels, respectively.*

have negative and significant effects on oil demand in the transport sector in the long run. The vehicle ownership variable has a positive and significant effect on the demand for transporting oil in Saudi Arabia. The signs of all the estimated coefficients are consistent with those of economic theory.

No such empirical study is available for Saudi Arabia or Gulf Cooperation Council (GCC) countries with which we can compare our results. However, Hasanov et al. (2023) and Gasim et al. (2023) estimated the price and income elasticities of diesel and gasoline for the transport sector in Saudi Arabia. In this study, we use total oil (the sum of diesel and gasoline) as the dependent variable, and the price of oil is calculated as the weighted average price of diesel and gasoline. Despite the differences in specifications, our price elasticity of oil demand is somewhat consistent with those of Hasanov et al. (2023) and Gasim et al. (2023). Gasim et al. (2023) reported long-run price elasticities of -0.16 and -0.29 for gasoline and diesel, respectively. Hasanov et al. (2023) estimated long-run price elasticities of -0.22 and -0.21 for diesel and gasoline, respectively. Atalla, Gasim, and Hunt (2018) reported that the long-run price elasticity of gasoline in the transport sector in Saudi Arabia is -0.15.

6. Projected Annual Oil Demand in the Transport Sector

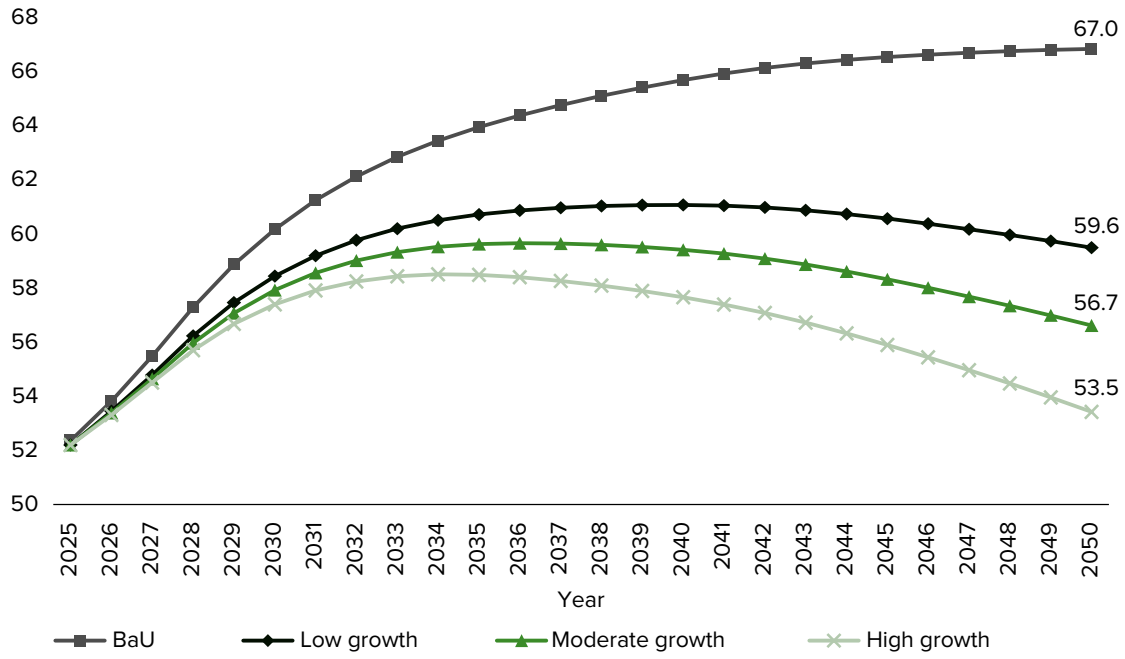
The estimated elasticities reported in Table 3 are used to project oil demand in the transport sector up to 2050, taking into account different assumptions for EV penetration. Figure 5 shows the projected oil demand by Saudi Arabia's transport sector under three different assumptions of EV penetration. In 2021, Saudi Arabia's diesel and gasoline consumption by vehicles on the road was 42.01 MTOE, approximately one-fourth of the country's total oil consumption. The oil demand for Saudi Arabia's road transport sector will rise at an annual growth rate of 1.2% between 2021 and 2050, reaching 67.02 MTOE by 2050 under a business-as-usual (BaU) scenario. This potential growth in oil demand for road transport will have consequences not only for oil exports but also for environmental degradation.

According to Figure 5, the oil demand in Saudi Arabia's road transport sector will decrease from 67.02 MTOE to 53.5 MTEO under the high-growth scenario until 2050. In the low- and moderate-growth scenarios, the transportation sector's oil demand will decline to 59.6 and 56.7 MTOE by 2050, respectively. The projected results show that by 2050, the adoption of EVs is expected to reduce road transportation oil consumption by 11% in the low-growth scenario, 15.4% in the moderate-growth scenario, and 20.2% in the high-growth scenario. EV adoption may help save 7.4, 103, and 13.5 MTOE of oil in the low, moderate-, and high-growth scenarios, respectively.

6.1 Projection of CO_2 in the Transport Sector

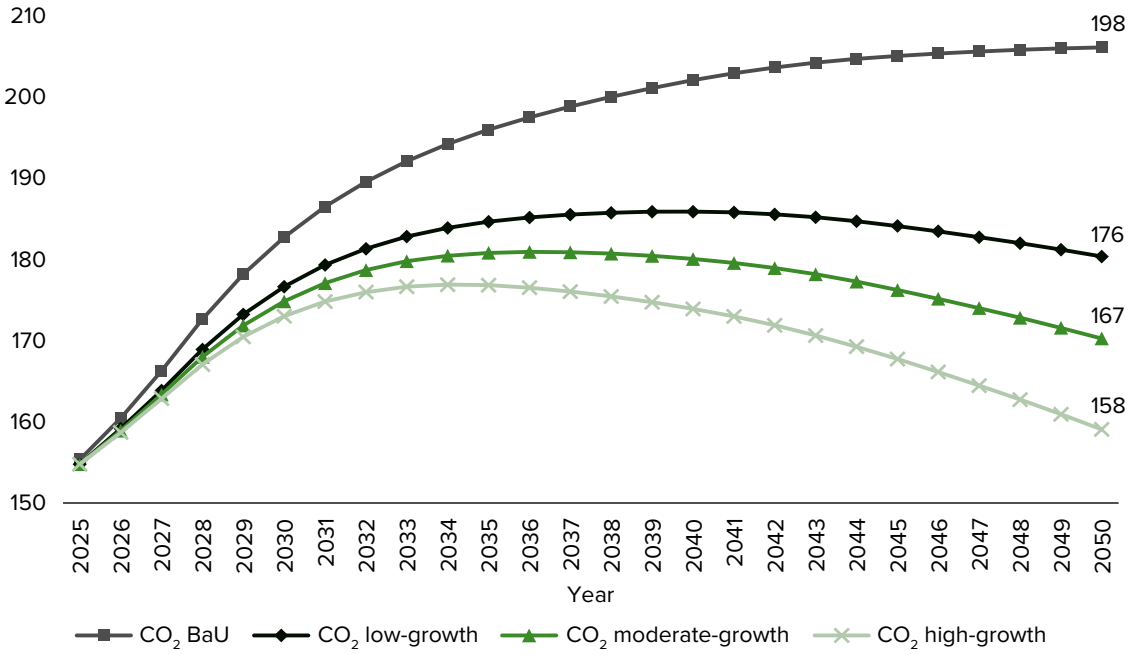
The projected results for the BaU scenario show that Saudi Arabia's number of vehicles on the road could emit 198 million tonnes of CO_2 by 2050 (see Figure 6). Our CO_2 projections for 2030 are consistent with those of Shannak, Mikayilov, and Dua (2022) for the transport sector in Saudi Arabia; these authors projected 181.65 million tonnes of

Figure 5. Projected oil demand in different scenarios (MTOE).



Source: Authors' projections based on the model specified in Equation (2).

Figure 6. Projected CO_2 emissions from oil consumption.



Source: Authors' projections; following the IEA, we use 2.95 million metric tonnes of CO_2 per MTOE, a CO_2 emission conversion factor.

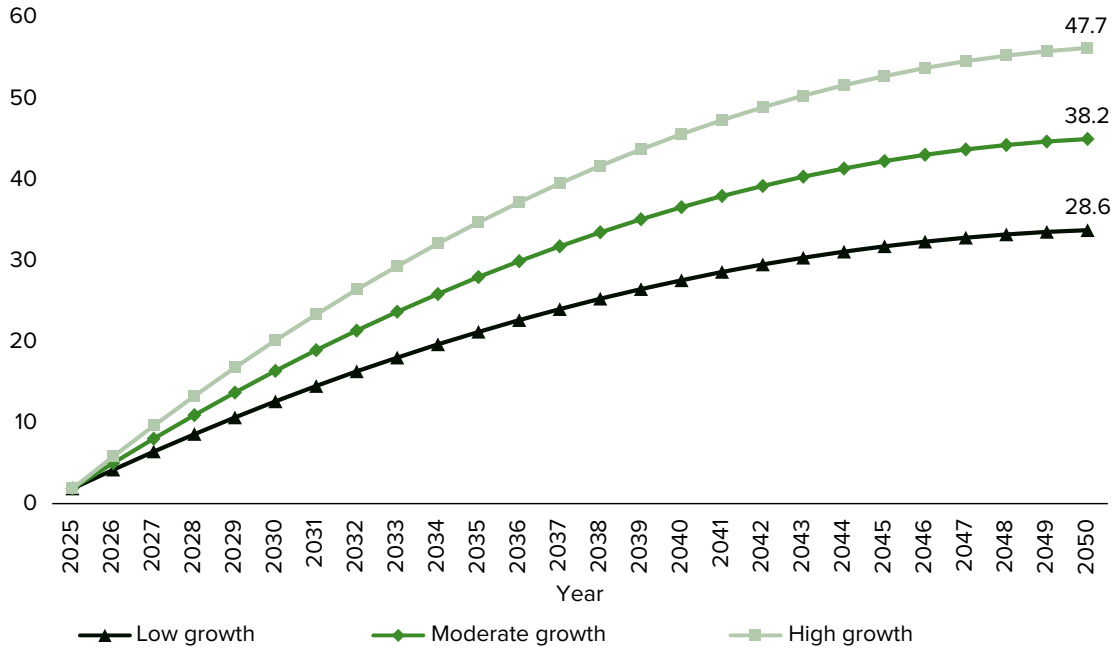
CO_2 emissions from the transport sector in Saudi Arabia in 2030. Our projection of CO_2 emissions for the same year is 178 million tonnes for the BaU scenario. We expect that the penetration of EV adoption will help achieve the ambitious target of reducing emissions in Saudi Arabia.

6.2 Projections for Electricity Demand for EVs

To calculate and forecast EV electricity demand in Saudi Arabia, we multiply the average EV electricity demand by the total distance driven by EVs in a year and adjust for EV fuel efficiency. According to Sheldon and Dua (2021), the annual distance traveled by vehicles in Saudi Arabia is approximately 16,000 miles (25,750 km). According to the IEA (2020),[2] electricity demand for EVs is between 0.20 and 0. 26 kWh/km for passenger light-duty vehicles (PLDVs). This range indicates variation across countries. In our study, we take the average of this range, i.e., 5.92 MWh/Veh/per year.[3] Following Trieb et al. (2015), electricity consumption per vehicle is assumed to fall to 1.8 MWh/Veh/year by 2050.

Figure 7 shows the electricity demand for EVs in Saudi Arabia under the low-, moderate-, and high-growth scenarios by 2050. For the three different EV scenarios, electricity demand by EVs in Saudi Arabia could reach 47.7 TWh for the high-growth scenario, 38.2 TWh for the moderate-growth scenario, and 28.6 TWh for the low-growth scenario. Our electricity demand projections indicate an average annual growth rate of approximately 14.3% for the low-growth scenario, 16.7% for the moderate-growth scenario, and 18.8% for the high-growth scenario by 2050. The electricity demand growth due to EVs is high in the early years for all three scenarios; however, as EVs gain energy efficiency, the electricity demand growth slows over time (see Figure 7).

Figure 7. Projected electricity demand for EVs (in TWh/year).



Source: Authors' projections.

7. Conclusions and Policy Insights

Saudi Arabia has experienced tremendous economic growth in recent years because of numerous megadevelopment projects and initiatives under the ambitious goals of the Saudi Vision 2030 plan, which aims to diversify the economy away from oil resources. This growth trend is expected to continue into the future. As a result, the demand for oil consumption, CO_2 emissions, and other environmental concerns have increased, particularly in the transport sector. To address environmental concerns and oil consumption in the transport sector, the Saudi government's ambitious goals for increasing the share of EVs reflect its commitment to diversifying the economy and promoting sustainable development, which aligns with the country's strategic economic diversification plan. Although numerous studies have reported on projected CO_2 emissions in the transport sector in Saudi Arabia, detailed projections of the number of vehicles on the road and associated oil consumption are often lacking. Consequently, policymakers may lack the information needed to formulate targeted and effective policies through which to manage vehicle growth and EV adoption, which will result in changes in oil demand and greenhouse gas (GHG) emissions in the transport sector.

The EV growth scenarios set out in this study reflect the media announcements made by the relevant authorities, as well as the trends observed in other parts of the region. The projected number of EVs is then used to assess the degree of improvement in environmental quality in terms of CO_2 emission reduction, oil savings, and future electricity demand for EVs in the country.

Our projections show that by 2050, the total number of ICE vehicles in Saudi Arabia's vehicle fleet could reach 29.6 million, approximately 2.5 times the 2023 level, and that oil consumption and associated CO_2 emissions could reach 67 MTOE and 198 million tonnes, respectively. Various scenario projections for EVs show that by 2050, the number of EVs could reach 14.8 million in the low-growth scenario, 17.8 million in the moderate-growth scenario, and 20.7 million in the high-growth scenario. By 2050, the adaptation of EVs is expected to reduce oil consumption in the road transport sector by 20.2% in the high-growth scenario, 15.4% in the moderate-growth scenario, and 11.0% in the low-growth scenario. CO_2 emissions are expected to decrease from 198 million tonnes in the BaU scenario to 176 million tonnes in the low-growth scenario, to 167 million tonnes in the moderate-growth scenario, and to 158 million tonnes in the high-growth scenario by 2050. By 2050, the electricity demand for EVs in Saudi Arabia is projected to reach 47.7 TWh per year in the high-growth scenario, 38.2 TWh per year in the moderate-growth scenario, and 28.6 TWh per year in the low-growth scenario.

The adoption of EVs in Saudi Arabia can play a crucial role in the country achieving its ambitious goal of reducing carbon emissions and domestic oil consumption. Vehicle electrification is crucial not only for achieving decarbonization goals but also for contributing to several other key development agendas, such as inclusive mobility, local air quality, energy security, and industrial policy.

Government policies, infrastructure development, public awareness, and the integration of renewable energy sources can accelerate the country's transition to EVs. Clear targets for EV adoption, subsidies, tax breaks, and incentives should be essential elements of government policy for the adoption of EVs. Infrastructure development, such as an extensive and reliable charging network, is another crucial component for the growth of EVs. EV infrastructure is also crucial for the electrification of public transportation, including buses and cabs. In addition, public awareness campaigns about the environmental benefits of EVs will increase the demand for EVs.

With respect to the environmental benefits of EVs, vehicle electrification can reduce CO_2 emissions and domestic oil consumption in the road transport sector only if sufficient renewable electricity generation capacity is added to meet the demand for electricity from clean sources. Thus, the government should focus on increasing the installed capacity of electricity generation from renewable sources.

Endnotes

[1] https://www.ic.gov.sa/industries-automotive.

[2] https://www.iea.org/data-and-statistics/charts/electricity-demand-from-the-electric-vehicle-fleet-by-country-and-region-2030. IEA analysis was developed with the mobility model (IEA 2020).

[3] The average of 0.20 and 0.26 is 0.23 kWh; we multiply 0.23 by the annual distance traveled by EVs, which is 25750 km (0.23*25750/1000=5.9225 mWh/km/vehicle).

References

Aklilu, Abenezer Zeleke. 2020. "Gasoline and Diesel Demand in the EU: Implications for the 2030 Emission Goal." *Renewable and Sustainable Energy Reviews* 118: 109530. https://doi.org/10.1016/j.rser.2019.109530.

Algadhi, Saad A., Rasin K. Mufti, and Daniel Malick. 2002. "Estimating the Total Number of Vehicles Active on the Road in Saudi Arabia." *Journal of King Abdulaziz University—Engineering Sciences* 14 (1): 3–28. https://doi.org/10.4197/ENG.14-1.1.

Alkhathlan, Khalid, and Muhammad Javid. 2015. "Carbon Emissions and Oil Consumption in Saudi Arabia." *Renewable and Sustainable Energy Reviews* 48: 105–111. https://doi.org/10.1016/j.rser.2015.03.072.

Astute Analytica. 2024. "Eco-Drive in the Desert: Saudi Arabia Unveils Plans for Electric Vehicle (EV) Adoption." LinkedIn. May 9. https://www.linkedin.com/pulse/eco-drive-desert-saudi-arabia-unveils-plans-electric-a8t5e

Atalla, Tarek N., Anwar A. Gasim, and Lester C. Hunt. 2018. "Gasoline Demand, Pricing Policy, and Social Welfare in Saudi Arabia: A Quantitative Analysis." *Energy Policy* 114: 123–133. https://doi.org/10.1016/j.enpol.2017.11.047.

Briceno-Garmendia, Cecilia, Vivien Foster, and Wenxin Qiao. 2022. *The Economics of Electric Vehicles for Passenger Transportation*. World Bank. https://doi.org/10.1596/38265.

Castle, Jennifer L., Jurgen A. Doornik, and David F. Hendry. 2023. "Robust Discovery of Regression Models." *Econometrics and Statistics* 26 (April): 31–51. https://doi.org/10.1016/j.ecosta.2021.05.004.

Dargay, Joyce, and Dermot Gately. 1999. "Income's Effect on Car and Vehicle Ownership, Worldwide: 1960–2015." *Transportation Research Part A: Policy and Practice* 33 (2): 101–138. https://doi.org/10.1016/S0965-8564(98)00026-3.

Dargay, Joyce, and Dermot Gately. 2001. "Modelling Global Vehicle Ownership." In *Proceedings of the Ninth World Conference on Transport Research*, 22–27. July.

Dargay, Joyce, Dermot Gately, and Martin Sommer. 2007. "Vehicle Ownership and Income Growth, Worldwide: 1960–2030." *The Energy Journal* 28 (4): 143–170. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol28-No4-7.

De Carvalho, Enio Nascimento, Antônio César Pinho Brasil Junior, and Augusto César de Mendonça Brasil. 2023. "Energy Impact Assessment of Electric Vehicle Insertion in the Brazilian Scenario, 2020–2050: A Machine Learning Approach to Fleet Projection." e-Prime – Advances in Electrical Engineering, Electronics and Energy 4: 100184. https://doi.org/10.1016/j.prime.2023.100184.

Dickey, David A., and Wayne A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74 (366): 427–431. https://doi.org/10.2307/2286348.

Dua, Rubal. 2020. "Estimating the Size and Efficiency of the Saudi Vehicle Fleet." Riyadh: King Abdullah Petroleum Studies and Research Center (KAPSARC). https://www.kapsarc.org/research/publications/estimating-the-size-and-efficiency-of-the-saudi-vehicle-fleet.

Espey, Robert. n.d. "Saudi Arabia Fosters E- and H2-Mobility." Germany Trade and Invest. Translated by the German-Saudi Arabian Liaison Office for Economic Affairs (GESALO). https://saudiarabien.ahk.de/en/market-information/automotive-industry/e-mobility-saudi-arabia.

Gasim, Anwar A., Paolo Agnolucci, Paul Ekins, and Vincenzo De Lipsis. 2023. "Modeling Final Energy Demand and the Impacts of Energy Price Reform in Saudi Arabia." *Energy Economics* 120: 106589. https://doi.org/10.1016/j.eneco.2023.106589.

General Authority of Statistics (GaStat). 2024. https://www.stats.gov.sa/en.

Hasanov, Fakhri J., Frederick L. Joutz, Jeyhun I. Mikayilov, and Muhammad Javid. 2023. *A Macroeconometric Model for Saudi Arabia: A Case Study on the World's Largest Oil Exporter*. Springer Nature. https://link.springer.com/book/10.1007/978-3-031-12275-0.

Hendry, David F. 2020. *First In, First Out: Econometric Modelling of UK Annual CO_2 Emissions: 1860–2017*. Oxford, UK: Nuffield College, University of Oxford. https://www.nuffield.ox.ac.uk/economics/Papers/2020/2020W02_CO2UKEmissionsModel20.pdf.

Huo, Hong, Michael Wang, Larry Johnson, and Dongquan He. 2007. "Projection of Chinese Motor Vehicle Growth, Oil Demand, and CO2 Emissions Through 2050." *Transportation Research Record* 2038 (1): 69–77. https://doi.org/10.3141/2038-09.

Huo, Hong, and Michael Wang. 2012. "Modeling Future Vehicle Sales and Stock in China." *Energy Policy* 43: 17–29. https://doi.org/10.1016/j.enpol.2011.09.063.

Industrial Clusters. 2018. "Automotive Aftermarket Parts Study for Local KSA Manufacturing and Regional Export." https://www.ic.gov.sa/media/42852/14-industrial-clusters_business-cases_shock-absorber-strut_ic.pdf.

International Energy Agency (IEA). 2023a. *Global Energy and Climate Model*. https://www.iea.org/reports/global-energy-and-climate-model.

International Energy Agency (IEA). 2023b. *World Energy Outlook 2023*. https://iea.blob.core.windows.net/assets/86ede39e-4436-42d7-ba2a-edf61467e070/WorldEnergyOutlook2023.pdf.

International Energy Agency (IEA). 2024. *World Energy Statistics and Balances*. https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances.

Kwiatkowski, Denis, Peter C. B. Phillips, Peter Schmidt, and Yongcheol Shin. 1992. "Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure Are We That Economic Time Series Have a Unit Root?" *Journal of Econometrics* 54 (1-3): 159–178. https://doi.org/10.1016/0304-4076(92)90104-Y.

Mena Show. n.d. "Driving the Future: Saudi Arabia's Vision for Electric Vehicles." https://menaevshow.com/driving-the-future-saudi-arabias-vision-for-electric-vehicles.

Mikayilov, Jeyhun I., Marie Petite, and Rubal Dua. 2024. "Assessing the Impact of Electric Vehicle Penetration on Electricity Demand in Riyadh." Riyadh: King Abdullah Petroleum Studies and Research Center (KAPSARC). https://www.kapsarc.org/research/publications/assessing-the-impact-of-electric-vehicle-penetration-on-electricity-demand-in-riyadh.

Narayan, Paresh Kumar. 2005. "The Saving and Investment Nexus for China: Evidence From Cointegration Tests." *Applied Economics* 37 (17): 1979–1990. https://doi.org/10.1080/00036840500278103.

Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. 2001. "Bounds Testing Approaches to the Analysis of Level Relationships." *Journal of Applied Econometrics* 16 (3): 289–326. https://www.jstor.org/stable/2678547.

Phillips, Peter C. B., and Pierre Perron. 1988. "Testing for a Unit Root in Time Series Regression." *Biometrika* 75 (2): 335–346. https://doi.org/10.1093/biomet/75.2.335.

Saudi Energy Efficiency Center (SEEC). 2018. "Enhancing Vehicles Energy Efficiency in Saudi Arabia." https://theicct.org/sites/default/files/KSA_AlRoge_Enhancing%20Vehicles%20Energy%20Efficiency%20in%20Saudi%20Arabia.pdf.

Shannak, Sa'd, Jeyhun Mikayilov, and Rubal Dua. 2022. "How to Mitigate Transportation Emissions in Saudi Arabia?" Riyadh: King Abdullah Petroleum Studies and Research Center (KAPSARC). https://doi.org/10.30573/KS--2022-DP04.

Shannak, Sa'd, Jeyhun Mikayilov, and Rubal Dua. 2024. "Energy Price Reform to Mitigate Transportation Carbon Emissions in Oil-Rich Economies." *Environmental Economics and Policy Studies* 26 (2): 263–283. https://doi.org/10.1007/s10018-024-00400-9.

Sheldon, Tamara L., and Rubal Dua. 2021. "How Responsive Is Saudi New Vehicle Fleet Fuel Economy to Fuel- and Vehicle-Price Policy Levers?" *Energy Economics* 97: 105026. https://doi.org/10.1016/j.eneco.2020.105026.

Torok, Adam. 2022. "Prediction of Vehicle Ownership Growth Using Gompertz Model, Case Study of Hungary." *System Safety: Human-Technical Facility-Environment* 4 (1): 164-169. https://doi.org/10.2478/czoto-2022-0017.

Trieb. F., Fichter T., Kern J., Stökler., S. 2015. *Technical and Economic Framework for Sustainable Energy Supply Systems of the Arabian Peninsula*. Unpublished manuscript. DLR Institute of Engineering Thermodynamics, Department of Systems Analysis and Technology Assessment.

Vega-Perkins, Jesse, Joshua P. Newell, and Gregory Keoleian. 2023. "Mapping Electric Vehicle Impacts: Greenhouse Gas Emissions, Fuel Costs, and Energy Justice in the United States." *Environmental Research Letters* 18 (1): 014027. https://doi.org/10.1088/1748-9326/aca4e6.

Wu, Tian, Hongmei Zhao, and Xunmin Ou. 2014. "Vehicle Ownership Analysis Based on GDP per Capita in China: 1963–2050." *Sustainability* 6, no. 8: 4877–4899. https://doi.org/10.3390/su6084877.

Notes

Notes

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About the Project

This study is part of the KGEMM Policy and Research Studies project.

The KGEMM Policy and Research Studies project produces policy and applied research studies that can provide Saudi Arabian decisionmakers with a better understanding of domestic and international macroeconomic-energy relationships. The project employs mainly the KGEMM, an energy-sector augmented general equilibrium macroeconometric model, as well as partial equilibrium frameworks.



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