

Article

Economic Growth, Urbanization, and Transport Emissions: An Investigation of Elasticity-Based Decoupling Metrics in the Gulf

Sadiq H. Melhim ^{1,*}  and Rima J. Isaifan ^{2,*} ¹ International Economics Department, School of Foreign Service, Georgetown University, Doha P.O. Box 23689, Qatar² Department of Environmental Sciences, Cambridge Corporate University, 6006 Lucerne, Switzerland

* Correspondence: sm3837@georgetown.edu (S.H.M.); risaifan@cambridgecu.ch (R.J.I.)

Abstract

Transport is among the fastest-growing contributors to carbon dioxide (CO₂) emissions in the Gulf Cooperation Council (GCC) region, where rapid urbanization, population growth, and high mobility demand continue to shape energy use. This study aims to quantify the extent to which economic growth and urbanization drive transport-related CO₂ emissions across Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates between 2012 and 2022. Using sector-specific data from the International Energy Agency and World Bank, we apply panel and country-level log–log regression models to estimate long-run and short-run elasticities of transport CO₂ emissions with respect to GDP and urban population. The analysis also includes robustness checks excluding the COVID-19 pandemic year to isolate structural effects from temporary shocks. Results show that transport emissions remain strongly correlated with GDP in most countries, indicating emissions-intensive growth, while the influence of urbanization varies: positive in Kuwait and Saudi Arabia, where expansion is car-dependent, and negative in Oman and Qatar, where compact urban forms and transit investments mitigate emissions. The findings highlight the importance of differentiated policy responses—fuel-pricing reform, vehicle efficiency standards, electrification, and transit-oriented planning—to advance low-carbon mobility. By integrating elasticity-based diagnostics with decoupling analysis, this study provides the first harmonized empirical framework for the GCC to assess progress toward transport-sector decarbonization.

Keywords: transport CO₂ emissions; elasticity; decoupling; urbanization; economic growth; Gulf Cooperation Council (GCC)



Academic Editor: Sajid Anwar

Received: 17 October 2025

Revised: 5 November 2025

Accepted: 5 November 2025

Published: 11 November 2025

Citation: Melhim, S. H., & Isaifan, R. J. (2025). Economic Growth, Urbanization, and Transport Emissions: An Investigation of Elasticity-Based Decoupling Metrics in the Gulf. *Economies*, 13(11), 323. <https://doi.org/10.3390/economies13110323>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Transport is among the largest and fastest-growing sources of energy-related carbon dioxide (CO₂) emissions (Akinyemi & Ramonu, 2019). Over recent decades, rapid motorization, expanding freight activity, and urban growth have made the sector central to national decarbonization strategies (Szczepański et al., 2025). Although many countries have begun to separate, or “decouple,” emissions from economic output, the extent and stability of decoupling in transport varies widely across regions and over time (Foster et al., 2023).

In the Gulf Cooperation Council (GCC), Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates, transport systems have evolved rapidly alongside high urbanization rates, large infrastructure programs, and shifting energy-price policies (Ramadan, 2015). The GCC is already one of the most urbanized regions in the world, with

large shares of people living in a handful of metropolitan areas (Marzouk, 2017). For two decades, everyday mobility in these cities was shaped by cheap fuel and abundant road capacity, which made private cars the default transport option and limited the business case for mass transit (Qadir et al., 2024). That combination is locked in high car ownership, long average trip distances, and rising transport energy use (Al-Thani, 2023).

Since 2015–2016, governments have begun to reform energy prices and phase out parts of fuel subsidies, lifting pump prices closer to international levels (The Official Portal of the UAE Government, 2023; The Peninsula Newspaper, 2016). At the same time, they have launched big public-transport investments, metro and Bus Rapid Transit (BRT) systems, investment in renewable energy solutions (Hassabou et al., 2025) (Melhim & Isaifan, 2025), along with policies to promote electric vehicles (EVs) and charging networks (Yahia et al., 2025). These shifts raise the operating cost of car travel while improving the speed, reliability, and convenience of non-car options (Koimur et al., 2014). Hence, the pricing and infrastructure changes are reshaping travel demand and technology choices: nudging some trips away from private cars, improving the efficiency of remaining road travel, and accelerating the diffusion of cleaner vehicle technologies. Consequently, the policy environment is moving from one that reinforced car dependency to one that supports a gradual decoupling of transport emissions from growth.

A large body of literature investigates whether economic growth can be decoupled from emissions. Results are mixed: some high-income economies exhibit relative or absolute decoupling, whereas many others do not (Foster et al., 2023). For transport specifically, cross-country studies often find positive income–emissions links, but the magnitude of elasticities and their persistence differ by context (Amer et al., 2025). Urbanization can reduce per capita emissions through density and transit viability, or raise them if growth occurs through low-density, car-dependent expansion (Sinha, 2003). In the GCC, empirical work has grown significantly, but is still dominated by economy-wide CO₂ studies; fewer papers estimate sector-specific transport elasticities with comparable country-level time series (Binsuwadan, 2024). In addition, despite major investments and policy changes in the GCC, there is no consistent set of country-level estimates that quantify how transport CO₂ responds to income and urban population using sector-specific data. Existing publications often use aggregate emissions, mix countries in panels that hide country dynamics, or report associations without an elasticity/decoupling lens.

Against this backdrop, a compact, replicable dashboard of transport-sector elasticities for all six GCC economies (2012–2022) is developed in this work to address a key research gap and to quantify the sensitivity of transport CO₂ emissions to changes in income and urban population. Sensitivity is measured using elasticities, the percentage change in emissions associated with a 1% change in a driver, and patterns are compared across countries and over time, with a robustness specification that excludes the exceptional year 2020.

Despite growing interest in the environmental dynamics of Gulf economies, the transport sector remains underexplored in quantitative carbon studies. Most prior GCC analyses have focused on aggregate CO₂ emissions, leaving a significant gap in sector-specific evidence, particularly on transport. Furthermore, the few available studies often rely on inconsistent datasets or time spans, limiting comparability across countries and over time. No prior work has produced a harmonized set of transport CO₂ elasticities derived from common and validated sources such as the International Energy Agency (IEA) and the World Development Indicators (WDI). Equally important, the dual influence of economic growth and urbanization on transport emissions has rarely been modeled jointly; existing research typically treats them as independent or secondary variables rather than as parallel structural drivers. Finally, empirical understanding of shock sensitivity,

especially in relation to the COVID-19 period, remains fragmentary; most Gulf studies omit or understate how short-term disruptions interact with long-run elasticity trends. By addressing these four gaps, this study provides the first integrated, cross-country elasticity assessment that quantifies the simultaneous effects of income and urbanization on transport-related CO₂ emissions in the GCC and tests their robustness to pandemic-era fluctuations. Ultimately, our contribution is to produce a consistent, country-level elasticity dashboard with decoupling diagnostics and policy-relevant interpretation for Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE (2012–2022).

To guide this analysis, the study addresses the following research questions:

1. To what extent are transport-related CO₂ emissions in GCC countries driven by economic growth and urbanization during 2012–2022?
2. Do patterns of elasticity differ across countries, and can these differences be interpreted as evidence of relative or absolute decoupling?
3. How does the exclusion of the COVID-19 pandemic year affect the stability and direction of these elasticities?
4. What policy insights can be derived from the observed relationships for achieving low-carbon transport systems in the GCC?

Based on the literature and contextual trends, the following hypotheses are tested:

H1. *Economic growth exerts a positive and elastic influence on transport CO₂ emissions across GCC countries (elasticity > 1), indicating emissions-intensive growth.*

H2. *The effect of urbanization on transport CO₂ emissions is heterogeneous—positive in low-density, car-oriented countries and negative where compact urban form and public transport investments prevail.*

H3. *Excluding the pandemic year reduces elasticity magnitudes, reflecting structural rather than shock-driven relationships between economic activity, urbanization, and transport emissions.*

2. Literature Review

2.1. Global Transport-Emissions Trends and Context

Across assessment syntheses and agency statistics, transport remains a major and fast-growing source of CO₂ (Kaššaj & Peráček, 2024). It was reported that transport directly emitted ~8.9 GtCO₂-eq in 2019, 23% of global energy-related CO₂, with steady growth since 1990 (Akimoto, 2023; IPCC, 2020). Recent IEA tracking shows energy-related CO₂ rose 0.9% in 2022 to 36.8 Gt, with oil-related rebounds (notably aviation) important post-pandemic (IEA, 2023). Within transport, on-road modes dominate the global sectoral CO₂ (≈three-quarters), with aviation and shipping forming sizable shares, implying that road policy and technology (efficiency, electrification, modal shift) are central to near-term mitigation (IEA, 2023).

Having established the global context and scale of transport-related CO₂ emissions, it is essential to interpret these trends within a conceptual framework that distinguishes between growth-driven emissions and structural improvements in efficiency (Dong et al., 2020). Understanding whether rising transport activity necessarily implies higher emissions, or whether economic expansion can occur with reduced carbon intensity, requires a systematic lens for analyzing the relationship between output and emissions. The next section, therefore, introduces the concept of decoupling, outlines the principal metrics used to quantify it, and situates this study within the broader empirical literature on elasticity-based assessments of transport emissions.

2.2. Decoupling: Concepts, Metrics, and Global Evidence

In climate and energy economics, “decoupling” describes the weakening, or breaking, of the historical link between economic growth and emissions. The most widely used classification is the Tapio framework, which evaluates how emissions change relative to GDP (Tapio, 2005). Under this approach, absolute decoupling is said to occur when the economy expands while emissions decline; relative decoupling refers to cases where emissions still increase but at a slower rate than GDP; and no decoupling (or coupling) describes situations in which emissions grow as fast as, or faster than, the economy (Table 1).

Table 1. Elasticities from log–log regressions implications.

Elasticity Value	Indication
Elasticity < 0	absolute decoupling
$0 < \text{Elasticity} < 1$	relative decoupling
Elasticity ≈ 1	proportional growth
Elasticity > 1	emissions-intensive growth

In practice, decoupling can be diagnosed with several complementary metrics: comparisons of GDP and emissions growth rates (the Tapio lens), declines in CO₂ intensity of GDP, and elasticity estimates from log–log models that quantify the percentage change in emissions associated with a one-percent change in economic activity (Tapio, 2005). Applied to the transport sector, these indicators provide a consistent way to judge whether mobility systems are becoming cleaner as economies expand and, in the GCC context, compare progress across countries and policy periods.

Foster et al. (2023) conducted a large cross-country World Bank study (145 countries) where they applied a modified Tapio approach to transport CO₂ specifically (Foster et al., 2023). The authors reported that absolute decoupling is rare, relative decoupling occurs in many cases, and progress is closely tied to intensity improvements and policy/structural factors. This underlines why both elasticities (percent responsiveness of CO₂ to GDP) and intensity (CO₂ per unit GDP) should be tracked together (Foster et al., 2023).

While decoupling frameworks provide a valuable foundation for understanding the macroeconomic relationship between growth and emissions, they do not fully capture the spatial and demographic forces shaping energy demand in the transport sector. Urbanization, in particular, alters mobility patterns, modal choices, and land-use intensity, factors that can either amplify or mitigate transport-related emissions depending on urban form and infrastructure planning. To contextualize the elasticity results within these structural dynamics, the next section reviews the literature linking urban expansion and transport CO₂ emissions, emphasizing how Gulf cities’ unique settlement patterns and policy environments influence their decarbonization trajectories.

2.3. Urbanization, Urban Form, and Transport CO₂

Urbanization affects transport emissions through density, spatial form, and modal structure. Recent empirical work shows heterogeneity: some contexts see higher density and transit access moderate transport CO₂; others see rapid, car-dependent expansion raise it. City-scale analyses document that urban CO₂ is rising overall, but the drivers differ by development level (density vs. per capita demand) (Luqman et al., 2023). Several multi-country studies report mixed signs for the urbanization–CO₂ link once income and other controls are added, reinforcing the need for sector-specific estimation and careful interpretation (Fan et al., 2023). For the GCC, where urban shares are already high and

growing, separating income from urban population effects (partial elasticities) is essential to avoid conflating correlated drivers.

2.4. Evidence from the GCC

Time-series studies for GCC economies (1960s–2010s) often find long-run links among GDP, energy use, and CO₂, with causality patterns varying by country. These papers typically use aggregate emissions, not transport-specific series (Magazzino, 2016). Transport-focused analyses are also emerging. Recent GCC work begins to use transport CO₂ directly and to examine modal channels (e.g., air transport). Results generally show positive long- and short-run associations between economic activity (and air traffic) and transport CO₂, using time-series methods (Aldegheishem, 2024). Country case studies (e.g., Oman) document rising transport shares of national GHG over 2000–2015, underscoring the sector's growing importance in regional inventories (Charabi et al., 2020). Moreover, in terms of policy context, the UAE deregulated fuel prices in August 2015, moving to monthly price setting linked to global markets; Saudi Arabia has also undertaken fuel-price reforms and studied fuel-demand elasticities to gauge impacts on transport emissions. Such policies can break historical relationships by changing consumption incentives (The Official Portal of the UAE Government, 2023).

While there is a sizeable GCC literature on aggregate emissions and several transport-specific case studies, there are few comparable, country-by-country estimates of transport CO₂ elasticities with respect to GDP and urban population using the same data definitions and years.

3. Methods

3.1. Study Design and Scope

This study estimates the responsiveness of transport CO₂ emissions to income and urbanization in six GCC countries (2012–2022) through log–log regressions for long-run elasticities and log-growth ratios for short-run elasticities, with robustness checks excluding the 2020 COVID-19 shock.

In addition to the quantitative techniques applied in this study, several general scientific methods were systematically employed to structure the research process in accordance with Kaššaj and Peráček (2024). The analytical method was used to decompose the complex relationship between transport-related CO₂ emissions, economic growth, and urbanization into measurable components and variables. The synthetic method then integrated these findings to construct a coherent regional understanding across the GCC, combining national results into a comparative framework. The deductive method guided hypothesis formulation from established economic-environmental theories, whereas the inductive method supported generalization from the observed empirical patterns identified through regression and elasticity estimation. The comparative method was also essential in evaluating differences in elasticity magnitudes and decoupling patterns among GCC countries, allowing the study to highlight structural and policy-based contrasts.

3.2. Data Sources and Construction

Transport CO₂ emission data (megatons) were extracted from the International Energy Agency's CO₂ by sector statistics for the Transport sector (International Energy Agency, 2025). However, the GDP (constant 2015 USD), total population, urban population (total), and the urban percentage share data were taken from the World Bank World Development Indicators (World Bank Group, 2025). For each year, the parameters in Table 2 have been defined.

Table 2. Parameters derived from open-source data used in this research.

Parameter	Defined as
Per capita transport CO ₂ emissions	$\frac{CO_2 \times 10^6}{Population}$ ton/person
CO ₂ per unit of GDP	$\frac{CO_2 \times 10^9}{GDP}$ kg/USD
natural logarithms of CO ₂ , GDP, and urban population	$\ln CO_{2t}$, $\ln GDP_t$, and $\ln Urban_t$
log growth rates for CO ₂ , GDP, and urban population	$gt^{CO_2} = \ln CO_{2t} - \ln CO_{2t-1}$ $gt^{GDP} = \ln GDP_t - \ln GDP_{t-1}$ $gt^U = \ln Urban_t - \ln Urban_{t-1}$
year-over-year (YoY) elasticities	$\epsilon^{YoY}_{t,GDP} = \frac{gt^{CO_2}}{gt^{GDP}}$ $\epsilon^{YoY}_{t,U} = \frac{gt^{CO_2}}{gt^U}$

Observations with zero/blank values (which invalidate logs) are excluded from regressions, which was the reason why the time window 2012–2022 was chosen for this study.

3.3. Long-Run Elasticity Model

For each country, we estimate the log–log linear model:

$$\ln CO_{2t} = \beta_0 + \beta_1 \cdot \ln GDP_t + \beta_2 \cdot \ln Urban_t + \epsilon_t.$$

Here β_1 is the partial elasticity of transport CO₂ with respect to GDP (holding urban population fixed), and β_2 is the partial elasticity with respect to urban population (holding GDP fixed). A value β in (0, 1) indicates relative decoupling; $\beta \approx 0$ indicates weak sensitivity; $\beta < 0$ indicates absolute decoupling (emissions fall as the driver rises).

3.4. Estimation Procedure

Parameters are estimated by ordinary least squares (OLS). In the accompanying workbook, the model is implemented with STATA (BE 18 64-bit) and Excel's LINEST on the filtered country rows as shown in Appendix A. To align coefficient order with labels, predictors are stacked as $[\ln Urban_t, \ln GDP_t]$ so the first returned slope corresponds to GDP. We report coefficients (elasticities), standard errors, t-statistics, two-tailed p-values, and R².

3.5. Short-Run Elasticities

Year-over-year elasticities are computed as ratios of log growth rates. These are descriptive indicators of short-horizon responsiveness and can spike during shocks. They provide high-frequency signals of responsiveness and can flag policy or shock years but are noisier. We summarize them as:

- $\epsilon^{YoY} > 1$ (emissions grow faster than GDP/urban);
- $0 < \epsilon^{YoY} \leq 1$ (relative decoupling);
- $\epsilon^{YoY} < 0$ (absolute decoupling).

Log transformation was applied to reduce skewness and produce interpretable elasticity coefficients. Given the relatively small sample size for each country (around 10–11 years), formal time-series corrections would lack statistical power; therefore, the analysis emphasizes effect sizes, the stability of coefficients across specifications (including and excluding 2020), and visual inspection of log–log scatter plots with fitted regression lines. Potential multicollinearity between $\ln GDP$ and $\ln Urban$ was monitored through large standard errors and coefficient instability across specifications, with bivariate fits provided as a robustness check.

Elasticities were jointly interpreted with the evolution of CO₂ intensity trends to assess decoupling dynamics. A decline in CO₂ per unit of GDP (kg/USD) supports a decoupling narrative even when statistical significance is weak due to small sample size. Based on this diagnostic framework, outcomes were categorized as absolute decoupling ($\beta < 0$), relative decoupling ($0 < \beta < 1$), proportional growth ($\beta \approx 1$), or emissions-intensive growth ($\beta > 1$).

To test the robustness of results, two main model specifications, with and without the year 2020, were estimated. Complementary analyses included bivariate regressions ($\ln\text{CO}_2$ on $\ln\text{GDP}$ and $\ln\text{CO}_2$ on $\ln\text{Urban}$), alternative time windows to capture the effect of fuel-price reforms (pre- and post-2015), and rolling seven-year regressions to examine how elasticities evolved over time.

All data transformations and computations, including logs, growth rates, intensities, and elasticity estimates, were formula-based within the shared Excel workbook and supported by STATA output reports (Figures A1 and A2). The “Regressions” sheet in the workbook allows users to replicate country-specific estimates using a dropdown menu for country selection and a toggle to include or exclude 2020, ensuring full transparency and reproducibility of the analysis.

4. Results and Discussions

4.1. Historical Trend of Transport CO₂ Emissions and GDP/Capita

Figure 1 shows the historical trend of transport CO₂ emissions and GDP/capita in the GCC countries for the period studied (2012–2022).

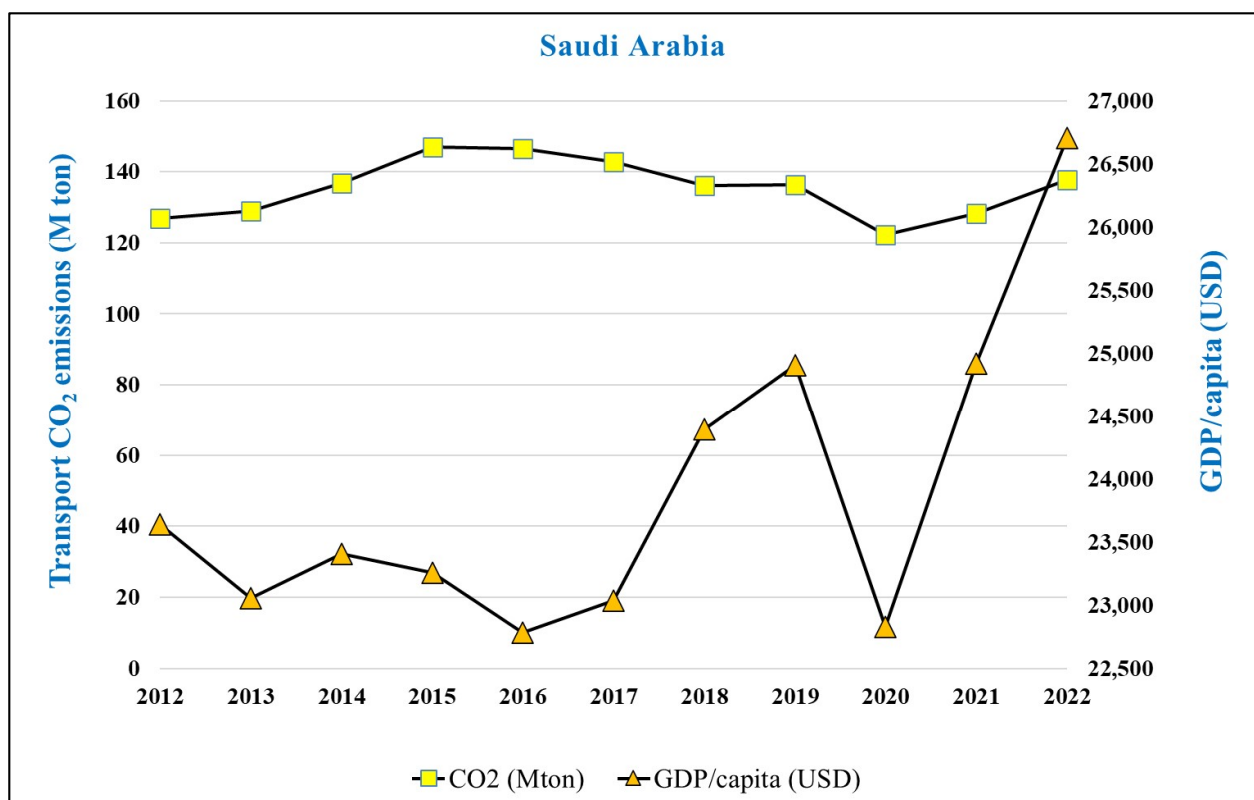


Figure 1. Cont.

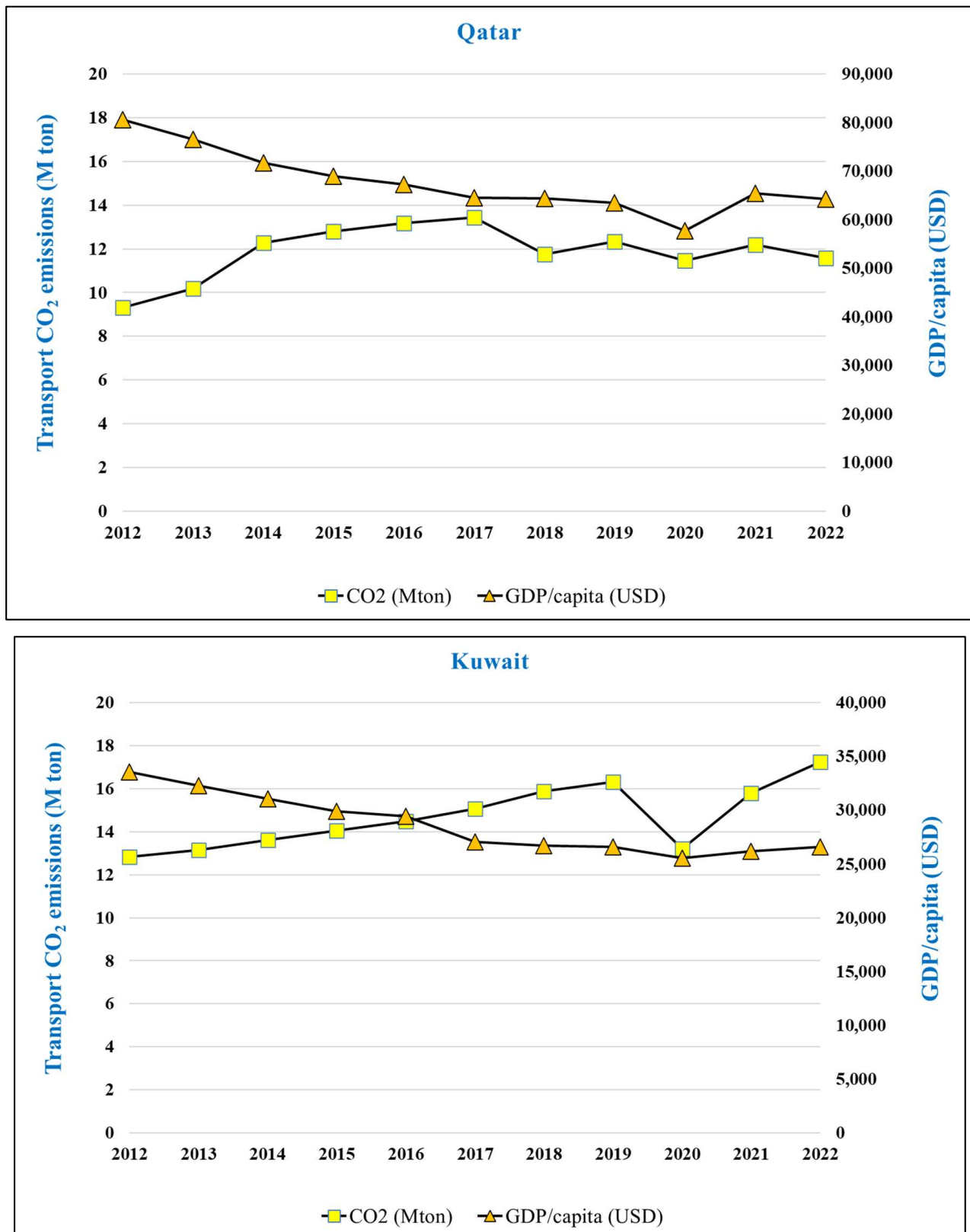


Figure 1. Cont.

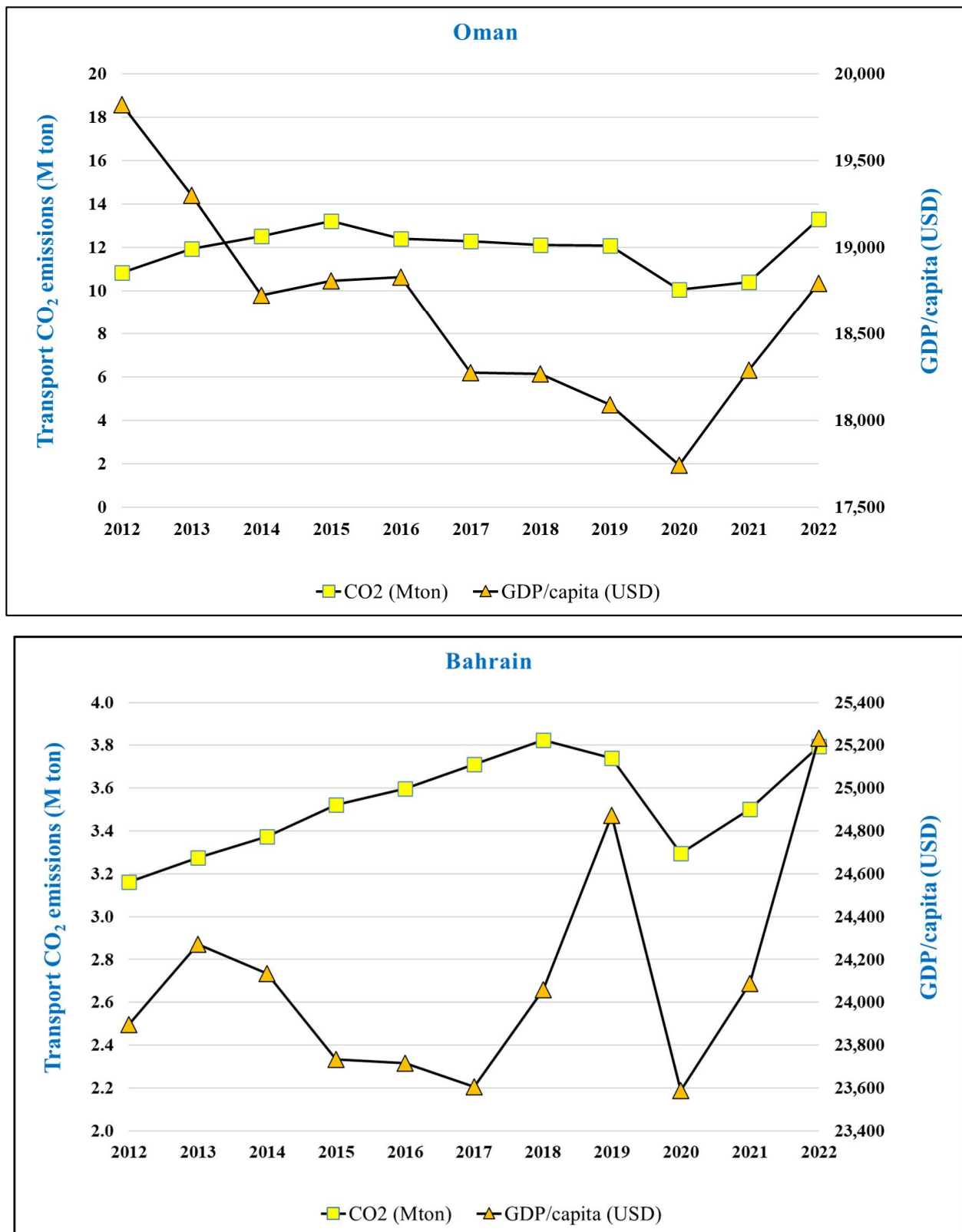


Figure 1. Cont.

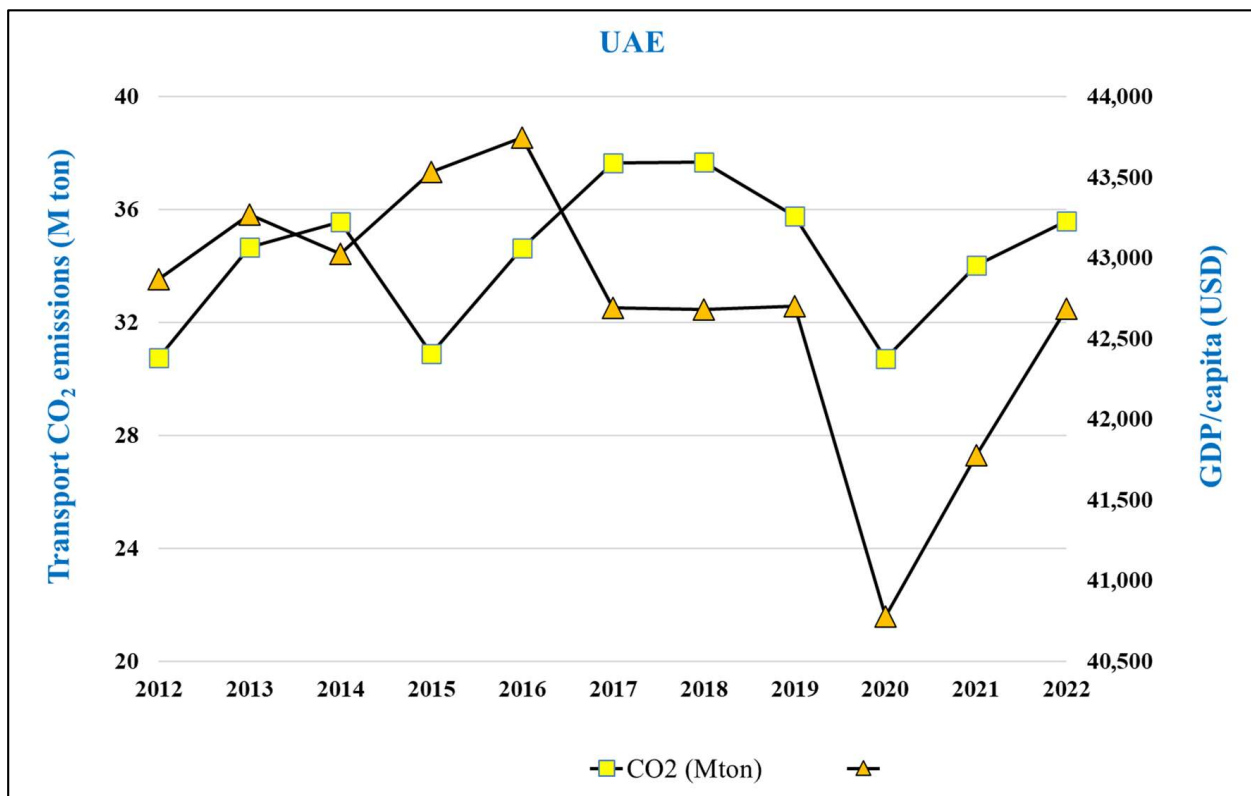


Figure 1. Historic trend in Transport CO₂ emissions and GDP/capita in the GCC countries.

Across the Gulf Cooperation Council (GCC), transport-related carbon dioxide (CO₂) emissions have followed distinct yet converging trajectories over the past decade, reflecting each country's economic structure, energy policy, and progress toward sustainability. While economic growth remains closely tied to hydrocarbon revenues, several GCC economies have shown early signs of decoupling transport emissions from income growth, signaling improved energy efficiency and a gradual transition toward lower-carbon mobility (Hamdi & Sbia, 2013).

In Saudi Arabia, emissions fluctuated between 120 and 145 million tons of CO₂ despite substantial changes in GDP per capita, which ranged from USD 26,000 in 2012 to nearly USD 27,000 in 2022. Following an initial rise linked to oil-driven prosperity, emissions stabilized after 2016 as the government began reforming fuel subsidies and promoting diversification under Vision 2030 (Moshashai et al., 2020). This steady emissions profile, combined with rising income levels, indicates progress toward energy-efficient transport and partial decoupling.

Qatar presents an even clearer case of divergence between emissions and income. Transport CO₂ emissions grew modestly from about 9 to 13 million tons until 2017, then declined to roughly 11–12 million tons by 2022 amid improvements in vehicle efficiency, cleaner fuels, and expanded public transport. Meanwhile, GDP per capita fell from about USD 85,000 to USD 60,000, reflecting population growth and shifting investment priorities. The opposite movements of income and emissions illustrate successful decoupling, consistent with Qatar's National Vision 2030 and its emphasis on sustainable mobility.

In Kuwait, emissions climbed steadily from 13 to 17 million tons, while GDP per capita dropped from USD 37,000 to roughly USD 30,000. This pattern reveals persistent carbon intensity and limited progress in transport efficiency. The dominance of private vehicles and slow adoption of low-emission alternatives suggest that Kuwait remains more tightly

coupled to fuel consumption than its regional peers, underscoring the need for fuel-pricing reform and public transit investment.

Oman exhibited moderate and relatively balanced trends. Emissions increased slightly from 10 to 13 million tons by 2015, then stabilized near that level through 2022, while GDP per capita declined from nearly USD 19,800 to around USD 19,000. The stability of emissions despite income fluctuations indicates partial decoupling, supported by emerging policies on energy efficiency and public transport expansion.

In Bahrain, emissions remained largely stable, around 3 to 4 million tons, throughout the decade, even as GDP per capita swung sharply with oil market cycles, dipping after 2013 and rising again to roughly USD 25,000 by 2022. The resilience of emissions to economic volatility suggests a more efficient, mature transport sector relative to its size.

Finally, in the United Arab Emirates, transport CO₂ emissions rose from 31 to 38 million tons by 2016 but later stabilized at about 35 million tons as the country advanced low-carbon transport and urban planning initiatives. GDP per capita followed a cyclical pattern, peaking near USD 43,500 and recovering to similar levels by 2022. The UAE's steady emissions despite a strong economic recovery reflect significant decoupling driven by electric mobility, clean fuels, and urban sustainability measures under the UAE Net Zero 2050 strategy.

4.2. GCC Transport-CO₂-Emission Elasticities

Figure 2 shows the results of the elasticity analysis for the period 2012–2022. Across the Gulf Cooperation Council, transport CO₂ is primarily driven by economic activity. Long-run log–log regressions indicate GDP elasticities above unity in Qatar, Kuwait, Oman, and the United Arab Emirates, implying that a 1% increase in GDP is associated with more than a 1% rise in transport emissions, conditional on urbanization.

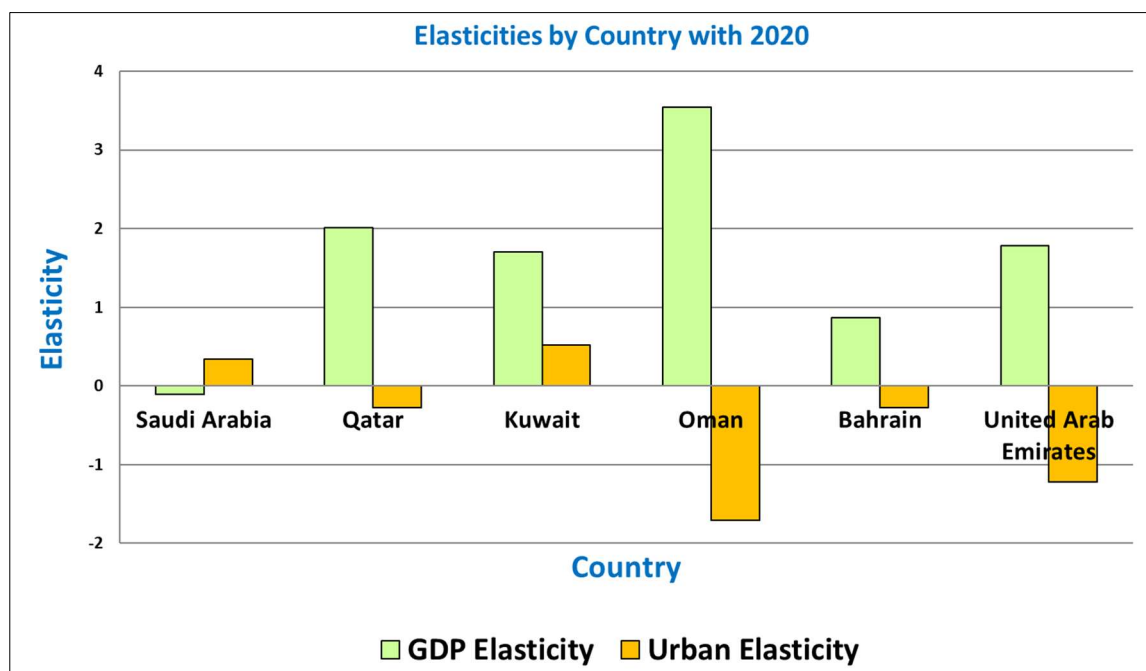


Figure 2. Comparison of GDP elasticity and urban elasticity across six GCC countries. Green bars represent GDP elasticity, and orange bars represent urban elasticity. Source: The authors.

In Bahrain, the GDP elasticity is close to one, while Saudi Arabia exhibits a near-zero (slightly negative) coefficient with very low explanatory power. Urbanization effects are heterogeneous: they are positive in Kuwait and Saudi Arabia, consistent with car-oriented

expansion, and negative in Oman, UAE, Qatar, and Bahrain, a pattern compatible with densification, transit capture, or residual collinearity with income.

As per Table 3, the model fit varies widely, with higher R^2 in Kuwait (~ 0.78), Bahrain (~ 0.71), and Qatar (~ 0.65), moderate fit in Oman (~ 0.59), and modest to weak fit in the UAE (~ 0.34) and Saudi Arabia (~ 0.07). In this log–log setting, an elasticity of 1.70, for example, means that a 1% increase in GDP is associated with a 1.7% increase in transport CO_2 , holding the other regressor constant.

Table 3. Regression analysis results showing GDP and urban elasticity coefficients and model fit (R^2) for six GCC countries.

Country	GDP Elasticity	Urban Elasticity	R^2
Saudi Arabia	−0.111042367	0.33889488	0.066819333
Qatar	2.011017076	−0.280226546	0.652021181
Kuwait	1.69962538	0.517150104	0.783009837
Oman	3.542883461	−1.70766139	0.593345905
Bahrain	0.872468534	−0.272083259	0.708211162
UAE	1.783062335	−1.217766397	0.338916252

Country patterns align with these aggregates. Saudi Arabia shows limited explanatory power from aggregate GDP and urbanization, suggesting that sector-specific factors, fuel-price reforms, aviation/freight cycles, and the timing of major infrastructure play a larger role. Qatar displays elastic GDP sensitivity and a small negative urban coefficient with a good overall fit, indicating that growth pressures dominate while urban structure may modestly dampen emissions. Kuwait combines elastic GDP and a positive urban effect, consistent with car-dependent urban growth and a well-explained series. Oman presents a very elastic GDP and a strongly negative urban coefficient; while this could reflect concentration of activity along efficient corridors, it also warrants caution given multicollinearity and the 2020 shock. Bahrain exhibits a near-unit GDP elasticity with a slightly negative urban effect, which may be influenced by compact geography and cross-border traffic. The UAE shows elastic GDP and a negative urban coefficient but only a modest fit, again pointing to omitted sectoral drivers (e.g., aviation, pricing, network roll-outs).

Policy implications follow directly. Where GDP elasticities exceed one, growth-driven pressure will outpace incremental efficiency unless binding measures are adopted: fuel-economy/ CO_2 standards, accelerated EV uptake with corridor fast-charging, bus electrification, and heavy-duty vehicle efficiency and logistics programs. Where urbanization raises emissions (Kuwait, Saudi Arabia), priority should fall on urban form and pricing, including transit-oriented development, parking, road-space management, and first/last-mile integration. Where urbanization appears emissions-dampening (Oman, UAE, Bahrain, Qatar), investments should consolidate those gains through network quality, access, and land-use coordination. Across the region, freight decarbonization is likely high yield given its large share of transport CO_2 . Monitoring should be resilient to shocks: excluding 2020, modeling it with a dummy variable, or using multi-year windows, reduces the influence of anomalous years on elasticity (Table 4).

These findings should be interpreted with standard caveats. Samples are short (≈ 11 years), and GDP and urbanization trend together, which inflate standard errors and can destabilize signs, particularly for the urban coefficient. Sectoral coverage and the mix of road versus aviation/freight can differ across countries, affecting comparability. The estimates describe associations rather than causal effects. Robustness checks (with/without

2020; bivariate fits; intensity and per capita views) and, where data permit, extensions that incorporate fuel prices, vehicle stock composition, transit supply, aviation passengers, and freight activity can strengthen inference and sharpen policy targeting.

Table 4. Summary of main transport–CO₂ policy priorities by GCC country (2012–2022).

Country	Elasticity Pattern	Key Policy Focus
Saudi Arabia	Near-zero GDP elasticity, positive urban elasticity, very low R ²	Sector-specific measures (aviation, freight), fuel-price and infrastructure reforms, targeted urban planning to curb car dependency
Qatar	Very high GDP elasticity (>2), slightly negative urban elasticity, strong fit	Manage growth pressure via CO ₂ /fuel economy standards, EV uptake, bus electrification, consolidate urban efficiency gains
Kuwait	High GDP elasticity (~1.7), positive urban elasticity, highest R ² (~0.78)	Address car-dependent urban growth with transit-oriented development, parking and road-space management, EV charging corridors
Oman	Extremely high GDP elasticity (~3.5), strongly negative urban elasticity, moderate fit	Reinforce efficient corridors, land-use coordination, and monitor for multicollinearity; adopt strong vehicle efficiency and freight programs
Bahrain	Near-unit GDP elasticity (~0.87), slightly negative urban elasticity, strong fit	Consolidate compact geography gains with quality transit, access management, and cross-border traffic coordination
United Arab Emirates	High GDP elasticity (~1.8), negative urban elasticity, modest R ² (~0.34)	Focus on omitted drivers (aviation, logistics), expand EV and heavy-duty vehicle programs, land-use/transit integration

4.3. GCC Transport-CO₂ Elasticities Emission Excluding 2020

Figure 3 shows the results of the elasticity analysis excluding the year 2020. Removing 2020 yields a cleaner read on structural relationships by minimizing pandemic-driven distortions.

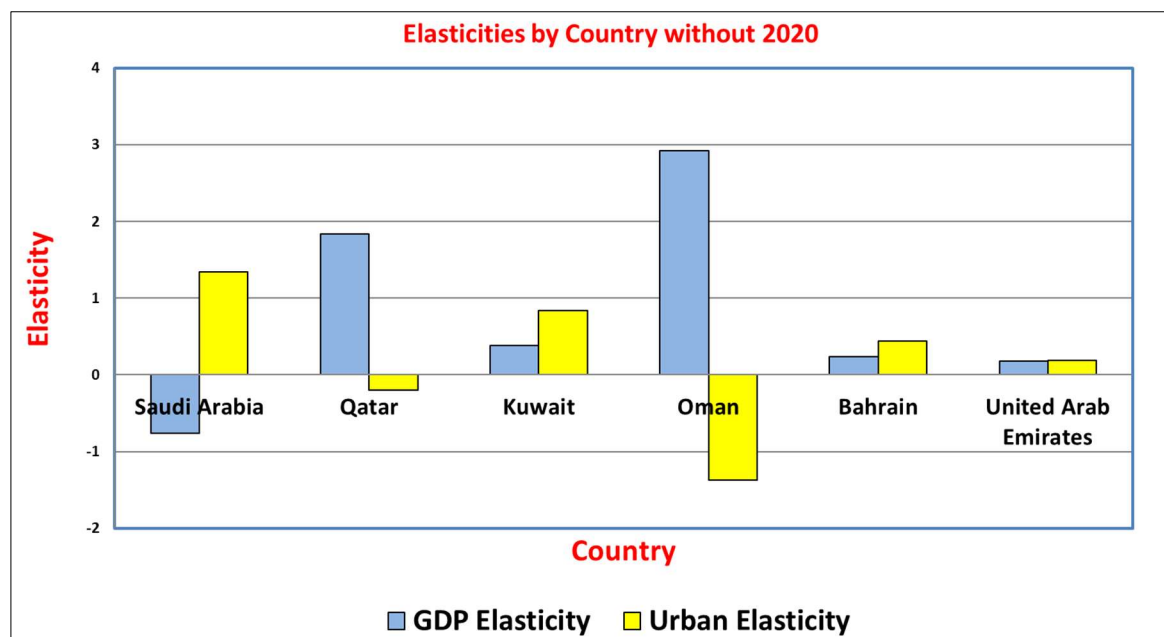


Figure 3. Comparison of GDP elasticity and urban elasticity across six GCC countries, excluding 2020. Blue bars represent GDP elasticity, and yellow bars represent urban elasticity. Source: The authors.

Two broad patterns emerge. First, GDP elasticities fall in most countries relative to the full sample but remain elastic (>1) in Qatar (~1.83) and Oman (~2.92), indicating that income

growth still raises transport CO₂ more than proportionally. In Kuwait (~0.38), Bahrain (~0.24), and the UAE (~0.17), GDP becomes inelastic, consistent with relative decoupling. Second, urbanization effects diverge; they are positive in Kuwait (~0.83), Bahrain (~0.44), Saudi Arabia (~1.34), and UAE (~0.19)—consistent with car-oriented expansion—while remaining negative in Oman (~−1.37) and Qatar (~−0.20), suggesting densification or transit capture once income is controlled for. Model fit improves or remains strong in several cases (Kuwait $R^2 \approx 0.98$; Bahrain 0.86; Qatar 0.65), is moderate in Saudi Arabia (0.59) and Oman (0.39), and remains modest in the UAE (0.30) (all $n = 10$).

In terms of regression, and as shown in Table 5, country patterns align with these aggregates. Saudi Arabia shows a negative GDP coefficient (−0.76) and a positive urban effect (+1.34) with $R^2 \approx 0.59$, implying that aggregate macro variables alone do not capture key sector drivers; price reforms, aviation/freight cycles, and fleet composition likely mediate emissions.

Table 5. Regression analysis, excluding 2020, results showing GDP and urban elasticity coefficients and model fit (R^2) for six GCC countries.

Country	GDP Elasticity	Urban Elasticity	R^2
Saudi Arabia	−0.75980478	1.339145507	0.593198515
Qatar	1.833242992	−0.20003415	0.649368063
Kuwait	0.382566179	0.833685353	0.978564084
Oman	2.922226829	−1.368374502	0.389752948
Bahrain	0.236429795	0.438801313	0.864890571
UAE	0.174749085	0.190413686	0.299598215

Qatar retains a robust, elastic GDP effect (+1.83) and a small negative urban coefficient (−0.20) with $R^2 \approx 0.65$, indicating growth-driven pressure tempered slightly by urban structure. Kuwait pivots to an urban-dominant profile (GDP +0.38; Urban +0.83) with very high fit ($R^2 \approx 0.98$), pointing to land-use and modal mix as primary levers. Oman remains GDP-elastic (+2.92) with negative urban (−1.37) but lower fit ($R^2 \approx 0.39$), suggesting omitted sectoral variables (freight corridors, ports, fuel pricing). Bahrain exhibits inelastic GDP (+0.24) and a positive urban effect (+0.44) with $R^2 \approx 0.86$, consistent with a compact yet car-reliant setting influenced by cross-border flows. In the UAE, both elasticities shrink toward zero (GDP +0.17; Urban +0.19) and $R^2 \approx 0.30$, indicating that aggregate GDP/urban proxies under-explain transport CO₂ amid aviation cycles, logistics growth, and rapid EV/transit roll-outs.

5. Conclusions and Policy Implications

5.1. Key Findings

The analysis shows that transport CO₂ emissions in the GCC remain closely tied to GDP growth. Long-run elasticities indicate that a one percent rise in GDP is associated with more than a one percent increase in transport emissions in Qatar, Oman, Kuwait, and the UAE, even after excluding the 2020 pandemic year, confirming emissions-intensive growth where economic expansion outpaces incremental efficiency gains. Urbanization exerts heterogeneous effects across the region. In Kuwait, Saudi Arabia, Bahrain, and the UAE, the positive elasticities are consistent with car-dependent urban expansion, while the negative elasticities observed in Oman and Qatar suggest either densification benefits or statistical overlap with income. Model performance also varies markedly between countries: Kuwait and Bahrain display high explanatory power, whereas Saudi Arabia and the UAE show weaker fits, pointing to sector-specific drivers such as fuel-price reforms,

aviation cycles, and freight activity that macro indicators alone cannot capture. Across the GCC, freight emerges as a major decarbonization priority because freight movements account for a disproportionate share of transport CO₂ and therefore offer the highest leverage for emissions reductions.

5.2. Policy Implications

Policy implications follow directly from the elasticities. Where GDP remains elastic (Qatar, Oman), binding measures are required to prevent emissions from outpacing growth: fuel-economy/CO₂ standards for light- and heavy-duty vehicles (Harrington & Krupnick, 2012), accelerated EV adoption with corridor fast-charging (Wolbertus & Van den Hoed, 2019), accelerated EV adoption with corridor fast-charging (Chiranjivi et al., 2024), and logistics efficiency programs (Dachkovskyi, 2021). Where urbanization is the main amplifier (Kuwait; also, Bahrain and Saudi Arabia to a degree), urban form and pricing dominate transit-oriented development, BRT/bus network upgrades with first/last-mile access, and parking/road-space management. Where macro elasticities are small (UAE), sector-specific levers—aviation and logistics efficiency, public-fleet electrification, targeted EV codes—are more informative than macro proxies for near-term planning.

These results should be interpreted with standard caveats. Samples are short ($n = 10$), and $\ln GDP$ and $\ln Urban$ are highly collinear in several countries, inflating standard errors and occasionally destabilizing signs. The estimates are associational, not causal. Reporting both panels (with and without 2020) or including a 2020, alongside bivariate checks and intensity/per capita trends, provides a transparent and defensible portrayal of elasticity-based decoupling across the GCC.

5.3. Limitations and Future Work

This study's conclusions should be interpreted with caution because of several limitations. The time series is relatively short at around ten to eleven years, which makes the elasticities sensitive to outliers, structural breaks, and COVID-19 shocks. GDP and urban population also trend together, inflating standard errors and sometimes destabilizing coefficients, particularly for the urban variable. Incorporating additional controls such as fuel prices, vehicle stock composition, transit supply, aviation passengers, and freight volumes would sharpen inference and allow clearer attribution of effects. The estimates presented here describe statistical responsiveness rather than direct causality; future research could employ instrumental-variable approaches, structural models, or panel methods to identify causal channels. Sectoral granularity is another limitation, since aviation, shipping, and road freight are aggregated in some national datasets; disaggregating transport CO₂ by mode and energy type would enable more targeted policy recommendations. Finally, rolling or time-varying elasticities and scenario analyses would reveal how fuel-price reforms, electric-vehicle adoption, and infrastructure investments alter elasticities over time, helping policymakers design adaptive strategies that respond to evolving transport and energy systems.

Author Contributions: Conceptualization, S.H.M.; methodology, S.H.M.; software, S.H.M.; validation, S.H.M.; formal analysis, S.H.M.; investigation, S.H.M.; resources, S.H.M.; data curation, S.H.M.; writing—original draft preparation, S.H.M.; writing—review and editing, S.H.M. and R.J.I.; visualization, S.H.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: All data related to this research is included in this manuscript and the Appendices A and B.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. STATA Analysis Including 2020.

Country	Year	Transport_co2_Mt	gdp_const_2015_usd	urban_pop_total	urban_pop_pct	pop_total	co2_per_capita_tonnes	co2_per_usd_kg	ln_co2	ln_gdp	ln_urban_pop	Growth_co2_pct	Growth_gdp_pct	Growth_urban_pct	yoy_elasticity_vs_gdp	yoy_elasticity_vs_urban
Saudi Arabia	2012	126.81	618,711,129,254	21,594,544	82.52	26,168,861	4.85	0.20	4.84	27.15	16.89					
Saudi Arabia	2013	128.90	636,936,502,413	22,856,101	82.74	27,624,004	4.67	0.20	4.86	27.18	16.94	1.64	2.90	5.68	0.56	0.29
Saudi Arabia	2014	136.72	662,570,908,160	23,485,373	82.96	28,309,273	4.83	0.21	4.92	27.22	16.97	5.89	3.95	2.72	1.49	2.17
Saudi Arabia	2015	146.94	693,414,400,000	24,801,267	83.18	29,816,382	4.93	0.21	4.99	27.26	17.03	7.21	4.55	5.45	1.58	1.32
Saudi Arabia	2016	146.45	705,230,699,063	25,816,111	83.40	30,954,198	4.73	0.21	4.99	27.28	17.07	−0.33	1.69	4.01	−0.20	−0.08
Saudi Arabia	2017	142.91	713,567,089,639	25,903,884	83.62	30,977,355	4.61	0.20	4.96	27.29	17.07	−2.45	1.18	0.34	−2.08	−7.21
Saudi Arabia	2018	136.10	736,593,549,190	25,317,770	83.84	30,196,281	4.51	0.18	4.91	27.33	17.05	−4.88	3.18	−2.29	−1.54	2.13
Saudi Arabia	2019	136.43	748,758,860,046	25,273,133	84.07	30,063,799	4.54	0.18	4.92	27.34	17.05	0.24	1.64	−0.18	0.15	−1.36
Saudi Arabia	2020	122.32	720,270,347,023	26,594,664	84.29	31,552,510	3.88	0.17	4.81	27.30	17.10	−10.92	−3.88	5.10	2.81	−2.14
Saudi Arabia	2021	128.22	767,229,070,839	26,015,266	84.51	30,784,383	4.17	0.17	4.85	27.37	17.07	4.71	6.32	−2.20	0.75	−2.14
Saudi Arabia	2022	137.77	859,301,066,621	27,261,746	84.73	32,175,224	4.28	0.16	4.93	27.48	17.12					
Qatar	2012	9.30	138,866,156,528	1,699,995	98.70	1,722,438	5.40	0.07	2.23	25.66	14.35					
Qatar	2013	10.19	146,581,616,624	1,893,141	98.79	1,916,426	5.32	0.07	2.32	25.71	14.45	9.10	5.41	10.76	1.68	0.85
Qatar	2014	12.27	154,400,753,941	2,127,387	98.87	2,151,745	5.70	0.08	2.51	25.76	14.57	18.56	5.20	11.67	3.57	1.59
Qatar	2015	12.79	161,739,955,577	2,319,822	98.95	2,344,557	5.46	0.08	2.55	25.81	14.66	4.20	4.64	8.66	0.90	0.48
Qatar	2016	13.18	166,695,978,169	2,452,713	99.02	2,477,113	5.32	0.08	2.58	25.84	14.71	2.99	3.02	5.57	0.99	0.54
Qatar	2017	13.45	164,199,531,362	2,522,348	99.08	2,545,820	5.28	0.08	2.60	25.82	14.74	2.04	−1.51	2.80	−1.35	0.73
Qatar	2018	11.76	166,227,185,730	2,558,411	99.14	2,580,734	4.56	0.07	2.46	25.84	14.75	−13.44	1.23	1.42	−10.95	−9.47
Qatar	2019	12.33	167,371,229,300	2,617,231	99.19	2,638,657	4.67	0.07	2.51	25.84	14.78	4.74	0.69	2.27	6.91	2.09
Qatar	2020	11.45	161,416,823,769	2,772,773	99.24	2,794,148	4.10	0.07	2.44	25.81	14.84	−7.39	−3.62	5.77	2.04	−1.28
Qatar	2021	12.18	164,042,828,071	2,486,825	99.28	2,504,910	4.86	0.07	2.50	25.82	14.73	6.18	1.61	−10.88	3.83	−0.57
Qatar	2022	11.58	170,908,036,354	2,639,210	99.32	2,657,333	4.36	0.07	2.45	25.86	14.79					
Kuwait	2012	12.85	112,054,550,828	3,337,109	100.00	3,337,109	3.85	0.11	2.55	25.44	15.02					
Kuwait	2013	13.15	113,342,579,056	3,507,844	100.00	3,507,844	3.75	0.12	2.58	25.45	15.07	2.35	1.14	4.99	2.06	0.47
Kuwait	2014	13.62	113,910,328,740	3,665,876	100.00	3,665,876	3.71	0.12	2.61	25.46	15.11	3.48	0.50	4.41	6.97	0.79
Kuwait	2015	14.05	114,585,555,831	3,834,574	100.00	3,834,574	3.66	0.12	2.64	25.46	15.16	3.14	0.59	4.50	5.31	0.70
Kuwait	2016	14.50	117,938,416,139	4,004,096	100.00	4,004,096	3.62	0.12	2.67	25.49	15.20	3.15	2.88	4.33	1.09	0.73
Kuwait	2017	15.08	112,380,895,320	4,154,812	100.00	4,154,812	3.63	0.13	2.71	25.45	15.24	3.90	−4.83	3.69	−0.81	1.06
Kuwait	2018	15.89	115,463,874,741	4,323,515	100.00	4,323,515	3.68	0.14	2.77	25.47	15.28	5.25	2.71	3.98	1.94	1.32
Kuwait	2019	16.31	118,077,765,457	4,442,316	100.00	4,442,316	3.67	0.14	2.79	25.49	15.31	2.58	2.24	2.71	1.15	0.95
Kuwait	2020	13.21	112,389,026,890	4,400,267	100.00	4,400,267	3.00	0.12	2.58	25.45	15.30	−21.06	−4.94	−0.95	4.26	22.14
Kuwait	2021	15.80	114,268,887,222	4,360,865	100.00	4,360,865	3.62	0.14	2.76	25.46	15.29	17.89	1.66	−0.90	10.79	−19.89
Kuwait	2022	17.24	121,991,940,847	4,589,643	100.00	4,589,643	3.76	0.14	2.85	25.53	15.34					
Oman	2012	10.84	70,318,260,490	2,751,277	77.56	3,547,106	3.06	0.15	2.38	24.98	14.83					
Oman	2013	11.95	73,994,291,063	3,024,267	78.88	3,833,913	3.12	0.16	2.48	25.03	14.92	9.72	5.10	9.46	1.91	1.03
Oman	2014	12.54	74,950,483,987	3,207,755	80.15	4,002,439	3.13	0.17	2.53	25.04	14.98	4.83	1.28	5.89	3.76	0.82
Oman	2015	13.21	78,710,793,238	3,404,412	81.35	4,184,895	3.16	0.17	2.58	25.09	15.04	5.23	4.90	5.95	1.07	0.88
Oman	2016	12.41	82,682,873,556	3,622,474	82.50	4,390,877	2.83	0.15	2.52	25.14	15.10	−6.24	4.92	6.21	−1.27	−1.00
Oman	2017	12.30	82,934,277,089	3,791,448	83.56	4,537,396	2.71	0.15	2.51	25.14	15.15	−0.87	0.30	4.56	−2.88	−0.19
Oman	2018	12.14	84,001,727,416	3,886,999	84.54	4,597,877	2.64	0.14	2.50	25.15	15.17	−1.37	1.28	2.49	−1.07	−0.55
Oman	2019	12.09	83,053,651,985	3,922,894	85.44	4,591,241	2.63	0.15	2.49	25.14	15.18	−0.38	−1.14	0.92	0.33	−0.41
Oman	2020	10.05	80,246,670,661	3,901,830	86.28	4,522,497	2.22	0.13	2.31	25.11	15.18	−18.46	−3.44	−0.54	5.37	34.29
Oman	2021	10.41	82,318,780,120	3,917,349	87.04	4,500,424	2.31	0.13	2.34	25.13	15.18	3.45	2.55	0.40	1.35	8.70
Oman	2022	13.30	88,892,516,940	4,150,773	87.75	4,730,226	2.81	0.15	2.59	25.21	15.24					
Bahrain	2012	3.16	28,888,050,242	1,073,101	88.76	1,208,964	2.61	0.11	1.15	24.09	13.89					
Bahrain	2013	3.28	30,416,985,616	1,113,272	88.84	1,253,191	2.61	0.11	1.19	24.14	13.92	3.57	5.16	3.68	0.69	0.97
Bahrain	2014	3.37	31,727,610,008	1,168,843	88.92	1,314,562	2.57	0.11	1.22	24.18	13.97	2.95	4.22	4.87	0.70	0.61
Bahrain	2015	3.52	32,523,297,872	1,219,573	89.00	1,370,322	2.57	0.11	1.26	24.21	14.01	4.29	2.48	4.25	1.73	1.01
Bahrain	2016	3.60	33,764,059,499	1,268,397	89.09	1,423,726	2.53	0.11	1.28	24.24	14.05	2.16	3.74	3.93	0.58	0.55
Bahrain	2017	3.71	35,436,675,411	1,338,785	89.19	1,501,116	2.47	0.10	1.31	24.29	14.11	3.04	4.84	5.40	0.63	0.56
Bahrain	2018	3.82	36,164,044,588	1,342,065	89.29	1,503,091	2.54	0.11	1.34	24.31	14.11	3.03	2.03	0.24	1.49	12.37
Bahrain	2019	3.74	36,906,448,211	1,326,389	89.39	1,483,756	2.52	0.10	1.32	24.33	14.10	−2.22	2.03	−1.17	−1.09	1.89
Bahrain	2020	3.29	34,724,774,104	1,317,711	89.51	1,472,204	2.24	0.09	1.19	24.27	14.09	−12.70	−6.09	−0.66	2.08	19.35
Bahrain	2021	3.50	36,235,315,986	1,348,242	89.62	1,504,365	2.33	0.10	1.25	24.31	14.11	6.12	4.26	2.29	1.44	2.67
Bahrain	2022	3.80	38,474,716,945	1,368,305	89.74	1,524,693	2.49	0.10	1.33	24.37	14.13					
United Arab Emirates	2012	30.76	316,857,313,566	6,264,178	84.75	7,391,448	4.16	0.10	3.43	26.48	15.65					
United Arab Emirates	2013	34.67	332,876,224,084	6,544,154	85.07	7,693,031	4.51	0.10	3.55	26.53	15.69	11.97	4.93	4.37	2.43	2.74
United Arab Emirates	2014	35.58	346,742,821,790	6,880,747	85.38	8,059,440	4.41	0.10	3.57	26.57	15.74	2.58	4.08	5.02	0.63	0.51

Table A1. Cont.

Country	Year	Transport_co2_Mt	gdp_const_2015_usd	urban_pop_total	urban_pop_pct	pop_total	co2_per_capita_tonnes	co2_per_usd_kg	ln_co2	ln_gdp	ln_urban_pop	Growth_co2_pct	Growth_gdp_pct	Growth_urban_pct	yoy_elasticity_vs_gdp	yoy_elasticity_vs_urban
United Arab Emirates	2015	30.88	370,275,469,571	7,286,777	85.67	8,505,237	3.63	0.08	3.43	26.64	15.80	−14.16	6.57	5.73	−2.16	−2.47
United Arab Emirates	2016	34.63	390,868,305,597	7,681,054	85.97	8,935,095	3.88	0.09	3.54	26.69	15.85	11.46	5.41	5.27	2.12	2.17
United Arab Emirates	2017	37.66	393,741,456,224	7,954,847	86.25	9,223,225	4.08	0.10	3.63	26.70	15.89	8.39	0.73	3.50	11.46	2.40
United Arab Emirates	2018	37.67	398,914,879,875	8,086,953	86.52	9,346,701	4.03	0.09	3.63	26.71	15.91	0.02	1.31	1.65	0.02	0.01
United Arab Emirates	2019	35.78	403,336,245,504	8,197,902	86.79	9,445,785	3.79	0.09	3.58	26.72	15.92	−5.15	1.10	1.36	−4.67	−3.78
United Arab Emirates	2020	30.71	383,342,656,333	8,183,416	87.05	9,401,038	3.27	0.08	3.42	26.67	15.92	−15.28	−5.08	−0.18	3.00	86.38
United Arab Emirates	2021	34.02	400,036,290,964	8,359,012	87.30	9,575,152	3.55	0.09	3.53	26.71	15.94	10.24	4.26	2.12	2.40	4.82
United Arab Emirates	2022	35.59	430,077,804,445	8,819,937	87.54	10,074,977	3.53	0.08	3.57	26.79	15.99	4.50	7.24	5.37	0.62	0.84

```
. reg ln_co2 ln_gdp ln_urban_pop if country=="Saudi Arabia"
```

Source	SS	df	MS	Number of obs	=	11
				F(2, 8)	=	0.29
Model	.002420233	2	.001210116	Prob > F	=	0.7583
Residual	.033800316	8	.004225039	R-squared	=	0.0668
				Adj R-squared	=	-0.1665
Total	.036220548	10	.003622055	Root MSE	=	.065

ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	-.1110424	.4750134	-0.23	0.821	-1.206425	.9843406
ln_urban_pop	.3388949	.6185926	0.55	0.599	-1.087582	1.765372
_cons	2.165181	6.223446	0.35	0.737	-12.18611	16.51647

```
. reg ln_co2 ln_gdp ln_urban_pop if country=="Qatar"
```

Source	SS	df	MS	Number of obs	=	11
				F(2, 8)	=	7.49
Model	.078084334	2	.039042167	Prob > F	=	0.0147
Residual	.041673024	8	.005209128	R-squared	=	0.6520
				Adj R-squared	=	0.5650
Total	.119757358	10	.011975736	Root MSE	=	.07217

ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	2.011017	1.055407	1.91	0.093	-.4227569	4.444791
ln_urban_pop	-.2802265	.438935	-0.64	0.541	-1.292412	.7319593
_cons	-45.30154	21.2907	-2.13	0.066	-94.39798	3.794905

Figure A1. Cont.

. reg ln_co2 ln_gdp ln_urban_pop if country=="Kuwait"						
Source	SS	df	MS	Number of obs	=	11
				F(2, 8)	=	14.43
Model	.076647395	2	.038323697	Prob > F	=	0.0022
Residual	.021240769	8	.002655096	R-squared	=	0.7830
				Adj R-squared	=	0.7288
Total	.097888163	10	.009788816	Root MSE	=	.05153
ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	1.699625	.7374832	2.30	0.050	-.0010139	3.400265
ln_urban_pop	.5171501	.1828008	2.83	0.022	.0956106	.9386896
_cons	-48.47075	17.43286	-2.78	0.024	-88.67099	-8.270513
. reg ln_co2 ln_gdp ln_urban_pop if country=="Oman"						
Source	SS	df	MS	Number of obs	=	11
				F(2, 8)	=	5.84
Model	.050307291	2	.025153645	Prob > F	=	0.0273
Residual	.034478481	8	.00430981	R-squared	=	0.5933
				Adj R-squared	=	0.4917
Total	.084785772	10	.008478577	Root MSE	=	.06565
ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	3.542883	1.041182	3.40	0.009	1.141913	5.943854
ln_urban_pop	-1.707661	.5405034	-3.16	0.013	-2.954065	-.4612582
_cons	-60.70485	18.50799	-3.28	0.011	-103.3843	-18.02536

Figure A1. Cont.

```
. reg ln_co2 ln_gdp ln_urban_pop if country=="Bahrain"
```

Source	SS	df	MS	Number of obs	=	11
				F(2, 8)	=	9.71
Model	.030034585	2	.015017293	Prob > F	=	0.0072
Residual	.012374497	8	.001546812	R-squared	=	0.7082
				Adj R-squared	=	0.6353
Total	.042409082	10	.004240908	Root MSE	=	.03933

ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	.8724685	.6162919	1.42	0.195	-.5487031	2.29364
ln_urban_pop	-.2720833	.642742	-0.42	0.683	-1.754249	1.210082
_cons	-16.07693	6.494081	-2.48	0.038	-31.05231	-1.101554

```
. reg ln_co2 ln_gdp ln_urban_pop if country=="United Arab Emirates"
```

Source	SS	df	MS	Number of obs	=	11
				F(2, 8)	=	2.05
Model	.019442423	2	.009721212	Prob > F	=	0.1910
Residual	.03792403	8	.004740504	R-squared	=	0.3389
				Adj R-squared	=	0.1736
Total	.057366454	10	.005736645	Root MSE	=	.06885

ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	1.783062	1.127784	1.58	0.153	-.8176117	4.383736
ln_urban_pop	-1.217766	.950512	-1.28	0.236	-3.409651	.9741181
_cons	-24.69907	15.65499	-1.58	0.153	-60.79955	11.40141

Figure A1. Stata data analysis of 6 GCC countries including 2020.

Appendix B. STATA Analysis Excluding 2020

. drop if year == 2020 (6 observations deleted)						
. reg ln_co2 ln_gdp ln_urban_pop if country=="Saudi Arabia"						
Source	SS	df	MS	Number of obs	=	10
				F(2, 7)	=	5.10
Model	.014949298	2	.007474649	Prob > F	=	0.0429
Residual	.010251875	7	.001464554	R-squared	=	0.5932
				Adj R-squared	=	0.4770
Total	.025201173	9	.00280013	Root MSE	=	.03827
ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	-.7598048	.3230959	-2.35	0.051	-1.523805	.0041957
ln_urban_pop	1.339146	.4414377	3.03	0.019	.2953112	2.38298
_cons	2.852403	3.668113	0.78	0.462	-5.821306	11.52611
. reg ln_co2 ln_gdp ln_urban_pop if country=="Qatar"						
Source	SS	df	MS	Number of obs	=	10
				F(2, 7)	=	6.48
Model	.077126582	2	.038563291	Prob > F	=	0.0255
Residual	.041645169	7	.00594931	R-squared	=	0.6494
				Adj R-squared	=	0.5492
Total	.11877175	9	.013196861	Root MSE	=	.07713
ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	1.833243	2.832328	0.65	0.538	-4.864148	8.530634

Figure A2. Cont.

. reg ln_co2 ln_gdp ln_urban_pop if country=="Qatar"						
Source	SS	df	MS	Number of obs	=	10
				F(2, 7)	=	6.48
Model	.077126582	2	.038563291	Prob > F	=	0.0255
Residual	.041645169	7	.00594931	R-squared	=	0.6494
				Adj R-squared	=	0.5492
Total	.11877175	9	.013196861	Root MSE	=	.07713
ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	1.833243	2.832328	0.65	0.538	-4.864148	8.530634
ln_urban_pop	-.2000341	1.262354	-0.16	0.879	-3.185028	2.784959
_cons	-41.89031	54.79985	-0.76	0.470	-171.4714	87.69074
. reg ln_co2 ln_gdp ln_urban_pop if country=="Bahrain"						
Source	SS	df	MS	Number of obs	=	10
				F(2, 7)	=	22.40
Model	.032481146	2	.016240573	Prob > F	=	0.0009
Residual	.005074063	7	.000724866	R-squared	=	0.8649
				Adj R-squared	=	0.8263
Total	.037555209	9	.004172801	Root MSE	=	.02692
ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	.2364298	.4670724	0.51	0.628	-.868021	1.340881
ln_urban_pop	.4388013	.4937328	0.89	0.404	-.7286912	1.606294
_cons	-10.62867	4.765547	-2.23	0.061	-21.89739	.6400602

Figure A2. Cont.

```
. reg ln_co2 ln_gdp ln_urban_pop if country=="United Arab Emirates"
```

Source	SS	df	MS	Number of obs	=	10
Model	.013219765	2	.006609883	F(2, 7)	=	1.50
Residual	.030905215	7	.004415031	Prob > F	=	0.2876
				R-squared	=	0.2996
				Adj R-squared	=	0.0995
Total	.04412498	9	.004902776	Root MSE	=	.06645

ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	.1747491	1.6768	0.10	0.920	-3.790253	4.139752
ln_urban_pop	.1904137	1.445263	0.13	0.899	-3.227091	3.607919
_cons	-4.128659	22.23556	-0.19	0.858	-56.70741	48.45009

```
. reg ln_co2 ln_gdp ln_urban_pop if country=="Kuwait"
```

Source	SS	df	MS	Number of obs	=	10
Model	.08451165	2	.042255825	F(2, 7)	=	159.78
Residual	.001851268	7	.000264467	Prob > F	=	0.0000
				R-squared	=	0.9786
				Adj R-squared	=	0.9724
Total	.086362918	9	.00959588	Root MSE	=	.01626

ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	.3825662	.2789885	1.37	0.213	-.2771368	1.042269
ln_urban_pop	.8336854	.0685209	12.17	0.000	.6716592	.9957116
_cons	-19.72481	6.445306	-3.06	0.018	-34.96554	-4.484083

```
. reg ln_co2 ln_gdp ln_urban_pop if country=="Oman"
```

Source	SS	df	MS	Number of obs	=	10
Model	.02101159	2	.010505795	F(2, 7)	=	2.24
Residual	.032898433	7	.004699776	Prob > F	=	0.1775
				R-squared	=	0.3898
				Adj R-squared	=	0.2154
Total	.053910023	9	.005990003	Root MSE	=	.06855

ln_co2	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ln_gdp	2.922227	1.525762	1.92	0.097	-.6856281	6.530082
ln_urban_pop	-1.368375	.813009	-1.68	0.136	-3.290835	.5540864
_cons	-50.23677	26.44773	-1.90	0.099	-112.7757	12.30218

Figure A2. Stata data analysis of 6 GCC countries excluding 2020.

References

- Akimoto, K. (2023). Assessment of road transportation measures for global net-zero emissions considering comprehensive energy systems. *IATSS Research*, 47(2), 196–203. [CrossRef]
- Akinyemi, T. O., & Ramonu, O. J. (2019). Mitigation of CO₂ emissions in transportation and industrial processes using renewable energy technologies: A review. *European Journal of Engineering and Technology Research*, 4(5), 58–66. [CrossRef]
- Aldegheishem, A. (2024). The impact of air transportation, trade openness, and economic growth on CO₂ emissions in Saudi Arabia. *Frontiers in Environmental Science*, 12, 1366054. [CrossRef]
- Al-Thani, M. (2023). *Traffic accident predictive model for better resources in Qatar*. Hamad bin Khalifa University.
- Amer, E. A. A. A., Xiuwu, Z., Meyad, E. M. A., Alareqi, M. M., Bather, S. M. H., & Abdelwahed, A. (2025). Urbanization, growth, and carbon footprints: A GCC perspective on sustainable development. *Sustainable Futures*, 9, 100631. [CrossRef]
- Binsuwadan, J. (2024). Transport sector emissions and environmental sustainability: Empirical evidence from GCC economies. *Sustainability*, 16(23), 10760. [CrossRef]
- Charabi, Y., Al Nasiri, N., Al Awadhi, T., Choudri, B. S., & Al Bimani, A. (2020). GHG emissions from the transport sector in Oman: Trends and potential decarbonization pathways. *Energy Strategy Reviews*, 32, 100548. [CrossRef]
- Chiranjivi, D. M., Suresh, M. K., & Siddhartha, M. M. (2024). Navigating the present and future dynamics of electric vehicle fast charging and its impact on grid. *CVR Journal of Science and Technology*, 26(1), 68–75. [CrossRef]
- Dachkovskiy, V. (2021). Methods of evaluation of efficiency of logistic operations. *Social Development and Security*, 11(1), 179–196. [CrossRef]
- Dong, B., Xu, Y., & Fan, X. (2020). How to achieve a win-win situation between economic growth and carbon emission reduction: Empirical evidence from the perspective of industrial structure upgrading. *Environmental Science and Pollution Research*, 27(35), 43829–43844. [CrossRef]
- Fan, J., Meng, X., Tian, J., Xing, C., Wang, C., & Wood, J. (2023). A review of transportation carbon emissions research using bibliometric analyses. *Journal of Traffic and Transportation Engineering (English Edition)*, 10(5), 878–899. [CrossRef]
- Foster, V., Dim, J. U., Vollmer, S., & Zhang, F. (2023). Understanding the challenge of decoupling transport-related CO₂ emissions from economic growth in developing countries. *World Development Sustainability*, 3, 100111. [CrossRef]
- Hamdi, H., & Sbia, R. (2013). Dynamic relationships between oil revenues, government spending and economic growth in an oil-dependent economy. *Economic Modelling*, 35, 118–125. [CrossRef]
- Harrington, W., & Krupnick, A. (2012). *Improving fuel economy in heavy-duty vehicles* (SSRN Scholarly Paper No. 2038842). Social Science Research Network. [CrossRef]
- Hassabou, A., Melhim, S. H., & Isaifan, R. J. (2025). Techno-economic analysis and assessment of an innovative solar hybrid photovoltaic thermal collector for transient net zero emissions. *Sustainability*, 17(18), 8304. [CrossRef]
- IEA. (2023). *CO₂ emissions in 2022*. IEA.
- International Energy Agency. (2025). *Energy statistics data browser—Data tools*. Available online: <https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser> (accessed on 29 August 2025).
- IPCC. (2020). *Transport*. Available online: https://www.ipcc.ch/report/ar6/wg3/chapter/chapter-10/?utm_source=chatgpt.com (accessed on 29 August 2025).
- Kaššaj, M., & Peráček, T. (2024). Synergies and potential of industry 4.0 and automated vehicles in smart city infrastructure. *Applied Sciences*, 14(9), 3575. [CrossRef]
- Koimur, I., Kangogo, L. K., & Nyaoga, R. (2014). Assessment of commuter preferences of 14-seater public service vehicles versus alternative modes of public service transport in Nairobi city. *Journal of Business Economics and Finance*, 3(1), 115–132.
- Luqman, M., Rayner, P. J., & Gurney, K. R. (2023). On the impact of urbanisation on CO₂ emissions. *Npj Urban Sustainability*, 3(1), 6. [CrossRef]
- Magazzino, C. (2016). The relationship between real GDP, CO₂ emissions, and energy use in the GCC countries: A time series approach. *Cogent Economics & Finance*, 4(1), 1152729. [CrossRef]
- Marzouk, O. A. (2017, November 13–14). *Benchmarking the trends of urbanization in the gulf cooperation council: Outlook to 2050*. 1st National Symposium on Emerging Trends in Engineering and Management (NSETEM'2017) (pp. 1–9), Muscat, Oman.
- Melhim, S. H., & Isaifan, R. J. (2025). The energy-economy nexus of advanced air pollution control technologies: Pathways to sustainable development. *Energies*, 18(9), 2378. [CrossRef]
- Moshashai, D., Leber, A. M., & Savage, J. D. (2020). Saudi Arabia plans for its economic future: Vision 2030, the national transformation plan and saudi fiscal reform. *British Journal of Middle Eastern Studies*, 47(3), 381–401. [CrossRef]
- Qadir, S. A., Ali, A., Islam, M. T., & Shahid, M. (2024, November 24–27). *Evolution in the GCC: Assessing the progress and prospects of electric vehicle policies*. 2024 IEEE Sustainable Power and Energy Conference (iSPEC) (pp. 291–296), Kuching, Malaysia. [CrossRef]
- Ramadan, E. (2015). Sustainable urbanization in the arabian gulf region: Problems and challenges. *Arts and Social Sciences Journal*, 6(2), 1000109. [CrossRef]
- Sinha, K. C. (2003). Sustainability and urban public transportation. *Journal of Transportation Engineering*, 129(4), 331–341. [CrossRef]

- Szczepański, E., Żochowska, R., Izdebski, M., & Jacyna, M. (2025). Decision-making problems in urban transport decarbonization strategies: Challenges, tools, and methods. *Energies*, 18(15), 3970. [CrossRef]
- Tapio, P. (2005). Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transport Policy*, 12(2), 137–151. [CrossRef]
- The Official Portal of the UAE Government. (2023). *Deregulation of fuel prices*. Available online: https://u.ae/en/information-and-services/environment-and-energy/water-and-energy/energy-and-fuel-prices/deregulation-of-fuel-prices?utm_source=chatgpt.com (accessed on 29 August 2025).
- The Peninsula Newspaper. (2016, April 26). *Qatar to link petrol and diesel prices to global market from May 1*. Available online: <https://thepeninsulaqatar.com/article/26/04/2016/Qatar-to-link-petrol-and-diesel-prices-to-global-market-from-May-1> (accessed on 29 August 2025).
- Wolbertus, R., & Van den Hoed, R. (2019). Electric vehicle fast charging needs in cities and along corridors. *World Electric Vehicle Journal*, 10(2), 45. [CrossRef]
- World Bank Group. (2025). *World development indicators databank*. Available online: <https://databank.worldbank.org/reports.aspx?source=2&country=WLD> (accessed on 29 August 2025).
- Yahia, O., Chohan, A. H., Arar, M., & Awad, J. (2025). Toward sustainable urban mobility: A systematic review of transit-oriented development for the appraisal of dubai metro stations. *Smart Cities*, 8(1), 21. [CrossRef]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.