

## Introduction

Electric vehicles (EVs) are widely recognized as a critical pathway toward carbon neutrality in the transport sector, and governments across the world have actively promoted EV adoption through subsidies, tax credits, and exemptions from fuel taxes, registration fees, and road charges. However, because EVs incur no fuel tax liability during operation, they generate a free-riding problem within the current ICE-centered tax system - accelerating the structural decline of transport revenues. This is not simply a matter of revenue leakage, but a consequence of policy design.

### 1. Erosion of Fuel Tax Revenue

- EV diffusion is reducing the fuel tax base - the primary source of road infrastructure financing
- Vehicle efficiency gains + frozen nominal tax rates → long-term structural revenue decline

### 2. The Structural Paradox of EV Adoption

- EV adoption simultaneously undermines revenue stability & tax equity
- ~70% of fuel tax revenue losses are attributable to high-income EV adopters (Davis & Sallee, 2020)

### 3. Regressivity and Distributional Inequity

- Fuel taxes are inherently regressive: lowest-income households spend ~5% of expenditures on gasoline vs. <2% for highest-income households (Glaeser et al., 2023)
- As high-income households exit the fuel tax base, the burden shifts increasingly to low-income, ICE-dependent households (Burns et al., 2025)

As Caulfield et al. (2022) emphasize, the challenge is not to discourage EV transition, but to ensure that the transition is fiscally sustainable and distributionally fair. This study examines whether a Vehicle Miles Traveled (VMT) tax can serve as a viable alternative that addresses both revenue stability and tax equity in the Korean context.

## Research Questions & Aim

### Research Questions

- RQ1. How does heterogeneous EV adoption across expenditure quintiles reshape revenue structure and tax equity over time?
- RQ2. To what extent does a VMT tax alter revenue stability and tax equity compared to a fuel tax, given heterogeneous EV adoption patterns over time?

### Research Aim

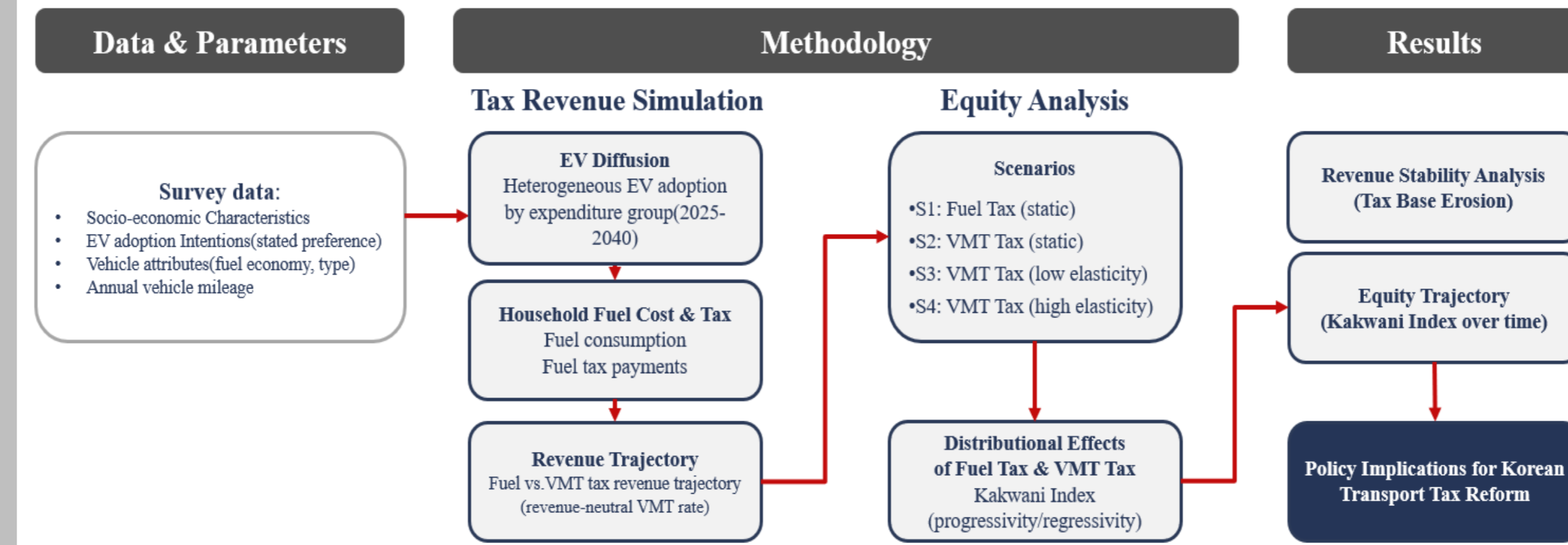
This study proposes a novel approach integrating:

- Empirical identification of heterogeneous EV adoption patterns across expenditure quintiles using Korean household survey data
- Dynamic revenue simulation (2024–2040) to assess the fiscal sustainability of fuel tax vs. VMT tax systems.
- Evaluation of the time-varying distributional equity through dynamic Kakwani Index estimation, identifying the structural inflection point

## Data

- *Consumer Perception and Preference Survey on Electric Vehicles and Energy Demand Management*, South Korea (N = 769, aged 20–69)
- Administered by Consumer Insights, professional market research firm
- Vehicle-owning households only; households with three or more vehicles excluded
- Stated EV adoption timing measured by expenditure quintile → used as key simulation parameters
- Top and bottom 5% of annual mileage removed as outliers

## Methodology



## Result 1

### Heterogeneous EV Adoption by Expenditure Group

High-income households lead EV transition, low-income households are left behind

- EV adoption intention is high across all groups (Low: 56.8%, Middle: 63.0%, High: 63.9%), but diverges sharply in timing and vehicle type
- High-expenditure households (10th decile): 44.1% early adoption (2025–2028), with disproportionate conversion of secondary and third vehicles (26.6% of total fleet by 2040)
- Low-expenditure households (1st decile): only 17.9% early adoption — 15.1% of total fleet by 2040 (EV Exclusion)
- This timing gap is the primary driver of worsening tax regressivity

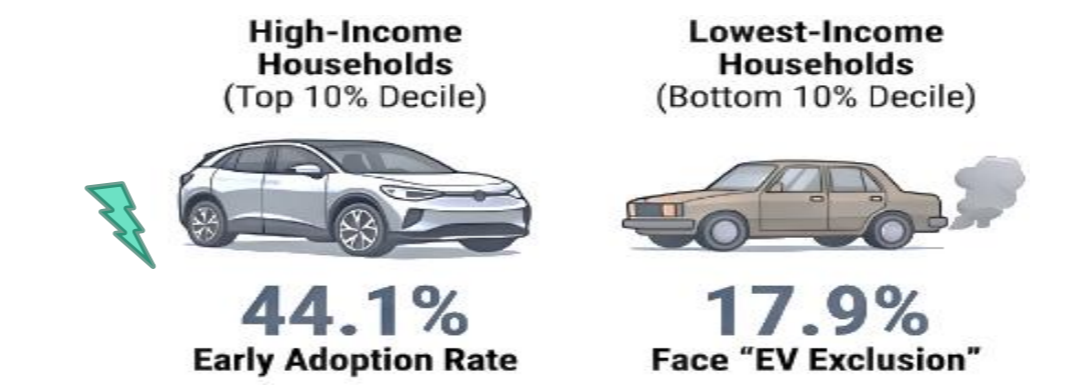


Figure 1. EV Adoption Intention by Expenditure Group

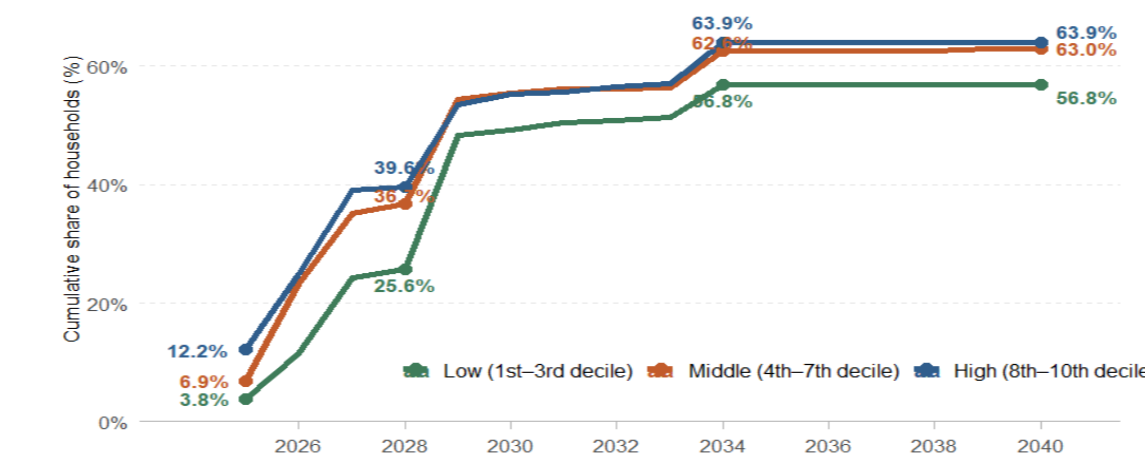
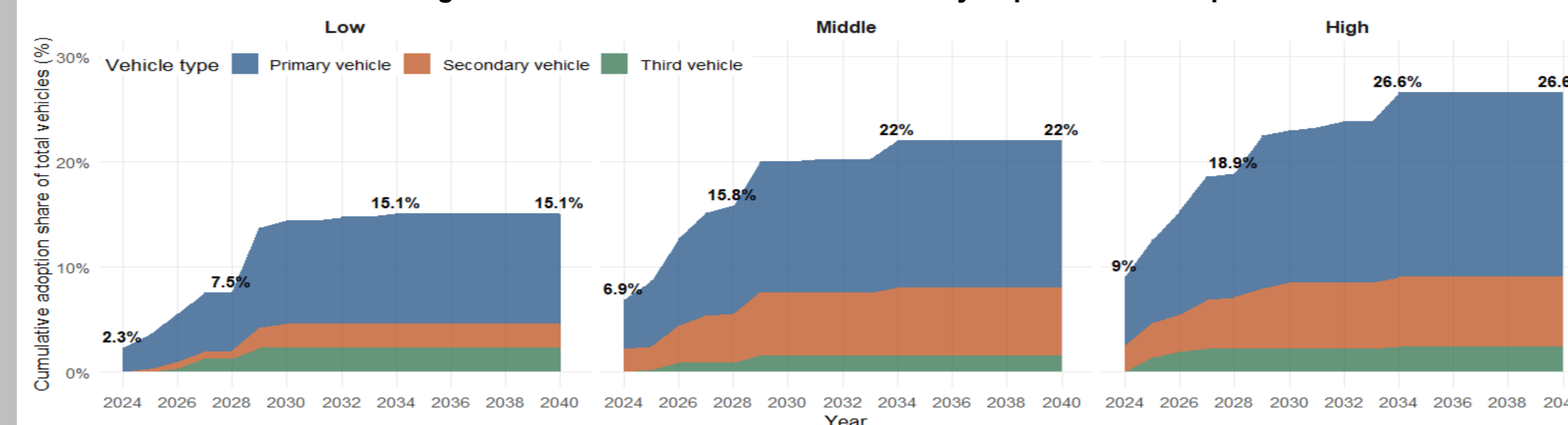


Figure 2. EV Share of Total Vehicle Fleet by Expenditure Group

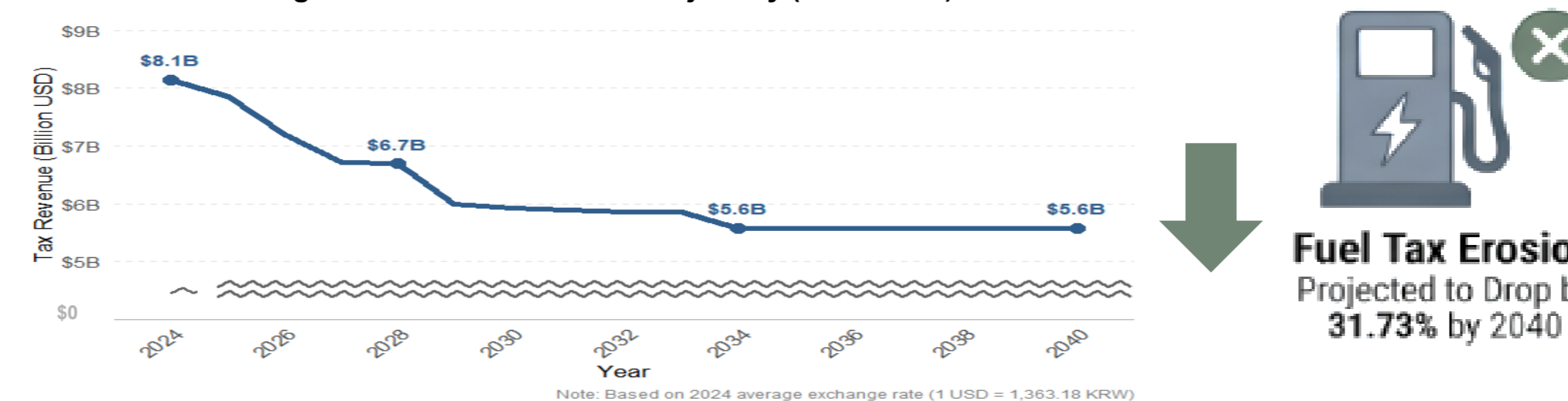


## Result 2

### Fuel Tax Revenue Erosion Under EV Diffusion

Fuel tax revenue declines by 31.7% over the simulation period (2024: \$8.1B → 2040: \$5.6B), driven by the high overall EV adoption intention across all expenditure groups

Figure 3. Fuel Tax Revenue Trajectory (2024–2040)



## Model Specification

### Scenario Analysis of Behavioral Responses

Scenario	Tax Regime	Behavioral Assumption	Elasticity	VMT Rate (¢/km)
S1	Fuel Tax	Static	—	—
S2	VMT Tax	Static	—	3.46
S3	VMT Tax	Dynamic	$\epsilon = -0.16$	3.56
S4	VMT Tax	Dynamic	$\epsilon = -0.70$	3.55

Table 1. Scenario Design for Tax Regime Simulation

Four scenarios were designed to assess the fiscal and distributional implications of transitioning from a fuel tax to a VMT tax under varying assumptions of household behavioral responses. Under the static scenarios, household mileage is assumed to remain unchanged following the tax regime transition. Under the dynamic scenarios, behavioral responses are incorporated through price elasticity of vehicle miles traveled, reflecting the degree to which households adjust their driving in response to changes in per-mile costs.

## Result 3

### Tax Equity Comparison: Fuel Tax vs. VMT Tax

Tax System	Year	Kakwani Index	Interpretation
Fuel Tax	2024	-0.3138***	Regressive
Fuel Tax	2028	-0.3262***	More regressive (worst)
Fuel Tax	2032	-0.3169***	Slight recovery
Fuel Tax	2040	-0.3175***	Persistent regressivity
VMT Tax	Static	-0.3146***	Regressive (≈fuel tax)
VMT Tax	Dynamic(-0.16)	-0.3176***	Regressive
VMT Tax	Dynamic(-0.7)	-0.3176***	Regressive

Table 2. Kakwani Index over Time (Fuel Tax vs VMT Tax)

Note: \*\*\* p < 0.001

- All tax systems exhibit negative Kakwani indices, confirming regressive structures
- Fuel tax regressivity worsens through 2028, coinciding with the peak early EV adoption wave, before partially recovering
- VMT tax Kakwani values remain statistically similar to the fuel tax across all scenarios
- Regardless of behavioral response intensity, higher-expenditure households reduce annual mileage more substantially (8th–10th decile: -864km vs. 1st–3rd decile: -307km), yet this does not translate into meaningful equity improvements
- Tax base restructuring alone is insufficient to address distributional inequities — complementary redistributive mechanisms are essential

## Discussion & Policy Implications

- EV diffusion creates a dual fiscal challenge: declining revenues and worsening equity
- High-expenditure households exit the fuel tax base first → remaining burden increasingly falls on low-income, ICE-dependent households
- VMT tax offers greater revenue stability, but does not automatically resolve regressivity
- Achieving both fiscal sustainability and distributional fairness requires complementary policy design:
  - Income-linked rate structures
  - Essential mileage exemptions for low-income households
- The findings are likely generalizable to other high-density, urbanized economies where residential location drives mileage heterogeneity and EV adoption is concentrated among higher-income households

### Key Message

- As EV adoption accelerates, fuel tax regressivity worsens until 2028 — and switching to a VMT tax alone does not resolve this inequity.
- Particularly in Korea, where mileage heterogeneity, rather than fuel efficiency, drives tax incidence, achieving both fiscal sustainability and equity requires integrated policy design, including income-linked rates and mileage exemptions for low-income households.