2023 GTAP Conference

Decarbonizing Road Transportation in Korea

: A Policy Analysis Using an Integrated Computable General Equilibrium Model

June 13th , 2023

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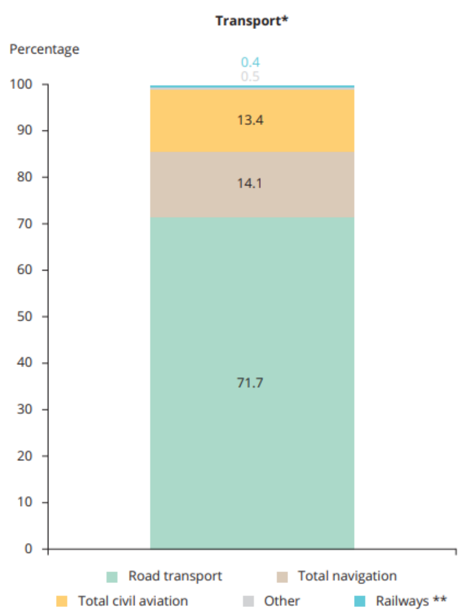
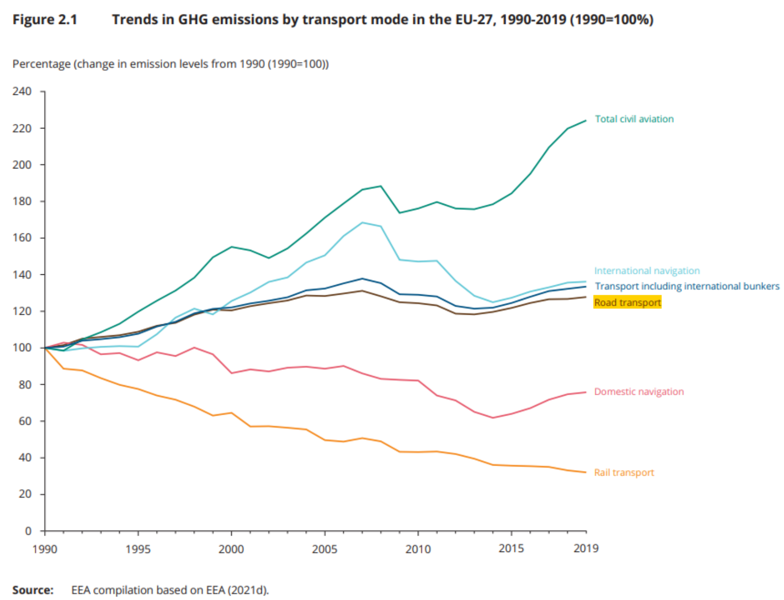
1. Introduction

GHG emissions in the transportation sector

- Over 70 countries have committed to achieving net-zero emissions, and the transportation sector is a crucial component
- Globally, the transport sector accounts for approximately 15% of greenhouse gas emissions (IPCC, 2022)
- Especially, the road transport sector is responsible for the largest share of emissions in the transportation sector, accounting for more than 72% of all transport emissions
  - The greenhouse gas emissions from the road transport sector have been continuously increasing since 1990





Source: EEA(2022)

Policy tools to decarbonize transport sector

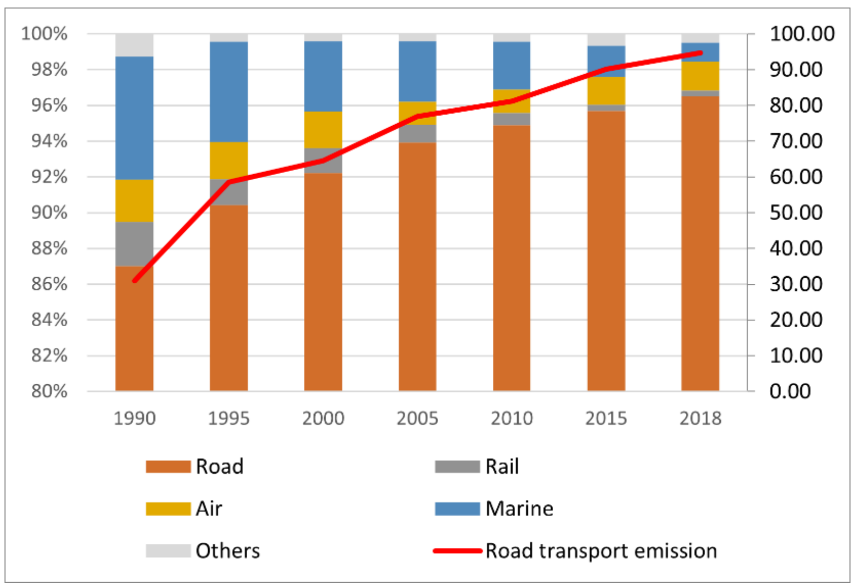
- Previous studies have identified three key strategies for reducing GHG emissions in road transport
  - Phasing out conventional Internal Combustion Engine Vehicles (ICEVs) (ZEVTC, 2021)
  - Shifting short- and medium-distance travel from private vehicles to alternative modes (Boehm et al., 2022)
  - Improving fuel and energy efficiency (EEA, 2022)

	Phasing out of ICEV			Reducing private vehicle use		Improving fuel efficiency
	ICEV sales ban	Subsidy for EV	Tax exemption for EV	Public transport promotion as a tool in NDC	VKT tax	CO2 standard for vehicles
US	-	O (income tax credit)	-	O	O (Oregon (2027) and California (pilot stage)	O
UK	2035	O (point-of-sale incentive)	O	-	O (pilot stage)	O
Germany	-	O (Rebate)	O	-	O (only for trucks)	O
Norway	2025	-	Δ (suspended from 2021)	-	-	O
China	-	O (Point-of-sale incentive)	O	-	-	O
Korea	-	O (Point-of-sale incentive)	O	O	-	O

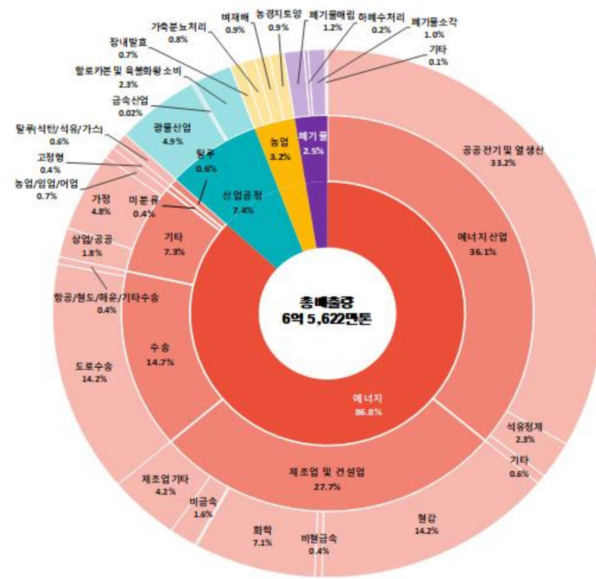
1. Introduction

Current Status of GHG Emissions in Korea

- South Korea's GHG emissions are on the decline **after reaching peak in 2018**
- However, decarbonization of the transportation sector has not been practically achieved
  - The transportation sector's GHG emissions have only decreased by 0.02% until 2021, and it is projected to increase after pandemic ends
  - the GHG emissions stemming from the road sector have continued to rise steadily
- In 2018, the transportation sector emitted 98.1 million tCO2, **accounting for 13.5% of total GHG emissions** in Korea.
  - **Road transport, which accounts for 97% of emissions** from the transportation sector, is the largest emitter of CO2, with emissions totaling 94.7 million tCO2



(Data source: KOTEMS)



Source: https://www.korea.kr/news/policyNewsView.do?newsId=148907427

1. Introduction

Korea's transportation policies for the net-zero target

- (2030 NDC) The 'Carbon Neutrality Act' mandates to reduce 40% of all GHG emissions until 2030, and the transportation sector should reduce its emissions by 37.8% from 2018 levels
  - It is the third-largest reduction target among all sectors, behind waste management and power generation
- (2050 Net Zero) The '2050 Carbon Neutrality Scenario' suggests that the land transport sector needs to reduce its emissions by at least 92% in order to achieve the net-zero target.
  - To achieve the target, government plans to supply up to 4.5 million electric and hydrogen vehicles by 2030, and electrify at least 85% of road vehicles by 2050

2030 NDC target

Sector (MtCO2eq)	emission level of 2018	2030 NDC target	
		Emission level	Reduction rate
Power generation	269.6	145.9	45.9%
Industry	260.5	230.7	11.4%
Building	52.1	35.0	32.8%
Transport	98.1	61.0	37.8%
Agriculture	24.7	18.0	27.1%
Waste	17.1	9.1	46.8%
Hydrogen	-	8.4	-
Fugitive emission	5.6	3.9	-

Transport sector target in 2050 Carbon Neutrality Scenario

Mode (MtCO2eq)	Emission level of 2018	2050 Carbon Neutrality Scenario target	
		Scenario A (Reduction rate)	Scenario B (Reduction rate)
Land trp	95.2	1.0 (99%)	7.4 (92%)
Rail trp	0.3	0	
Water trp	1.0	0.3	
Air trp	1.6	1.5	

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Policy tools proposed in major transportation plans in Korea

- main strategies of these plans:
  - ① improving the fuel efficiency of new internal combustion engine vehicles (ICEVs),
  - ② electrifying transportation modes by replacing ICEVs with EVs,
  - ③ managing private transport demand to reduce vehicle kilometers traveled (VKT).

Plan	Strategy	Explanation
2030 NDC	Demand management	Reducing the mileage of motor vehicles, such as improving the convenience of public transportation(4.5% reduction compared to 2018 by 2030)
	Promoting the use of eco-friendly cars	Supply of 4.5 million eco-friendly cars
	Behavior improvement	Energy saving by enhancing eco-friendly driving behavior
2050 Carbon Neutrality Scenario	Strengthening demand management	Reduce passenger traffic by 15% through public transportation and personal mobility
	Electrification and hydrogenation of road sector	Electrification and hydrogenation of the road sector (A) or the use of alternative fuels for some residual internal combustion vehicles (B)
2050 Carbon Neutral Roadmap for Land, Infrastructure and Transport	Accelerate the supply of electric and hydrogen cars	Cumulative supply of 4.5 million electric and hydrogen cars (2030) Purchase incentives (support for the difference in purchase price with internal combustion vehicles)
	Enhancing public transportation	Demand management for private vehicles by enhancing public transportation
4th Basic Plan for Eco-friendly Vehicles (2021~2025)	Accelerate the spread of eco-friendly cars	Reducing automobile greenhouse gases by 24% by 2030 through the spread of eco-friendly cars Cumulative supply of eco-friendly vehicles 2.83 million (2025) and 7.85 million (2030)
2nd Basic Plan for National Transportation Logistics Development (2021-2030)	Major conversion to eco-friendly cars	Cumulative supply of 4.5 million electric and hydrogen vehicles (2030)
	Tightening of fuel economy standard for Automobiles	Tightening greenhouse gas and fuel efficiency standards for passenger cars and vans GHG: 97k/km('20) → 70g/km('30) Fuel efficiency: 24.3km/l('20) → 33.1km/l('30)
	Strengthening the energy saving public transportation	Reducing the mileage of private cars by 4.5% and promoting the use of public transportation through traffic demand management
Comprehensive Plan for Fine Dust Management (2020~2024)	Accelerating the abolition of old diesel vehicles	Early abolition of old diesel vehicles
	Suppressing the demand for new diesel cars	Adjustment of the relative price of energy for transportation
	Expansion of low pollution vehicles	850,000 electric vehicles and 150,000 hydrogen cars by 2024
	Promoting public transportation convenience and managing transportation demand	Improvement of public transportation convenience

Objective of this research

- (Objective) This study focuses on analyzing the economic implications of policies aimed at reducing GHG emissions in the road transportation sector
  - We develop a comprehensive <u>national economic model that integrates a dynamic vehicle stock model with a top-down computable general equilibrium (CGE) model</u>
    - Nested CES structure of vehicle choice, which enables us to account for the substitution effects between different vehicle fuel types, new and vintage vehicles, as well as private and public transport options
    - we incorporate dynamic aspects of vehicle stocks to investigate the effects of older vehicle vintages
  - <u>Analyze six policy tools and three policy mix strategies</u> to achieve the net-zero target in the transportation sector
    - Our analysis reveals limitations in the current policy mix in terms of both the economy and the environment.
    - we suggest the adoption of additional policies that can expedite the shift toward a low-emission transportation system while minimizing adverse economic effects

2. Literature review

CGE for transportation system modelling

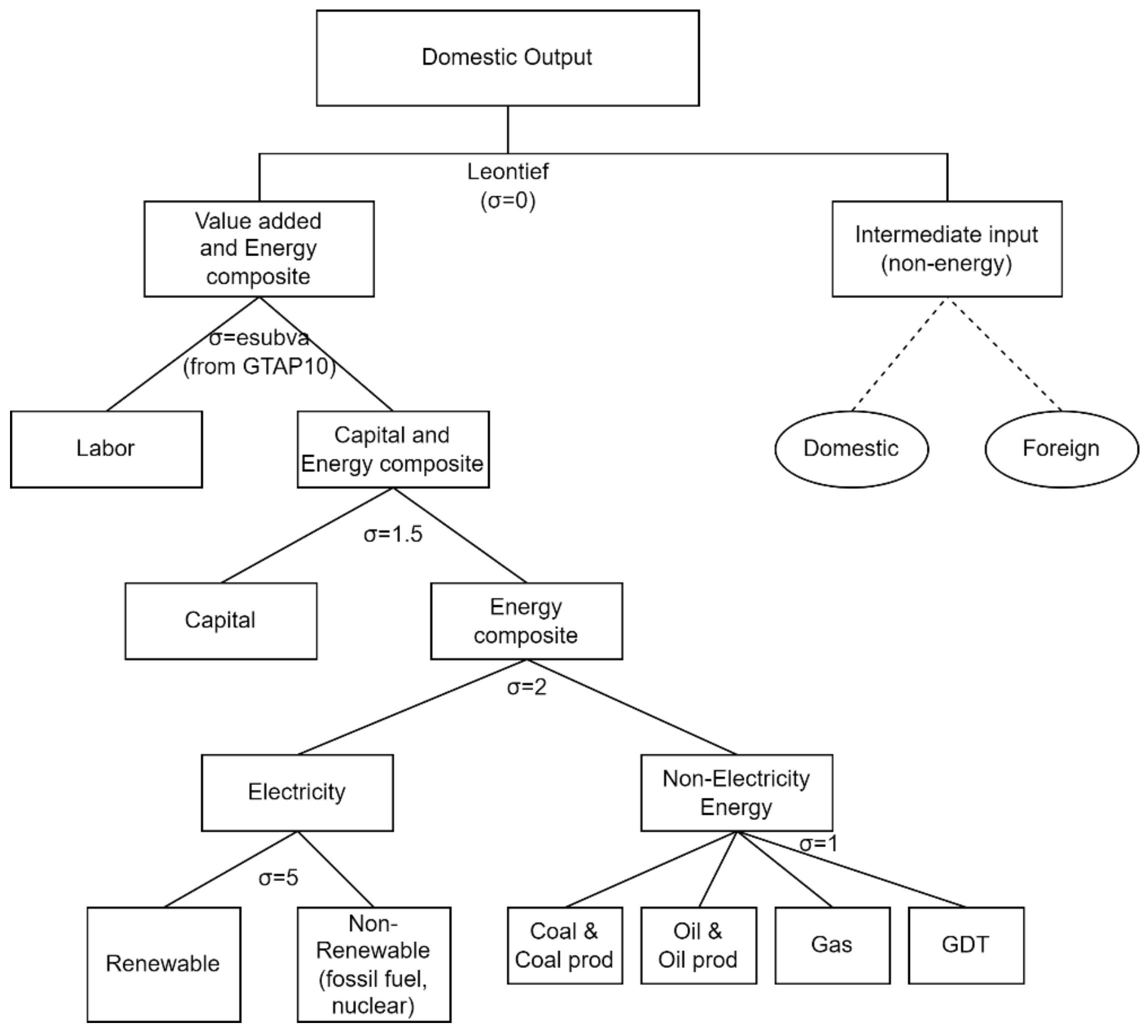
- MIT EPPA model
  - Considers the interactions between energy, economy, and environment, allowing policymakers to assess the impact of various policy options in achieving climate and energy goals while considering potential economic and social impacts
- Karplus et al. (2013)
  - Developed a model that integrates engineering and fleet details, such as vehicle powertrain technologies, fuel efficiency, and weight, as well as consumer preferences for vehicle attributes.
  - Allows for the analysis of the economic impacts of various policies related to passenger vehicle transport.
- Schmelzer et al. (2018)
  - Developed an hybrid model combines a detailed model of the German energy system with a macroeconomic model of the German economy to evaluate the economic impacts of policies aimed at promoting the adoption of EVs.
- Waisman (2013)
  - Analyzed the potential impacts of transport policies(promoting alternative fuel vehicles and increasing public transportation usage), including the creation of new jobs and industries, using the IMACLIM-R model to evaluate their impact on the transportation sector and the wider economy.
- Lee and Koo (2023)
  - Empirically analyzed the effect of alternative fuel vehicles on CO_2 emissions and the national economy by utilizing a discrete choice (DC) model to quantify the effect of individual vehicle choices on the overall economy using a CGE model
  - Replacement of internal combustion engine vehicles (ICEVs) with alternative fuel vehicles may decrease CO_2 emissions in the transportation sector, but may also have unintended effects due to the increased production of other industries.

3. Methods and Data

Method

- CGE model structure
  - <u>Based on the OECD ENV-Linkage model</u>, we develop a single country recursive dynamic model
    - Simplified the model by not distinguishing capital vintages
  - **Combines a top-down CGE model with a new vehicle stock model**
  - Calibrated the model with 2019 SAM data, and analyze the policy effect until 2050
  - Elasticity assumptions from GTAP 10 DB and previous literatures

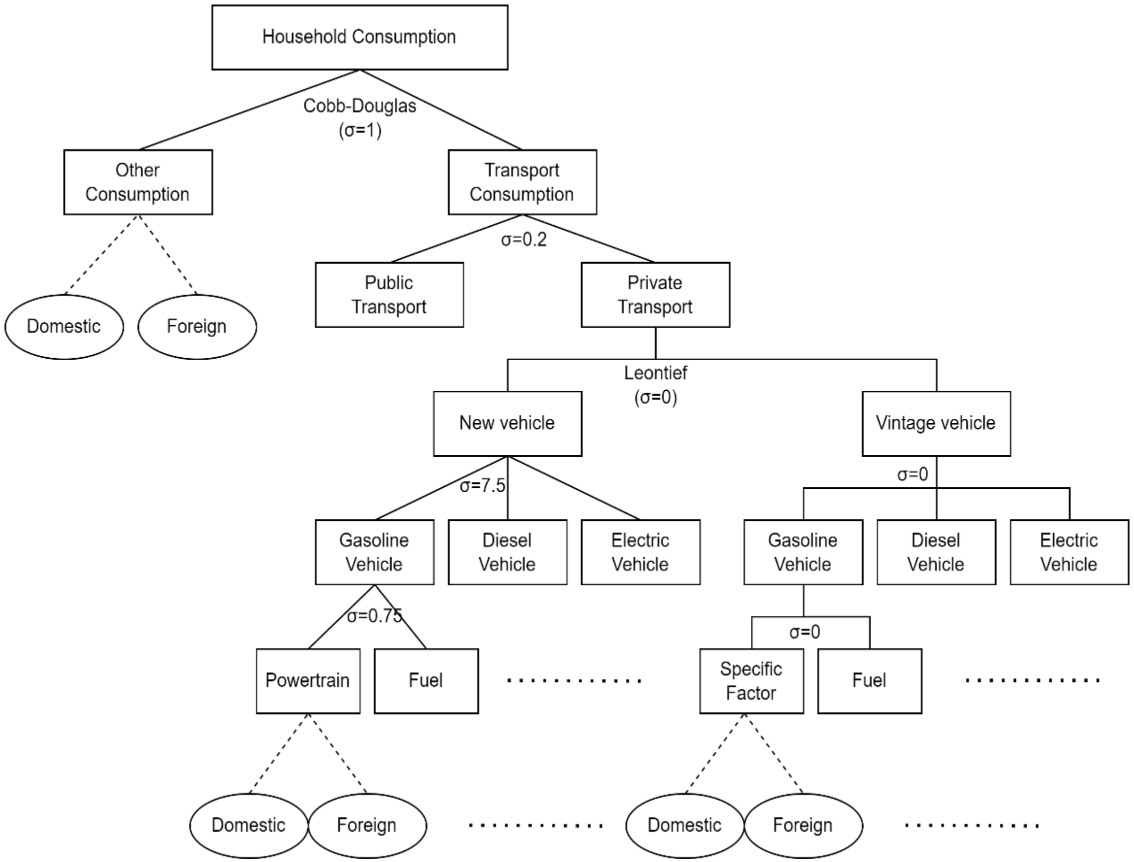
Production structure



Method

- CGE model structure
  - Consumption structure is based on Karplus et al. (2013) and the MIT EPPA model to represent the vehicle choice model structure
  - Elasticities are based on previous literatures (Paltsev et al., 2005; Karplus et al., 2013)
  - Elasticity of new vehicles by fuel type is calculated from Korean data from 2017 to 2022 using method suggested by Guo et al.(2021)

Consumption structure



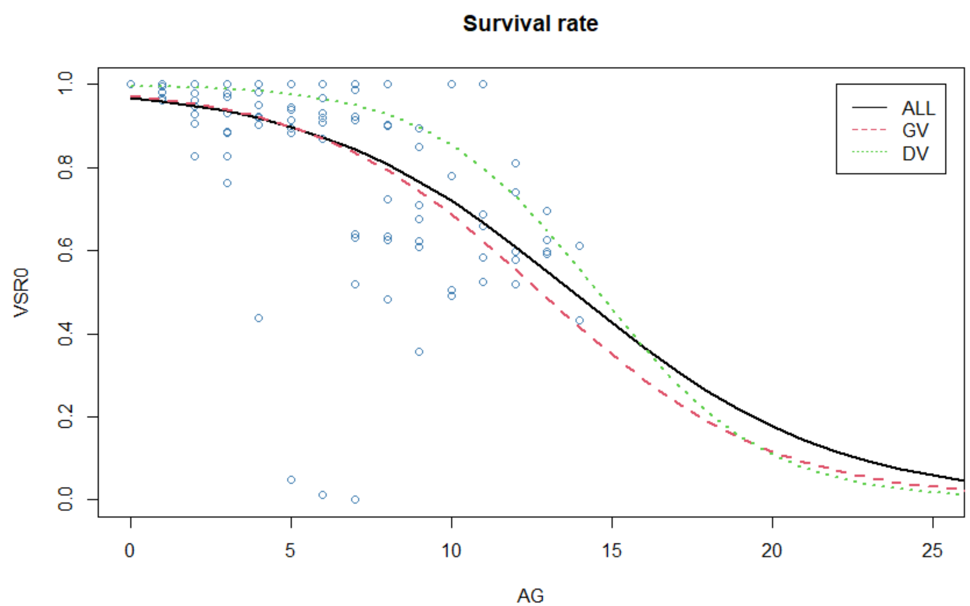
Method

- Vehicle stock model
  - We classified vehicles into gasoline, diesel, and electric types, and divided them into vintages ranging from 0 to 25 years
  - the number of vehicles by vehicle type(k) and age(n) follows a dynamic equation:

$$\mathrm{Vstock}(k,t,n) = \begin{cases} \dfrac{SR(k,n)}{SR(k,n-1)} \times Vstock(k,t-1,n-1) & if\ n > 0 \\ \dfrac{QC(k,t)\times(1+PTC(k,t))}{Vprice(k)} & if\ n = 0 \end{cases}$$

- Survival rate of a vehicle (SR)
  - The survival rate of a vehicle is primarily dependent on its age (Miaou, 1995)
  - we estimated the survival function of non-business vehicles, including gasoline, diesel, and EVs, using vehicle stock data from 2017 to 2022

$$P(Z_{t,m,i}=1) = \frac{1}{1+\exp(\alpha + \beta\ AG_{t,m,i})}$$

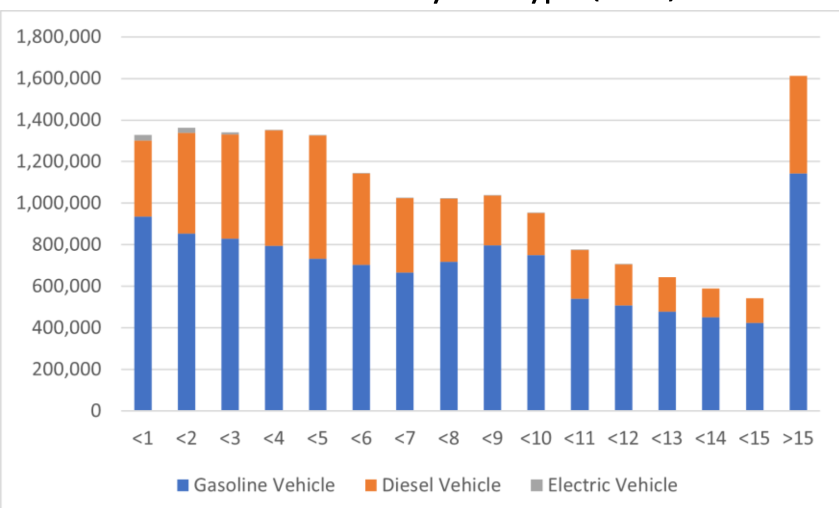


3. Methods and Data

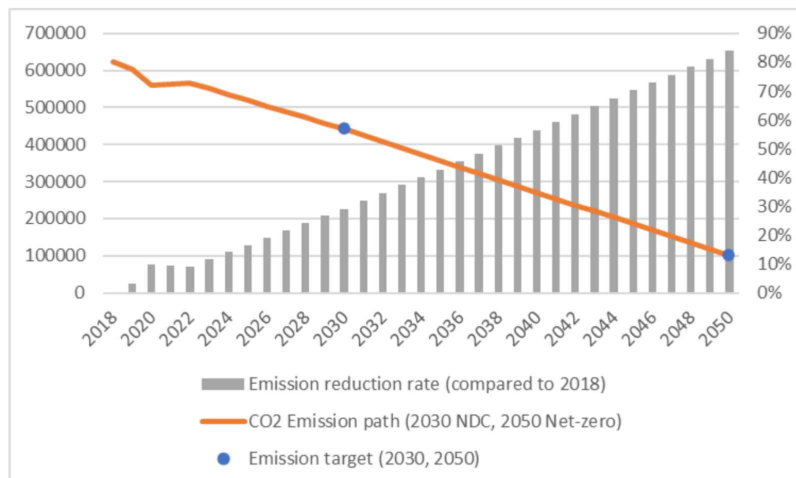
Data

- Social Accounting Matrix classification
  - Based on the **Input–Output table of the year 2019 published by the Bank of Korea** (BOK, 2019), this model separates the input structure of ICEVs and EVs and facilitates the analysis of the vehicle stock model by vehicle type (data from Shin (2022))
- Vehicle stock data
  - For this study, we focus specifically on private consumption vehicles, suggested in MLIT, among all passenger vehicles. including **<u>gasoline, diesel, and electric vehicles</u>**. **We did not include trucks or vehicles for commercial use**
    - * Gasoline 67.6%, Diesel 31.9%, EV 0.5%
- GHG emission path
  - We assume linear emission path to fulfill 2030 NDC and 2050 Net–zero target

Vehicle stock by fuel type (2019)



GHG emission path (MtcO2eq)



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Data

- Parameter assumptions

Type	Elasticity	Elasticity value	Elasticity	Elasticity value
Substitution elasticity	Value added composite and intermediates	0	Transport and other commodities	1 (from Paltsev et al.(2005))
	labor and capital-energy composite	0.2~1.68 (data from GTAP 10 DB)	Private and public transport	0.2 (from Paltsev et al.(2005))
	capital and energy	1.5	New vehicle purchase	7.5 (estimated with Korean data from 2017 to 2022)
	Electricity and non-electricity energy	2	New and used vehicle	0
	Renewable and non-renewable electricity	5	Powertrain and fuel	0.75 (from Karplus et al. (2013))
	Fossil fuel energies	1	Powertrain and specific factor for used vehicle	0
Armington Elasticity	Macro elasticity (Domestic and import goods)	3.8~16.0 (data from GTAP 10 DB)		
	Micro elasticity (Sources of imports)	3.8~34.4 (data from GTAP 10 DB)		

Policy scenarios analyzed by the model

Strategy	Scenario	Scenario description	Detailed description	Current status of the policy
BAU		Business-As-Usual	• EV subsidy ends in 2025 • No carbon price imposed	
Net-zero path	NZP	Net-zero path with carbon pricing	• Follows net-zero path with carbon pricing on CO2 emission	O
Transition to EV	NZP_DVEX	NZP + early exit of diesel vehicle	• Diesel vehicles must be scrapped after 15 years • An additional purchase tax is imposed on diesel fuel	O (planned)
	NZP_EVPS	NZP + EV purchase subsidy	• EV subsidy remains until 2050	X (subsidy will end after 2025)
	NZP_ICEVB	NZP + ICEV ban	• ICEV sales banned after 2035	X
Reducing VKT	NZP_PubS	NZP + additional subsidy to public transport use	• 20% subsidy to public transport	O (planned)
	NZP_VKTT	NZP + additional tax on VKT	• VKT tax with $0.02/km implemented for private vehicle use	X
Improving fuel efficiency	NZP_FEff	NZP + Fuel efficiency improvement	• Fuel efficiency of new vehicle improves 3.1% annually until 2030	O (implementd)

4. Result

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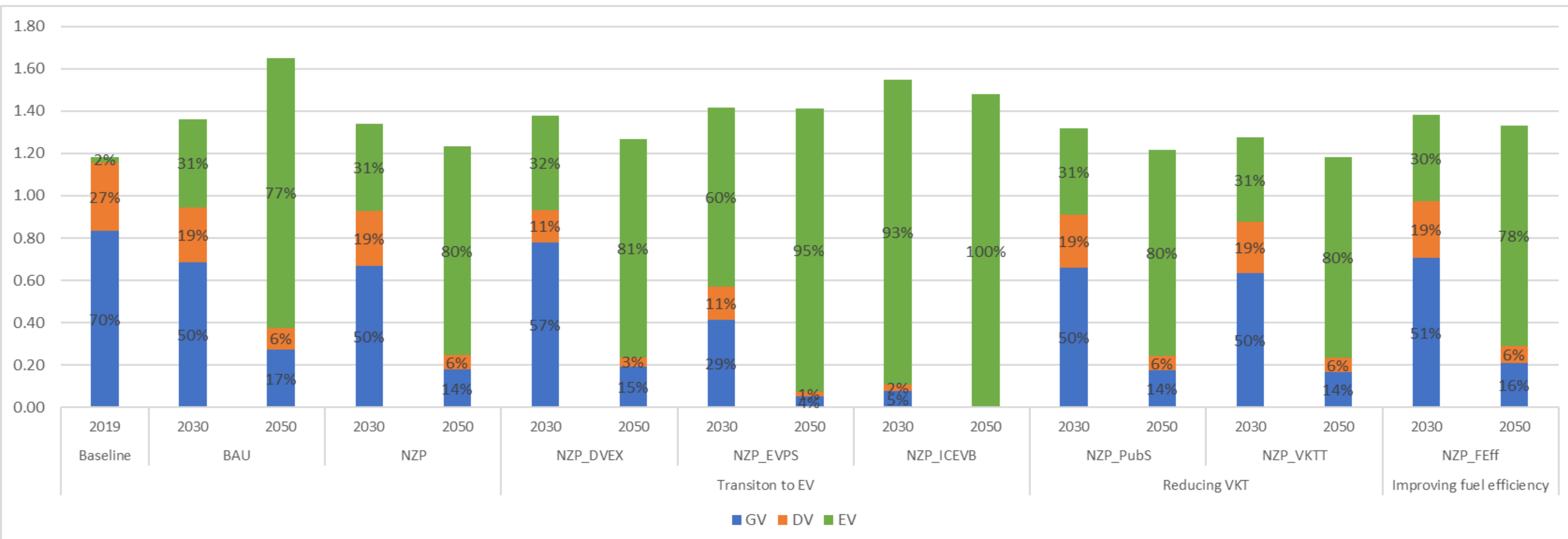
New vehicle purchase

- (BAU) total vehicle sales will continuously increase, and the proportion of EVs is expected to reach 77% by 2050 (similar to BNEF(2022) forecast)
- (NZP) carbon pricing will reduce vehicle purchase, and marginally increase EV adoption (80% by 2050)
- (DVEX) decline in DV purchases is primarily compensated for by increased GV purchases =〉 minor effect of EV
- <u>(EVPS, ICEVB) policies aimed at promoting the expansion of EVs have a significant impact on the EV sales ratio</u>
- (PubS, VKTT) new subsidies for public transport or new tax for VKT lead to a decrease in total purchases
- <u>(FEff) cost of ownership for fossil fuel vehicles decrease → the number of new ICEV sales increases</u>



Vehicle stock and VKT

- (NZP) implementing carbon price makes the vehicle stock to reach its peak around 2040 and decrease
- (VKTT, PubS, DVEX) Implementation of VKT tax, public transportation, and early exit of DV is effective in terms of reducing stocks and VKTs
- (EVPS) providing greater subsidies for EVs encourages people to consider buying new EVs
- (ICEVB) high productivity of EV → buying EV become more competitive and increases more utility

		Vehicle stock total (compared to BAU scenario)		Vehicle-Kilometers-Travelled (compared to BAU scenario)	
		2030	2050	2030	2050
NZP		-0.9%	-12.3%	-0.9%	-12.4%
Transition to EV	NZP_DVEX	-3.3%	-11.8%	-6.1%	-13.1%
	NZP_EVPS	1.5%	-2.8%	2.3%	-1.5%
	NZP_ICEVB	5.9%	2.2%	8.0%	4.4%
Reducing VKT	NZP_PubS	-2.2%	-13.4%	-2.2%	-13.5%
	NZP_VKTT	-5.0%	-16.0%	-5.0%	-16.1%
Improving fuel efficiency	NZP_FEff	0.2%	-6.8%	0.1%	-7.1%

4. Result

Macroeconomic effect

- Policies aimed at promoting the transition to EVs generally yield positive economic benefits
  - Ban on ICEVs have greater benefit on GDP perspective, but subsidy to EVs may be more favorable in terms of consumption
- Promoting public transport (NZP_PubS) and reducing private vehicle demand (NZP_VKTT) impose more burden on the overall economy
  - Manufacturing of EVs and other vehicles is more interconnected with various sectors and provides broader economic benefits compared to public transport
- Policy of tightening fuel efficiency standards for fossil fuels (NZP_FEff) exhibits a slight positive effect on GDP

(compared to BAU, %)		Macro economy			Carbon price in 2050 ($/tCO2)
		Real GDP	Total consumption	Net export	
	NZP	-2.39%	-2.36%	-2.52%	$484
Transition to EV	**NZP_ DVEX**	-2.34%	-2.30%	-2.46%	$478
	NZP_EVPS	-2.16%	-0.89%	-1.91%	$421
	NZP_ICEVB	-1.82%	-1.33%	-1.54%	$386
Reducing VKT	**NZP_PubS**	-2.44%	-2.38%	-2.57%	$483
	NZP_VKTT	-2.46%	-2.40%	-2.60%	$476
Improving fuel efficiency	**NZP_FEff**	-2.36%	-2.28%	-2.50%	$460

Policy mix scenarios

- Compared policy mix scenarios to identify an appropriate policy mix that minimizes economic burdens while achieving the net-zero target in the transportation sector

Strategy	Scenario	Scenario description	Detailed description	Current status of the policy
Policy mix	**NZP_Polmix1**	NZP + DVEX + PubS + FEff	• A mix of policies that are currently implemented or planned	O
	NZP_Polmix2	NZP_Polmix1 + NZP_EVPS + NZP_VKTT	• Advanced policy mix that includes market mechanism	
	NZP_Polmix3	NZP_Polmix2 + NZP_ICEVB	• Restrictive policy mix that exogenously restricts ICEVs	

Simulation results of the policy mix scenarios

- (Polmix2) More effective in terms of macro economy, but may increase VKTs
- (Polmix3) Restrictive policy mix can be rather beneficial to the economy

		NZP_Polmix1 **(Current mix)**	**NZP_Polmix2** **(Additional policy implemented)**	**NZP_Polmix3** **(Restrictive mix)**
Transportation sector	**purchase ratio of EVs in 2030 and 2050**	2030: 31.3% 2050: 80.0%	2030: 61.6% 2050: 95.5%	2030: 99% 2050: 100%
	Changes of VKT in 2050 (compared to BAU)	-9.2%	-5.7%	-11.8%
Macro economy (compared to BAU)	**Real GDP**	-2.37%	-2.25%	-2.24%
	Total consumption	-2.26%	-0.92%	-0.42%
	Net export	-2.49%	-2.02%	-1.80%
Sectoral production (compared to BAU)	**ICEV mfr**	-3.93%	-21.18%	-39.22%
	EV mfr	-7.19%	-3.02%	-0.13%
	Public trp	-2.02%	-2.14%	3.01%
	Chem mfr	-2.31%	-1.35%	-0.72%
	Metal mfr	-3.24%	-2.45%	-1.96%
	Service	-1.68%	-1.83%	-2.03%
Environment	**Carbon price in 2050**	$454	$405	$388
	CO2 emission reduction of transportation sector in 2030 and 2050 (compared to 2019)	2030: -16.9% 2050: -92.3%	2030: -19.8% 2050: -92.6%	2030: -23.5% 2050: -92.7%

5. Conclusion

Individual policy tools

- Newly purchased vehicles have an average lifespan of 15 years, which means that rapid action is necessary to successfully decarbonize the road transportation sector until 2050
- Korea has a high substitution elasticity between fuel types for new vehicle purchases (7.5), which is beneficial for the adoption of new EVs
  - Guo et al.(2021) : 3.8 for China case
  - Additional sensitivity analysis is needed

- Among the various policy tools, subsidies for EV purchases and ICEV ban have demonstrated the highest effectiveness in terms of overall GDP and consumption. However, it is important to note that these subsidies may inadvertently lead to an increase in VKTs, resulting in higher pollutant emissions
- On the other hand, policies aimed at managing private vehicle demand do not have a positive impact on GDP, primarily due to the significant role played by the vehicle manufacturing sector in Korea, which is crucial for economic growth
- Improving fuel efficiency is only a transitional policy since it does not contribute much to emissions reduction and hampers the deployment of EVs. In fact, the improvement of fuel efficiency makes ICEVs more appealing, leading to an increase in their sales

5. Conclusion

Policy mix

- Several policies should be implemented simultaneously to decarbonize road transportation and achieve the desired level of EV adoption in the Carbon Neutrality Scenario
- However, the current policy mix falls short in terms of efficiency and fails to meet the 2030 Nationally Determined Contributions (NDC) target

- To address this shortfall and achieve carbon neutrality while minimizing the economic burden, the implementation of additional policies, such as EV subsidies and a VKT tax, is necessary
- Also, prohibition of ICEV sales can be beneficial to the Korean economy

- These measures can provide the necessary incentives for EV adoption and encourage sustainable transportation choices, thereby facilitating the transition to a low–carbon future

THANK YOU

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