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Policies and predictions for a low-carbon transition by 2050 in passenger vehicles in East Asia by 2050: Based on the analysis using E3ME-FTT model

Aileen Lam
University of Macao

Co-Authored by
Soocheol Lee, Jean-François Mercure, Yongsung Cho, Chunhsu Lin, Hector Pollitt, Unnada Chewpreecha, Sohpie Billington

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Background

- East Asian countries, including China, Japan and Korea and Taiwan were responsible for CO_2 emissions totalling approximately 12% in 1980 and 18% in 2013 of global levels from consumption of petroleum.
- Decarbonization of the transport sector is critical in order to increase our probability of staying within 2℃ target of the Paris Agreement.
- The diffusion of zero emissions vehicles into the marketplace determine technological trajectories that are critical in emissions reductions.
- It is important to determine the relationship between policy instruments and the rate of adoptions for low emissions vehicles.

Gap in the existing literature

- Most existing studies feature a few policy instruments, for one particular country.
- It is not possible for these studies to compare the effectiveness of different instruments across countries.
- Most studies have not used an Integrated Assessment Model (IAM) to study the transport policies and therefore, cannot be used to understand the impact of policies on global climate change.
- The existing studies have either taken one particular car model or use a representative agent to examine the response of agents to a set of policy incentives, while in the real world, consumers are diverse and they do not respond to policy incentives collectively.

Research goal

- The main objective for this research is model of technological diffusion, called the FTT: Transport, to study *the possible future technological transitions in the passenger car sector and motorcycles in China, Taiwan, Japan, Korea.*
- The FTT-Transport is able to model the effect of different forms of policy incentives in the passenger transport sector, including fuel tax, vehicle tax/subsidies, annual tax, fuel economy standards, technology mandate and biofuel mandate for the East Asian countries
- We performed four policy scenario analysis for the four East Asian countries in order to *find a set of policy incentives that will lead to significant emissions reductions*

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E3ME

- E3ME model is an out-of-equilibrium macro-econometric model of the global economy.
- Used for economic evaluation of environmental policy.
- E3ME key strength

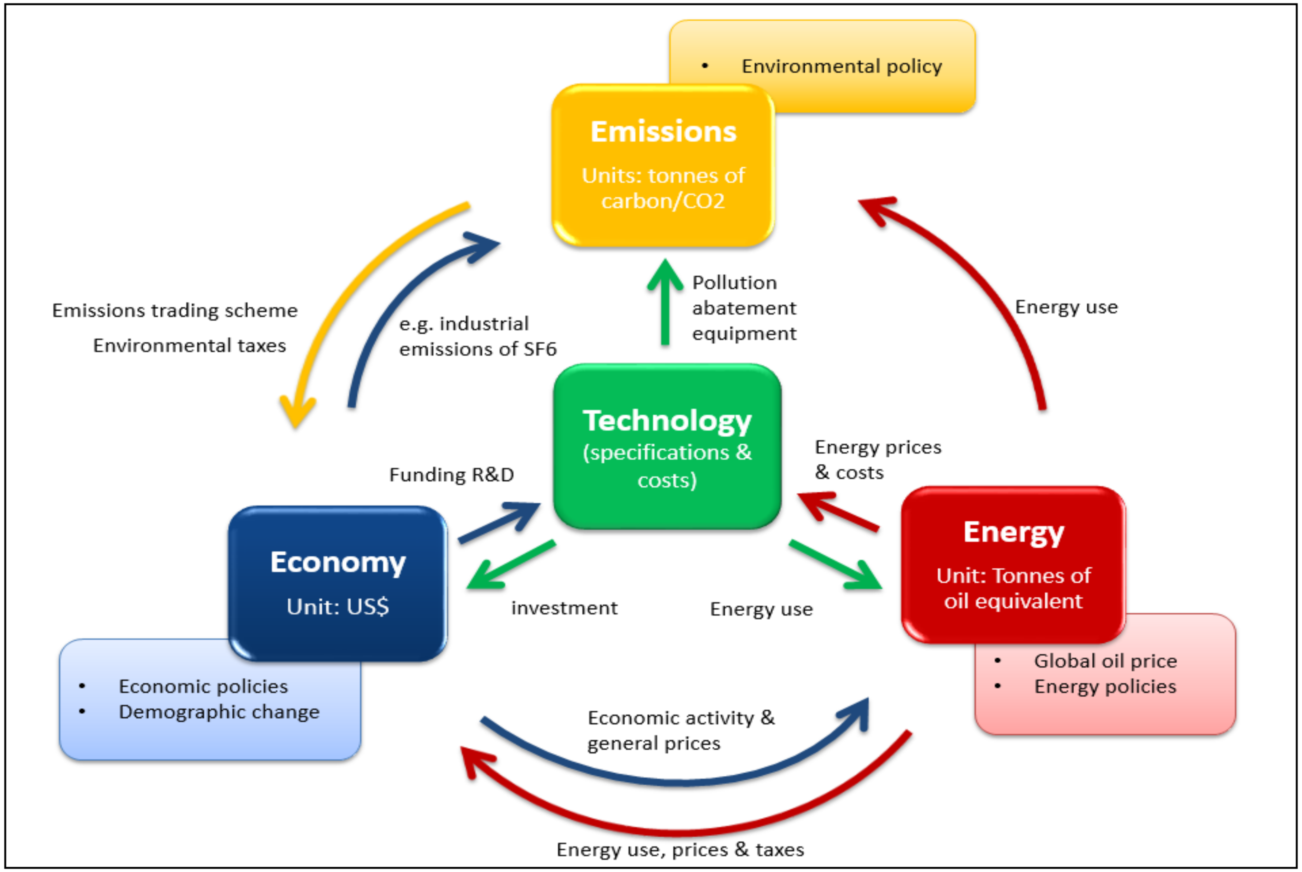
✓ Two-way linkages between economy, energy (and material) inputs and environmental systems

✓ Detailed sectoral disaggregation

✓ A strong empirical grounding

✓ Short and long-term econometric specification

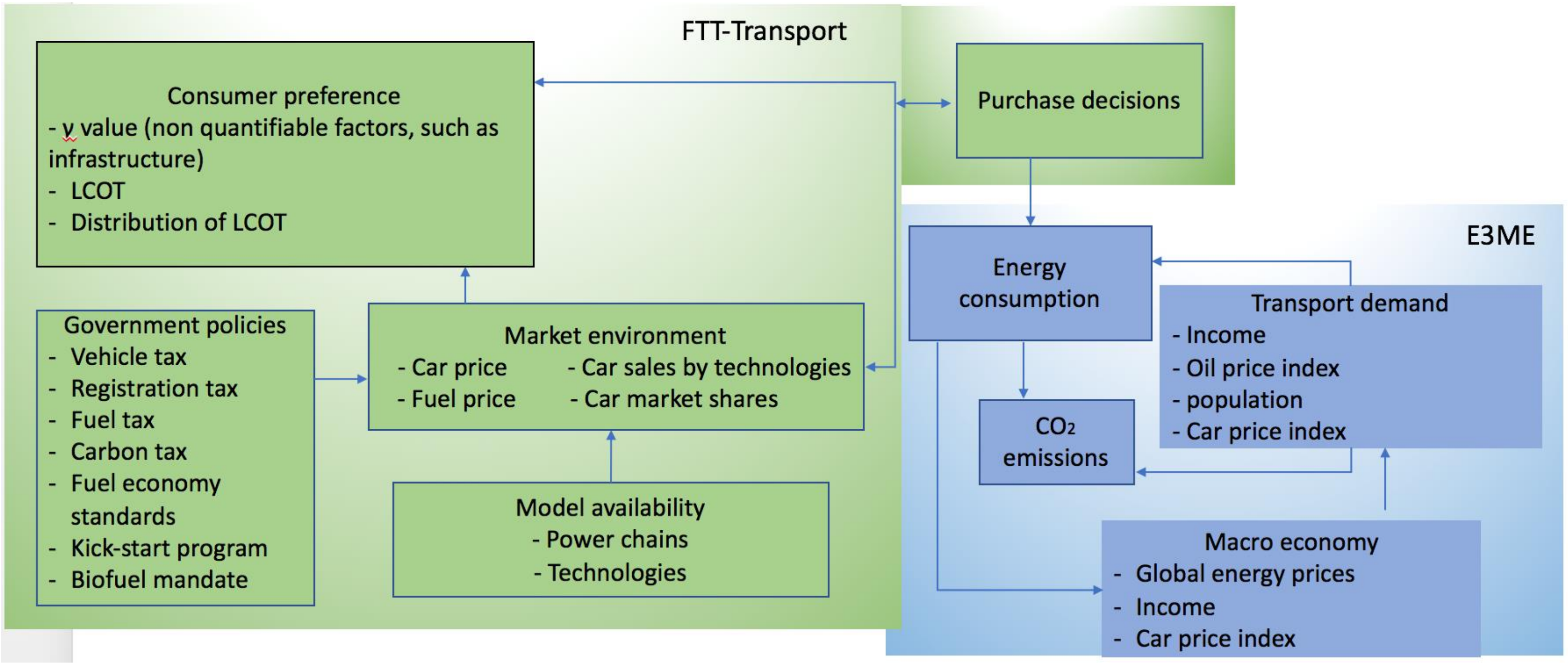
Structure of E3ME



E3ME-FTT-Transport

- The FTT-Transport model is a sub-module of the E3ME-FTT-GENIE.
- E3ME is a non-equilibrium macroeconometric simulation model based on a demand-led Post-Keynesian structure.
- FTT-Transport model (Future Technology Transformation)
- Uses Lotka-Volterra equations to model technology substitution and diffusion.
- Reproduces typical S-shape technology diffusion curves.
- Models consumer decision with discrete choice theory.

Framework



The model structure of the E3ME-FTT-Transport model. Tax policies are simulated in the model to influence the cost component. New car sales will eventually impact on global energy use and emissions from passenger transport.

Technological diffusion in the FTT model

The FTT framework models technological diffusion by a set of differential equations of the Lotka-Volterra family. The flow of market shares from technology *j* to technology *i* is

$$\Delta S_{j\rightarrow i} = S_i S_j A_{ij} F_{ij} \Delta t$$

And the flow of market shares from technology *i* to technology *j* is

$$\Delta S_{i\rightarrow j} = S_j S_i A_{ji} F_{ji} \Delta t$$

The market shares for technology *i* as a result of flow of market shares is

$$\Delta S_i(t) = \sum_{j=1}^{N} \left(F_{ij} - F_{ji}\right) S_i S_j \frac{1}{\tau} \Delta t,$$

Where *Fij* is the consumer choice matrix, *Si* is the shares for technology I, *Sj* is the shares for technology *j*, τ is the relative technological turnover rate.

The levelised cost of transportation

Following this, the Levelized Cost of Transport (LCOT) after the introduction of policies is defined as

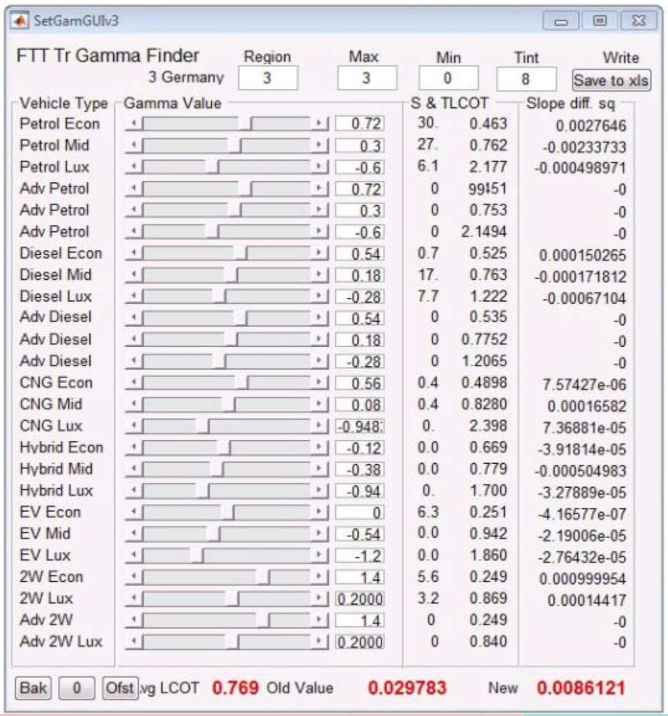
$$LCOT_i = \sum_t \frac{I_i + VT_i + CT(\alpha_i) + FU_i(t) \times FT(\alpha_i, t) + MR_i + RT_i(t)}{(1+t)^t} \tag{3}$$

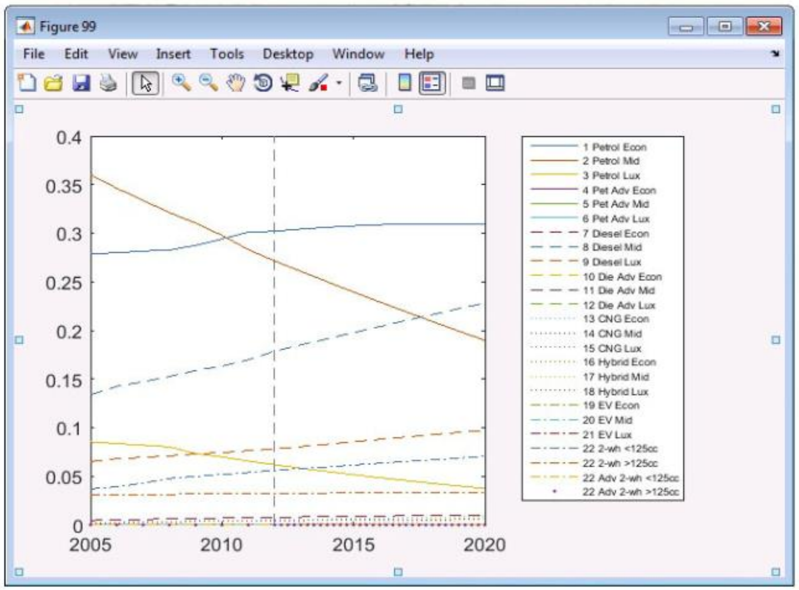
where,

- VT_i is a registration vehicle tax, in \$/vehicle, paid at purchase time,
- I_t is the capital cost of cars, in \$/vehicle
- $CT(\alpha_i)$ is the carbon tax based on fuel economy α_i, in \$/vehicle/(gCO^2/km)
- $FT(\alpha_i, t)$ is a tax on fuel consumption, in \$/L
- $FU_i(t)$ is the fuel consumption, in L/vehicle
- MR_i is the vehicle maintenance cost in \$/vehicle
- $RT_i(t)$ is a road tax in \$/vehicle

Intangible variable

- How do we find *non-financial cost (γi)* ?
- The *non financial cost* (constant) is adjusted so that the projected shares follow the overall historical trends.





Consumer choice

Learning by doing

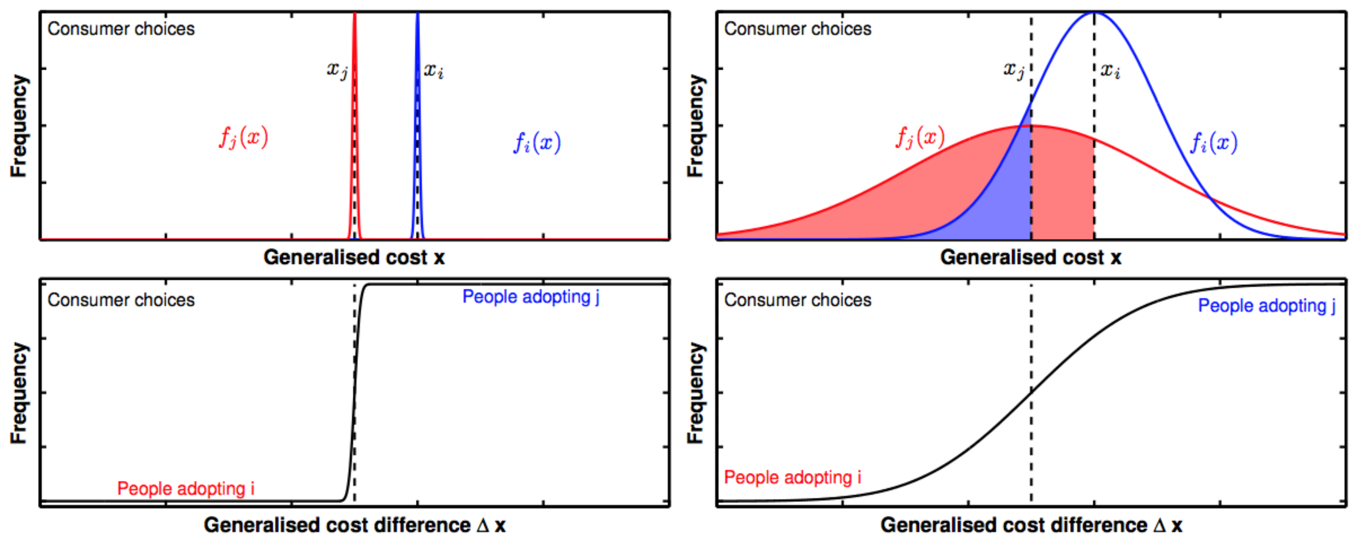
- Endogenous technical change is assumed in the E3ME:FTT both at the aggregate level in E3ME and through learning by doing.
- Capital costs for vehicle technologies ($I_i(t)$) fall by a certain percentage (learning rate b_i) every time the total quantity manufactured Wi(t) doubles:

$$I_i(t) = I_{0,i}\left(\frac{W_i(t)}{W_{0,i}}\right)^{-b_i}$$

- For niche technologies, the existence of technological learning implies that prices for the new technologies (e.g. electric cars) will fall as the quantity of production increases.

Consumer decision matrix

- For a model of technology diffusion, we require an aggregate representation of decision-making when agents are diverse, and cost have variations.
- We postulate that distributions of perceived costs correspond to distributions of observed costs.



Transport demand and vehicle sales

- Passenger transport demand can be measured in different ways, including the number of trips, vehicle kilometres and passenger kilometres.
- Two factors are particularly important in projecting emissions: the number of vehicles *VS* registered to be on the road and the number of passenger kilometres *PM*

$$VS_j = \beta_{1,j} * RRPD_j + \beta_{2,j} * PV_j + \beta_{3,j} * ST_j + \epsilon_j$$

$$PM_j = \alpha_{1,j} * RRPD_j + \alpha_{2,j} * PFRM_j + \epsilon_j$$

where *PM* is the demand for transport in passenger kilometres (pkm), *RRPD* is the real income, *PFRM* is the price of middle distillates for road transport, *VS* is the number of new vehicle sales and *PV* is the real price of vehicles and *ST* is the number of vehicles on the road, all specified for each region *j*.

Integration into E3ME

- The integration of FTT:Transport to E3ME is made through several variables. The vehicle and transport demand econometric equations are technically part of E3ME, not FTT, and interact directly with other variables such as income, prices and output (GDP).
- Changes in the demand for oil for transport affect the price of oil through our fossil resources depletion algorithm
- If the demand increases, more costly resources are developed and the marginal cost goes up, while if the demand declines, costly resources are abandoned and the marginal cost goes down.
- The demand for electricity from electric vehicles in FTT:Transport is also accounted for in E3ME, which is fed through to the sister model FTT:Power.

Data overview

Country		P(USD)			Engine sizes (cc)			Emissions (gCO_2/km	
	Average	Median	S.D.	Average	Median	S.D	Average	Median	S.D
USA	25959	23871	10570	3026	2550	1225	186	176	50
UK	34285	31520	18640	1576	1498	544	123.3	118.8	30
Japan	18317	14968	11526	1286	1252	728	113	102	44
China	22826	18970	16633	1704	1596	481	154	153	31
India	8674	6947	12418	1220	1170	445	140	145	27
Brazil	20642	16425	13770	1527	1558	458	112	106	29
Korea	19949	15432	13799	1840	1998	652	171	168	38
Argentina	20850	18720	11578	1646	1598	350	172	167	50
Australia	31948	28415	19029	2284	1998	863	127	123	34
Canada	21407	20914	10680	2857	2500	1285	210	206	60
Indonesia	11805	15654	10021	1630	1495	440	171	176	43
Malaysia	29976	14970	39277	1714	1586	628	183	181	47
Mexico	16630	13138	9253	2002	1800	779	168	171	57
New Zealand	52481	29611	72191	2280	2000	592	193	186	26
Russia	23560	23325	10690	1656	385	1600	188	190	54
South Africa	19976	1598	601	1869	1598	601	173	161	84
Taiwan	22922	21318	3250	1818	1798	247	146	160	64
Saudi Arabia	27027	22086	21600	2378	1180	2000	200	174	59

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Policy assumptions

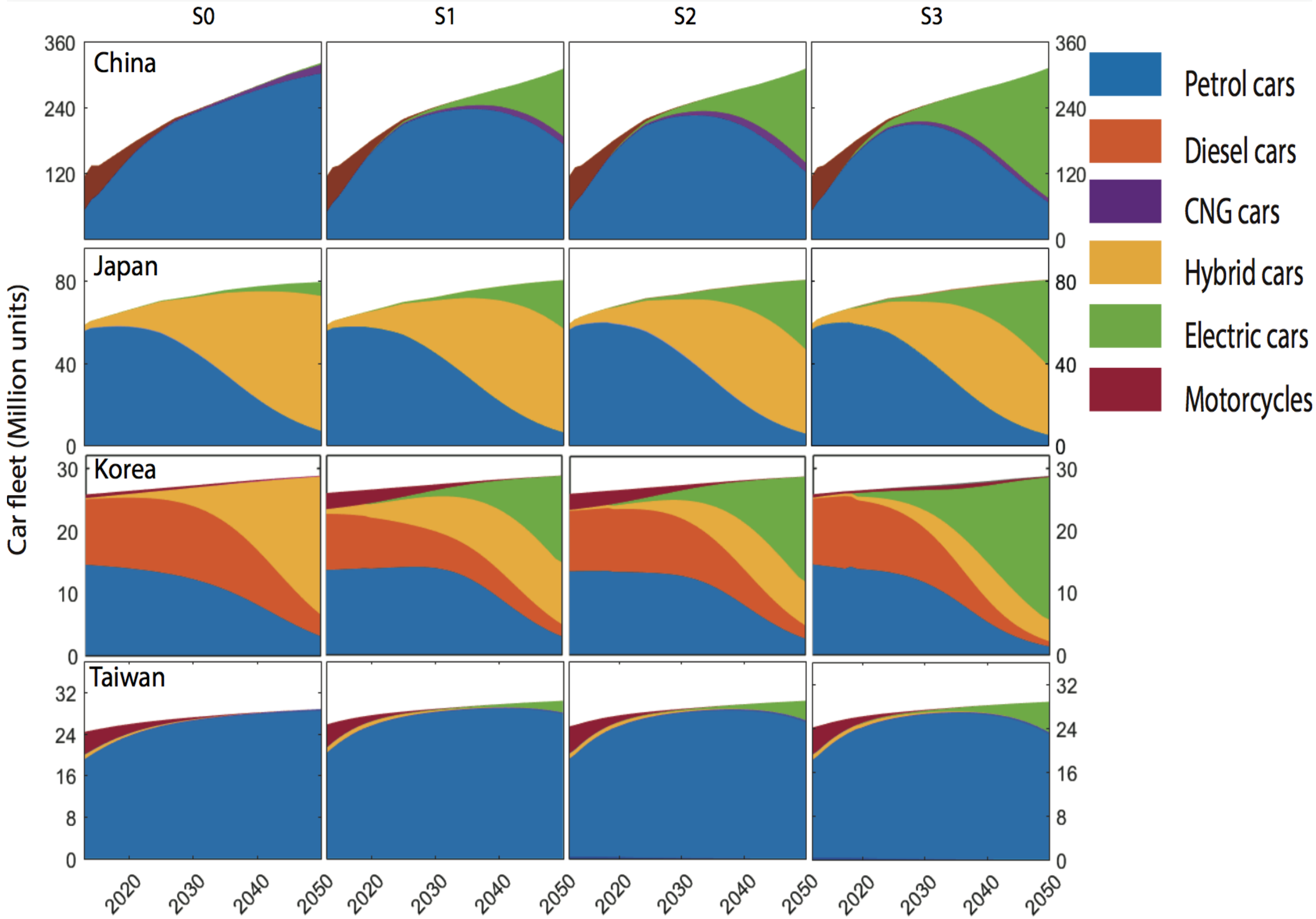
Policy incentives	Model representation	Examples of the real-world policy
Registration tax	As vehicle tax, this is a tax on expected (not yet emitted) CO_2 emissions. The tax is proportional to fuel economy in the unit of USD/(g CO_2/km). It is added to the annual costs summed to get the LCOT.	Acquisition tax based on fuel economy road tax
Fuel tax	Added to the fuel cost. As vehicle tax, this is a tax on expected (not yet emitted) CO_2 emissions. The tax is proportional to fuel economy in the unit of USD/(g CO_2/km).	Fuel tax (e.g. petrol tax, diesel tax); acquisition tax based on fuel economy
Biofuel mandate	Biofuel as a certain percentage of liquid fuels is added to fuel cost.	Biofuel mandate
Fuel economy regulation	The sale of lower efficiency liquid-fuel vehicles is banned.	Fuel economy standards
Kick-start program	A certain percentage of EVs are bought (e.g. by public or private institutions) as a policy or strategy.	Kick-start program
EV subsidies	EVs are financially subsidized by the public sector.	Government-financed purchases

Definition of policy incentives

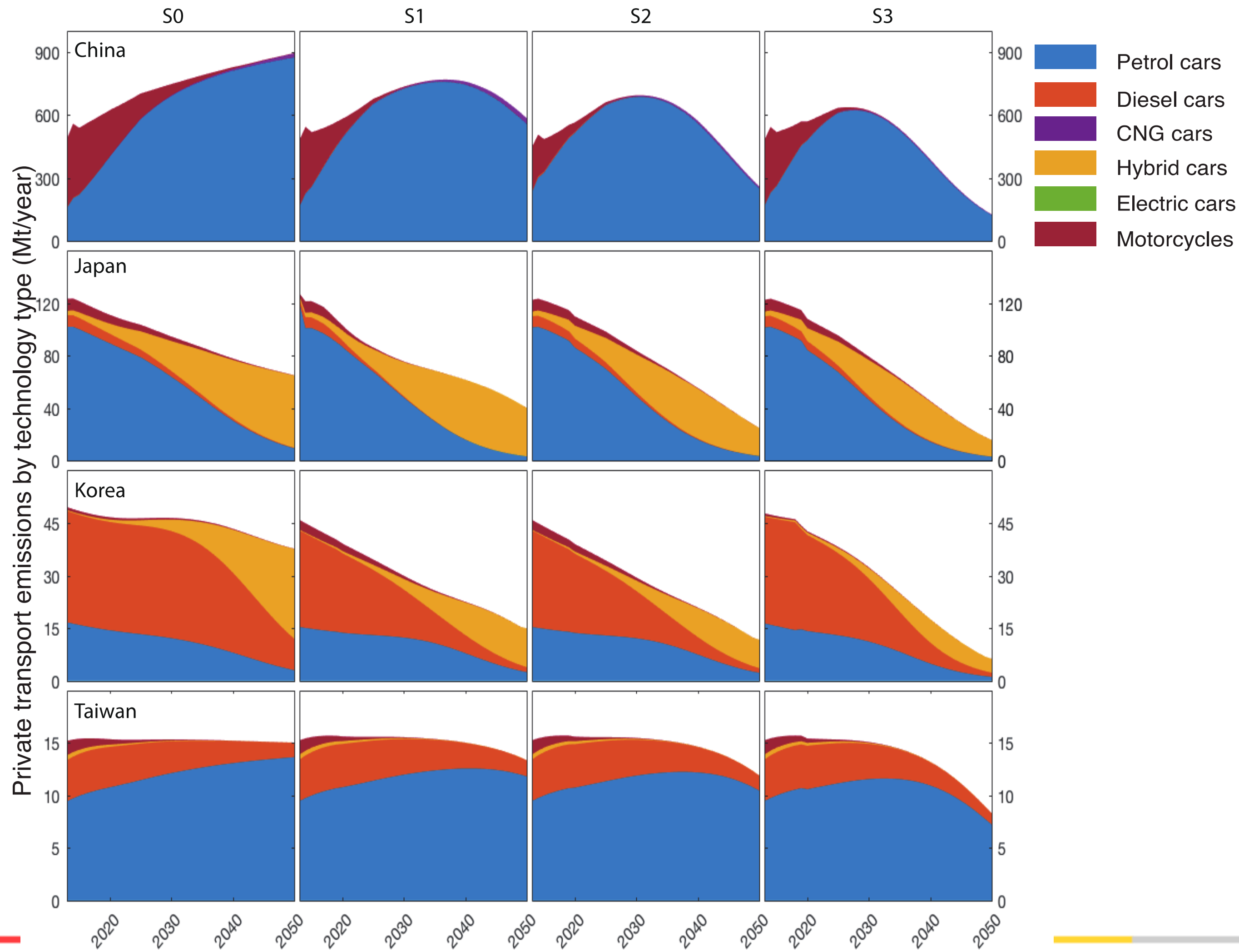
Assumptions of policy scenario for China, Japan, Korea and Taiwan

	EV subsidies (USD)	Fuel tax (USD/liter)	Carbon tax (USD/(t CO_2)	Kick-start program	Biofuel mandate
Baseline scenario	Current subsidy of each country	Current fuel tax of each country	0	0	0
Scenario 1	+1000	+0.1	20	3%	0
Scenario 2	+2000	+0.2	50	5%	5%
Scenario 3	+3000	+0.3	100	8%	10%

Results


S0
S1
S2
S3
China
Japan
Korea
Taiwan
Car fleet (Million units)
360
240
120
0
80
40
30
20
10
32
24
16
8
2020
2030
2040
2050
Petrol cars
Diesel cars
CNG cars
Hybrid cars
Electric cars
Motorcycles

Emissions

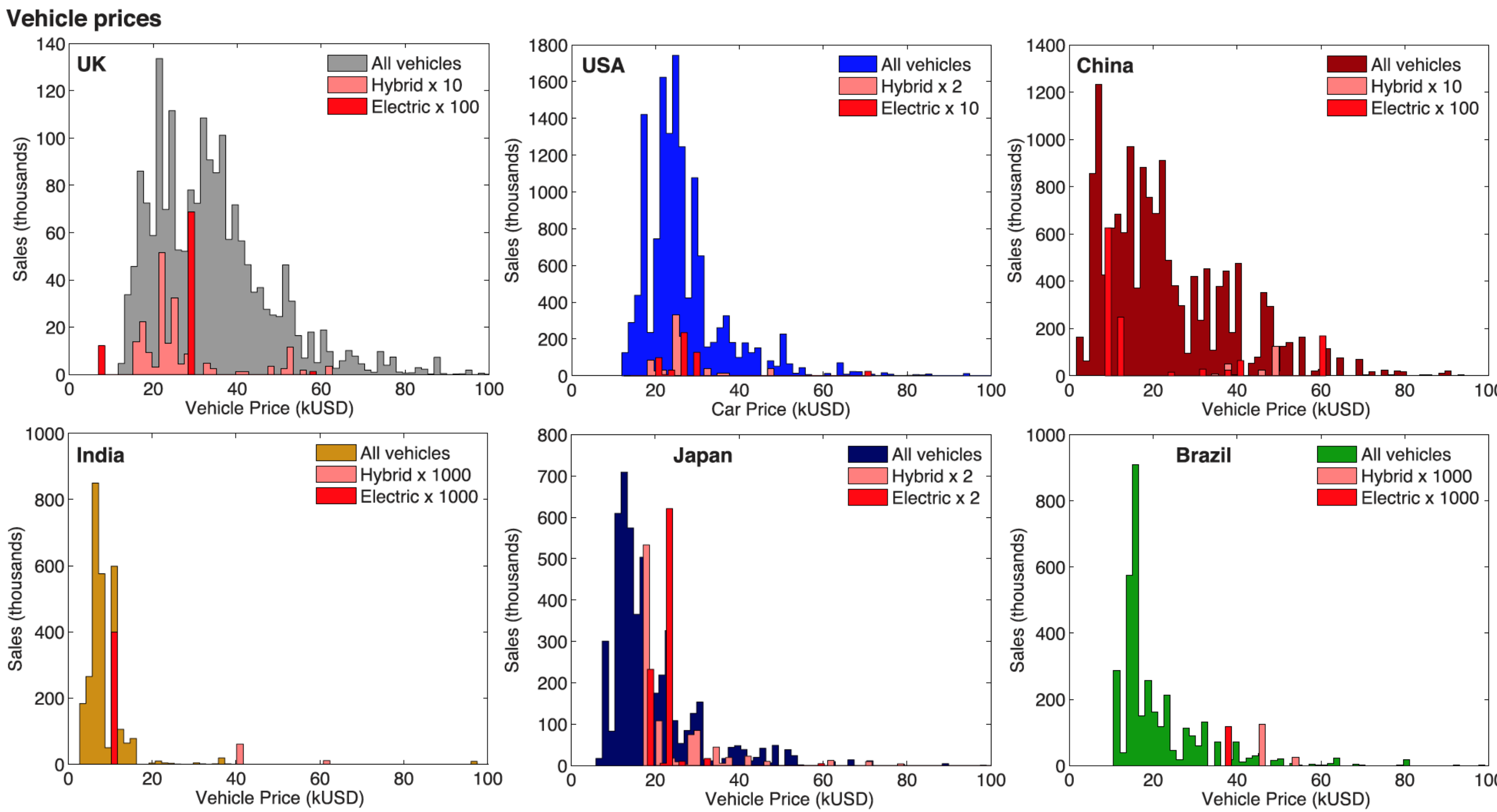


S0
S1
S2
S3
China
Japan
Korea
Taiwan
Private transport emissions by technology type (Mt/year)
900
600
300
0
120
80
40
45
30
15
10
5
2020
2030
2040
2050
Petrol cars
Diesel cars
CNG cars
Hybrid cars
Electric cars
Motorcycles

Conclusions

- It is possible for Japan to achieve over 50% emission reductions without any policy incentives.
- An integrated approach (combine tax incentives, subsidies and kick start program) will lead to more than 70% EV shares in China by 2050.
- We performed four scenario analysis to examine the interactive effect of the policy incentives in the four East Asian countries.
- We find that the tax incentives are not sufficient to cut emissions significantly for all countries
- The diffusion of hybrid cars in Korea will not lead to a significant emissions reduction in Korea. It is important to encourage the diffusion of EV in Korea by a kick-start program with an integrated set of policy instruments
- In the case of Taiwan, without a kick-start program, emissions from passenger cars in Taiwan will not be cut significantly.

Data


Vehicle prices
UK
All vehicles
Hybrid x 10
Electric x 100
Sales (thousands)
Vehicle Price (kUSD)
USA
All vehicles
Hybrid x 2
Electric x 10
Car Price (kUSD)
China
All vehicles
Hybrid x 10
Electric x 100
India
All vehicles
Hybrid x 1000
Electric x 1000
Japan
All vehicles
Hybrid x 2
Electric x 2
Brazil
All vehicles
Hybrid x 1000
Electric x 1000

澳門大學
UNIVERSIDADE DE MACAU
UNIVERSITY OF MACAU

Thank you!
Any questions?
Email: meimeilam@umac.mo