2018 SEOUL BIOETHANOL CONFERENCE

Biofuels and Fine Dust in Korea

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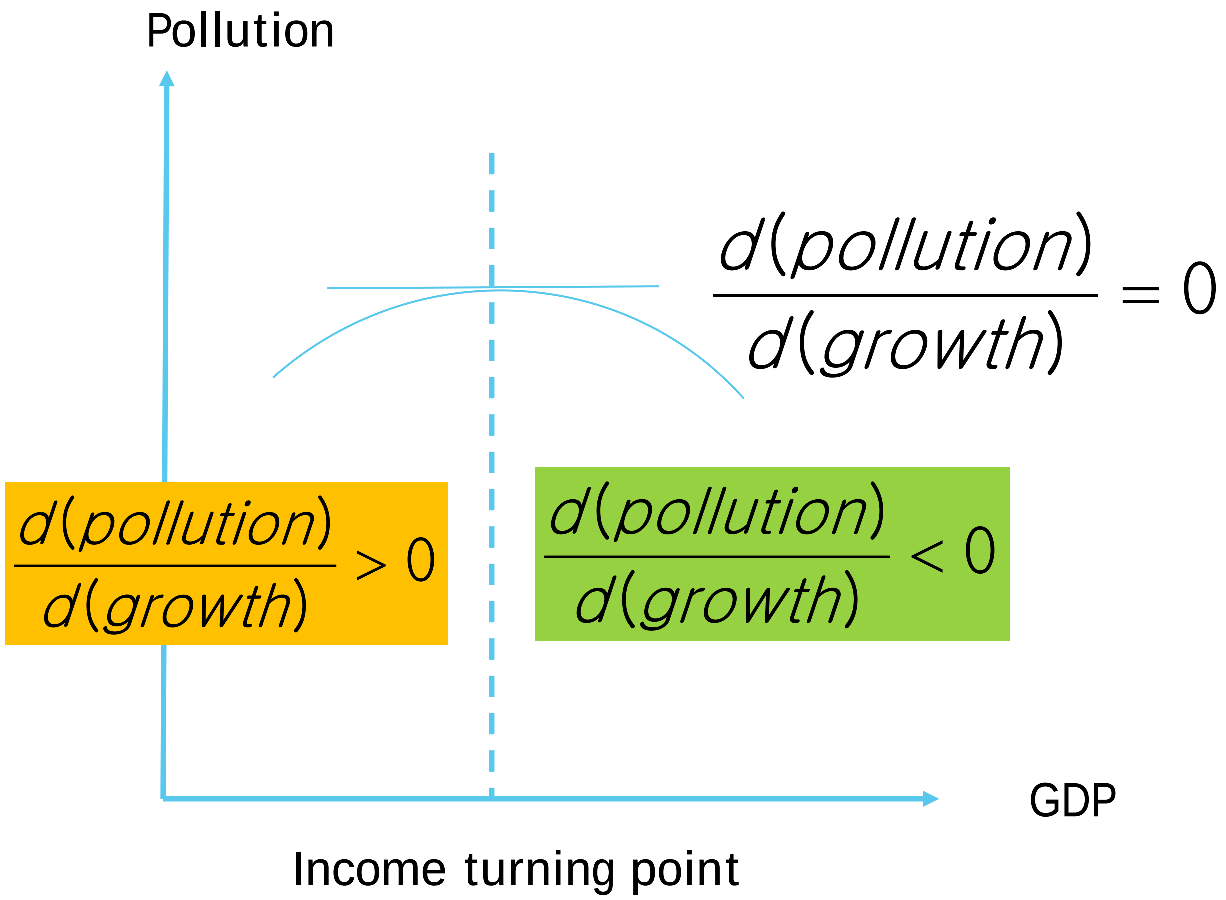
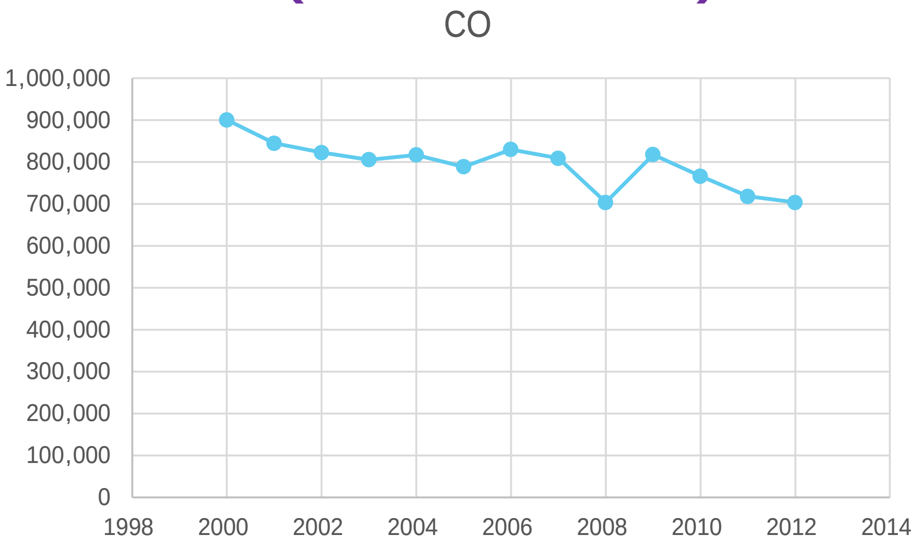
Environmental Kuznets Curve hypothesis

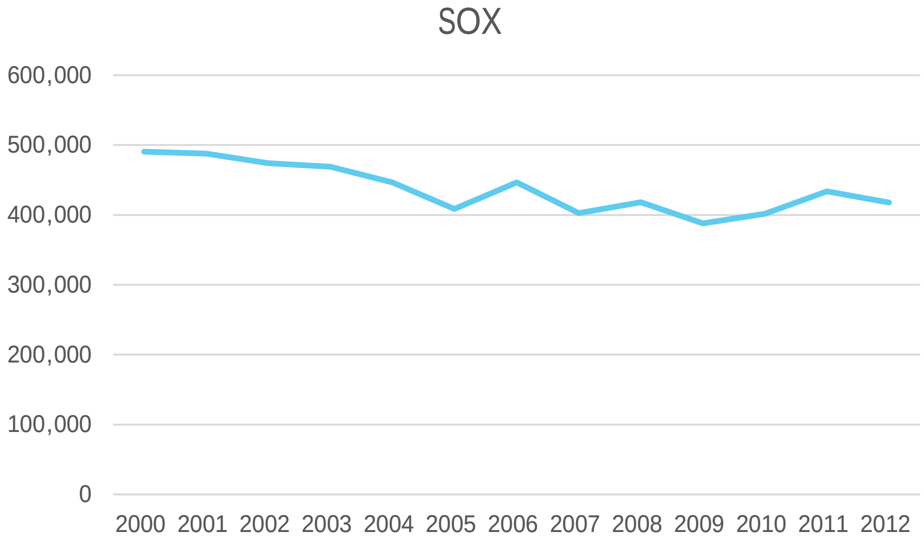
- What causes environmental pollution?
  - Market failure to reflect damage costs from environmental pollution
  - Economic growth is one of the most major factor of environmental pollution
  - People endure damage from pollution as they enjoy benefit from growth at first
  - However, as an economy grows beyond income turning point, people give more weight on quality of life than economic abundance
  - Industrial structure transfers from pollution-intensive to environment-friendly industry
  - Government strengthens environmental regulation to protect environment
- Evidence of the EKC tests
  - Developed countries: inverted U-shaped relations between GDP and pollutants such as NOX, SOX, and CO2 were observed (Grossman and Kruger, 1994, and hundreds of papers so far)
  - Developing countries: U or N-shaped relations were observed
  - Korea: inverted U or N shaped relations depending on types of pollutants, time period, estimation methods (Bae and Kim, 2012; Lee, 2010; Lee and Lee, 2009; Kim, 1999; Kim et al., 2008)

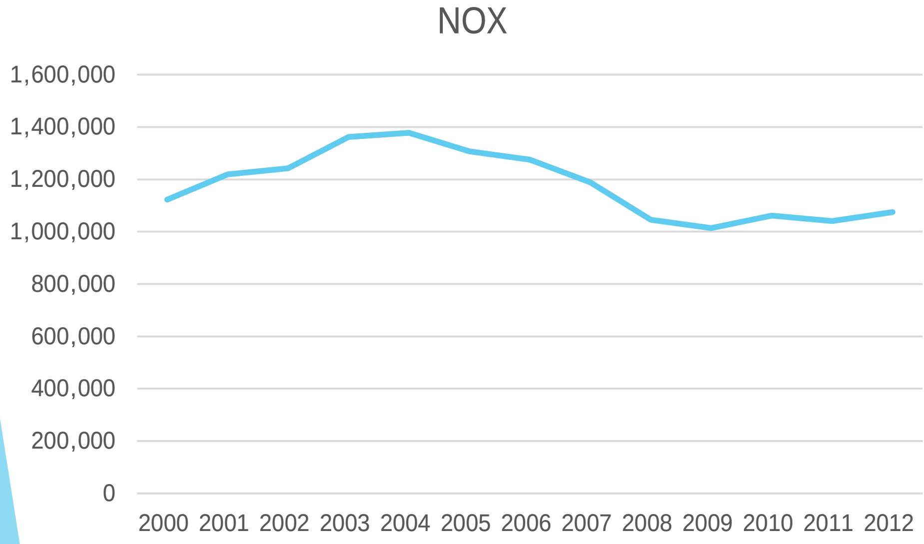
Inverted U-shaped relation between GDP and pollution

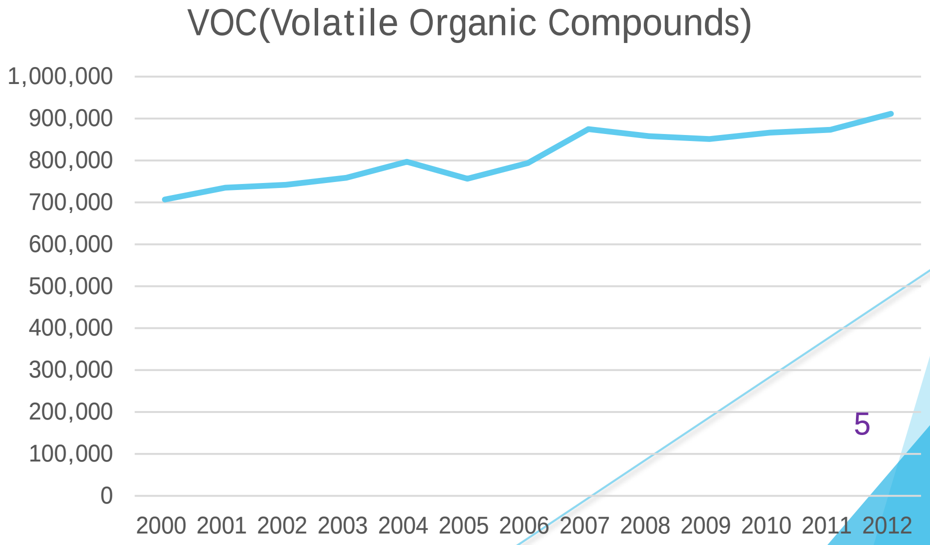


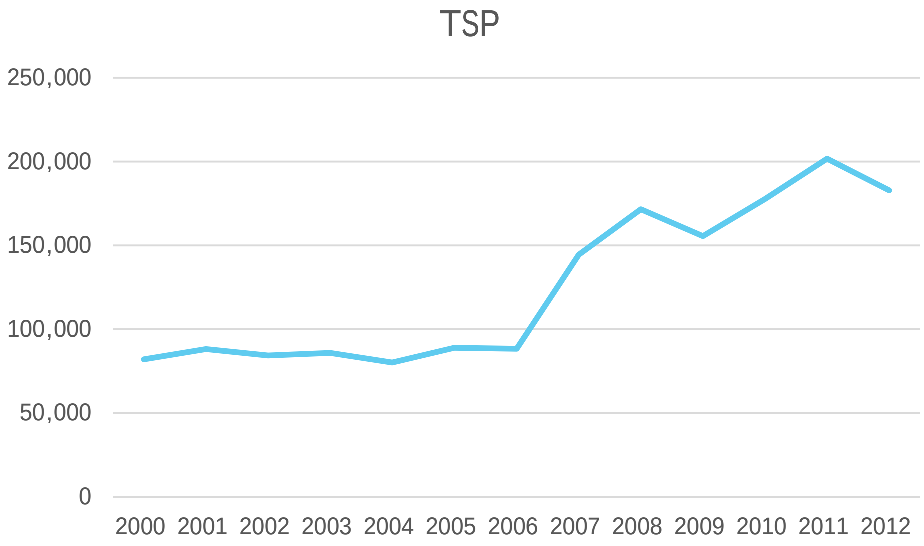
Trends of air pollution emissions (ton/year) in Korea (2000-2012)

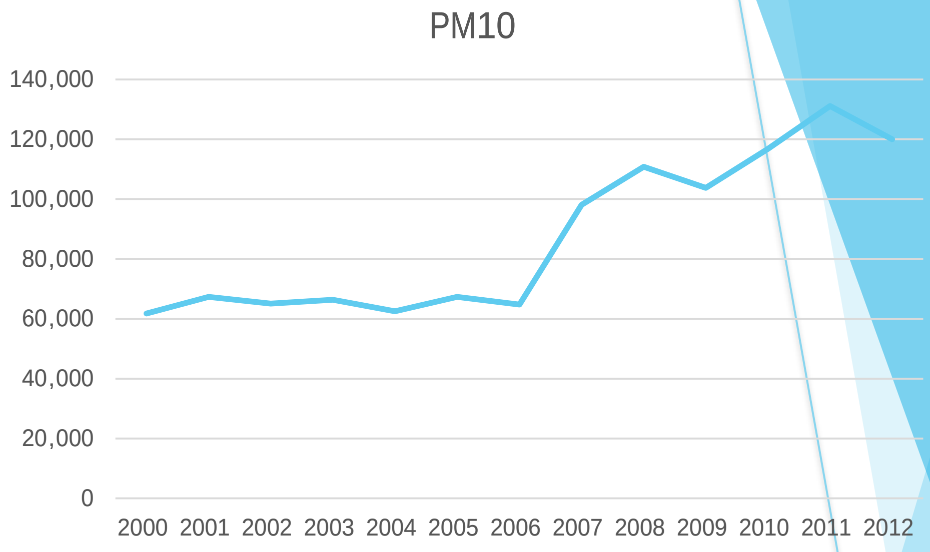












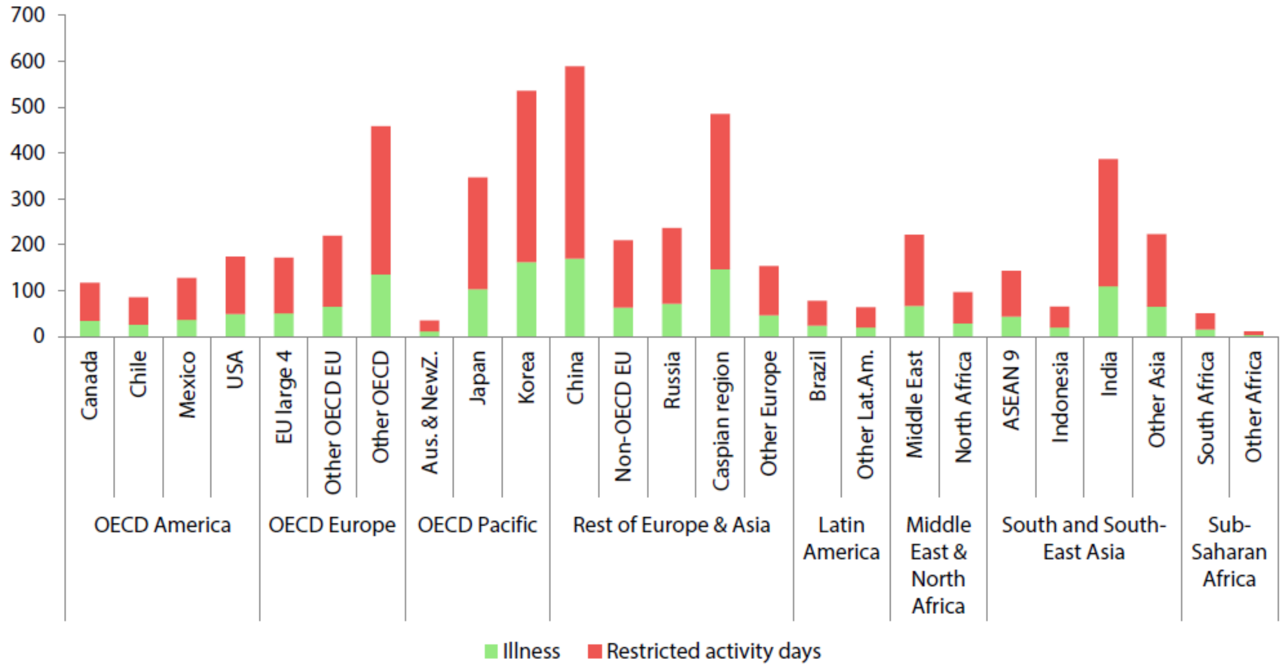
TSP and PM10: Imported coal began to be counted since 2007

PM2.5: Data for only 2011 and 2012 was available from national bureau of statistics

(Source: https://www.data.go.kr/main.jsp#/L21haW4=)

Comparison of social costs from air pollution in 2060

- OECD(2016) reported that social costs from air pollution in Korea would be ranked second to China
- Over $500 per Korean person will be the social cost in 2060



Source: OECD, The economic consequences of outdoor air pollution

Government policy on air pollution (fine dust)

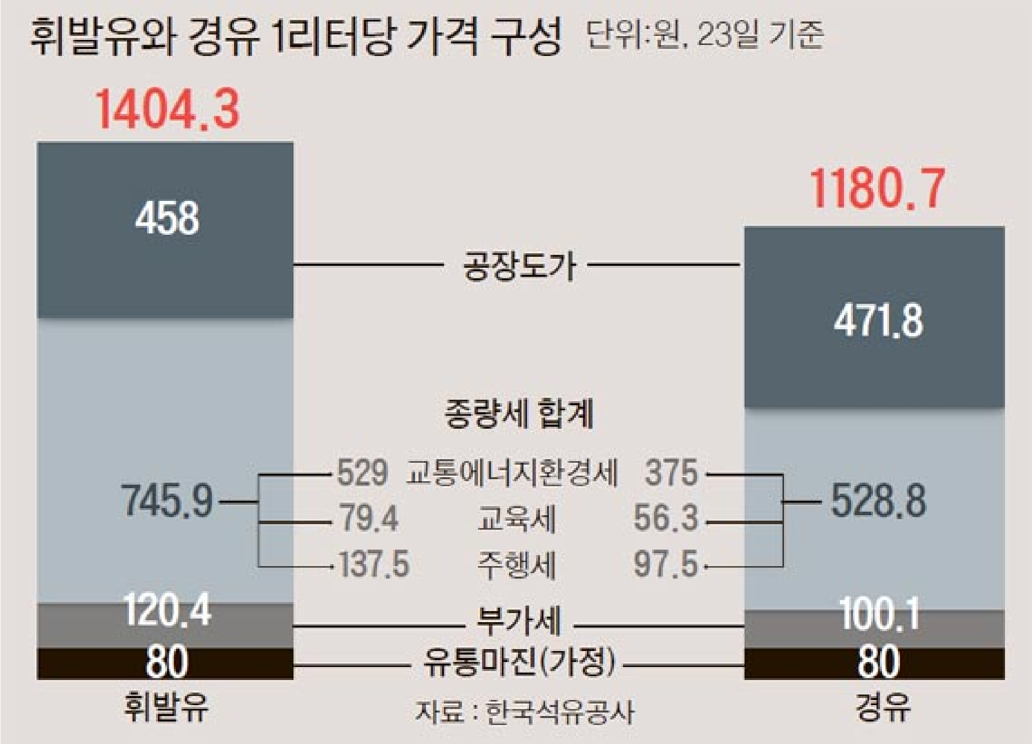
- Major causes of fine dust
  - Yellow dusts from China explain 30-50% of total
  - Domestic sources: diesel cars take about 29% in the Seoul metropolitan areas, while pollution intensive plants take 41% in the other cities
- Reduction strategy on fine dust
  - Management of domestic sources: reduction of fine dust for diesel cars, promotion of electric and hydrogen cars, restriction of driving, suspension of old coal fired power plants, more stringent regulation on pollution intensive plants, promotion of vacuum cars
  - Promotion of new industry on fine dust and CO2 reductions: promotion of environment-friendly buildings and smart city, obligation of energy zero buildings, breeding of prosumers
  - Environmental cooperation with China and Japan
  - Innovation of alarm system
  - Personal excise tax exemption by 70% for replacing old diesel cars for hybrid or electric cars
- Environmental & Energy economists claim that distorted oil taxes worsen air pollution

Comparison of gasoline and diesel prices

Unit: KRW/L (%)

Oil tax composition	Gasoline	Diesel
Consumer price	1404.3	1180.7
Transport, energy, and environmental tax	529(38)	375(32)
Education tax	79.4(6)	56.3(5)
Driving tax	137.5(10)	97.5(8)
Value-added tax	120.4(9)	100.1(8)

Source: 소비자시민연대모임 보도자료 (2012)



Distortions in oil taxes aggravate air pollution?

- Favorable tax system for diesel relative to gasoline
  - Tax burden between gasoline and diesel = 100 : 85
  - During the last decade, sharp increases in diesel cars might result from favorable diesel tax in addition to increases in leisure
- We analyzed whether diesel consumption, occurrence of yellow dusts, generation of coal fired powers, and reduction actions (promotion of NG buses) affect air pollution
- The analysis consists of two stages
  - 1st stage: we analyze price elasticity of diesel consumption
  - 2nd stage: we estimate relation between emission levels of air pollution and diesel consumption with other factors
  - Robustness test: we take the same analysis for emission density

1st stage: estimation of diesel consumption

- Econometric models: Panel fixed, random effect, GLS, and dynamic panel model
- Explanatory variables in the models
  - Diesel consumption in t-1 (previous year)
  - GRDP (Gross Regional domestic product)
  - Unemployment rate
  - Diesel price, gasoline price
- Price elasticity of diesel consumption
  - Short run price elasticity: -0.231
  - Long run price elasticity: -0.9868 (= -0.231/(1-0.766))
- The estimated diesel consumption goes into the 2nd stage model on air pollution
  - To analyze increases in diesel tax on air pollution via diesel consumption

Estimation results for 1st stage model

	Panel fixed	Panel random	Panel GLS	Dynamic panel
	coef/se	coef/se	coef/se	coef/se
Diesel demand in t-1	0.596***	0.978***	0.966***	0.766***
	(0.049)	(0.018)	(0.016)	(0.077)
GRDP	0.240***	0.019	0.034**	0.147*
	(0.069)	(0.016)	(0.015)	(0.086)
Unemployment rate	-0.078**	-0.053***	-0.047***	-0.100***
	(0.035)	(0.020)	(0.014)	(0.033)
Diesel price	-0.214***	-0.204***	-0.212***	-0.231***
	(0.047)	(0.049)	(0.035)	(0.044)
Gasoline price	0.014	0.344***	0.345***	0.177**
	(0.112)	(0.117)	(0.084)	(0.072)
Constant	0.843	-1.170**	-1.263***	-0.063
	(0.967)	(0.531)	(0.382)	(0.570)
Number of obs.	192	192	192	192
R-square	0.969	0.989		
F-statistics	44.85***			
Wald chi-square		17396***	23892.86***	842.53***

2^{nd} stage model on air pollution

- Dependent variables:
  - CO, TSP, NOX, SOX, VOC, and PM10
- Explanatory variables:
  - Macro variables: GRDP, Consumer price index(CPI), population density, dummy for 2007 (1=2007 and after, 0=otherwise)
  - Increasing factors: estimated diesel consumption, coal fired power capacity, occurrence of yellow dust, number of transport business, number of manufacturing business
  - Decreasing factors: number of natural gas buses,, precipitation, temperature
  - Test of EKC: Square and linear terms for GDP

Estimation results for 2nd stage models

Air pollutant	TSP	PM10	NOX	SOX	CO	VOC
GRDP	12.628***(2.76)	10.062***(2.420)	4.417***(1.632)	23.329***(3.337)	0.575***(0.047)	3.348**(1.643)
GRDP^2	-0.332***(0.075)	-0.262***(0.066)	-0.107**(0.045)	-0.634***(0.092)		-0.079*(0.046)
CPI	-2.572***(0.612)	-2.325***(0.568)	-1.799***(0.322)	-2.165***(0.585)	-1.600***(0.149)	-0.388(0.248)
Pop. Density	-0.547***(0.065)	-0.431***(0.061)	-0.190***(0.035)	-0.404***(0.061)	-0.014(0.017)	-0.059*(0.031)
Coal power	-0.019(0.016)	-0.011(0.015)	0.015**(0.007)	0.021(0.014)	-0.002(0.003)	0.008(0.006)
Diesel con.	0.281(0.219)	0.342*(0.203)	0.422***(0.130)	0.405(0.254)	0.324***(0.060)	0.534***(0.117)
Yellow dust	0.050*(0.027)	0.044*(0.025)	0.003(0.010)	0.047**(0.023)	-0.032***(0.010)	0.010(0.010)
NG Bus	-0.025(0.027)	-0.023(0.026)	-0.019*(0.011)	-0.007(0.025)	-0.010(0.010)	0.004(0.011)
Trans. Bus.	1.005***(0.339)	0.667**(0.307)	0.135(0.162)		0.617***(0.092)	
Precipitation	-0.068(0.088)	-0.009(0.083)	0.049(0.034)	-0.064(0.076)	-0.044(0.032)	-0.021(0.032)
Temperature	0.810(0.499)	0.834*(0.467)	-0.004(0.224)	0.424(0.478)	-0.565***(0.142)	0.976***(0.216)
Manufacture						0.246**(0.118)
Coal*D2007	0.007(0.019)	0.012(0.017)				
D2007	0.001(0.093)	-0.023(0.088)				
cons	-94.71***(24.25)	-76.15***(21.377)	-27.498*(14.259)	-196.144***(29.448)	9.910***(0.870)	-27.498*(14.605)
Wald chi2	**378.76*** **	**460.31*** **	**744.41*** **	**340.93*** **	**3021.98*** **	**989.36*** **

Impact of diesel price increase on air pollution

Pollutants	Elasticity of diesel consumption on pollution (%)	Short run price elasticity of diesel demand(%)	Short run diesel price elasticity on pollution(%)	Long run price elasticity of diesel demand(%)	Long run diesel price elasticity on pollution(%)
TSP	0.28	-0.2310	-0.0647	-0.9868	-0.2763
PM10	0.342**	-0.2310	-0.079	-0.9868	-0.3375
NOX	0.422***	-0.2310	-0.0975	-0.9868	-0.4164
SOX	0.405	-0.2310	-0.0935	-0.9868	-0.3996
CO	0.324***	-0.2310	-0.0748	-0.9868	-0.3197
VOC	0.534***	-0.2310	-0.1233	-0.9868	-0.5269

Robustness test for PM10 density

PM10 density (ug/m3)	APM1	APM2	APM3
GDP	0.756(0.691)	1.274*(0.661)	0.644(0.748)
GDP^2	-0.023(0.019)	-0.040**(0.018)	-0.020(0.021)
CPI	-0.698***(0.125)	-0.657***(0.115)	-0.557***(0.126)
Pop. Density	-0.010(0.014)	0.070***(0.013)	0.030**(0.013)
Coal power	-0.007**(0.003)	-0.009***(0.003)	-0.010***(0.003)
Diesel con.	0.212***(0.049)	0.315***(0.050)	0.177***(0.053)
Yellow dust	0.012(0.009)	0.011(0.010)	0.013(0.010)
NG Bus	0.004(0.007)	0.006(0.008)	0.002(0.009)
Trans. Bus.	0.449***(0.074)		
Precipitation	-0.086***(0.027)	-0.117***(0.030)	-0.084***(0.030)
Temperature	-0.250*(0.133)	-0.496***(0.133)	-0.367**(0.145)
Construction		0.297***(0.069)	
Manufacture			0.061(0.049)
Constant	2.717(5.841)	-2.375(5.601)	1.432(6.607)
Wald chi2	227.48***	264.04***	204.53***
N of Obs.	165	165	165

What can we do with tax revenue from increment in diesel taxes

- Amendment of oil tax structure
  - Gasoline tax : diesel tax = 95:90 or 90:95 ?
  - Relative tax burden between gasoline and diesel requires more discussion
- More on electric car subsidy?
  - Most electricity comes from coal and nuclear in Korea
  - More electric car can cause increases in coal and nuclear powers
- More on biofuels?
  - BD is environment friendly fuels, but Korea is lack of feedstock
  - Food stock cannot be used due to impact on food prices
  - Non-food stock is costly in Korea
  - Waste vegi oil, waste animal fat oil, or imported EFB from waste palm are feasible feedstock
  - Currently, BD5 is maximum level with domestic feedstock

No concerns over biofuels in mitigation policy on fine dust

- Major transport policy concentrates on promotion of hybrid, electric cars
- Although biodiesel is effective in reducing PM10 and SOx, current RFS allows for 3% of BD
- BD5 is expected to be blended with diesel until 2023
- There is no government plan for bioethanol blending with gasoline in Korea
- Demonstration project on bioethanol (E3-E6 and bio-buthanol) is implemented by this year
  - This project test economic as well as technological feasibility of E3-E6 with bio-buthanol in Korea

Impact of biodiesel on air quality

- National Environmental Science Institute: BD can reduce PM, CO, HC considerably as blending ratio increases
- But Nox stays constant even with 20% of blending ratio

Item	economic evalution						benefit (won)	
	BD		BD10		BD20			
	emission (g/kwh)	social cost (won)[1]	emission (g/kwh)	social cost (won)	emission (g/kwh)	social cost (won)	BD10	BD20
SUM	-	1,896	-	1,568	-	1,054		
PM	4.46	1,820	3.67	1,498	2.40	980		
CO	1.63	5	1.32	4	1.16	3	328	842
HC	0.10	0	0.04	0	0.01	0		
NOx	10.80	71	10.06	66	10.89	71		

[1] 인구 100만 기준(EC), 1€=1,155원

: PM 408,137원/kg, NOx 6,554원/kg, HC 3,276원/kg, CO 2,820원/kg,

배출량 결과는 본 연구에서 시험한 결과를 사용

Source: 국립환경과학원, 2013, “바이오디젤 연료사용에 따른 미세먼지(PM2.5)의 환경성 평가 연구”

How to improve RFS program in Korea?

- Bioethanol as well as biogas and others should be included in the RFS
  - Petroleum companies object to inclusion of bioethanol
- Higher blending ratios should be accounted for biofuels
  - By 2022, BD blending ratio is 7%!
  - As of 2013, USA average biofuel blending ratio is 9%
  - Major Southeastern countries have higher targets (BD10 – 20)
  - So, the maximum blending ratio should be at least up to 10%
- More investment on 2nd and third generation biofuel technology
  - R&D investment on biofuels from biomass, micro algae, and macro algae should be raised
  - But R&D supports as well as commercialization subsidy are not sufficient at present
  - There are no oil tax exemption subsidy on biofuels but no tax on electric cars!
  - More subsidy flows into electric or hydrogen fuel cell cars

RFS possible scenarios

Source: 김재곤, 2015 “RFS 제도 시행에 따른 바이오연료 보급 전략”, 신재생에너지 춘계 국제학술대회 발표자료

Thank all audiences with my presentation