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Effectiveness and macroeconomic impact analysis of policy instruments for sustainable transport in Korea: A CGE modeling approach

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Abstract

In evaluating policy measures' applicability, information on policy measures' effectiveness and its possible macroeconomic consequences would be essential for policy makers especially in cases where severe macroeconomic consequences are anticipated. In the transport sector various policy measures are being considered for satisfying specific environmental quality objectives and these policy instruments usually have macroeconomic implications in their implementation.

In this paper we first analyze the policy measures' effectiveness and we develop a computable general equilibrium model where the macroeconomic impacts of environmental and economic policy variables can be analyzed in the Korean context. We analyze the impacts of widely considered policy instruments for sustainable development in the transport sector. These include fuel pricing, public transport promotion and modal shift in freight transport. Changes in macroeconomic indicators such as GDP, trade account balances and government expenditures are estimated according to the change in the policy variables. The findings from this study can be consulted in prioritizing or analyzing feasibility of environmental policies in the transport sector.

1. Introduction

After the ratification of Kyoto Protocol in 1997, Annex B countries have to take on binding responsibility for their greenhouse gas (GHG) reductions. At the same time, increasing pressure is placed on developing countries requesting sharing the burden of GHG reduction from these unregulated countries. In light of this, Korea has been trying to find the way to share the burden and to develop consensus among governmental agencies, industrial sectors, academics and

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general public about how Korea should respond to the issue. As its economic development so heavily dependent on energy consumption, South Korea needs an effective domestic policy (portfolio) to control the growth GHG while avoiding unbearable adverse impacts on its economy. Therefore, the comprehension of the features of each policy instrument and the synergetic reconciliation with objectives other than GHG abatement is important.

The policy instruments that can be implemented in transport sector are diverse and comprehensive, ranging from economic incentives to control or guiding approaches. Given a number of issues surrounding various types of policy instruments, choice of appropriate domestic policy is very important. In addition to the usual command and control measures, various policy measures have been introduced or have been contemplated for implementation in order to reduce GHG emissions in the transport sector. These include fuel pricing, public transport promotion and modal shift in freight transport. However, these policies based on economic incentives and infrastructure provision might have severe economic consequences when implemented.

The objective of this study is to analyze and compare the impacts of widely considered policy instruments for sustainable development in the Korean transport sector. For analysis, a dynamic computable general equilibrium (CGE) model – called Korean Trade and Environment Model (KORTEM) - with extensively disaggregated energy sectors and nested structures for economic agent behaviors has been employed.

We first analyze the effectiveness of representative policy measures on reducing GHG emissions. This represents the bottom-up part of the analysis, which considers the reduction potential of a policy measure and the results from this analysis can also be used as an input to the macroeconomic impact analysis. Based on the findings from the bottom-up analysis, macroeconomic impact analysis is conducted for the policy measures. Information on the macroeconomic implications of the policy measures will be very beneficial for the policy makers to choose proper sets of policy measures for achieving the objectives while minimizing the adverse impact on the economy.

2. Modeling approach

KOTEM is a detailed dynamic model of the Korean economy designed specifically to analyze the economic impacts of national and international climate change policy on the Korean economy. Korea is a relatively small open economy that relies heavily on fossil fuel imports and on energy/emission intensive industries for export earnings. This implies that climate change response policies at both the national and international levels will have significant impacts on the Korean economy and trade. These include impacts on the competitiveness of energy intensive export industries, on non-traded energy related services such as transport and on fossil fuel imports. KORTEM also allows assessment of the impacts of domestic emission abatement on Korean economy and industries.

As a general equilibrium model, KORTEM include all the major structural details of, and interrelationships between, the different sectors of the Korean

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economy. Given the pervasive use of energy in the economy, policies affecting energy use have widespread ramifications that can be accounted for only in a general equilibrium setting. KORTEM is a dynamic model that is essential for climate change analysis to allow the impacts of emission abatement to be tracked over time and the impacts of alternative timetables for implementing emission abatement policies to be examined. KORTEM incorporates stock flow dynamics in investment and in labor force and population growth.

In KORTEM, there are 103 industries and commodities including 19 energies and 10 margins with 4 transport margins (i.e. road, rail, air and sea transportation). There are three types of primary factors – labor, capital and land. Labor is divided into eight different types in terms of occupations. With the detailed representation of the labor market, KORTEM has the capacity for detailed analysis of policy changes on various labor types and income distribution. Each commodity is supplied from two different sources – domestic and imported – with imperfect substitution (i.e. Armington elasticity).

Realistic specification of key energy using sector is essential for modeling climate change policies. KORTEM adopted the approach of nested production functions at this stage. KORTEM allows for inter-fuel and energy-capital substitution over a range of different technologies. For example, the adoption of more energy efficient but more costly equipment is modeled as energy-capital substitution. The extent of substitution is constrained to preclude unrealistic substitution possibilities.

The detailed treatment of margins is incorporated in KORTEM. The services of various trade (for example, wholesale trade, retail trade and insurance) and transport industries are often required for the transfer of goods and services between producers and purchasers (These industries account for about 20 percent of Korean GDP). KORTEM takes explicit account of margins in the supply chain. Apart from allowing simulation of the effects on the margin industries of structural change elsewhere in the economy, KORTEM allows substitution between different modes of transport. This allows the assignment of freight transport tasks between road, rail, sea and air in response to changes in relative freight costs. KORTEM, therefore, is able to capture any changes in the freight task arising from actions to reduce greenhouse gas emissions.

KORTEM also includes specific treatment of the government sector. The government sector purchases goods and services and collects taxation revenue from a number of sources. The explicit treatment of the government sector allows KORTEM to examine the fiscal dimensions of climate change policy. A key fiscal consideration for government is the revenue collected, or not collected, from market based instruments used to mitigate GHG emissions. For example, KORTEM has the capacity to assess the fiscal implications of carbon taxation versus domestic tradable emission permits. Furthermore, KORTEM allows detailed analysis of revenue recycling, such as the replacement of inefficient taxation by carbon taxation, that can confer benefits to the Korean economy - the so-called "double dividend".

A fundamental requirement for greenhouse policy analysis is the ability to account for all greenhouse gas emissions. In many current general equilibrium models, carbon dioxide (CO_2) from fossil fuel combustion is the only gas and source covered. KORTEM, however, incorporates a system of emission accounts

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that cover three major GHG gases – carbon dioxide, methane and nitrous oxide - from various sources – energy, industrial processes, agriculture and waste.

3. The reference case

A key determinant of the economic impact of the policy employed in transport sector for GHG emissions reduction is the deviation of projected GHG emissions level under a 'no policy' scenario – referred to here as the reference case – from its targeted emission level. The reference case projections determine the extent of emissions abatement required to meet the given target. The reference case does not include the impacts of policies that are currently being implemented or negotiated in response to concerns of climate change. Here, reference case GHG emissions, energy consumption and macro economy to year 2020 are presented. The reference case projections are based on current assumption about GDP and population growth and energy technology and, as such, should not be considered a prediction of the future.

Table 1. Macro-economy and energy consumption, reference case

Economic and environmental indicators	1995	2000	2010	2020	Growth rate *		
					1996-2000	2001-2010	2011-2020
Real GDP (1000 billion won)	377.4	442.4	729.6	1,067.6	3.23	5.13	3.88
Population (million)	45.0	47.2	50.8	52.4	0.96	0.74	0.30
GHG emissions (million TC)	120.0	138.1	215.1	313.5	2.85	4.53	3.84
Final energy consumption (million TOE)	120.9	149.6	253.1	380.9	4.35	5.40	4.17
Energy intensity (mil. TOE/1000 billion won)	0.320	0.338	0.347	0.357	1.08	0.26	0.28
Emission intensity (TC/million won)	0.318	0.312	0.295	0.294	-0.37	-0.57	-0.04

* Annual average growth rate

Korean economy has achieved the rapid recovery from the Asian financial crisis. The real GDP has grown by 3.23% a year over the period 1996-2000. The real GDP is projected to rise approximately by 5.1% and 3.9% a year over the period 2001-2010 and 2011-2020 respectively. Population growth rate is projected to be 0.74% and 0.30% respectively for the same period. The growth rate of final energy consumption is projected to be higher than that of real GDP. This is projected to raise energy intensity of production defined as the ratio of aggregate energy consumption to aggregate output (real GDP). On the other hand, as the GHG emissions are projected to increase by 4.53% and 3.84% a year over the period 2001-2010 and 2011-2020 respectively, the emission intensity of production defined as the ratio of aggregate emissions to aggregate output is projected to fall.

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Table 2. Growth rate of energy consumption and GHG emissions in transport sector, reference case

	Energy consumption		GHG emission	
	2001-2010	2011-2020	2001-2010	2011-2020
Rail	5.71	6.63	4.38	5.09
Road	3.33	3.15	3.52	2.55
Sea	3.92	2.90	3.79	3.79
Air	4.25	3.35	5.87	6.08
Total	3.56	3.19	3.58	2.72

* Annual average growth rate

Energy consumption of transport sector in total is projected to increase by 3.56% and 3.19% a year over the period of 2001-2010 and 2011-2020 respectively. The growth rate of energy consumption of rail is projected to be higher than that of other transport sectors. In terms of GHG emissions, emissions from rail and air are projected to lead in increasing emissions in transportation sector, highlighting the importance of the future abatement efforts of rail and air in reducing emission growth in transportation sector.

4. Policy scenarios and their effectiveness analysis

To compare the economic and environmental impacts of policy instruments for sustainable development in the Korean transport sector, this paper analyzes three different policy scenarios that are widely considered in Korea. They include fuel pricing, public transport promotion and modal shift in freight transport.

4.1 Public transport policy

Our first policy scenario is about maintaining current transport share of public transport up to year 2020. Current trend indicates that the share of public transport, especially the share of bus transport will be decreasing significantly in the future. Table 4 compares the base scenario with the public transport promotion policy. Table 5 estimates the potential savings from the increased public transport patronage in the Korean context. The estimated emission unit of private passenger car is 40.8 g-C/person km. The emission units of bus and subway are estimated to be 37.0% and 7.4% of passenger car's respectively due to the high occupancy rate. As shown in Table 5, it is estimated that 3.72% of the total transport emission can be reduced by the public transport promotion policy in 2020.

Table 3. Public transport policy scenarios

Scenario	Assumptions
BAU Scenario	Current trends scenario: Declining public transport modal share
Public transport scenario	Bus: Maintaining current modal share (9.96%) up to 2020. Subway: Maintaining current modal share (9.49%) up to year 2020.

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Table 4. Passenger transport demand forecast by public transport policy scenario

Unit: million person km

		2000	2005	2010	2015	2020
BAU Scenario	Passenger car	168,126	217,043	280,194	361,718	466,963
	Bus	27,695	25,917	24,253	22,695	21,238
	Subway	28,365	34,445	38,899	51,541	61,170
	Total	224,186	277,405	343,345	435,954	549,371
Maintaining public transport modal share	Passenger car	168,126	207,477	258,367	330,241	418,397
	Bus	27,695	35,254	42,842	53,297	66,032
	Subway	28,365	34,673	42,136	52,417	64,942
	Total	224,186	277,405	343,345	435,954	549,371

Table 5. Estimation of CO_2 emission under public transport policy

Unit: thousand TC

		2000	2005	2010	2015	2020
BAU Scenario	Passenger car	6,853	8,847	11,421	14,745	19,035
	Bus	417	390	365	342	320
	Subway	85	103	117	155	184
	Sub-total	7,355	9,341	11,903	15,241	19,538
	Total Emission[1)]	18,681	22,176	26,565	31,044	34,748
Maintaining public transport modal share	Passenger car	6,853	8,457	10,532	13,461	17,055
	Bus	417	531	645	803	994
	Subway	85	104	126	157	195
	Sub-total	7,355	9,092	11,303	14,421	18,244
	Estimated reduction compared with the total[2)]	-	249 (1.12%)	600 (2.26%)	820 (2.64%)	1,294 (3.72%)

1) Total emission in the transport sector

2) The estimated reduction is in comparison with the total transport emission.

4.2 Modal shift in freight transport

The freight transport sector accounts for 30.9% of the total transport CO_2 emission and it is also regarded the most inefficient sector of Korea's transport. The road transport, especially less efficient private freight vehicles plays the dominant role in Korea's freight transport sector. Various efforts are now being made to reduce this dependency on road sector and to increase the more energy efficient railway's share by increasing the capacity of the more environmentally friendly freight mode.

The emission units by each freight transport modes are calculated from the current emission and activities data. The results are shown in Table 6. Table 7 represents the target freight modal share set by the ambitious government plan to

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provide more environmentally friendly infrastructure.

Table 6. CO_2 emission units by freight transport modes (1999)

	Private freight vehicle	Commercial freight vehicle	Rail	Water	Air
Freight ton km (million ton-km)	33,376	9,227	10,072	33,699	151
Share (%)	38.6	14.6	11.6	38.9	0.2
CO_2 emission (thousand TC)	5,251.3	1,167.7	-	-	-
CO_2 emission unit (g-C/ton·km)	157.3	126.6	7.1	10.0	402.0

Table 7. Proposed freight modal share change

Unit: %

	1997	2010	2020
Road	56.6	48.2	41.2
Rail	14.2	15.5	20.3
Water	35.8	36.0	38.1
Air	0.1	0.3	0.4

Table 8. Freight modal shift policy scenarios

BAU Scenario	Current trend and no infrastructure investment
Modal shift scenario	Government infrastructure investment and modal shift plan

Table 9. Freight modal demand forecasting by scenario

Unit: million ton·km

		2000	2005	2010	2015	2020
BAU Scenario	Road Private	34,379	40,006	46,841	55,201	65,491
	Road Commercial	9,504	11,060	12,950	15,261	18,106
	Rail	10,375	12,073	14,136	16,659	19,764
	Water	34,712	40,394	47,295	55,736	66,125
	Air	156	182	213	251	298
	Total	89,126	103,715	121,435	143,108	169,784
Infrastructure & modal shift policy scenario	Road Private	34,379	38,448	40,972	41,468	41,971
	Road Commercial	9,504	10,417	17,560	22,494	27,980
	Rail	10,375	14,592	18,822	25,477	34,483
	Water	34,712	40,007	43,717	53,178	64,688
	Air	156	252	364	491	662
	Total	89,126	103,715	121,435	143,108	169,784

As shown in Table 10, it is estimated that 6.64% of CO_2 emission can be reduced by the long-term modal shift policy measures. This increased efficiency comes from the modal shift to more energy efficient modes such as rail and also from a shift to more efficient commercial vehicles within the road sector.

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Table 10. CO_2 emission forecasting and reduction potential under the infrastructure and modal shift policy

Unit: thousand TC

		2000	2005	2010	2015	2020
BAU Scenario	Road Private	5,409	6,294	7,370	8,685	10,304
	Road Commercial	1,203	1,400	1,639	1,931	2,291
	Rail	74	86	101	119	141
	Water	347	404	473	557	661
	Air	63	73	86	101	120
	Sub total	7,096	8,257	9,668	11,394	13,518
	Total	18,681	22,056	26,565	30,855	33,869
Infrastructure & modal shift policy Scenario	Road Private	5,409	6,049	6,446	6,525	6,604
	Road Commercial	1,203	1,318	2,222	2,847	3,541
	Rail	74	104	134	182	246
	Water	347	400	437	532	647
	Air	63	101	146	197	266
	Sub total	7,096	7,973	9,387	10,282	11,304
	Reduction potential	-	284 (1.29%)	282 (1.06%)	1,111 (3.60%)	2,214 (6.54%)

4.3 Fuel price policy

We first need to specify the policy scenario of fuel price increase. In our scenario fuel price is assumed to increase at a rate of 5% per annum in addition to the base scenario for eight consecutive years from the year 2001. In the base scenario, an annual 1.9% increase is adopted from the price change forecasting as a part of the base scenario. This represents an additional 48% increase in fuel price at the end of the policy period.

Table 11. Scenario for fuel price policy

Scenario	Assumptions
BAU	Annual increase rate of 1.9%
Fuel price increase	Additional 5% fuel price increase from 2001 for 8 years

There are two ways that the fuel price change can affect the carbon dioxide emission in the transport sector. The assumed fuel price change has some impact on the future vehicle ownership since our long-term vehicle ownership forecasting equation has fuel price as a component of the cost variable. And then the increased fuel price affects the vehicle travel according to the price elasticity.

Table 12 shows the estimated impact of fuel price increase on the vehicle ownership. It is estimated that the assumed fuel price hike will reduce the vehicle numbers by almost 1.4 million in the long run. This represents about 7.8% reduction of passenger cars compared with the BAU scenario.

The estimated reduction in the CO_2 emission is shown in the Table 13 below. It is estimated that about 4.8% of the total emission reduction can be expected under the fuel price policy. The estimated reduction in this case is measured against the total emission in the transport sector that was calculated by the emission units.

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Table 12. Forecasting of vehicle ownership under the fuel price policy scenario

Unit: vehicles

		2000	2005	2010	2015	2020
BAU Scenario	Passenger car (Gasoline)	7,624,013	10,319,880	13,470,977	15,710,622	17,535,395
	Bus (Gasoline)	44,993	52,837	58,379	67,320	73,877
	Truck (Gasoline)	62,473	73,364	81,059	93,474	102,578
	Subtotal	7,731,4797	10,446,081	13,610,415	15,871,416	17,711,850
Fuel price policy scenario	Passenger car (Gasoline)	7,624,013	9,943,312	12,317,773	14,567,116	16,542,085
	Bus (Gasoline)	44,993	50,012	52,443	61,323	68,467
	Truck (Gasoline)	62,473	69,442	72,817	85,147	95,067
	Subtotal	7,731,479	9,888,036	12,226,579	14,457,605	16,414,932
	Estimated reduction of vehicle numbers	-	558,045	1,383,836	1,413,811	1,296,918

Table 13. Estimated reduction of CO_2 under the fuel price policy

Unit: thousand TC

		2000	2005	2010	2015	2020
BAU Scenario	Passenger car (Gasoline)	7,024	9,436	12,317	14,364	16,033
	Bus (Gasoline)	50	58	64	74	81
	Truck (Gasoline)	77	89	99	114	125
	Subtotal	7,151	9,583	12,480	14,552	16,239
	Total Emission	18,681	22,176	26,565	31,044	34,748
Fuel price policy scenario	Passenger car (Gasoline)	7,024	8,809	10,726	12,684	14,404
	Bus (Gasoline)	50	54	56	65	73
	Truck (Gasoline)	77	83	86	100	112
	Subtotal	7,151	8,946	10,868	12,849	14,589
	Estimated reduction of CO_2 emission*	-	637 (2.87%)	1,612 (6.07%)	1,703 (5.49%)	1,650 (4.75%)

* The estimated reduction is in comparison with the total emission in the transport sector

5 The impacts on macro economy, energy consumption and GHG emissions

An assessment of the impacts of various policy scenarios to mitigate GHG emissions in transport sector is provided in this section. The economic and environmental impacts are measured by comparing results from counter factual runs of the model and the reference case.

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Table 14. Changes in economic and environmental indicators relative to the reference case

Economic and environmental indicators	Scenario 1 (Public transport promotion)		Scenario 2 (Modal shift in freight transport)		Scenario 3 (Fuel pricing)	
	2010	2020	2010	2020	2010	2020
Real GNP	0.31	0.45	-0.80	1.13	-0.51	-0.45
Household consumption	0.44	0.60	-1.11	1.70	-1.08	-0.91
Investment	0.32	0.49	-0.33	1.09	-0.09	-0.10
Government Consumption	0.44	0.60	-1.11	1.70	-1.08	-0.91
Export	-0.38	-0.49	1.04	-2.06	0.85	0.47
Import	-0.33	-0.02	0.75	-0.22	-0.08	-0.25
GHG emissions	-0.42	-0.74	-0.67	-1.95	-2.16	-2.63
Energy consumption	-0.80	-1.26	-0.97	-3.42	-2.54	-2.99
Energy intensity	-1.12	-1.70	-0.18	-4.50	-2.04	-2.55
Emission intensity	-0.77	-1.24	0.13	-3.18	-1.74	-2.29

Table 14 presents the impacts of three different policy scenarios on macro economy, aggregate energy consumption and aggregate GHG emissions in Korea. Scenario 1 (public transport promotion) is projected to increase real GDP by 0.31% and 0.45% relative to the reference case in 2010 and 2020 respectively, while GHG emissions is projected to be reduced by 0.42% and 0.74% in same year. The increase of real GDP relative to the reference case is led by the increase of household consumption, government consumption and investment. However, the deterioration of trade account partly offsets the increase of real GDP. The reduction of GHG emissions is mainly led by the decrease of emissions from driving private car. As GHG emissions fall and real GDP increases, the emission intensity is projected to decrease by 0.77% and 1.24% relative to the reference case in 2010 and 2020 respectively. Since the energy consumption is projected to decrease, the energy intensity is also projected to fall by 1.12% and 1.70% in same year.

On the other hand, scenario 2 is projected to decrease real GDP by 0.80% in 2010 and increase by 1.13% in 2020, while it is projected to reduce GHG emissions by 0.67% and 1.95% in 2010 and 2020 respectively. The significant reduction of road in freight transport after 2010 under scenario 2 is projected to lead the reduction of GHG emissions after 2010. Until 2010, the emission intensity is projected to increase by 0.13% led by small reduction of GHG emission relative the real GDP. However, the increase of real GDP is projected to contribute to the decrease of emission intensity in 2020 relative to the reference case. The increase of real GDP in 2020 is due to an increase of household consumption, investment and government consumption, while the trade account is deteriorated. As a result, scenario 2 is projected to shrink the economic activity during the short and middle terms with the reduction of GHG emissions. However, it is projected to expand the economy in the long run with the increased contribution of environment friendly road and sea transportation in total freight transportation.

Under scenario 3, fuel pricing, real GDP is projected to decrease by 0.51%

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and 0.45% in 2010 and 2020 respectively, while GHG emission is reduced with the higher rate (2.16% and 2.63%) than real GDP. Therefore, the emission intensity is also projected to fall. This result shows that the scenario 3 is effective for the abatement of GHG emissions, however it accompanies the curling up of economic activity. The reduction of real GDP is mainly due to the reduction of household and government consumption, while the trade account is projected to improve.

6. Summary and policy implications

After the climate change negotiation reaches an agreement in near future, the next main issue to be addressed is the way of involvement of developing countries in emission abatement commitments. Despite having no emission abatement commitments under the Kyoto Protocol, Korea is projected to face the increasing pressure from international society to contribute to the global efforts for greenhouse gas emission reduction. As Korea participates to the global efforts, it is believed that it will create the structural changes of Korean economy. This new situation will bring Korea to an unfamiliar economic and social environment. In this study we first analyze the policy measures' effectiveness and we develop a computable general equilibrium model where the macroeconomic impacts of environmental and economic policy variables can be analyzed in the Korean context. By utilizing a dynamic computable general equilibrium (CGE) model, this paper analyzed what kind of scheme for policy instruments in transport sector to reduce GHG emissions are desirable for Korea in complying with the international efforts to mitigate climate change, by focusing on three different policy scenarios.

This study shows that the policy focusing on the increase of fuel price (scenario 3) is projected to be effective in reducing GHG emissions. However, this kind of policy approach accompanies the shrinkage of economic activity simultaneously. On the other hand, even if the effectiveness in reducing GHG emission is lower than the case of fuel pricing, policies such as public transport promotion and modal shift in freight transport are found to be more feasible policy options in designing domestic policies in transport sector.

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