Carbon Tax, Carbon Reduction Potential, and Economic Impact in Japan:
Application of AIM (Asia-Pacific Integrated Model)

AIM Project Team
National Institute for Environmental Studies

February 12, 2004

1. Introduction

This paper examines the effects of carbon tax as a carbon reduction policy in Japan. For this analysis, the three models of AIM (Asia-Pacific Integrated Model) project are utilized; AIM/Enduse, AIM/Top-down, and AIM/Material. AIM is one of the integrated assessment models to assess policy options mainly in Asia-Pacific region for reducing the greenhouse gas emissions and avoiding the climate change impact. For a detailed description of the AIM model, refer Kainuma et al. (2002).

AIM/Enduse model, which includes the detailed technology selection, represents the potential carbon emissions reduction by using existing or practical technologies, and necessary carbon tax rate. Moreover, the policy mix to lower the carbon tax rate is proposed and its effectiveness is calculated. AIM/Top-down model and AIM/Material model, which are global and country economic model respectively, represent the economic impact of carbon tax policy in Japan.

2. Kyoto Protocol and CO2 reduction in Japan

According to the Kyoto Protocol, the greenhouse gas emissions in Japan in the first commitment period (from 2008 to 2010) should be reduced by 6% of those in 1990. In order to reduce the greenhouse gas emissions, the Government of Japan adopted the New Climate Change Policy Programme in March 2002, and various activities have been introduced to achieve the target. Under this program, the quantitative target of CO2 emissions reduction related to energy consumption is set to 2%. For the purpose of CO2 emissions reduction, the Ministry of the Environment is considering the introduction of carbon tax. At present, the proposal of Ministry of Environment is to introduce a combination of low price carbon tax and subsidy to support the purchase of the expensive energy saving devices. The necessary level of carbon tax price and economic impacts of this policy are estimated using the AIM modeling framework.

3. Outline of model analysis

In order to evaluate the price and economic impact of the carbon tax in Japan, 3 models interlinked models have been used (Fig. 1). The AIM/Enduse model gives detailed technology representation. The second model is the AIM/Material model, an economic model to simulate economic activity in Japan. The third model is the AIM/Top-down model, which is a global economic model. By using the AIM/Enduse model, potential of CO2 emissions reduction from the perspective of technology improvement is evaluated. Economic models help in estimating the economic impact of introduction of carbon tax. The AIM/Material model helps analyze the changes in domestic economic activities and

employment. Finally the AIM/Top-down model, helps examine the international competitiveness in energy intensive industries such as steel, pulp, chemical and cement industry.

(1) AIM/Enduse model.

The AIM/Enduse model focuses on individual technology devices.

In the AIM/Enduse, selection of technologies takes place in a linear optimization framework where system cost is minimized under several constraints like satisfaction of service demands, availability of energy and material supplies, and other system constraints. Tab. 1 shows the example of socioeconomic scenarios to estimate the energy service demand. For example, in steel and iron industry, the energy devices and energy types are selected in order to meet crude steel production through cost-minimization. Costs imply both running cost and initial cost based on the payback time of 3 years. By using this model, the necessary carbon tax rate and subsidy for each energy saving device can be calculated.

The procedure of CO2 reduction by imposing carbon tax is outlined next. Since the energy price becomes high by introducing the carbon tax, the differences of total costs between ordinary device and energy saving device will be small, although energy saving devices are somewhat expensive. When the tax ratio exceeds a level, the energy saving technology device would be selected. In the case of subsidy, tax revenue will be used to enhance the demand of these energy saving devices.

In case the new energy saving technologies do not spread in the future (Technology fix case), CO2 emissions will increase continuously until 2012 as shown in line A in Fig. 2. When the energy saving technology improvement is taken into consideration, the CO2 emission trajectory will correspond to line B in Fig. 2. In this case, the efficient technologies will be selected to minimize the total cost. The more energy efficient technology is usually expensive, and as a result, sufficient new technologies will not be introduced. When the carbon tax is imposed (Carbon tax case), the emissions of CO2 will be reduced. The reduction of CO2 emissions depends on the tax rate. If only carbon tax policy is introduced to achieve Kyoto Protocol, the tax rate will be about 45,000 Japanese yen/tC in the 1st commitment period.

It is assumed that the tax revenue from carbon tax is utilized to subsidize CO2 reduction countermeasures (Carbon tax + subsidy case). In this case, the carbon tax rate to achieve the Kyoto Protocol will be about 3,400 Japanese yen/tC. The subsidized countermeasures are shown in Tab. 2. As can be seen from the table, huge subsidy will be utilized as energy saving investment. This means that the CO2 reduction policy may help industries related to the energy saving technologies grow.

(2) AIM/Top-down model

The AIM/Top-down model is the global computable general equilibrium model and it can show the economic impacts of the Kyoto Protocol from the global perspective. Especially, the introduction of the carbon emission trading and the change of the climate policy in the USA are main issues in this model. This model includes 8 sectors and 21 regions as shown in Tab. 3. The scenarios are shown in Tab. 4.

When the USA and Australia do not ratify the Kyoto Protocol and the other Annex B countries comply with the Kyoto target without the carbon emission trade (Scenario 1), the carbon tax in 2010 will be about 350 $/tC at 1992 price. With the emission trade among Annex B countries except the USA and Australia, the carbon price will decrease to

150-300 $/tC. The more the emission credit will be imported, the less the carbon price will be. When the USA and Australia ratify the Kyoto Protocol (scenario 3), the price of carbon tax will increase slightly compared to scenario 2.

The GDP of scenario 1 in 2010 will decrease by 0.5% compared to that of the reference scenario. The energy production industry (COL, OIL, GAS and EGW) will suffer the severe damage. On the other hand, the damage of the energy intensive industry (EIS), such as steel, pulp and paper, cement and chemical, will not be drastic. Even in the worst case, the decrease of the production in 2010 will be about 1.5% compared to the reference case.

(3) AIM/Material model

Based on the results of the AIM/Enduse model, technology selection model, economic impacts are evaluated by using county base computable general equilibrium model, the AIM/Material model. Tab.5 shows the main framework of this model.

The index of the energy efficiency improvement both by sector and by energy are calculated using the results of the AIM/Enduse model. The results of AIM/Top-down model such as the changes of international prices and ratio of imported commodity to domestic produced commodity are also introduced to the AIM/Material model. The economic impacts are calculated for carbon tax scenario and for combined carbon tax and subsidy scenario. By using this model, 3 scenarios in Tab. 5 are evaluated. In the case of reference scenario, the average GDP growth rate from 2000 to 2012 is about 1.4 %/year (Fig. 5). As shown in Fig. 6, when only carbon tax is imposed to reduce CO2 emissions, the average GDP loss in the first commitment period will be 0.16 % compared to the GDP in the reference scenario. When tax and subsidy policy are introduced, the average GDP loss in the save period will be 0.061% of the GDP in the reference scenario. The whole GDP loss in the 1st commitment period will not be severe. On the other hand, the economic impact on sectors will be quite different. Fig. 7 and Fig.8 show the results of total output and employment respectively in each sector in the first commitment period as follows;

1) Thermal power generation sector, especially coal power plant (T_C), will drastically decrease.

2) The activities of the sectors which supply fossil fuels (COL, OIL and GAS) will also decrease.

3) The activity manufacturing the pollution prevention equipment (EMC) will decrease because of both the decrease of air pollution reduction equipment derived from the shrinkage of coal power plant (T_C) and the assumption without final disposal waste constraints.

4) Manufacturing of electric machinery, equipment and supplies (ELM) and transportation equipment (TRE) will increase because of the increase in demand of energy saving devices. The total production and employment of ELM and TRE will increase by 4.8 trillion yen and 200 thousand people, respectively, in the first commitment period.

4. Conclusion

From the simulation analysis based on the different 3 models, the existing or practical technologies can reduce the CO2 emissions in Japan to the target of the Kyoto Protocol in the first commitment period. In order to achieve the target of the CO2 emissions reduction, the necessary carbon tax rate will be about 45,000 yen/tC. When the policy of the carbon tax and the subsidy to the countermeasures to reduce CO2 emissions will be introduced simultaneously, the price of the

carbon tax will be 3,400 yen/tC. The GDP loss in Japan by introducing this carbon tax and subsidy policy will be 0.061% compared to the GDP in the reference scenario in the first commitment period. The sectors producing the energy saving devices will be able to mitigate the losses caused by the energy production sectors.

References

Kainuma, M., Matsuoka, Y., and Morita T. (2002) Climate Policy Assessment, Springer.

The Government of Japan (2002) the New Climate Change Policy Programme (http://www.env.go.jp/en/topic/cc/020319.pdf)

Central Environment Council (2003) Proposal on system to realize carbon tax.

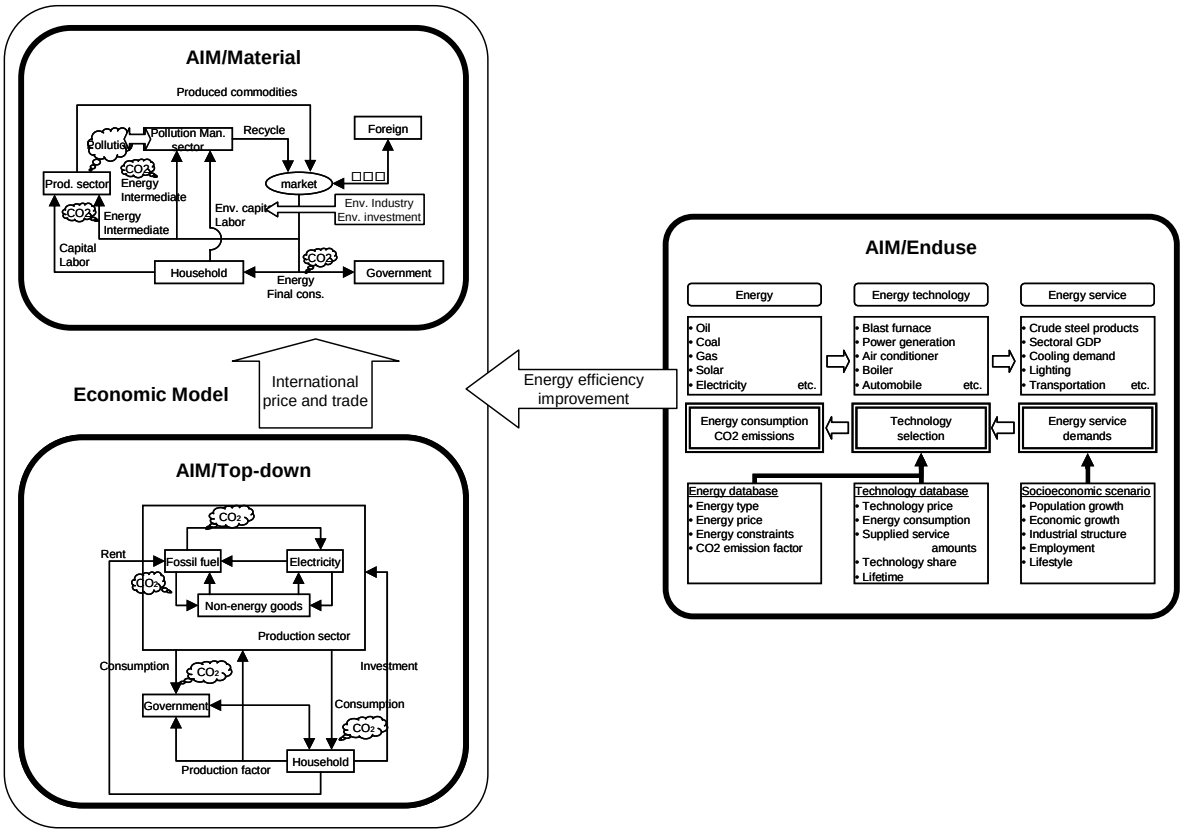
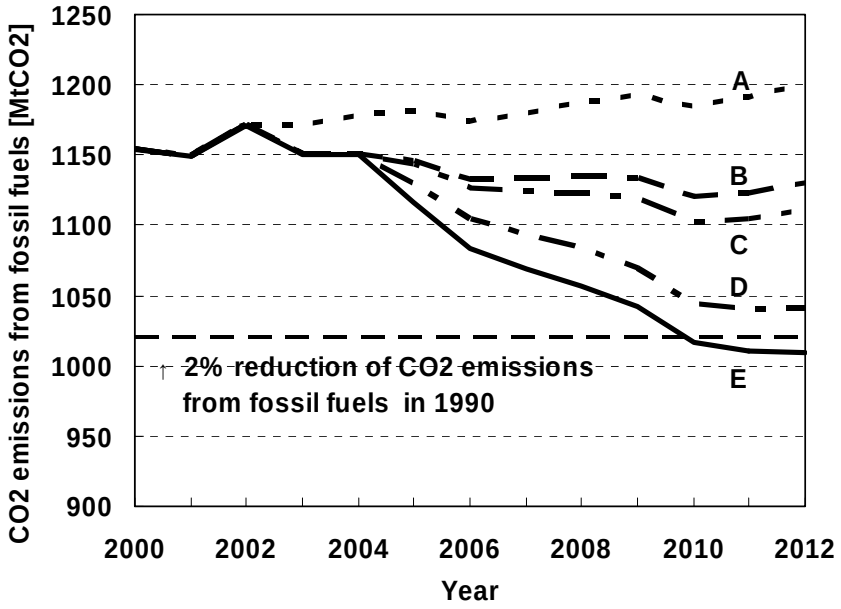


Fig. 1 Outline of 3 different models and their linkage

Tab. 1 Socioeconomic Scenarios

			2000	2010	2012	
Real GDP growth rate		(%/year)	0.9	1.9	1.9	*1
Raw material production	Crude steel	(mil. ton)	106.9	95.9	94.8	*2
	Cement	(mil. ton)	79.3	70.3	69.8	*2
	Ethylene	(mil. ton)	7.6	6.7	6.7	*2
	Paper and board	(mil. ton)	31.8	36.0	36.7	*2
Number of households		(mil.)	46.8	49.1	49.2	*3
Floor space in commercial sector		(mil. m^2)	1,655	1,793	1,844	*4
Passenger transportation		(tri.*person*km)	1.42	1.51	1.53	*5
Freight transportation		(tri.*ton*km)	0.56	0.57	0.57	*5
Nuclear power generation (new construction after 2002)				8 plants	8 plants	*6

*1: Council of Economic and Fiscal Policy (2003) Revolution and perspective, 2002 edition.
*2: The institute of Energy Economics, Japan (2002) Perspective on Long-term energy demand and supply in Japan.
*3: National Institute of Population and Social Security Research (1998)
*4: Estimated from real GDP growth rate in service sectors and elasticity.
*5: Council for Transport Policy (2000) and correction based on the economic growth.
*6: Electricity supply plan, 2002 edition.



Technology fix case (A)	New energy saving technologies will not spread in the future.
Cheapest choice case (B	Cheapest technologies will spread based on the market principle. Both the initial cost and running cost are taken into account. Payback time is assumed to be 3 years.
Carbon tax case (C,D)	In order to accelerate the introduction of energy saving technologies, the carbon tax will be imposed in proportion to the carbon contents. In this analysis, the carbon tax rates are 3,000 yen/tC (C), 15,000 yen/tC, and 30,000 yen/tC (D). Taxation will start in 2005.
Carbon tax + subsidy case (E)	Tax revenue will be used as the subsidy to reduce greenhouse gas emissions. In this simulation, the tax rate and subsidy is estimated in order to reduce the CO2 emissions from fossil fuel combustion in 2010 by 2% of those in 1990. Taxation and subsidy will start in 2005.

Fig. 2 CO2 emissions trajectories by scenarios

Tab. 2 Carbon tax rate and required additional investments for reducing CO2 emissions in Japan

sector	Subsidized measures and devices	Additional investment (bil. JPY / year)
Industrial sector	Boiler conversion control, High performance motor, High performance industrial furnace, Waste plastic injection blast furnace, LDF with closed LDG recovery, High efficiency continuous annealing, Diffuser bleaching device, High efficiency clinker cooler, Biomass power generation	101.3
Residential sector	High efficiency air conditioner, High efficiency gas stove, Solar water heater, High efficiency gas cooking device, High efficiency television, High efficiency VTR, Latent heat recovery type water heater, High efficiency illuminator, High efficiency refrigerator, Standby electricity saving, Insulation	353.9
Commercial sector	High efficiency electric refrigerator, High efficiency air conditioner, High efficiency gas absorption heat pump, High efficiency gas boiler, Latent heat recovery type boiler, Solar water heater, High efficiency gas cooking device, High frequency inverter lighting with timer, High efficiency vending machine, Amorphous transformer, Standby electricity saving, Heat pump, Insulation	194.5
Transportation sector	High efficiency gasoline private car, High efficiency diesel car, Hybrid commercial car, High efficiency diesel bus, High efficiency small-sized truck, High efficiency standard-sized track	106.6
Forest management	Plantation, Weeding, Tree thinning, Multilayered thinning, Improvement of natural forest	195.7
Total		952.0
Tax rate to appropriate required subsidiary payments (JPY/tC)		3,433

Tab. 3 Sectors and regions of AIM/Top-down model

(1) Sectors

code	Sector
Y	Agricultures, other manufactures and services
COL	Coal
CRU	Crude CRU
GAS	Natural gas
EGW	Electricity
OIL	Petroleum and coal products (refined)
EIS	Energy intensive products
TRN	Transport industries
CGD	Savings good

(2) Regions

code	Region	code	Region
JPN	Japan	CHN	China
AUS	Australia	IDI	India
NZL	New Zealand	IDN	Indonesia
USA	United States of America	MYS	Malaysia
CAN	Canada	PHL	Philippines
EUR	Western Europe	THA	Thailand
TWN	Taiwan	LAM	Latin America
KOR	Republic of Korea	MEA	Middle East and North Africa
HKG	Hong Kong	SSA	Sub Saharan Africa
SGP	Singapore	ROW	Rest of World
EEU+ CIS	Eastern Europe + Commonwealth of Independent States		

Tab. 4 Scenarios of AIM/Top-down model

	Climate policy in USA and Australia	Other Annex B countries	Carbon emission trade (max quantity)	
			Japan	Other regions
Reference	No carbon reduction			
Scenario 1	Keep original policy	Ratify Kyoto Protocol	No trade	
Scenario 2	Keep original policy		1.6% of emissions in 1990	Half of reduction
Scenario 3	Ratify Kyoto Protocol (2008-)		1.6% of emissions in 1990	Half of reduction
Scenario 4	Keep original policy		Half of reduction	

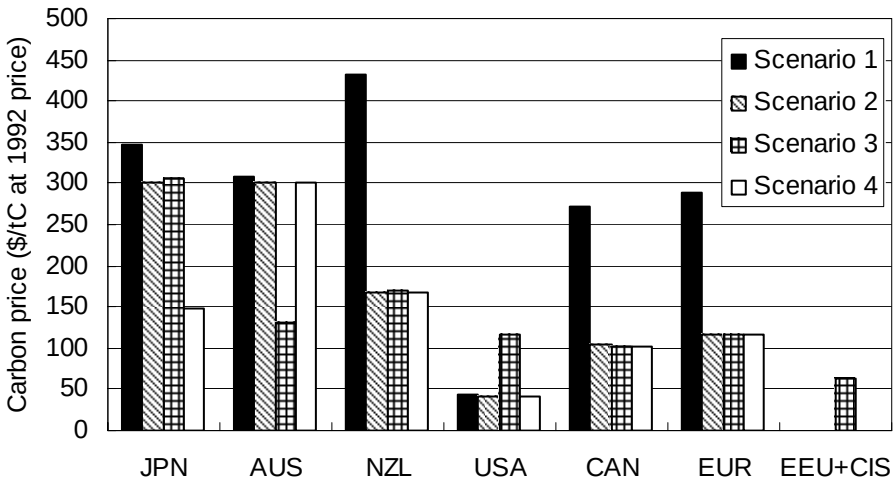


Fig.3 Price of carbon tax in 2010

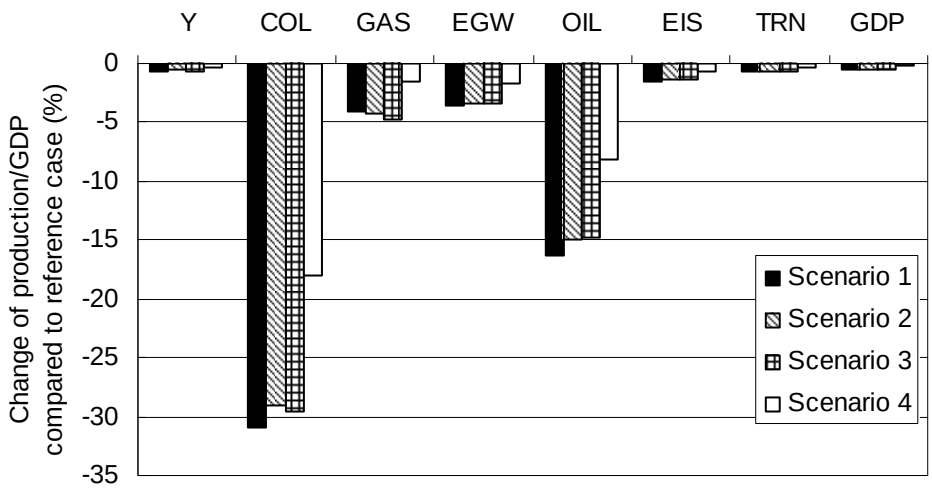


Fig. 4 Production in each sector and GDP change in Japan (2010)

Tab. 5 Outline of AIM/Material

Model	Computable general equilibrium model
Country	Japan
Time period	1995 to 2010, year by year (recursive dynamic)
Activity	41 sectors and 49 commodities (including environmental industry, see Tab.6)
Solid waste	18 waste types of industrial waste and 8 types of municipal waste. In this analysis, the constraint on solid waste is not taken into account.
Other features	Both economic balance and material balance are kept. Energy efficiency improvement is given from solution of AIM/End-use model
Scenarios	Reference Case: Without CO2 constraints. Equivalent to “Cheapest choice case” in AIM/Enduse model Tax case: CO2 reduction by only introducing carbon tax. Equivalent to “Carbon tax case” in AIM/Enduse model Tax + subsidy case: CO2 reduction by introducing carbon tax with subsidy for energy saving equipment. Equivalent to “Carbon tax + subsidy case” in AIM/Enduse model

Tab. 6 Sectors and commodities

Sector		Commodity	
agr	Agriculture, forestry and fisheries		
min	Mining except energy		
m_c	Coal mining	mcc	Coking coal
		msc	Coal for general use, lignite, anthracite
m_o	Crude oil mining		
m_g	Natural gas mining		
fod	Manufacture of food		
tex	Manufacture of textile mill products		
plp	Manufacture of lumber, wood products, pulp, paper and paper products		
chm	Manufacture of chemical and allied products		
pls	Manufacture of plastic		
nmm	Manufacture of ceramic, stone, and clay products		
stl	Manufacture of iron, steel, ferrous metals and products		
nsm	Manufacture of non-ferrous metals and products		
fmt	Manufacture of fabricated metal products		
mch	Manufacture of general machinery		
elm	Manufacture of electrical machinery, equipment and supplies		
tre	Manufacture of transportation equipment		
pri	Manufacture of precision instruments and machinery		
oth	Miscellaneous manufacturing industries		
cns	Construction		
het	Steam and hot water supply		
wtr	Water supply		
sal	Wholesale and retail trade		
fin	Finance and insurance		
est	Real estate		
trs	Transportation and communications		
pub	Education, research, medical service, health & hygiene, and social welfare		
rnt	Goods renting and leasing		
rep	Car and machine repairing		
prs	Other service		
gov	Government service		
emc	Manufacture of pollution prevention devices		
sew	Sewage service		
mwm	Municipal solid waste treatment service		
iwm	Industrial solid waste treatment service		
col	Manufacture of coal products	cck	Coke
		ccg	Other coal products
		cbf	Paving materials
oil	Manufacture of petroleum	ogl	Gasoline
		ojf	Jet fuel oil
		okr	Kerosene
		olo	Light oil
		oho	Heavy oil
		onp	Naphtha
		olp	LPG
		oot	Other petroleum refinery products
gas	Manufacture of gas	gtg	Town gas
c_t	Coal power generation	ele	Electricity
o_t	Oil power generation		
g_t	Gas power generation		
hyd	Hydro power generation		
nuc	Nuclear power generation		

Note: In the model, one sector can produce plural commodities using V matrix (make matrix).

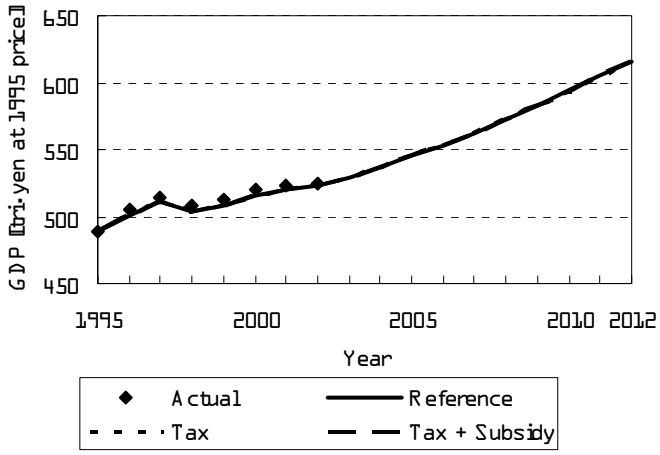


Fig. 5 Future GDP estimated from AIM/Material model

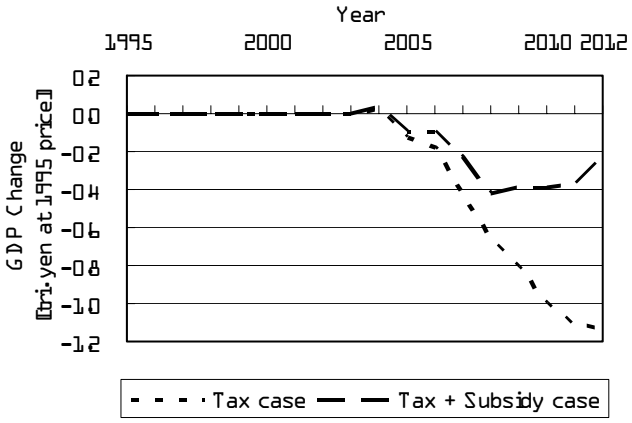


Fig. 6 GDP change compared to the reference case

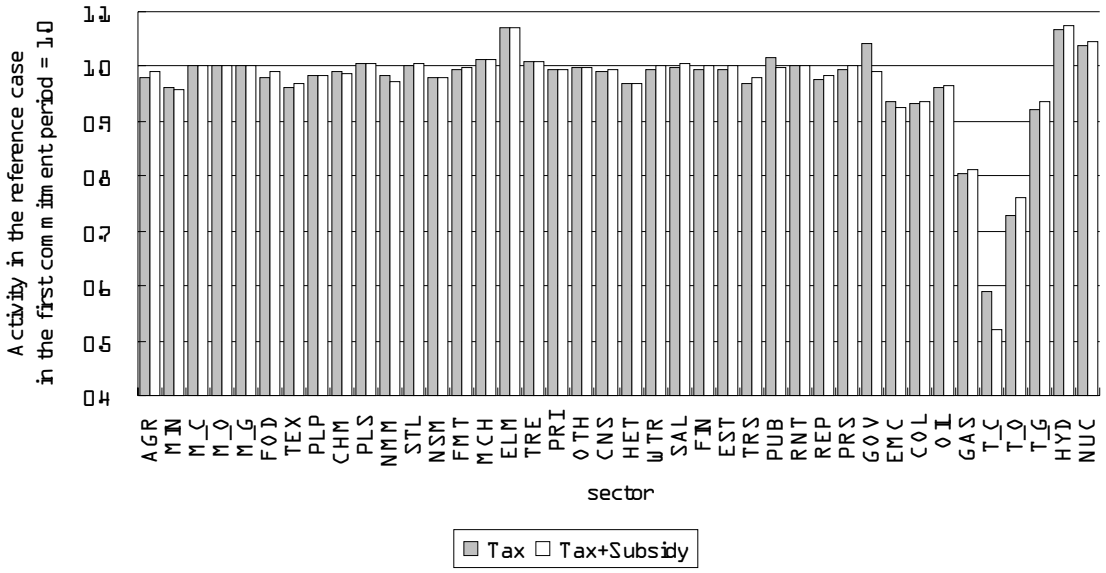


Fig. 7 Activity Change of each sector in the first commitment period (compared to reference case)

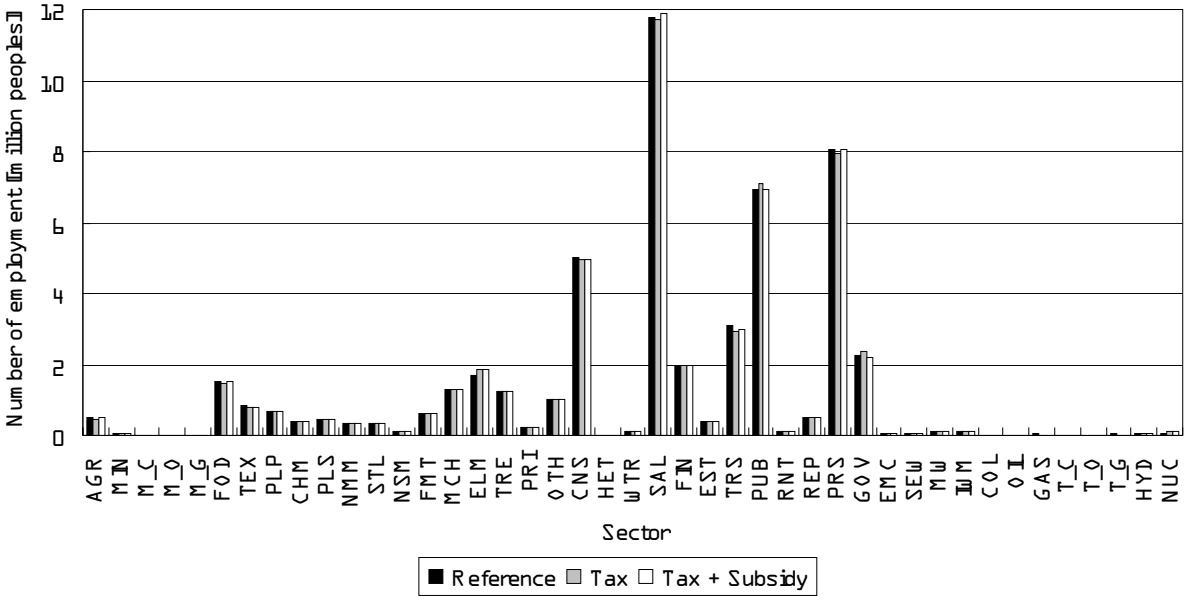


Fig. 8 Number of employment in the first commitment period