AUSTRALIA–JAPAN RESEARCH CENTRE
ANU COLLEGE OF ASIA & THE PACIFIC
CRAWFORD SCHOOL OF ECONOMICS AND GOVERNMENT

HOW DOES A DECREASE IN OIL PRODUCTION AFFECT THE WORLD ECONOMY?

Naohiko Yahaba

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Abstract

The world's oil consumption has been increasing for more than a century with a few exceptions. However, there would be a possibility that the recent increase in oil consumption in developing countries such as China and India tighten the long term oil market. Since the exact amount of oil reserves is unknown, it is difficult to predict when the ultimate decrease in oil production will come. However, for the last two decades, the amount of oil consumption per year has surpassed the amount of oil reserves newly found. Therefore, the possibility of ultimate decrease in oil production may increase. This paper examines the impact of the decrease in oil production on major economies using a computable general equilibrium model. Under the simulations in this paper, the oil exporting economies increase their GDPs, the utilities and the terms of trade. The oil importing regions, especially in newly industrialised and developing regions, decrease their GDPs, utilities and the terms of trade. All industry sectors decrease their world output. Among industry sectors, oil industry affects most and the industry sectors which use large amount of oil such as petroleum industry and chemical industry decrease its outputs significantly.

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1. Introduction

World oil consumption has been increasing for more than a century with a few exceptions. Oil consumption increased by 171 per cent during the period of 1965 to 2008.[1] World oil consumption in 2008 was 30.8 billion barrels per year. The International Energy Agency (IEA) of the Organisation of Economic Cooperation and Development (OECD) predicted in its reference scenario that world oil consumption will reach to 105 million barrels per day (38.3 billion barrels per year) in 2030.[2] The Energy Information Administration (EIA) of the U.S. Department of Energy predicted in its reference scenario that world oil consumption will reach to 106.6 million barrels per day (38.9 billion barrels per year) in 2030.[3] However, it is possible that the recent increase in oil consumption in developing countries such as China and India will tighten the long-term oil market. According to the IEA's reference scenario in 2007, the increase in energy consumption in developing countries represents 74 per cent of the world increase in energy consumption between 2005 and 2030.[4]

Energy is indispensable for prosperous life; it is used for transporting and producing goods, transmitting information, and providing light and heat. Without a large supply of oil, it would have not been possible to realise the economic growth we enjoy today. Since oil occupies one third of the primary energy supply, change in oil production would have enormous influence on the world economy.[5]

How long will the increase in oil production last? This depends on the amount of oil

reserves. The world declared proven reserves in 2008 accounted for 1.41 trillion barrels.[6] The IEA reports that the world is not running short of oil yet. It says that the world's total endowment of oil is large enough to support the projected rise in production beyond 2030 in its Reference Scenario in 2007.[7] However, there are doubts about the reliability of the declared reserves in many major producing countries, which are not subject to external audit or verification. OPEC countries increased their reserves from around 667 billion barrels in 1980 to 1005 billion barrels in 1989 without any significant actual discovery of new reserves.[8]

Since the exact amount of oil reserves is unknown, it is impossible to predict when the ultimate decrease in oil production will come. However, for the last two decades, the amount of oil consumption per year has surpassed the amount of oil reserves newly found. Therefore, the possibility of an ultimate decrease in oil production is growing.[9]

This paper examines the impact of a decrease in oil production on the economies of some countries and regions by using a computable general equilibrium model. The scenario is as follows: Increases in oil production cause the drying up of oil fields which can produce oil with relatively less cost, and oil production will shift to more costly oil fields. The analysis is conducted using Global Trade Analysis Project (GTAP) model, which is a computable general equilibrium model developed by the Global Trade Analysis Project.

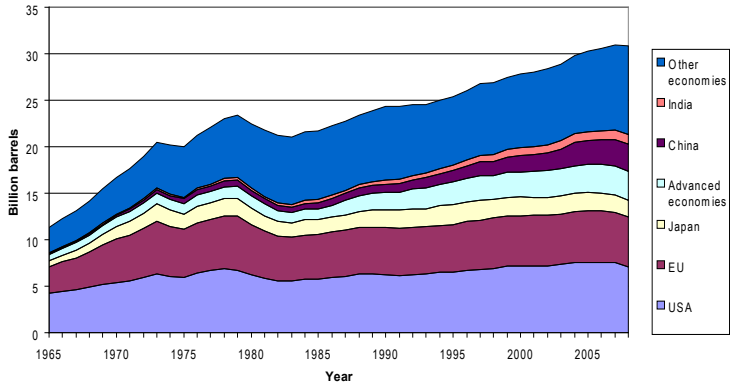
This paper is organised as follows: Section 2 reviews the trend of oil production, oil consumption, oil price and oil reserves and the relationship of oil consumption and economic growth; Section 3 outlines the structure of the GTAP model and presents the scenario for simulations and the sectors and regions used in the analysis; Section 4 presents the results of the analysis on changes in production, trade and welfare.

2. Review of world oil production and consumption

2.1 Oil consumption

For the last four decades, world oil consumption has increased constantly except two oil crises in 1973 and 1980 and recent global financial crisis in 2008. Figure 1 shows the world oil consumption between 1965 and 2008. The world oil consumption increased from 11.4 billion barrels to 30.8 billion barrels during the period.

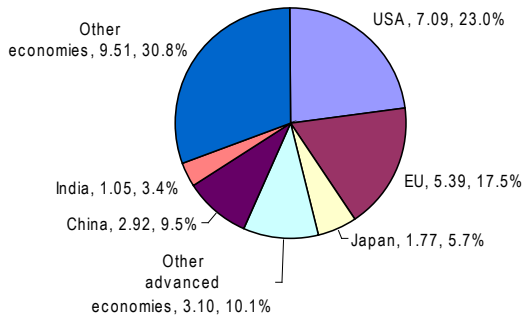
Figure 1 World Oil Consumption (1965 to 2008)



Source: BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965).

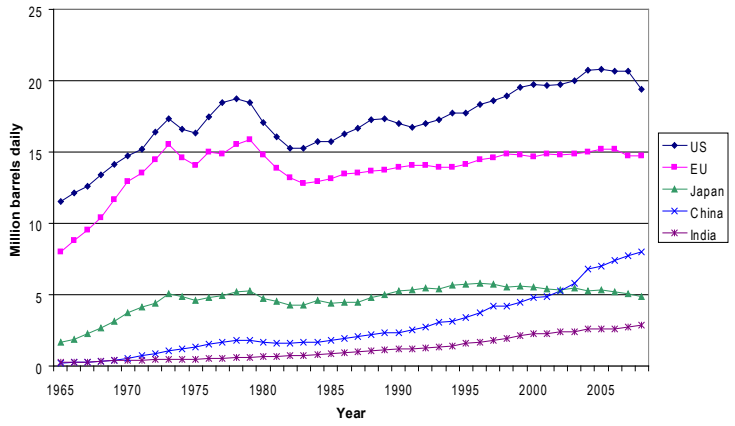
Figure 2 shows oil consumption in 2008 by country/region. The consumption in all advanced economies accounts for 56.3 per cent of the total and the consumption in developing economies accounts for 43.7 per cent. The consumption in the United States accounts for 23.0 per cent and the consumption in the EU members accounts for 17.5 per cent. China occupies 9.5 per cent, Japan occupies 5.7 per cent and India occupies 3.4 per cent. Figure 3 shows the trend in consumption in major economies. The increase in oil consumption in the United States, the EU and Japan is slow, while the increase in consumption in China and India is rapid. According to the IEA's reference scenario in 2007, the increase in energy consumption in developing countries represented 74 per cent of the increase in world energy consumption between 2005 and 2030. China and India alone took up45 per cent of the increase.[10]

Figure 2 Oil consumption by country/region (2008)



Source:BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965)
Note: Advanced economies are the following: USA, EU, Japan, Australia, Hong Kong, Iceland, Korea, New Zealand, Norway, Singapore, Switzerland and Taiwan.

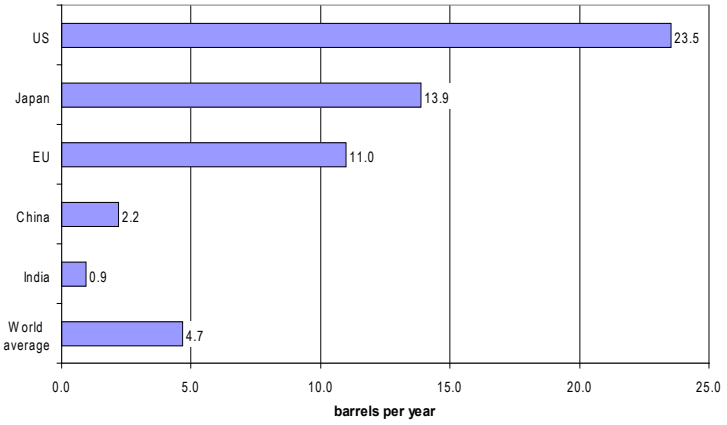
Figure 3 Oil consumption in major economies (1965 to 2008)



Source: BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965).

As regards the oil consumption per capita in major economies in 2008, per capita consumption is 23.5 barrels per day in the United States, 13.9 barrels in Japan, 11.0 barrels in the EU, 2.2 barrels in China and 0.9 barrels in India, as shown in Figure 4.

Figure 4 Per capita oil consumption in major economies (2008)

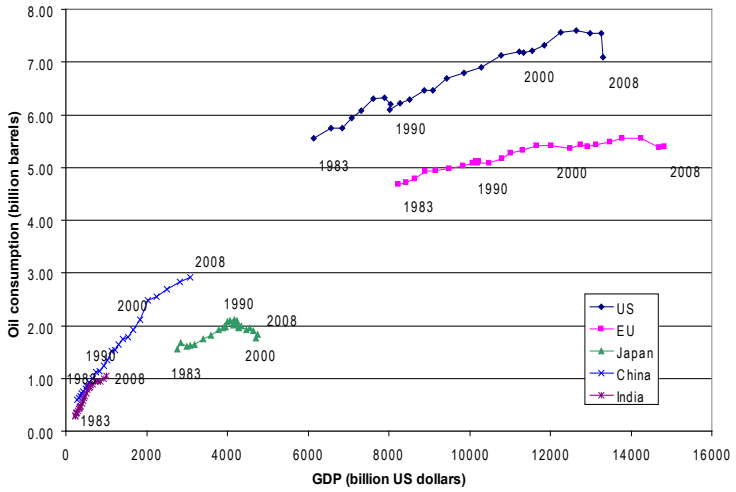


Sources: BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965); CIA World Factbook 2008.

2.2 Economic growth and oil consumption

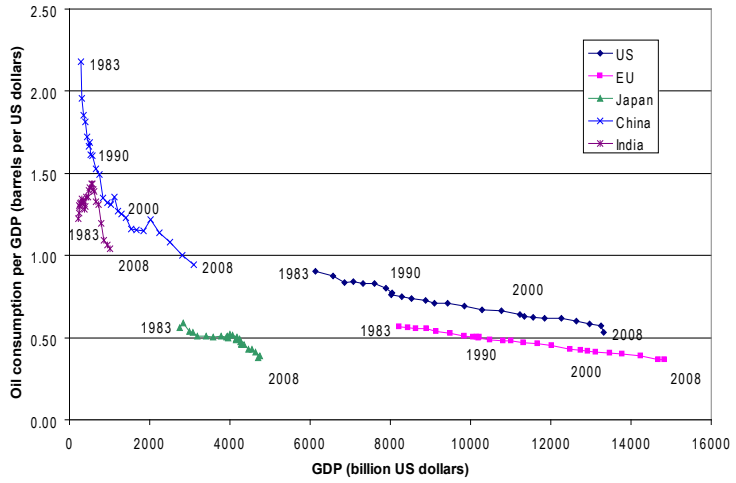
There is a strong correlation between economic growth and oil consumption. Figure 5 shows the relations of GDP and oil consumption in major economies. In each economy, a strong correlation between GDP and oil consumption is observed. This implies that the oil consumption in China and India would increase as their GDP increase in future.

Figure 5 GDP and oil consumption (1983 to 2008)



Sources: BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965); IMF World Economic Outlook Database, GDP.

Figure 6 GDP and oil consumption per GDP



Sources: BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965); IMF World Economic Outlook Database.

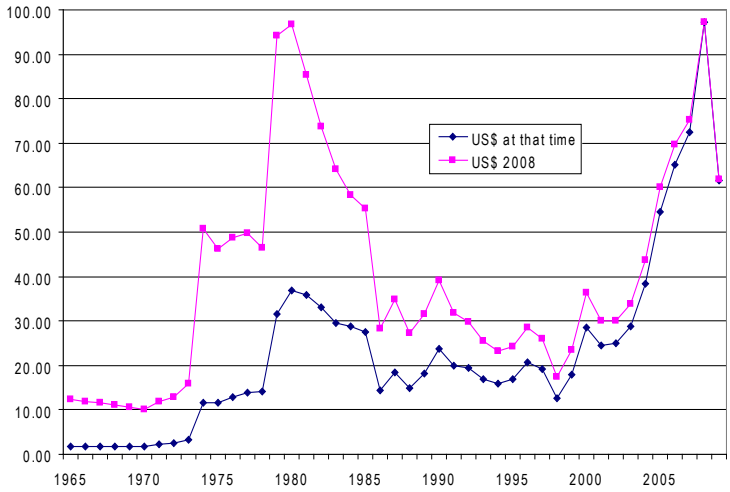
Figure 6 shows the relation of the oil consumption per unit of GDP and the GDP in major economies. In each economy, oil consumption per unit of GDP decreases as its GDP increases. This is true for the comparison among different economies. Oil consumption per unit of GDP of China and India is bigger than that of developed countries such as the United States and Japan. There are some differences in oil consumption per unit of GDP among developed countries. The EU and Japan have lower oil consumption per

unit of GDP while the United States has higher oil consumption per unit of GDP. This figure implies that, in future, oil consumption as a proportion of GDP would decrease in China and India as the development of these countries advances.

2.3 Oil price

Figure 7 shows the history of oil prices. The oil industry is an oligopolistic industry. The price fluctuates by the decision of relatively small number of oligopolistic producers and by the political instability at the oil producing area. The trend shows that oil prices rose sharply at the time of two oil shocks in 1974 and 1979. After the oil shocks, the price fell gradually due to the efforts for energy saving and the improvement of efficiency in oil consuming countries. In 2007 the price rose again because of political instability in Middle East. After that the price fell due to worldwide economic recession caused by the global financial crises.

Figure 7 Oil prices (1965 to2009)



Sources: BP Statistical Review of World Energy 2009, Crude Oil Prices (1861-2008), Brent Oil Price; US EIA Petroleum Navigator, Spot Crude Oil Prices, Brent Oil Price (2009); US Bureau of Labor Statistics, Consumer Price Index (2009).

2.4 Oil reserves

As described above, oil consumption and production have increased and shows a trend to increase into the future. It depends on the amount of oil reserves whether the increase in oil production lasts into the future. Oil reserves are categorised into three groups based on confidence level: proven reserves, probable reserves and possible reserves. Proved

reserves are the reserves claimed to have normally 90 per cent of certainty of containing the amount specified. Probable reserves are the reserves which are not yet proven, but are claimed to have a better than 50 per cent of certainty of recovery, and possible reserves are the reserves which cannot be regarded as probable, but are claimed to have at least 10 per cent of certainty of recovery.[11]

Table 1 shows proven reserves by country. The world declared proven reserves in 2008 account for 1.41 trillion barrels. The IEA reports in 2007 that the world is not running short of oil yet. It says that the world's total endowment of oil is large enough to support the projected rise in production beyond 2030 in its Reference Scenario.

Table 1 Proven reserves by country

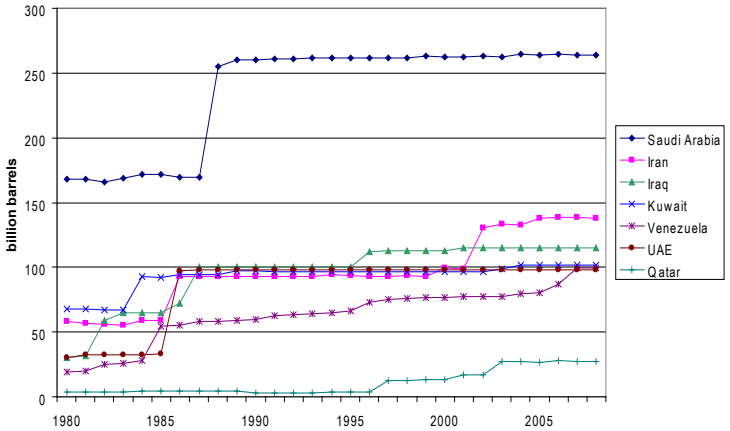
Country	Reserves (billion barrels)	Share (per cent)
Saudi Arabia	264.1	18.7
Canada	179.3	12.7
Iran	137.6	9.8
Iraq	115.0	8.2
Kuwait	101.5	7.2
Venezuela	99.4	7.1
United Arab Emirates	97.8	6.9
Russia	79.0	5.6
Libya	43.7	3.1
Kazakhstan	39.8	2.8
Nigeria	36.2	2.6
United States	30.5	2.2
Qatar	27.3	1.9
China	15.5	1.1
Angola	13.5	1.0
Brazil	12.6	0.9
Algeria	12.2	0.9
Mexico	11.9	0.8
World total	1,408.7	100.0

Source: BP Statistical Review of World Energy 2009, Proved Reserves - barrels (from 1980).

However, there are doubts about the reliability of the declared reserves in many major producing countries, which are not subject to external audit or verification. It is suggested that the member countries of the Organisation of Petroleum Exporting Countries (OPEC) have economic incentives to overstate their reserves, since there were discussions in the 1980s among OPEC countries over setting production quotas based, at least partly, on reserves. Figure 8 shows declared reserves of some OPEC member countries. There have been significant increases in declared reserves in the 1980s without any significant

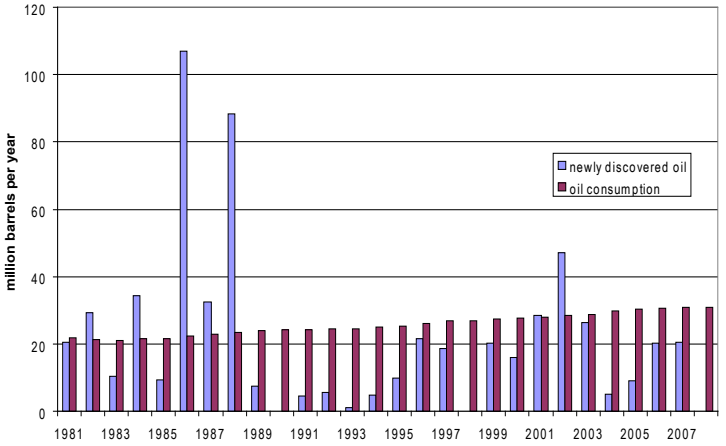
actual discovery of new reserves. For example, Kuwait increased its proven reserves from 67 billion barrels to 93 billion barrels in 1984. The UAE raised its reserves from 33 to 97 billion barrels in 1986. Saudi Arabia increased its reserves from 170 to 255 billion barrels in 1988. In total, world oil reserves, except Canadian oil sands, increased from around 667 billion barrels in 1980 to 1,006 billion barrels in 1989 and reached 1,258 in 2008.

Figure 8 Declared proved reserves in OPEC member countries (1980 to 2008)



Source: Statistical Review of World Energy 2009, Proved Reserves - barrels (from 1980).

Figure 9 Changes in proved reserves and oil consumption (1981 to 2008)



Source: Statistical Review of World Energy 2009, Proved Reserves - barrels (from 1980).

It is very difficult to tell exactly when oil production will ultimately reach the point of decline, due to the finite quantity of actual oil reserves, without knowing the accurate amount of reserves. However, world annual oil consumption has exceeded the

increase in reserves in most years since 1989. Figure 9 shows the world oil consumption and volume of oil reserves from 1980 to 2008. In the 1980s there was large increase in reserves due to revisions made in 1980s in OPEC countries, not by new discovery of oil reserves. Modest increases have continued since 1990. Though the increase in reserves in the 2000s is higher than in the 1990s, the volume of consumption continues to outstrip the increase in reserves. Therefore, there would be some possibility of a tight supply-demand situation for oil caused by ultimate production decline.

3. Model structure and scenario

Based on the circumstances described in Section 2, the effect of decrease in oil production on major economies is examined in this section. The assumed situation is as follows: As oil production increases, the ratio of oil production from the oil reserves which produces oil with less cost declines, and the ratio of oil production from more costly oil reserves increases. The analysis is conducted by using GTAP model, which is a computable general equilibrium model developed by the Global Trade Analysis Project.

3.1 Structure of GTAP model

The GTAP model consists of database, model and software. The current database covers 113 countries/regions and 57 sectors. The database covers input-output data of sectors in each country/region, trade between countries/regions transportation cost and trade barriers. The basic structure of GTAP is explained in the following paragraphs.[12]

3.1.1 Firm behaviour

In GTAP model, firm behaviour is determined by minimising the cost for certain amount of output. The quantities of input of production factors and intermediate commodities are determined by the following Leontief type production function;

$$QO_{jr} = e^{aot} \min\left\{QVA_{jr} e^{ava_{jr} t}, QF_{ijr} e^{af_{ijr} t}\right\} \qquad (1)$$

QO_{jr} : quantity of commodity j output in region r

QVA : quantity of composite production factors used for producing commodity j of region r

QF_{ijr} : quantity of composite intermediate commodity i used for producing commodity j of region r

ao, ava_{jr}, af_{ijr} : parameters for technology progress

Factors of production, which are the composite goods of land, capital and labour, are described as the following CES (Constant Elasticity of Substitution) type production function:

$$QVA_{jr} = e^{ava_{jr}t}\left\{\sum_{i\in ENDW} d_{ijr}\left(QFE_{ijr}e^{afe_{ijr}t}\right)^{-\frac{1-\sigma_j}{\sigma_j}}\right\}^{-\frac{\sigma_j}{1-\sigma_j}} \qquad (2)$$

QFE_{ijr} : quantity of factor of production i used for producing commodity j
QFM_{ijr} of region r
d_{dijr}, d_{mijr} : share of production factor i in all production factors used for producing commodity j of region r
afe_{ijr} : progress in production increasing technology for factor i used for producing commodity j of region r
σ_j : elasticity of substitution among production factors used in sector j

The shares of domestic commodity and imported commodity in each composite intermediate commodity are determined by the following CES type production function:

$$QF_{ijr} = e^{af_{ijr}t}\left\{d_{dijr}QFD_{ijr}^{-\frac{1-\sigma_{Di}}{\sigma_{Di}}} + d_{mijr}QFM_{ijr}^{-\frac{1-\sigma_{Di}}{\sigma_{Di}}}\right\}^{-\frac{\sigma_{Di}}{1-\sigma_{Di}}} \qquad (3)$$

QFD_{ijr} : quantity of domestic commodity i used for producing commodity j of region r
QFM_{ijr} : quantity of imported commodity i used for producing commodity j of region r
d_{dijr}, d_{mijr} : share of domestic/imported commodity
σ_{Di} : elasticity of substitution between domestic and imported commodities in commodity i

3.1.2 Household behaviour

In GTAP, household expenditures are governed by an aggregate utility function that allocates expenditure across three broad categories, private households, government households

and saving expenditures. Households behave so as to maximise their welfare subject to budget constraints described as follows:

$$INCOME_r = PRIVEXP_r + GOVEXP_r + SAVE_r \quad (4)$$

$INCOME_r$: value of net income in region r

$PRIVEXP_r$: value of private household expenditure in region r

$GOVEXP_r$: value of government household expenditure in region r

$SAVE_r$: value of net saving in region r

Utility fuction used in GTAP is as follows:

$$U_r = C\left(UP_r\right)^{DPPRIV_r}\left(UG_r\right)^{DPGOV_r}\left(\frac{QSAVE_r}{POP_r}\right)^{DPSAVE_r} \quad (5)$$

U_r : per capita utility from aggregate household expenditure in region r

UPr : quantity of per capita private household expenditure in region r

UGr : quantity of per capita government household expenditure in region r

$QSAVEr$: quantity of net saving in region r

$POPr$: population in region r

$DPPRIVr$, $DPGOVr$, $DPSAVEr$: distribution parameters of private household consumption, government household consumption and saving in region r

3.1.3 Market equilibrium

In GTP model, market equilibrium for tradable goods is described as follows:

$$VOM_{ir} = VDM_{ir} + VST_{ir} + \sum_{s \in REG} VXMD_{irs} \quad (6)$$

VOM_{ir} : value of commodity i produced in region r

VDM_{ir} : value of domestic sales of commodity i in region r

VST_{ir} : value of international transportation cost for exports of commodity i in region r

$VXMD_{irs}$: value of exports of commodity i from region r to region s

Market equilibrium for production factors is described as follows:

$$VOM_{ir} = \sum_{j \in PROD} VFM_{ijr} \quad (7)$$

VFM_{ijr} : value of production factor i demanded by sector j of region r

$= PM_{ir} * QFE_{ijr}$

Value of domestic sales of commodity i (VDM_{ir}) is described as follows:

$$VDM_{ir} = VDPM_{ir} + VDGM_{ir} + \sum_{j \in PROD} VDFM_{ijr} \qquad (8)$$

$VDPM_{ir}$: value of private household expenditure on domestic commodity i in region r

$VDGM_{ir}$: value of government household expenditure on domestic commodity i in region r

$VDFM_{ijr}$: value of purchase of domestic commodity i by sector j in region r

Value of imports of commodity i (VIM_{ir}) is described as follows:

$$VIM_{ir} = VIPM_{ir} + VIGM_{ir} + \sum_{j \in PROD} VIFM_{ijr} \qquad (9)$$

$VIPM_{ir}$: value of private household expenditure on imports of commodity i in region r

$VIGM_{ir}$: value of government household expenditure on imports of commodity i in region r

VIFMijr : value of purchase of imports of commodity i by sector j in region r

Since the zero profit condition is assumed in the GTAP model, cost structure of thee value of commodity output at agent's price (VOA) is described as follows:

$$VOA_{jr} = \sum_{i \in PROD} VDFA_{ijr} + \sum_{i \in PROD} VIFA_{ijr} + \sum_{i \in ENDOW} VFA_{ijr} \qquad (10)$$

3.2 Scenario, sectors and regions

3.2.1 Scenario

The scenario of the change is as follows: Increase in oil production causes the dry up of the oil fields which can produce oil with relatively less cost, and the oil production will shift to more costly oil field. Therefore, aggregate oil production becomes more inefficiently.

In the GTAP model, aosec (output augmenting technical change of all regions) for oil sector is used for the simulation of this scenario. The shock is described as the decrease in aosec for oil sector. The degree of the shock is –10 per cent and –20 per cent. This does not mean that the possibility of occurrence of these levels of shock is high. These levels of shock are chosen just for simulate certain levels of shock. The changes in oil output under these shocks are described in Table 2 below:

Table 2 Changes in oil outputs

Shock	Change in oil output
10 per cent decrease in technology change parameter	–3.73 per cent
20 per cent decrease in technology change parameter	–8.26 per cent

For closure for this simulation, the standard closure for GTAP model is adopted.[13]

3.2.2 Sectors and regions

For this simulation, industry sectors are aggregated into 14 sectors and world countries and regions are aggregated into 11 regions as shown in Table 3 and 4:

Table 3 Industry sectors

Industry Sector	Composing categories
Agriculture, food and extracts	paddy rice, wheat, cereal grains n.e.c., vegetables/fruit/nuts, oil seeds, sugar cane/sugar beet, plant-based fibers, crops n.e.c., cattle/sheep/goats/horses, animal products n.e.c., raw milk, wool/silkworm cocoons, forestry, fishing, minerals n.e.c., meat (cattle/sheep/goats/horses), meat products n.e.c., vegetable oils/fats, dairy products, processed rice, sugar, food products n.e.c., beverages/tobacco products
Gas and coal	coal, gas
Oil	oil
Textiles and apparel	textiles, wearing apparel, leather products
Wood and paper products	wood products, paper products/publishing
Petroleum, coal products	petroleum/coal products
Chemical products	chemical/rubber/plastic products
Metal and Mineral products	mineral products n.e.c., ferrous metals, metals n.e.c., metal products
Transport equipment	motor vehicles/parts, transport equipment n.e.c.
Electronic equipment	electronic equipment
Machinery	machinery/equipment n.e.c., manufactures n.e.c.
Utilities and construction	electricity, gas manufacture/distribution, water, construction
Trade and transport	trade, transport n.e.c., sea transport, air transport
Other services	communication, financial services n.e.c., insurance, business services n.e.c., recreation/other services, public administration/defence/health/education, dwellings

Table 4 Regions

Region	Composing countries and regions
Net oil importers (major economies)	
USA	USA
EU	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK
Japan	Japan
Newly Industrialised Asian economies	Korea, Singapore, Taiwan, Hong Kong
ASEAN 5	Indonesia, Malaysia, Philippines, Thailand, Viet Nam
China	China
India	India
Brazil	Brazil
Net oil exporters[14]	
Russia	Russia
Other oil exporting countries	Rest of Western Asia (including Saudi Arabia, UAE, Kuwait, Iraq, Qatar, Oman, Yemen, Syria, Bahrain), Iran, Norway, South Central Africa (Angola, D.R. Congo), Venezuela, Rest of North Africa (Algeria, Libya), Nigeria, Kazakhstan, Canada, Mexico, Azerbaijan, Central Africa (including Cameroon, Chad, Congo, Equatorial Guinea, Gabon), Colombia, Ecuador, Argentina, Rest of Southeast Asia (Brunei, East Timor)
Rest of the world	Other countries and regions

4.Results of the simulation

4.1Production

4.1.1 GDP

Under the simulations, the GDPs of oil producing regions increase, while the GDPs of oil importing regions decrease. Among oil importing regions, decrease in the GDP in developed countries is smaller than decrease in the GDP in developing countries. Table 5 shows the change in GDP of regions under two scenarios (10 per cent decrease in technology change parameter and 20 per cent decrease in technology change parameter. Hereinafter, '10 per cent decrease scenario' and '20 per cent decrease scenario', respectively.)[15] For 20 per-cent decrease scenario, the GDP value of Russia and the GDP value of other Oil Exporting Countries (Other OECs) increase by 18.61 per cent and 19.83

per cent, respectively. Among oil importing regions, the average change in GDP value of the United States, the EU and Japan is –0.42 per cent, while the average change in GDP value of Newly Industrialised Asian Economies (NIAEs), ASEAN 5, China, India and Brazil is 3.09 per cent. The reason the effect of oil productivity decrease is more significant in developing countries than in developed countries is that the oil consumption per GDP is bigger in developing countries than in developed countries.

Table 5 Changes in GDP by region (percentage change)

Region	10 per cent decrease scenario			20 per cent decrease scenario		
	Quantity	Price	Value	Quantity	Price	Value
USA	-0.14	0.04	-0.09	-0.36	-0.03	-0.39
EU	-0.29	0.29	-0.01	-0.82	0.57	-0.25
Japan	-0.13	0.00	-0.13	-0.36	-0.26	-0.62
NIAEs	-0.26	-1.30	-1.56	-0.79	-4.07	-4.83
ASEAN 5	-0.70	0.46	-0.24	-1.84	1.12	-0.74
China	-0.26	-0.43	-0.69	-0.68	-1.67	-2.34
India	-0.51	-1.77	-2.28	-1.58	-5.30	-6.80
Brazil	-0.60	0.44	-0.16	-1.64	0.91	-0.74
Russia	-2.15	8.08	5.76	-5.22	25.15	18.61
Other OECs	-1.86	8.00	5.99	-4.35	25.27	19.83
Rest of the world	-0.29	0.16	-0.13	-0.78	0.24	-0.55

4.1.2 Production quantity

The output quantities of industry sectors are shown in Table 6 below.[16] The output quantities of all industry sectors except 'other services' decrease under the two scenarios. The Oil sector decreases by 8.83 per cent, the petroleum products sector decreases by 8.94 per cent and the gas and coal sector decreases by 2.96 per cent under 20 per-cent decrease scenario. Decreases in output of other sectors are less than 2 per cent.

Table 6 Change in output quantities by industry sector (percentage change)

Industry sector	10 per cent decrease scenario	20 per cent decrease scenario
Agriculture, food & extracts	-0.43	-1.22
Gas and coal	-1.12	-2.96
Oil	-3.73	-8.83
Textiles and apparel	-0.48	-1.34
Wood and paper products	-0.19	-0.49
Petroleum, coal products	-3.76	-8.94
Chemical products	-0.46	-1.32
Metal and Mineral products	-0.09	-0.26
Transport equipment	-0.30	-0.79
Electronic equipment	-0.06	-0.12
Machinery	-0.10	-0.24
Utilities and construction	-0.14	-0.34
Trade and transport	-0.51	-1.48
Other services	0.07	0.30
Total	-0.40	-1.03

Table 7 Changes in production quantities by region by industry sector (percentage change)

	USA	EU	Japan	NIAEs	ASEAN 5	China	India	Brazil	Russia	Other OECs	ROW	**Total**
Agri., food,	-0.02	-0.35	-0.45	-0.11	-0.14	-0.17	-0.15	-0.04	-1.21	-2.30	-0.08	-0.43
extracts	-0.02	-1.05	-1.40	-0.56	-0.18	-0.41	-0.33	0.21	-3.09	-6.49	-0.14	-1.22
Gas and	-0.39	-0.19	-0.21	-7.45	0.25	-0.27	0.71	0.08	-2.04	-2.08	-0.37	-1.12
coal	-0.34	0.34	0.12	-54.73	1.74	-0.12	2.32	0.99	-6.23	-6.09	-0.20	-2.96
Oil	-3.49	-2.96	-3.48	-3.26	-2.61	-3.33	-2.27	-3.55	-3.88	-3.94	-3.11	-3.73
	-8.26	-7.31	-8.56	-9.10	-6.59	-8.24	-5.99	-9.43	-9.18	-9.19	-7.87	-8.83
Textiles and	0.23	-1.14	-0.11	-2.05	-0.82	1.31	4.01	0.30	-5.72	-7.94	0.64	-0.48
apparel	0.45	-3.59	-0.41	-7.15	-2.08	4.65	12.43	1.27	-16.08	-21.81	1.96	-1.34
Wood/paper	0.63	0.24	0.15	0.66	0.54	0.63	0.90	0.86	-7.22	-6.14	0.36	-0.19
products	1.91	0.70	0.43	1.64	1.92	2.15	2.56	2.87	-19.50	-17.36	1.10	-0.49
Petroleum/	-4.87	-4.67	-3.55	-5.75	-3.70	-0.19	-4.27	-2.78	-4.25	-2.66	-2.85	-3.76
coal products	-11.17	-10.71	-8.14	-14.10	-9.21	-1.00	-11.03	-7.30	-9.81	-6.56	-6.89	-8.94
Chemical	0.99	0.41	0.35	-10.44	3.93	1.40	-4.03	-1.26	-13.52	-8.27	3.18	-0.46
products	2.53	0.81	0.69	-27.44	11.97	4.03	-11.76	-3.82	-34.35	-21.85	9.51	-1.32
Metal/mineral	1.51	0.53	0.85	2.51	-0.82	-0.69	1.41	-0.42	-10.25	-8.00	1.15	-0.09
products	4.51	1.45	2.56	6.92	-2.79	-2.20	3.18	-1.42	-27.18	-22.02	3.25	-0.2
Transport	0.45	-0.16	0.92	1.82	-0.68	-0.30	0.42	0.59	-5.33	-5.99	0.29	-0.30
equipment	1.44	-0.44	2.96	5.10	-1.79	-0.82	0.92	2.32	-14.77	-17.27	1.02	-0.79
Electronic	-0.69	-0.49	0.51	4.23	1.05	1.05	0.39	0.50	-13.06	-13.92	0.32	-0.06
equipment	-2.45	-1.65	1.41	12.43	3.41	3.45	-0.16	1.86	-34.40	-36.72	0.88	-0.12
Machinery	1.05	0.01	0.61	3.10	-0.53	-0.28	2.91	0.99	-4.63	-10.5	0.08	-0.10
	3.08	-0.01	1.81	8.83	-1.39	-0.68	8.32	3.21	-13.39	-28.93	0.21	-0.24
Utilities and	0.10	0.06	0.27	-1.41	-2.49	-0.64	-1.80	-0.51	-1.48	0.80	-0.54	-0.14
construction	0.41	0.24	0.96	-4.25	-8.26	-2.19	-5.87	-1.81	-3.79	2.90	-1.74	-0.34
Trade and	-0.61	-0.42	-0.18	0.07	-1.93	-0.28	-1.22	-1.40	-0.49	-0.90	-0.60	-0.51
transport	-1.83	-1.30	-0.52	0.10	-5.50	-0.77	-3.82	-4.14	-1.01	-2.13	-1.78	-1.48
Other	-0.11	0.12	-0.12	-0.02	-0.21	-0.38	0.67	0.13	1.54	1.36	-0.10	0.07
services	-0.30	0.43	-0.39	-0.08	-0.21	-1.07	2.49	0.51	4.97	4.58	-0.20	0.30
Total	-0.14	-0.29	-0.13	-0.26	-0.70	-0.26	-0.51	-0.60	-2.15	-1.86	-0.29	-0.40
	-0.36	-0.82	-0.36	-0.79	-1.84	-0.68	-1.58	-1.64	-5.22	-4.35	-0.78	-1.03

Note: 10 per cent decrease scenario on upper line and 20 per cent scenario on lower line.

For gas and coal sector, the quantity of output decreases under these simulations. This is contrary to common sense. It would be probable that the demand for gas and coal increases as a substitute of oil when the output of oil decreases and the price of oil increases. However, the results of the simulations are opposite. It is considered that the substitution among intermediate commodities in each sector is not fully described by the model. When the quantity of output of some intermediate commodity changes significantly, it is usual that the producers would shift the intermediate commodity to another intermediate commodity. However, the GTAP model adopts the Leontief-type production function for the use of intermediate commodities as explained in Section 3.1.1, the substitution of intermediate commodities may not be appropriately described. As a result, when the output of oil decreases and the price of oil increases, the firm's activity as a whole shrinks and the consumption of other energy such as coal and gas decreases in these simulations.

4.1.3 Production quantity by region and by industry

Table 7 shows the production quantities by region and by industry sector.[17] Russia and other OECs decrease their out put in all sectors except other services. For oil importing economies, the output change differs among regions in some industry sectors. In textiles and apparel sector, the outputs in India and China increase while the outputs in NIAEs and the EU decrease. For chemical products sector, the outputs in the ASEAN 5, China and the USA increase while the outputs in NIAEs, India and Brazil decrease.

The reason for the difference in output of a sector among regions is not clear. In general, the industry sector of a region that is more productive than the same industry sector of other regions could increase its output even though the industry sector of the world as a whole decreases its output. Each region would concentrate on producing commodity that is the most appropriate to the region, according to the endowment of production factors. For example, India increases the output in textile and apparel sector and ASEAN 5 increases the output in chemical products sector. India increases the outputs of these sectors because the price of production factors decrease significantly after the shock and the outputs of the industry sectors, which use large amount of production factors and intermediate commodities except for oil, increase.

4.1.4 Price of commodities

The price of commodities increases after the shocks except gas and coal. Table 8 shows the price change in commodities.[18] The price of oil increases by 109.40 per cent under the 20 per cent decrease scenario. The price of commodities which need large amount of oil increases significantly, while the price of commodities which needs less oil for production shows moderate increase. The price of petroleum products increases by 84.66 per cent

and the price of chemical products increases by 7.89 per cent, while the price of textile and apparel increases by 1.28 per cent and the price of electronic equipment increases by 0.74 per cent.

Table 8 Changes in price of commodities (per cent change)

Industry sector	10 per cent decrease scenario	20 per cent decrease scenario
Agriculture, food & extracts	0.55	1.62
Gas and coal	-0.68	-0.57
Oil	34.76	109.40
Textiles and apparel	0.48	1.28
Wood and paper products	0.54	1.48
Petroleum, coal products	26.89	84.66
Chemical products	2.60	7.89
Metal and Mineral products	1.06	3.10
Transport equipment	0.48	1.30
Electronic equipment	0.32	0.74
Machinery	0.36	0.91
Utilities and construction	0.68	2.06
Trade and transport	1.50	4.58
Other services	-0.10	-0.44

4.2 Trade

4.2.1 Import and export

The value of global imports increases under the simulation except for gas and coal. Table 9 shows the changes in the values of merchandise imports.[19] Under the 20 per-cent decrease scenario, the value of global oil imports increases by 87.00 per cent and the value of global petroleum products imports increases by 72.65 per cent. The values of imports by region show that all regions increase its importation. Russia and other OECs increase their imports by 15.21 per cent and 15.95 per cent, respectively, and Japan increases its imports by 11.63 per cent. The value of imports increases because the prices of imports increase, although the quantities of imports decrease.

The values of exports increase in all regions too. Table 10 shows the values of merchandise exports.[20] The value of exports in Russia increases by 19.81 per cent and the value of India's exports increases by 24.56 per cent. The same explanation can apply to the increase in value of exports as increase in the value of imports.

4.2.2 Terms of trade

Table 11 indicates the terms of trade of economies.[21] Under the 20 per-cent decrease

Table 9 Changes in value of regional imports by commodity (percentage change)

	USA	EU	Japan	NIAEs	ASEAN 5	China	India	Brazil	Russia	Other OECs	ROW	**Total**
Agri., food,	-0.60	0.15	0.37	-1.11	-1.04	-1.22	-5.43	-1.56	4.02	4.83	-0.51	0.35
extracts	-1.82	0.30	1.03	-3.35	-3.05	-3.97	-15.58	-4.94	13.70	16.46	-1.63	1.23
Gas and	-3.91	-0.84	-1.08	-2.14	-5.50	-7.79	-14.17	-2.11	-6.15	-0.45	-1.87	-1.84
coal	-8.87	-1.09	-1.40	-3.94	-13.89	-22.53	-41.54	-5.25	-11.75	1.89	-4.35	-3.64
Oil	26.10	27.52	28.79	25.73	31.22	38.85	27.08	34.85	36.48	38.32	31.13	28.47
	79.52	84.17	88.85	76.15	94.32	123.21	79.88	108.59	112.19	118.35	95.96	87.00
Textiles &	-0.31	0.21	-0.03	-1.02	-0.42	-0.30	-6.45	-1.23	3.39	4.41	-0.18	0.33
apparel	-0.77	0.51	-0.21	-3.02	-1.28	-1.16	-17.25	-3.74	10.92	14.66	-0.69	1.10
Wood/paper	-1.90	0.02	-0.31	-0.65	-0.08	-0.69	-6.37	-1.46	3.87	4.60	-0.31	0.05
products	-5.44	-0.08	-0.94	-1.75	-0.31	-2.35	-17.66	-4.45	12.89	16.05	-1.06	0.38
Petroleum/	21.57	22.66	25.01	24.85	24.74	23.89	27.26	25.53	29.97	24.33	24.38	23.53
coal products	66.87	69.99	78.39	73.39	75.24	75.30	80.93	78.91	92.97	76.01	75.41	72.65
Chemical	0.20	1.64	2.04	2.78	1.74	1.32	5.52	2.83	6.17	4.63	1.35	1.92
products	1.19	4.91	6.57	9.30	5.48	4.22	18.45	8.93	19.66	14.90	4.10	6.08
Metal/mineral	-1.36	0.68	0.10	1.42	0.34	1.73	0.54	2.26	3.95	2.90	0.31	0.78
products	-3.91	2.00	0.40	4.23	0.74	5.22	1.82	6.86	13.17	9.72	0.86	2.46
Transport	-0.40	0.11	0.12	-1.06	-1.68	-0.34	-6.49	-0.76	3.50	2.20	-0.32	0.17
equipment	-1.14	0.22	0.32	-3.17	-5.45	-1.48	-18.78	-2.47	11.04	7.47	-1.20	0.55
Electronic	0.36	0.21	0.53	1.83	-0.04	0.68	-3.87	-0.65	0.73	1.55	-0.37	0.54
equipment	1.41	0.52	1.59	5.16	-0.40	1.91	-11.69	-2.34	1.95	5.86	-1.38	1.64
Machinery	-1.00	0.22	0.09	-0.21	-1.13	0.10	-3.77	-1.24	4.57	3.67	-0.22	0.33
	-2.71	0.55	0.25	-0.78	-4.14	-0.27	-10.85	-4.46	14.47	11.93	-0.93	1.03
Utilities and	-1.44	-0.42	0.31	-2.12	-0.77	0.32	-5.36	-1.71	7.74	8.63	0.35	0.86
construction	-3.88	-1.27	1.18	-5.80	-3.15	0.94	-15.44	-5.82	25.81	29.75	1.20	3.12
Trade and	0.53	0.63	-0.88	-0.91	2.95	0.41	-2.26	1.85	6.97	8.78	0.45	1.21
transport	1.73	1.83	-2.77	-2.49	9.18	1.04	-6.30	5.68	22.08	28.82	1.35	3.86
Other	-0.27	-0.51	-0.03	-1.95	-2.06	-1.19	-4.96	-1.80	6.32	7.00	-0.82	0.26
services	-0.83	-1.76	-0.21	-5.79	-6.42	-4.02	-14.59	-6.04	20.75	24.23	-2.70	1.01
Total	2.20	1.64	3.74	2.69	2.33	2.83	3.85	3.32	4.67	4.80	2.28	2.47
	6.98	4.93	11.63	8.04	6.87	8.71	11.79	10.18	15.21	15.95	6.95	7.69

Note: 10 per cent decrease scenario on upper line and 20 per cent scenario on lower line.

Table 10 Changes in value of regional exports by commodity (percentage change)

Total	USA	EU	Japan	NIAEs	ASEAN 5	China	India	Brazil	Russia	Other OECs	ROW
Agri., food,	1.63	0.54	-0.73	2.02	1.58	2.53	9.83	1.38	-5.05	-6.02	1.26	0.28
extracts	5.32	1.62	-2.30	5.78	4.92	8.29	31.62	4.70	-15.15	-18.29	3.97	0.98
Gas and	-1.63	-0.66	-12.42	-23.05	0.28	-0.23	14.72	-12.29	-1.05	-3.08	-2.26	-1.93
coal	-0.26	1.12	-24.81	-82.17	3.98	12.86	120.58	-22.54	-5.33	-7.76	-3.57	-3.91
Oil	51.27	35.12	50.07	48.76	35.71	28.28	54.59	34.64	30.28	29.21	34.83	29.88
	164.45	107.34	155.92	151.58	109.47	79.41	184.02	100.42	92.31	89.23	105.09	91.20
Textiles and	1.82	-1.07	0.71	-1.19	-0.04	2.34	11.37	2.62	-8.54	-12.65	1.44	0.25
apparel	5.38	-3.68	2.07	-4.87	-0.05	7.71	34.87	8.61	-24.41	-34.90	4.20	0.82
Wood/paper	3.00	1.25	1.91	3.12	1.55	3.23	11.34	3.13	-10.50	-9.14	1.42	-0.06
products	9.80	3.63	5.58	8.53	4.82	10.43	36.42	10.06	-28.84	-26.89	4.26	0.01
Petroleum/	32.89	21.81	30.68	22.13	25.73	35.05	21.28	27.61	19.56	26.07	25.90	24.97
coal products	103.56	67.36	95.05	68.06	79.02	108.96	65.75	84.68	60.65	80.04	79.81	77.13
Chemical	5.35	3.51	4.31	-9.99	7.71	4.84	-7.77	0.32	-13.76	-11.21	7.47	2.01
products	15.81	10.12	12.20	-27.28	24.28	14.78	-22.98	0.50	-35.80	-30.79	23.34	6.31
Metal/mineral	5.43	2.25	3.38	4.77	1.40	-0.03	6.22	-0.28	-12.15	-10.65	2.99	0.74
products	17.10	6.47	10.01	13.51	3.89	-0.57	16.99	-1.21	-32.85	-30.21	8.80	2.35
Transport	0.86	0.37	1.87	3.41	1.29	0.92	10.41	2.28	-8.79	-6.10	1.27	0.14
equipment	2.74	1.05	5.75	9.82	4.41	3.20	33.30	7.84	-24.42	-18.36	4.02	0.45
Electronic	-1.63	-0.28	1.28	4.44	1.40	1.94	7.22	4.19	-18.77	-16.90	0.95	0.51
equipment	-5.23	-1.31	3.24	12.87	4.24	5.95	20.51	14.10	-47.10	-44.72	2.64	1.54
Machinery	2.10	0.56	1.12	4.07	0.23	0.69	9.99	4.20	-11.33	-12.83	0.79	0.29
	6.23	1.42	3.01	11.49	0.75	2.28	30.50	14.04	-31.45	-35.65	2.26	0.88
Utilities and	3.71	2.93	2.62	3.89	-0.67	1.53	8.18	5.92	-10.15	-10.59	0.83	0.86
construction	11.85	9.23	8.25	11.20	-2.09	4.80	25.33	20.40	-28.16	-29.41	2.24	3.12
Trade and	1.44	1.54	2.43	2.78	-1.95	2.30	3.67	-0.84	-3.18	-4.46	1.40	1.14
transport	4.46	4.98	8.06	8.51	-5.42	7.51	11.38	-2.22	-8.32	-12.27	4.40	3.83
Other	0.34	0.70	0.00	3.58	2.22	1.41	9.42	2.83	-7.23	-8.41	0.94	0.26
services	1.02	2.29	0.05	10.82	7.57	4.93	31.36	9.72	-20.74	-24.75	3.06	1.01
Total	2.25	1.55	1.97	2.58	2.90	2.30	7.84	2.90	6.03	4.43	2.83	2.47
	6.89	4.56	5.74	7.70	9.12	7.33	24.56	9.25	19.81	14.85	8.72	7.69

Note: 10 per cent decrease scenario on upper line and 20 per cent scenario on lower line.

scenario, the terms of trade of oil exporting economies increase significantly, while the terms of trade of oil importing economies decrease. The terms of trade of Russia and other OECs increases by 45.98 per cent and 40.68 per cent, respectively, and the terms of trade of India and Japan decrease by 19.64 per cent and 10.81 per cent, respectively. Since the price of oil increases by more than 100 per cent while the price of other merchandise commodities increase moderately compared with oil, oil exporting economies' terms of trade are improved significantly and the terms of trade of oil importing economies decrease.

Table 11 Changes in terms of trade (percentage change)

Region	10 per cent decrease scenario	20 per cent decrease scenario
USA	-3.12	-8.63
EU	-1.07	-3.11
Japan	-3.81	-10.81
NIAEs	-2.38	-6.87
ASEAN 5	-1.45	-4.26
China	-2.27	-6.87
India	-7.17	-19.64
Brazil	-2.20	-6.67
Russia	14.26	45.98
Other OECs	12.59	40.68
Rest of the world	-1.68	-4.91

4.3 Welfare

4.3.1 Income

Under the simulations, the incomes of oil exporting economies increase and the incomes of oil importing economies decrease. Table 12 indicates the changes in household incomes.[22] The income of Russia and the income of other OECs increase by 19.08 per cent and 21.05 per cent, respectively. Among oil importing economies, the incomes of developing economies decrease more than incomes of developed economies. Under the 20 per cent decrease scenario, India, NIAEs, China and ASEAN 5 decrease their incomes by 7.25 per cent, 5.39 per cent, 2.70 per cent and 1.26 per cent, respectively, while the incomes of the EU, the United States and Japan decrease by 0.36 per cent, 0.55 per cent and 0.85 per cent, respectively. The incomes of developing economies decrease relatively by large number because the price of labour and capital decreases significantly in those countries. Table 13 shows the price of production factors.[23] The cost of unskilled labour and capital of India decrease 12.88 per cent and 13.53 per cent, respectively, while the cost of unskilled workers and capital of the United States decrease by 1.52 per cent and 1.48 per cent, respectively.

Table 13 Changes in the price of primary factors (percentage change)

	USA	EU	Japan	NIAEs	ASEAN 5	China	India	Brazil	Russia	Other OECs	ROW
Land	-0.45	-1.37	-1.27	-2.55	-2.23	-2.09	-4.61	-1.51	-1.44	-2.04	-1.10
	-1.48	-4.40	-4.10	-8.23	-6.69	-6.58	-13.53	-4.51	-3.16	-4.88	-3.46
Unskilled labour	-0.45	-0.77	-0.42	-2.32	-2.14	-1.76	-4.28	-1.63	0.38	1.90	-1.00
	-1.52	-2.61	-1.49	-7.08	-6.83	-5.81	-12.88	-5.36	1.56	6.92	-3.34
Skilled labour	-0.43	-0.69	-0.40	-2.28	-1.98	-1.85	-4.01	-1.46	1.97	3.05	-1.00
	-1.46	-2.36	-1.45	-6.96	-6.32	-6.09	-11.97	-4.85	6.40	10.57	-3.31
Capital	-0.38	-0.71	-0.44	-2.28	-1.63	-1.59	-4.25	-1.35	2.19	3.38	-0.87
	-1.35	-2.45	-1.56	-6.94	-5.60	-5.42	-12.80	-4.69	6.16	10.56	-3.01
Natural resources	36.97	24.30	-0.32	-2.09	36.26	19.25	23.40	82.13	57.35	61.24	24.48
	127.03	83.95	-0.88	-5.14	124.50	67.39	79.41	275.75	193.65	203.51	85.03

Note: 10 per cent decrease scenario on upper line and 20 per cent scenario on lower line.

Table 12 Changes in household income (percentage change)

Region	10 per cent decrease scenario	20 per cent decrease scenario
USA	-0.15	-0.55
EU	-0.04	-0.36
Japan	-0.20	-0.85
NIAEs	-1.74	-5.39
ASEAN 5	-0.41	-1.26
China	-0.81	-2.70
India	-2.43	-7.25
Brazil	-0.17	-0.75
Russia	5.90	19.08
Other OECs	6.35	21.05
Rest of the world	-0.22	-0.85

Table 14 Changes in per capita utility from household expenditure (percentage change)

Region	10 per cent decrease scenario	20 per cent decrease scenario
USA	-0.66	-1.87
EU	-0.72	-2.07
Japan	-0.65	-1.93
NIAEs	-1.78	-5.40
ASEAN 5	-1.56	-4.39
China	-1.11	-3.35
India	-2.18	-6.62
Brazil	-0.88	-2.50
Russia	2.62	8.46
Other OECs	2.75	9.02
Rest of the world	-1.01	-2.94

4.3.2 Per capita utility from household expenditure

Per capita utility from household expenditure shows the same trend as income. Table 14 indicates the change in per capita utility from aggregate household.[24] Per capita utility of oil exporting regions economies increases, while per capita utility of oil importing economies decreases. For example, other OECs increase their utility by 9.02 per cent, while NIAEs decreases their utility by 5.40 per cent.

4.3.3 Equivalent variation

Changes in equivalent variations show the same trend as changes in incomes and per capita utilities. Table 15 shows the changes in equivalent variations.[25] Equivalent variations in oil exporting economies increase, while equivalent variations of oil importing economies

decrease. For example, Russia increases its equivalent variation by US$45,979, while the United States decreases its equivalent variation by US$198,648. Figure 10 show the decomposition of change in equivalent variation.[26] In all regions, changes in terms of tradeshow the biggest effect.

Table 15 Changes in equivalent variation (2005 $ US million)

Region	10 per-cent decrease scenario	20 per-cent decrease scenario
USA	-69,707	-198,648
EU	-80,401	-231,800
Japan	-25,838	-76,876
NIAEs	-19,902	-60,297
ASEAN5	-9,015	-25,292
China	-16,867	-50,832
India	-12,799	-38,810
Brazil	-4,811	-13,643
Russia	14,227	45,979
Other OECs	84,706	277,836
Rest of the world	-27,510	-80,250
World total	-167,917	-452,631

Figure 10 Decomposition of Change in equivalent variation

5. Conclusion

This paper analyses the effects of the decrease in oil production on some economies using a computable general equilibrium model. Under the simulations, the world output of oil decreases. In oil exporting economies, the GDPs increase, the utilities increase, and the terms of trade increase. In oil importing economies, the GDPs decrease, the utilities decrease, and the terms of trade decrease. Among oil importing economies, the developing economies and newly industrialised economies affects more than developed economies. Most industry sectors decrease their world outputs. Among industry sectors, oil industry affects most and the industry sectors which use large amount of oil such as petroleum industry and chemical industry decrease its output significantly.

The results of the simulations show that the economies which are expected to increase their oil consumption such as India and China would be affected significantly by the decrease in oil production. If they cannot change their economic structures which are dependent on oil, they cannot maintain their economic growth or they would economically decline. Unlike the oil price increase due to speculation, the oil price increase due

to the decrease in oil production would last a longer time, unless new technology for oil production is introduced. Therefore, its influence on economies would be more serious than the previous oil shocks in the 1970s.

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Notes

1 BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965).

2 IEA World Energy Outlook 2009.

3 US EIA International Energy Outlook 2009.

4 IEA World energy Outlook 2007.

5 IEA Key World Energy Statistics 2009.

6 BP Statistical Review of World Energy 2009, Proved Reserves - barrels (from 1980).

7 IEA World energy Outlook 2007.

8 BP Statistical Review of World Energy 2009, Proved Reserves - barrels (from 1980).

9 BP Statistical Review of World Energy 2009, Oil Consumption - barrels (from 1965).

10 IEA World energy Outlook 2007.

11 Society of petroleum Engineers, Glossary of Terms Used in Petroleum Reserves/Resources, Petroleum Reserve Definitions 1997.

12 For more details, see Ban, K., Ōtsubo, S., Kawasaki, K., et al. (1998).

13 Exogenous variables: pop (population), psaveslack (slack variable for the savings price equation), pfactwld (world price index of primary factors), profitslack (slack variable in the zero profit equation), incomeslack (slack variable in the expression for regional income), endwslack (slack variable in endowment market clearing condition), cgdslack (slack variable for qcgds (output of capital sector)), tradslack (slack variable in tradables market clearing condition), ams (import augmenting technical change), atm (technical change in transportation mode) atf (technical change in shipping, worldwide), ats (technical change in shipping from region r), atd (technical change in shipping to region s), aosec (output technical change of sector j), aoreg (output technical change of region r), avasec (value added technical change of sector j), avareg (value added technical change of region r), afcom (factor input technical change of input i), afsec (factor input technical change of sector j), afreg (factor input technical change of region r), afecom (factor input technical change of input i), afesec (factor input technical change of sector j), afereg (factor input technical change of region r), aoall (output augmenting technical change) afall (intermediate input augmenting technical change) afeall (primary factor augmenting technical change), au (input-neutral shift in utility function), dppriv (private consumption distribution parameter), dpgov (government consumption distribution parameter), dpsave (saving distribution parameter), to (output (or income) tax) tp (shift in tax on private consumption), tm (change in tax on imports), tms (change in tax on imports from region r), tx (change in subsidy on exports), txs (change in subsidy on exports to region s), qo(ENDW_COMM, REG) (primary factor output). Rest of variables are endogenous.

14 These countries cover more than 97 per cent of world net oil exports.

15 Represented as 'qgdp', 'pgdp' and 'vgdp' in GTAP model.

16 Represented as 'qow' in GTAP model.

17 Represented as 'qo' and 'qgdp' in GTAP model.

18 Represented as 'pw' in GTAP model.

19 'Represented as viwcif', 'viwcom' and 'viwreg' in GTAP model.

20 Represented as 'vxwfob', 'vxwcom' and 'vxwreg' in GTAP model.

21 Represented as 'tot' in GTAP model.

22 Represented as 'y' in GTAP model.

23 Represented as 'pm' in GTAP model.

24 Represented as 'u' in GTAP model.

25 Represented as 'EV' in GTAP model.

26 Represented as 'EV Decomposition' in GTAP model.

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