Green or greener? Resource consumption reduction towards green economy

Satoshi Kojima*, Takashi Yano, and Yasuhiko Hotta

Institute for Global Environmental Strategies, 2108-11 Kamiyamaguchi, Hayama, Kanagawa 240-0115, Japan

Abstracts: The definition of green economy is still controversial in the ongoing international discussion towards Rio+20. When a society is in excess of environmental carrying capacity of the Earth, it is not enough to simply make the economy ‘greener’, that is, to improve environmental efficiency. What is essential is to make the economy ‘green’ in the sense that the system is consistent with the carrying capacity of the Earth. The current empirical evidence suggests that making the economy ‘green’ in the latter sense may require resource consumption reduction in absolute terms at least in rich countries. Furthermore, resource consumption reduction in developed countries may be essential to meet basic needs all over the world, which requires rapid and substantial economic growth and material demands increase in less developed countries. However, several challenges hinder unilateral implementation of policies to reduce resource usage, such as concern for negative impacts on international competitiveness and international leakage effects. Against this background this paper tries to demonstrate potential benefits of international policy coordination to reduce resource consumption between countries with differing production, trade and consumer behaviours with respect to resources. To quantitatively measure the effects of international policy coordination, a 4-country computable general equilibrium (CGE) model of Japan, China, Korea and Australia was developed to evaluate resource consumption reduction policies, with focusing on iron because of their significant economic recycling value and data availability. Our analysis shows that compared with Japan’s unilateral efforts to reduce iron ore consumption, joint policy efforts by four countries to attain the same degree of iron ore consumption as the whole region is economically beneficial in terms of gross domestic product (GDP) over the evaluation period, increases household assets at the end of the period, and reduces carbon emissions.

Keywords: Non-market value, Sustainable ecosystem service use, Bounded rationality

* Corresponding author. E-mail address: kojima@iges.or.jp

1. Introduction

The definition of green economy is not clear in the ongoing international discussion towards Rio+20. Even if we confine our consideration in an economy-environment segment, it is not clear whether green economy explicitly brings compatibility of economic system and the carrying capacity of the Earth into view. When a society is in excess of environmental carrying capacity of the Earth in the sense that the Earth would suffer too heavy a burden to withstand if all people in the world realised a standard of living on par with that society, it is not enough to simply make the economy ‘greener’, that is, to improve environmental efficiency. What is essential is to make the economy ‘green’ in the sense that the system is consistent with the carrying capacity of the Earth (Kojima et al. 2011). The current empirical evidence suggests that making the economy green in the latter sense may require resource consumption reduction in absolute terms at least in rich countries. This is indeed the main massage of the report on decoupling published by the International Resource Panel: we need ‘absolute decoupling’ rather than ‘relative decoupling’ (UNEP 2011). Furthermore, resource consumption reduction in developed countries may be essential to meet basic needs all over the world, which requires rapid and substantial economic growth and material demands increase in less developed countries.

In Europe, progressive measures toward sustainable resource usage are incorporated as one pillar of the EU Sustainable Europe 2020 programme. In Japan, high technical and funding capabilities coupled with a rising awareness of overconsumption set relatively favourable conditions for restraining resource usage. This mindset is reflected in Article 2 of Japan’s Basic Law for Establishing the Recycling-based Society that defines a recycling-based society as “a society where the consumption of natural resources will be restrained and the environmental load will be reduced as far as possible”. These conditions thus provide a context for deeper countermeasures to evolve towards sustainability (Matsuno and Moriguchi 2003).

Nevertheless, several challenges hinder Japan unilaterally implementing reductions in resource usage. One is concern surrounding international competitiveness, as any internalisation of environmental impact would boil down to increased production costs in the short term, which could trigger further relocation of manufacturing activities overseas, incurring “carbon leakage”—an issue already being debated on with regard to carbon taxes and other measures. Another challenge is that any unilateral action by Japan could have ramifications for international trade. In other words, the effects and impacts of any policy measures designed to restrain resource usage will vary in accordance with the stage in a product’s life cycle at which intervention takes place, and for minerals, fossil fuels, and other resources the imports of which Japan relies on, it would be impracticable to intervene at upstream ends in raw materials markets, such as mining (Kojima et al. 2011). To bridge these challenges, policy coordination via international cooperation looks hopeful. Policy designed according to the domestic conditions of each country would enable more efficacious packaging of the policies and also mitigate carbon leakage and other undesirable ripple effects. In the wider context the world as a whole needs to reign in its resource usage, and lowering the burden for each country could be realised through policy coordination. Based on this premise, this paper quantitatively assesses, using a computable general equilibrium (CGE) model, the effects of international policy coordination with focusing on iron and steel. Iron is chosen as a major recycled resource that is widely used and recycled. Furthermore, the relevant data is relatively easily obtained. It should be noted that it is not our intention to be prescriptive as regards consumption patterns of iron.

This research covers four countries; Japan, China, Korea, and Australia, chosen for their varying mineral ore production and import/export patterns, with the aim being to provide a broad basis for international policy formulation. Australia is a major iron ore producer and exporter; China is also a major iron ore producer, but also imports iron ores due to domestic demand; Korea and Japan are major steel producers, but they import large quantities of iron ores due to lack of domestic supply. Table 1 shows the production, export, import, and consumption quantities for iron ore, for each country.

Table 1 Iron ore production, export, import, and consumption in 2005

Unit: Thousands of tons

	Production	Export	Import	Consumption
Japan	0	55	132,285	132,230
China	284,500	2	275,260	559,758
South Korea	451	0	42,250	42,701
Australia	257,525	238,763	1,547	20,309

Source: Steel Statistical Yearbook 2011

The remaining paper is structured as follows. Section 2 briefly reviews the relevant literature. The four-country CGE model to assess policy impacts is explained in Section 3. Section 4 assesses international policy coordination impacts, and Section 5 concludes this paper with summarising policy implications derived from this analysis.

2. Literature review

Literature available on CGE models examining the iron and steel sector includes Schumacher and Sands (2007) single-country CGE model for Germany, which is a comparative analysis how carbon pricing effects emissions of CO_2. They treat iron manufacturing and steel as one sector divided into five production processes, including two blast furnace processes and two electric furnace processes, and did not distinguish production processes on the demand side. That is, it was premised on perfect substitution among steel products. For Japan, a paper by Takayama and Masui (2009) covers a resource-recycling structure-adjustment scenario; the iron and steel sector is divided into five categories, including blast-furnace and electric-furnace crude steel (based on the 2000 inter-industry relations table) to create a single-country CGE model. In the model the recycling sector is divided into scrap iron recycling and other resource recycling, which was then combined with a steel stock quantity estimation model to form a research tool used to analyse the effect on reduction in CO_2 emissions and economic impact via an exogenous rise in ratio of electric furnace steel. The research utilised the Leontief function, which assumes zero input substitution of any intermediate materials, including blast-furnace and electric-furnace steel. A paper by Yamazaki (2010) uses data from the 2000 Asia international inter-industry relations table (IDE 2006), the 2000 Ministry of Internal Affairs and Communications of Japan inter-industry relations table, and the 2002 National Bureau of Statistics of China input-output table to divide the iron and steel sector into three categories (blast furnace, converter furnace, and electric furnace) to form a two-country CGE model (Japan and China) involving the scrap iron recycling sector, and analysed the economic effects and influence on CO_2 emissions in the steel industry of a hypothetical rapid rise in scrap iron exports to China from Japan associated with China's economic growth. This scenario utilises imperfect substitution (CES function) for the input of intermediate materials for blast-furnace and electric-furnace crude steel in the metal manufacturing sector and the Leontief function (with zero substitution for all other inputs of intermediate materials).

Our research adopts a model to analyse iron ore consumption restraints and the policy effects on scrap iron recycling, drawing on Takayama and Masui (2009) and Yamazaki (2010) for blast furnace and electric furnace classifications and scrap iron recycling. We further covered copper as an example of a non-ferrous metal and looked at the policy implications of varying the resources covered. In contrast with a focus on the impact on CO_2 emissions in the prior research mentioned above, our research embraces international policy coordination of measures to restrain natural resource consumption and resource recycling measures, which represents a highly original approach.

3. Policy Impact Assessment Model

The multi-region CGE model for Japan, China, South Korea, and Australia used in this research is a multi-sector Ramsey growth model that performs utility maximisation based on future projections of the prices of goods and services, factor prices, and other prices in the household sector, with the savings rate and rate of household asset return (interest rate) for household income sought as endogenous variables. In this model it should be understood that if the savings rate falls, consumption could rise even if income remains constant or falls, and that the household consumption standard or social welfare standard could increase even if real GDP declines.

This model differs from the conventional Ramsey model: our model assumes the simplest expectation formation process, wherein dynamic optimisation is performed based on fixed future prices of goods and services, factor prices, and so on in the household sector.

The economic agents consist of households, businesses and government. For international trade, on the import side we assumed the imperfect substitution, following the approach proposed by Armington (1969), indicated in the CES function in the two stages between domestically produced goods and imported goods and between the same imported goods from different importers, and on the export side we assumed the imperfect substitution indicated in the CET function, likewise in the two stages between goods for the domestic market and exported goods and between the same exported goods from different exporters. We assumed that bilateral trade between the four countries would be driven by import demand with the prices determined endogenously, and for trade with the rest of the world (RoW) we adopted the small-open-economy hypothesis, assuming that the international prices for goods and services would be determined by exogenous factors.

Households

Households either purchase goods and services via income from labour, capital, or other factors of production from the industrial sector, or save that income as a household asset. Since this model distinguishes between the capital (materials) input by the manufacturing sector as a factor of production and household assets (value), the income from household assets is treated differently from other factor income. In other words, the income from factors of production other than capital is the product of the per capita supply (x^f) of the factor of production *f* and the factor price (w^f), but income from household assets is the product of the per capita household assets expressed as currency units (*m*) and the rate of return (*r*). Accordingly, the per capita restriction on household income and expenditures is expressed as follows:

$$\sum_f w_t^f x_t^f + r_t m_t = \sum_i p_t^i c_t^i + S_t$$

Here, p^i is the price of the good/service *i*, c^i is the per capita consumption quantity of good/service *i*, and *S* is per capita savings.

In the household production function approach (Becker 1965), households are assumed to produce and consume “utility services” by consuming goods and services transacted on various markets, i.e.:

$$c_t = \prod_i \left(c_t^i\right)^{\varphi_i}$$

where *c* is the utility services produced/consumed, and φ_i is the share parameter for the good/service *i* in the household production function.

In this model, the household utility at time *t* is assumed to be determined by the present value at time *t* of the sufficiency (felicity) obtainable from the consumption of the utility service at each point in time (Kojima 2007). Assuming CIES (Constant Inter-temporal Elasticity of Substitution) felicity function $u(c_t) \equiv \frac{(c_t)^{1-\sigma}}{1-\sigma}$ with *s* as the constant inter-temporal elasticity of substitution, the household utility maximisation problem can be formulated as follows:

$$\underset{\{c_t^i\}}{Max}\, U_t \equiv \sum_{s=t}^{\infty} \left(\frac{1+\nu}{1+\rho} \right) u(c_s)$$

s.t. $\quad m_{t+1} = \dfrac{m_t + S_t}{1+\nu}$ and $\sum_f w_t^f x_t^f + r_t m_t = \sum_i p_t^i c_t^i + S_t$

where ρ represents the net time preference rate and ν represents the population growth rate.

Assuming here the simplest household expectation formation process wherein dynamic optimisation allows for the future course of the prices for goods and services, factor prices, and other exogenous variables to be fixed at current levels, we derive the following optimal consumption level for utility services as the interior solution to this household utility maximization problem:[†]

$$c_t^* = \left[\prod_i \left(\frac{\varphi^i}{p_t^i} \right)^{\varphi^i} \right] \times \left[1 + r_t - (1+\nu) \left(\frac{1+r_t}{1+\rho} \right)^{1/\sigma} \right] \times \left[m_t + \frac{1}{r_t - \nu} \sum_f w_t^f x_t^f \right]$$

Note that in the policy simulation, we used the following formula, which is expanded to incorporate various taxes:

$$c_t^* = \left\{ \prod_i \left[\frac{\varphi^i}{(1+ts_t^i) p_t^i} \right]^{\varphi^i} \right\} \times \left\{ 1 + (1-td_t)(1-tk_t) r_t - (1+\nu) \left[\frac{1 + (1-td_t)(1-tk_t) r_t}{1+\rho} \right]^{1/\sigma} \right\} \times$$

$$\times \left[m_t + \frac{(1-td_t)}{(1-td_t)(1-tk_t) r_t - \nu} \sum_f \left(1 + tf_t^f\right) w_t^f x_t^f \right]$$

Here ts^i represents the consumption tax on good/service *i*, tf^f represents the tax on factor income from non-capital factor *f*, *tk* represents the tax on interest, and *td* represents the income tax on overall household income.

Based on this optimum consumption standard for utility services, the optimal consumption standard for the good/service *i* transacted on the market is given as follows:

$$c_t^{i*} = c_t^* \times \frac{\varphi^i}{(1+ts_t^i) p_t^i} \prod_k \left[\frac{(1+ts_t^k) p_t^k}{\varphi^k} \right]^{\varphi^k}$$

[†] For the details of this derivation, see Appendix at the end of this paper.

Ultimately, the optimal savings amount is determined as the difference between disposable income and optimal consumption expenditures.

Businesses

Decision-making in the business sector is formulated as a profit optimisation problem in each general period. With production technologies as given, businesses input intermediate materials and factors of production to produce goods and services with the aim of profit maximisation. The products and services they produce are assumed to be divided into domestic markets and exports via the CET (Constant Elasticity of Transformation) function, and then allocated by CET function to export locations, including the rest of the world. For the goods and services supplied to the domestic market we adopt the Armington hypothesis of imperfect substitution indicated in the same classification of imported goods and services and the CES (Constant of Elasticity Substitution) function, further assuming the two-stage CES approach of imperfect substitution indicated in the CES function for imported goods and services from different importers. Based on the assumption of a perfectly competitive market, in market equilibrium, supply and demand for goods, services, and factors of product become equal and business profits go to zero.

We used the following 23 industry types for business sector classification as shown in Table 2.

Table 2 Sector classification

No.	Code	Sector	No.	Code	Sector
1	xag	Agriculture, forestry, and fisheries	13	fmp	Metal products
2	coa	Coal	14	mvh	Motor vehicles
3	oil	Crude oil	15	otn	Other transportation equipment
4	gas	Natural gas	16	ome	Machinery and equipment
5	ior	Iron ore	17	rcy	Recycling
6	cor	Copper ore	18	xmf	Other manufacturing
7	omn	Other mining	19	ely	Electricity
8	p_c	Petroleum and coal products	20	cns	Construction
9	i_sb	Blast furnace steel	21	otp	Land transport
10	i_se	Electric furnace steel	22	tpn	Other transport
11	cop	Copper	23	xsv	Other services
12	xnf	Other non-ferrous metals			

Regarding production technologies, we assumed imperfect substitution (CES function) for technologies that use capital, labour, or other factors of production to produce value-added goods. We treated skilled labour, unskilled labour, capital, land, and natural resources as factors of production, assuming that labour and capital could move among sectors but that land and natural resource were innate to the sector. The abundance of natural resources and land was assumed to be fixed at the quantity of the reference year, whereas the abundance of skilled and unskilled labour was assumed to grow based on macro-economic forecast data prepared by the Center for Global Trade Analysis at Purdue University. Capital was endogenously determined by the model based on the assumption that all household savings each year would be invested into capital accumulation.

Technologies that produce goods and services as products from value-added goods and each of the intermediate materials are assumed to follow the no-substitution Leontief production function. Accordingly, a decrease in iron ore input in blast furnace steel production will result in a decrease in blast furnace steel production in the same ratio. However, we assumed imperfect substitution (CES function) for the input of intermediate materials for blast furnace steel and electric furnace steel in each industrial sector, as well as for the input of intermediate materials for blast furnace steel and recycling sector products in the electric furnace steel sector. Regarding the constant elasticity of substitution between blast-furnace and electric-furnace steel, Shimizu et al. (2004) statistically estimated the constant elasticity of substitution among blast-furnace, electric-furnace, and imported shaped steel to be approximately 3 for shaped steel (a type of steel material). Yamazaki (2010) adopts 2.5 in the Japan model and 0.5 in the China model regarding intermediate inputs of blast-furnace and electric-furnace crude steel in the metal products sector. Referencing these figures, in this research we set the constant elasticity of substitution to 0.2 for the three sectors of motor vehicles, other transportation equipment, and machinery and equipment, where the use of high-grade steel is important, and 2 for all other sectors. In the electric furnace steel sector we assumed a constant elasticity of substitution of 2 between input of blast-furnace steel and blast-furnace steel recycling-sector-product intermediate materials.

Government

The government imposes taxes or pays out subsidies in its policy measures to restrain natural resource consumption. Government consumption and government investment were treated as fixed at the level of the reference year for per capita government consumption and total quantity of government investment, because services that generate government consumption and government capital are not reflected in the utility function.

Macro closures

Regarding macroclosures, we transferred the surplus (or deficit) government balance en bloc between government and households in order to achieve a balanced government budget. We also fixed the current account balance at the level of the reference year.

Environmental impact assessment module

For estimating CO_2 emissions, we used energy flow data associated with the use of fossil fuels and the CO_2 emission coefficient during combustion for each fossil fuel (Lee 2008) obtained from the 7th edition of the Global Trade Analysis Project (GTAP) database (Center for Global Trade Analysis at Purdue University, US), with 2004 as the reference year. Note that since most of the input of crude oil and coal intermediate materials via the petroleum and coal product sector is thought to be used as raw material, we assumed it involved no CO_2 emissions. We also introduced an adjustment coefficient to match the CO_2 emissions in each country with International Energy Agency estimates (IEA 2011) for the reference year.

The quantities of iron ore consumed were estimated by multiplying the consumption quantities for the reference year as shown in Table 1.

Simulation setting

With the time step in the policy simulation set to one year, we ran the simulation from the database reference year of 2005 through to 2020. The model was developed using GAMS (General Algebraic Modeling System) software by formulating it as an MCP (Mixed Complementarity Problem) solved using PATH.

The assessment indicators for policy impact on the overall economy analyse the impact on sales in the automotive sector for iron and the machinery and equipment sectors for copper as major raw material users, for which the effects of policy impact are large in real GDP and international competitiveness. For environmental impact, we analyse the impact on CO2 emissions due to fossil-fuel burning.

Note that in this study, rather than adopt the method of assessing policy impact by omitting established policies (the so-called BAU scenario), we assess policy impact for a standard policy scenario after having set the policy goals, an approach we considered more accurate. Further, as assessing only the costs of a policy would ignore its benefits (reduction in passive costs) would lead the debate astray we aimed at formulating better policy options based on a premise of realistic and socially (or politically) acceptable policy goals.

Data

We created the four-country Social Accounting Matrix (SAM), which is a basic database, based on each country's inter-industry relations tables. The inter-industry relations tables used are as follows:

- Japan: 2005 Inter-Industry Relations Table Basic Classification Table, Statistics Bureau, Ministry of Internal Affairs and Communications (407 sectors classified)
- China: 2007 Inter-Industry Relations Table (135 sectors classified)
- Korea: 2005 Inter-Industry Relations Table (403 sectors classified)
- Australia: 2007-2008 Inter-Industry Relations Table (111 sectors classified)

Data on direct taxation and trade that could not be estimated from the inter-industry relations tables was estimated from the 7th edition of the GTAP database. We assumed using this database for 2005 data, even though it covers 2004, would not be problematic. We also used this database for the constant elasticity of substitution between factors of production, the constant elasticity of substitution (Armington coefficient) between domestic goods and imported goods and other parameter values. Refer to the Appendix at the end of this chapter for more details on the creation of the SAM.

4. Impact assessment of joint policy efforts in reducing iron ore consumption

4.1 Policy scenarios

Here, three policy scenarios were considered in addition to the business-as-usual scenario (BAU). The first scenario—Japan "acting alone" (J)—is that Japan unilaterally reduces resources and resource circulation. This scenario assumes the use of volume-based waste emission charges for scrap iron and the disbursements of revenues from the charges to the recycling sector as subsidies. The rates were set so that Japan's iron ore consumption in 2015 (target year) will be 10% lower than in Scenario BAU.

The second scenario—policy coordination between Japan and Australia (JA)—is that Australia introduces natural resource taxes on iron ore as an "upstream" measure and Japan takes the above-mentioned steps. The third scenario—policy coordination among Japan, Australia, China, and South Korea (JACK)—is that South Korea and Japan introduce similar volume-based waste emission charges while Australia and China adopt natural resource taxes. Scenarios JA and JACK were compared with Scenario J to analyse policy implications for international policy coordination. For the purpose of comparison, the tax and charge rates were set so that the total iron ore consumption of the four countries combined will remain at the same level in 2015 under all scenarios.

The three scenarios are described in detail below:

- Scenario J: Fix-rate charges are levied on per-unit emissions of scrap iron for all the sectors except steel (blast furnace steel and electric furnace steel) and recycling. Revenues from these charges offset the subsidies, effectively reducing sales taxes on the recycling sector. The tax and charge rates were set so that Japan's iron ore consumption in 2015 will be 10% lower than in Scenario BAU.
- Scenario JA: Japan implements the same policy as in Scenario J (though with a different charge rate). Australia levies natural resource taxes on iron ore mining sector sales, and tax revenues are transferred en masse to the household budget. The tax and charge rates were set so that total iron ore consumption of the four countries combined in 2015 will be at the same level as in Scenario J, with consideration given to the balance in the reduction in iron ore consumption between Japan and Australia.
- Scenario JACK: Japan and South Korea carry out the same policy as in Scenario J (though with a different charge rate). Australia and China levy natural resource taxes on domestic iron ore mining sector sales, and revenues from these taxes are transferred en masse to their household budgets. The tax and charge rates were set so that total iron ore consumption of

the four countries combined in 2015 will be at the same level as in Scenario J, with consideration given to ensure that the rate of reduction in iron ore consumption will be approximately equal across the four countries.

In order to avoid calculation-related problems with the introduction of a policy shock in the base year, policy implementation is assumed as beginning in 2006. The tax and charge rates were fixed from 2006 to 2020. The subsidy rate for the recycling sector was set so that application in any particular year would result in revenues from emission charges being equal to subsidy spending, calculated based on income from emission charges and recycling sector sales. However, the subsidy rate thus set is applied to the subsequent year. Therefore, revenues from emission charges do not necessarily match the subsidy spending for each year.

Table 3 shows the tax and charge rates in each policy scenario. Note that the total of iron ore consumption of the four countries combined in 2015 in these scenarios is projected to be 1.4% lower than in Scenario BAU.

Table 3 Tax and charge rates under the three policy scenarios

		J	JA	JACK
Japan:	Volume-based waste emission charges [USD/ton]	4224	2862	647
Australia:	Natural resource taxes [%]	0	21.5	5.86
China:	Natural resource taxes [%]	0	0	14.65
Korea:	Volume-based waste emission charges [USD/ton]	0	0	625

Figure 1 shows the projected changes in the cyclical use rate for iron in Japan under these scenarios. This rate refers to the ratio of the input of iron & steel scrap to the total input of pig iron and steel scrap combined. The changes in the input of pig iron are based on those in the intermediate input of blast furnace steel products, in the blast furnace steel sector. Likewise, the changes in the input of iron and steel scrap are based on those in the intermediate input of recycling sector products, in the electric-furnace steel sector.[‡]

[‡] The combined input of pig iron and iron and steel scrap in 2005 was taken from Table II-1-2, Japan Ferrous Raw Materials Association, Tetsugen Nenpo [annual report on ferrous raw materials] (18), 2007.

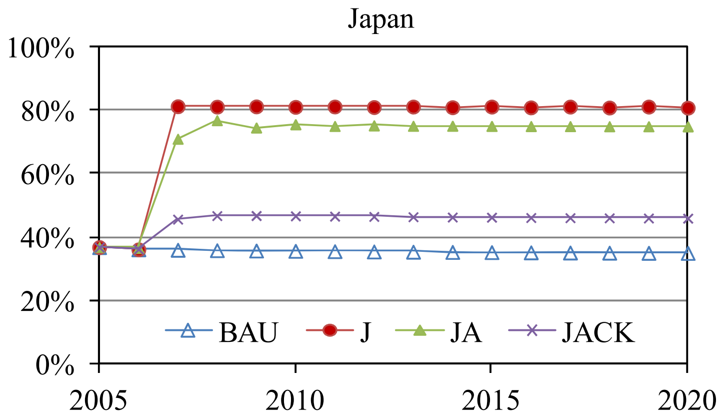

Figure 1 Cyclical use rate for iron in Japan under the three scenarios (%)

Projections show that the higher the tax/charge rate, the higher the iron cyclical use rate will be, since revenues from volume-based waste emission charges will offset the subsidies. The cyclical use rate of over 80% in Scenario J implies excess demand for scrap, which could destabilise the material balance.

The impacts under the two policy scenarios of international coordination (JA and JACK) are shown below as a percentage change from the baseline Scenario J.

4.2 Impact on iron ore consumption

Figure 2 shows the impact of international policy coordination on iron ore consumption in the four countries.

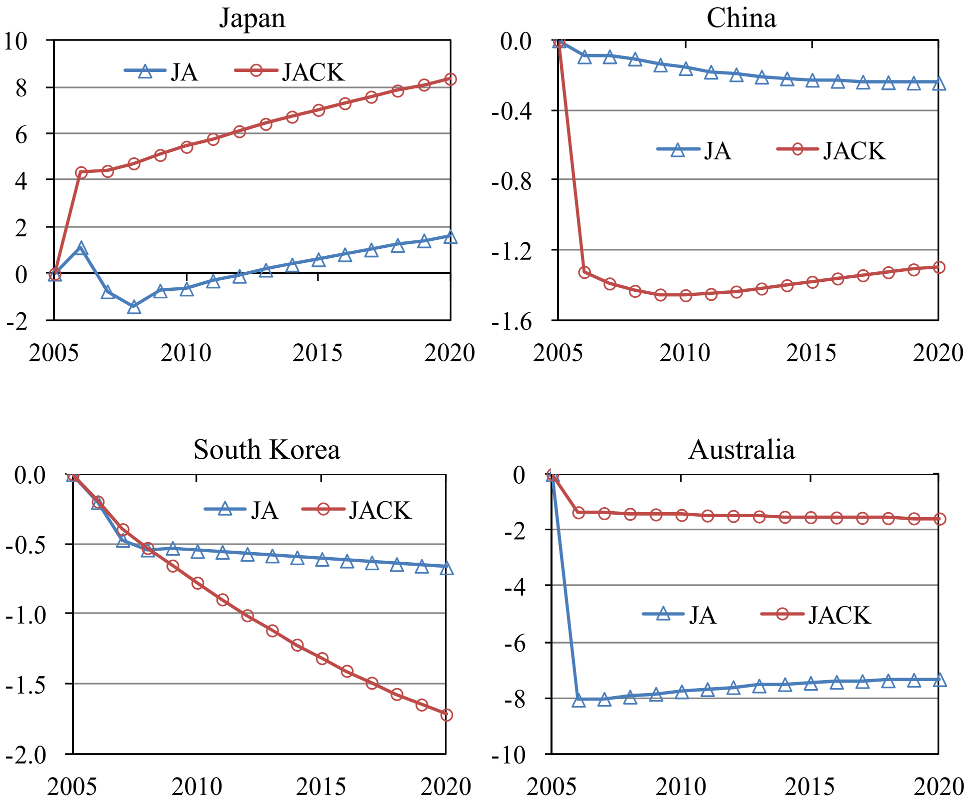

Figure 2 Impact of policy coordination on iron ore consumption in the four countries (%)

Note that under Scenario JA, the consumption of the resource will be lower even in China and Korea compared with Scenario J. Further, while the resource consumption reduction effect of natural resource taxes (in Australia and China) remains almost flat since introduction of the policy, that of the package comprising volume-based waste emission charges and resource-recycling measures (in Japan and Korea) is on a gradual increase.

Figure 3 shows the impact of international policy coordination on the total iron ore consumption of the four countries combined.

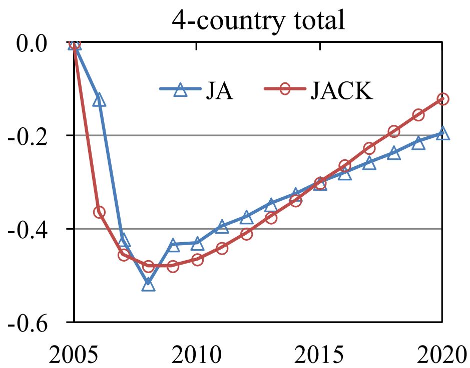

Figure 3 Impact of policy coordination on the total iron ore consumption of the four countries combined (%)

The impact on the total iron ore consumption of the four countries combined is minimal since the benchmarking was made to keep the rate of reduction until 2015 on the same level as in Scenario J. The approximate 0.3% reduction in 2015 is within the reduction target benchmarking margin of error.

4.3 Impact on real GDP

Figure 4 shows the impact of international policy coordination on real GDP of the four countries.

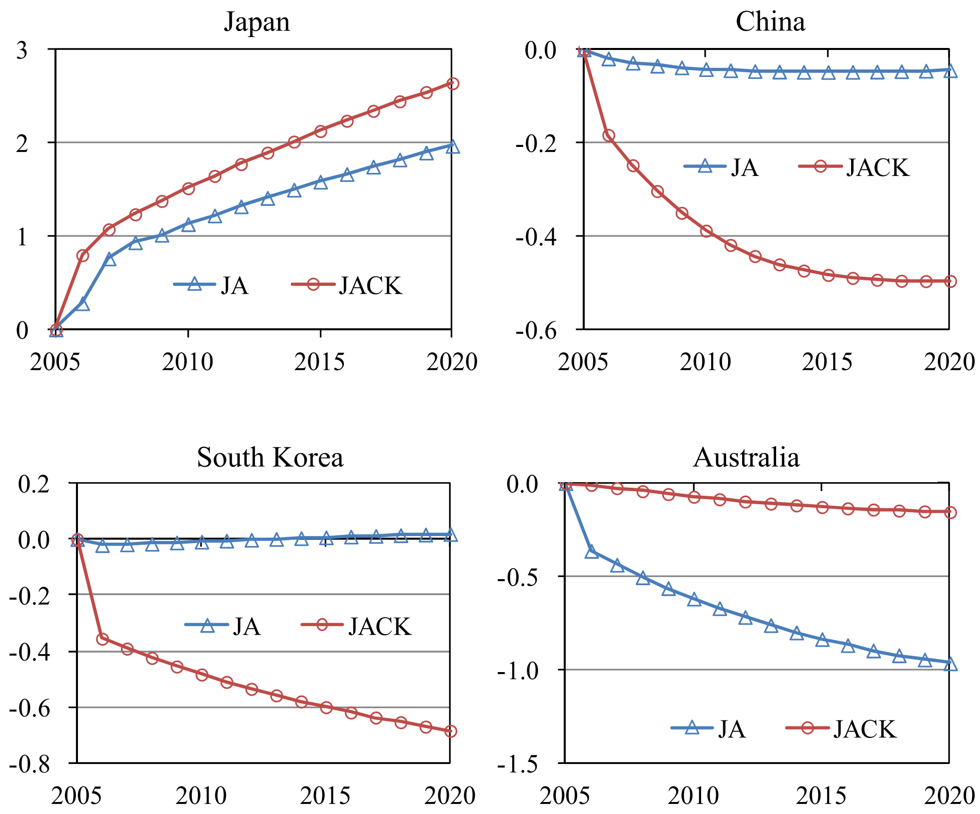

Figure 4: Impact of policy coordination on real GDP of the four countries (%)

As expected, it has been found that real GDP will be lower due to the resource use reduction policy; however, GDP of the four countries combined will be higher due to international policy coordination, as shown in Figure 5. This is because international policy coordination will have a more positive impact in Japan—where the rate of volume-based waste emission charges will be lower—compared with Scenario J.

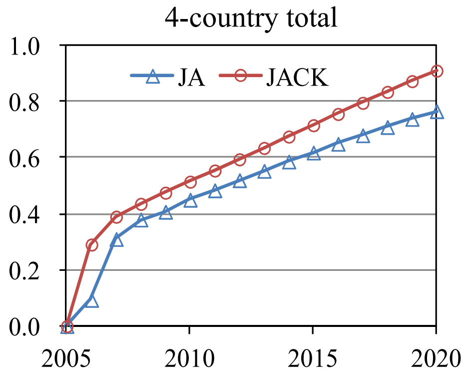

Figure 5 Impact of policy coordination on real GDP of the four countries combined (%)

Scenario JACK will have a more positive impact than Scenario JA.

4.4 Impact on international competitiveness

To illustrate the impact of international policy coordination on international competitiveness, Figure 6 shows the impact on the production (sales) of the automobile sector, a major steel-consuming sector.

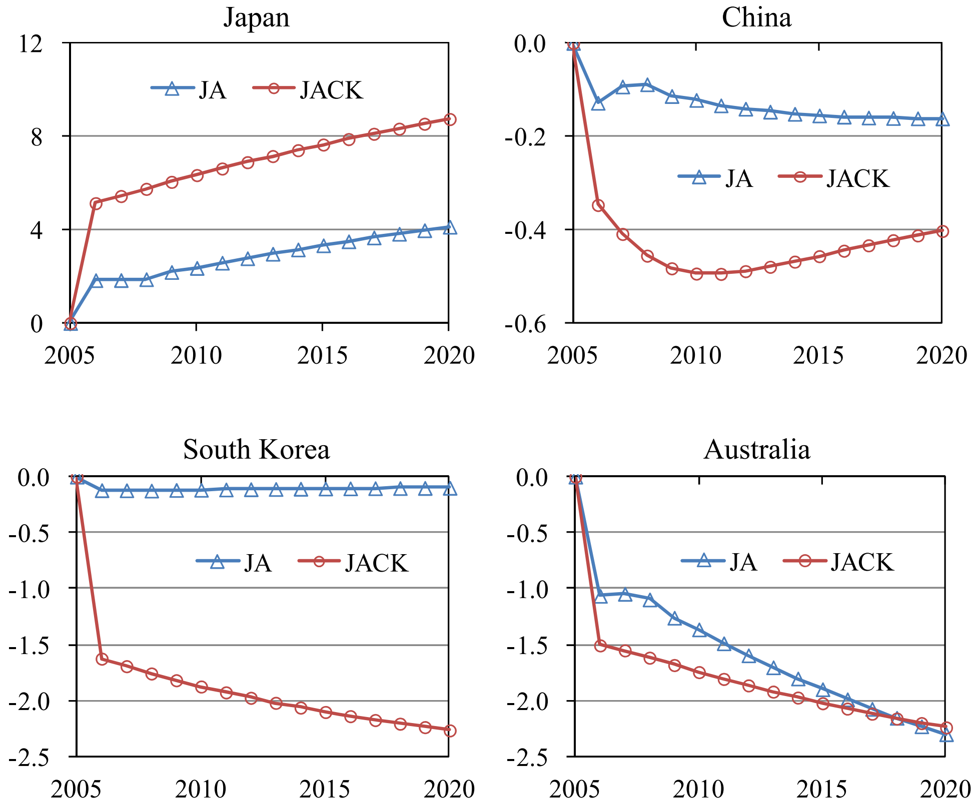

Figure 6 Impact of policy coordination on the production (sales) of the automobile sector in the four countries (%)

Despite the similarities with the impact on real GDP (Figure 4), there are major differences; a marked increase in sales for Japan under Scenario JACK and a larger decline for Australia in

Scenario JACK than in Scenario JA. As shown in Fig.ure 7, policy coordination positively benefits total sales for the four countries combined, and Scenario JACK demonstrates the biggest effect.

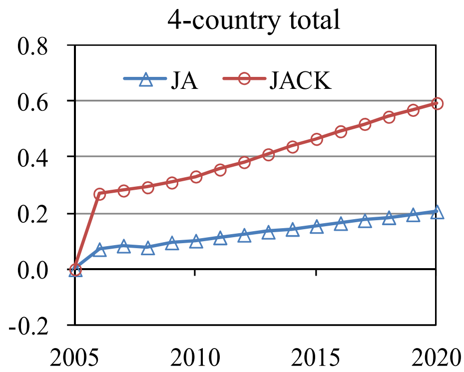

Figure 7 Impact of policy coordination on the total production (sales) of the automobile sector of the four countries combined (%)

4.5 Impact on CO_2 emissions

Figure 8 shows the impact of policy coordination on CO_2 emissions in the four countries.

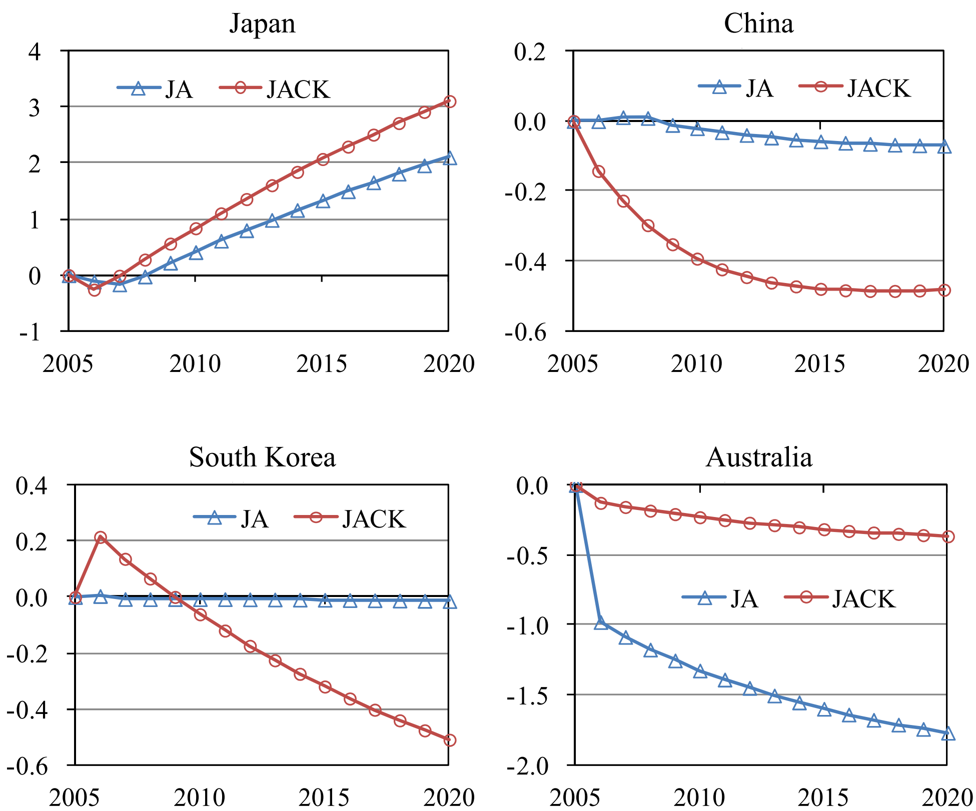

Figure 8 Impact of policy coordination on CO2 emissions in the four countries (%)

This closely correlates with the impact on real GDP (Figure 4). Interestingly, total CO_2 emissions of the four countries combined will be slightly lower in the policy coordination scenarios than in Scenario J, as shown in Figure 9. This suggests that policy coordination will help to achieve the two seemingly contradictory objectives: an increase in real GDP and reduction in CO_2 emissions, i.e., will help decouple them.

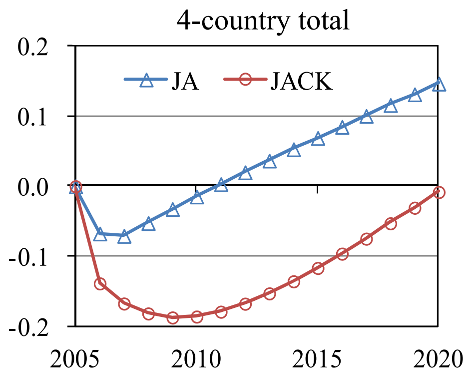

Figure 9 Impact of policy coordination on total CO2 emissions of the four countries combined (%)

4.6 Total impact over the period under study

All the results shown above are summarised in Table 4, which represents, over the period under study, real GDP, sales of the automobile sector in terms of net present value and CO_2 emissions in terms of cumulative total.

Since this model endogenously determines the household savings rate, how household assets are accumulated depends on the scenario, but at the end of the period this represents key data as it provides capital for economic activity for the future. Table 4 thus shows the impact of international policy coordination on end-of-period household assets.

Table 4 Assessed impact of international policy coordination
(% change from baseline Scenario J)

Country/region	Indicator	JA	JACK
4-country total	Impact on the net present value (NPV) of real GDP	0.55%	0.65%
	Impact on the NPV of sales of the automobile sector	0.29%	0.63%
	Impact on the cumulative total of CO_2 emissions over the period	0.05%	- 0.12%
	Impact on end-of-period household assets	0.67%	0.94%
Japan	Impact on the NPV of real GDP	1.24%	1.69%
	Impact on the NPV of sales of the automobile sector	2.69%	6.52%
	Impact on the cumulative total of CO_2 emissions over the period	0.89%	1.44%
	Impact on end-of-period household assets	1.14%	1.63%
China	Impact on the NPV of real GDP	- 0.04%	- 0.38%
	Impact on the NPV of sales of the automobile sector	- 0.13%	- 0.42%
	Impact on the cumulative total of CO_2 emissions over the period	- 0.04%	- 0.40%
	Impact on end-of-period household assets	- 0.08%	- 0.38%
Korea	Impact on the NPV of real GDP	- 0.00%	- 0.50%
	Impact on the NPV of sales of the automobile sector	- 0.10%	- 1.84%
	Impact on the cumulative total of CO_2 emissions over the period	- 0.01%	- 0.19%
	Impact on end-of-period household assets	- 0.01%	- 0.44%
Australia	Impact on the NPV of real GDP	- 0.62%	- 0.08%
	Impact on the NPV of sales of the automobile sector	- 1.44%	- 1.68%
	Impact on the cumulative total of CO_2 emissions over the period	- 1.37%	- 0.26%
	Impact on end-of-period household assets	- 1.16%	- 0.30%

International policy coordination will have positive effects on the four countries as a whole. For example, it will bring about economic benefits over the period under study and bolster end-of-period household assets, a basis for future economic activity. In Scenario JACK, economic benefits will be higher, and the cumulative total of CO_2 emissions over the period drop by 0.12%.

International policy coordination has different implications for different countries, however. Japan will enjoy economic benefits due to relaxation of policy demanding natural resource reductions. In the other three countries, however, iron ore consumption and CO_2 emissions will fall, and so will real GDP. To satisfy all four countries would therefore necessitate providing economic incentives to China, South Korea and Australia.

4.7 Sensitive analysis of elasticity of substitution

The elasticity of substitution between blast furnace steel and the intermediate input of electric furnace steel was set at 0.2 for the three sectors requiring high-grade steel—automobile, other transport machinery, and machinery and equipment—and at 2 for the other sectors.

For the use of metal scrap in the electric furnace steel sector, the elasticity of substitution between converter-furnace steel and the intermediate input of recycling-sector products in the sector was set at 2.

Because these parameters lack empirical substantiation, a sensitive analysis was conducted as shown below:

Case 1: A reduction of 20% (to 0.16) in the elasticity of substitution between blast furnace steel and electric furnace steel in the automobile, other transport machinery and machinery and equipment sectors.

Case 2: A reduction of 20% (to 1.6) in the elasticity of substitution between blast furnace steel and electric furnace steel in all sectors except the three sectors above.

Case 3: A reduction of 20% in the elasticity of substitution between blast furnace steel and electric furnace steel in all sectors (Case 1 and Case 2 combined).

Case 4: A reduction of 20% (to 1.6) in the elasticity of substitution between blast furnace steel and recycling sector products in the electric-furnace steel sector.

Case 5: A combination of Case 3 and Case 4

Table 5 shows the impact on the simulation results under Scenario JACK using these parameters.

Table 5 Results of the sensitive analysis (% change from the baseline elasticity of substitution)

Unit: %

Indictor (4-country total)	Case 1	Case 2	Case 3	Case 4	Case 5
Cumulative total of iron ore consumption over the period	- 0.0001	- 0.0033	- 0.0034	- 0.0231	- 0.0267
Net present value of real GDP	0.0000	0.0000	0.0000	- 0.0100	- 0.0100
Net present value of the sales of the automobile sector	- 0.0000	- 0.0002	- 0.0002	- 0.0342	- 0.0343
Cumulative total of CO_2 emissions over the period	- 0.0000	- 0.0001	- 0.0001	- 0.0229	- 0.0230
End-of-period household assets	- 0.0000	- 0.0000	- 0.0000	- 0.0269	- 0.0269

This sensitive analysis reveals that despite the relatively large impact in the case of the elasticity of substitution between blast-furnace steel and recycling-sector products in the electric furnace steel sector, reducing this elasticity of substitution by 20% has little effect; between 0.01% and 0.04%. In other words, this model is robust in relation to the elasticity of substitution.

5. Conclusions

In this research, we assumed that measures for reducing resource consumption will grow in importance in the context of sustainable use of resources, as well as aid in resource efficiency improvements. We studied the case where Japan promotes international policy coordination with China, South Korea and Australia to reduce iron ore consumption. The purpose of this research was to provide a hypothetical model of how international policy coordination could bring about a reduction in resource consumption, rather than to provide a specific method of how to reduce the consumption of iron ore.

It should be noted that our evaluation is not a comparison based on a BAU scenario isolated from policy—as is often the case in the other studies—but one that assumes policy goals for Japan achievable through international coordination. This means our scenario does not involve passive costs (a problem occurring when no measures are taken), because if only the policy costs were evaluated without any policy benefit (reduction of passive costs), this would have risked misleading the debate. In this research, on condition that policy goals can be validated from a societal (or political) point of view, we have arrived at a better means of planning options for policymaking.

Our analysis shows that compared with Japan's sole achievement of a consumed iron ore reduction goal via measures including disposal charges for scrap iron, coordinating policy over the four countries to attain the same level of iron ore consumption as the whole region is economic beneficial over the evaluation period and increases household assets at the end of the period—the basis for future economic activities. The former effect is significant as coordination not only reduces CO_2 emissions over the period but also increases real GDP, which suggests the possibility of decoupling both effects. The downside is that the countries other than Japan would suffer a drop in real GDP, requiring providing them with economic incentives in order to level the benefits received. Further, the scenario of Japan acting alone presents an iron recycling rate (ratio of input of scrap iron to sum of pig and scrap iron in steel production) of over 80%, likely to cause excess scrap supply and loss of material balance. This is another factor in support of policy coordination.

The sensitivity analysis on elasticities of substitution employed by the CGE model developed in this research shows that the model is robust with respect to all parameter settings. However, the model does present some problems, one of which is that it does not reflect the mechanism of recycling scrap iron or final consumable products containing iron, which limited the policy options for analysis. This is because a social accounting matrix (SAM) involves the use of an inter-industry relations table containing basic data, but would benefit from connection to a quantity-based analysing tool that utilises material-flow analysis.

Acknowledgement

This paper utilises a part of the research results of "Research on Assessment of the Environmental, Economic, and Social Impacts of Resource Circulation Systems in Asia" funded by the Ministry of the Environment, Japan. The authors would like to express our sincere appreciation to the Ministry of the Environment, Japan. However, the opinions contained in this paper are those of the authors, not of the Ministry of the Environment. The usual disclaimer is applied.

References

Armington P.S. 1969. 'A theory of demand for products distinguished by place of production', *IMF Staff Papers*, 16 (1):159–176.

Becker G.S. 1965. A theory of the allocation of time. Economic Journal 75 (259):493-517.

Kojima S. 2007. Sustainable Development in Water-stressed Developing Countries: A Quantitative Policy Analysis. Cheltenham: Edward Elgar.

Kojima S., Kabaya K, and Yano T. 2011. Green Economy for Sustainable Development: Japan should lead the policy shift towards global poverty alleviation IGES Policy Brief Vol. 12. Hayama: IGES.

Lee, H-L. 2008. The combustion-based emission data for GTAP version 7 data base. West Lafayette, IN: Center for Global Trade Analysis, Purdue University.

Schumacher K. and Sands R.D. 2007. Where are the industrial technologies in energy–economy models? An innovative CGE approach for steel production in Germany. Energy Economics 29:799–825.

Takayama H. and Masui T. 2009. Analysis on impacts of iron resource circulation on climate change countermeasures. SEEPS 2009. (in Japanese)

UNEP. 2011. Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Paris: UNEP.

Yamazaki M. 2010. Simulation analysis of environmental impacts of steel scrap trades. Sophia University Discussion Paper J-10-3. Tokyo: Sophia University. (in Japanese)

Appendix Derivation of the optimal household consumption function

The current value Hamiltonian of the households' problem is

$$\widetilde{H}_t = \frac{c_t^{1-\sigma}}{1-\sigma} + \frac{1+\nu}{1+\rho}\lambda_{t+1}\frac{S_t - \nu m_t}{1+\nu}$$
$$= \frac{c_t^{1-\sigma}}{1-\sigma} + \frac{\lambda_{t+1}}{1+\rho}\left[\sum_f w_t^f x_t^f + (r_t - \nu)m_t - \sum_i p_t^i c_t^i\right]$$

where λ is the Lagrange multiplier of this problem.

Assuming an interior solution, the necessary conditions are as follows.

$$\frac{\partial \widetilde{H}_t}{\partial c_t^i} = 0 \quad \text{for all } i \Rightarrow \quad \varphi_i \frac{c_t^{\ 1-\sigma}}{c_t^i} = \lambda_{t+1}\frac{p_t^i}{1+\rho} \quad \text{for all } i \tag{A1}$$

$$\frac{1+\nu}{1+\rho}\lambda_{t+1} - \lambda_t = -\frac{\partial \widetilde{H}_t}{\partial m_t} \quad \Rightarrow \quad \lambda_t = \lambda_{t+1}\frac{1+r_t}{1+\rho} \tag{A2}$$

A1 and the household satisfaction production function $c_t = \prod_i \left(c_t^i\right)^{\varphi_i}$ gives

$$c_t^i = c_t \times \frac{\varphi^i}{p_t^i}\prod_k\left(\frac{p_t^k}{\varphi^k}\right)^{\varphi^k} \tag{A3}$$

From Equations A1 and A3 we obtain

$$\lambda_{t+1}\frac{1}{1+\rho} = (c_t)^{-\sigma} \times \prod_i\left(\frac{\varphi^i}{p_t^i}\right)^{\varphi^i} \tag{A4}$$

From Equations A2 and A4, we have

$$c_{t+1} = c_t\left[\frac{1+r_t}{1+\rho}\prod_k\left(\frac{p_t^k}{p_{t+1}^k}\right)^{\varphi^k}\right]^{1/\sigma} \tag{A5}$$

By applying A5 for t+2, t+3, and so on, we obtain

$$c_{t+T} = c_t\left[\prod_{s=1}^{T}\frac{1+r_t}{1+\rho} \times \prod_k\left(\frac{p_t^k}{p_{t+T}^k}\right)^{\varphi^k}\right]^{1/\sigma} \tag{A6}$$

Here, we introduce the simplest expectation formation process in which households assume that exogenous variables will stay constant at the current levels, which makes A6 as follows.

$$c_{t+T} = c_t\left(\frac{1+r_t}{1+\rho}\right)^{T/\sigma} \tag{A7}$$

Now, let's consider intertemporal budget constrain of household. From the equation of motion of household asset we derive

$$m_{t+1} = \frac{1+r_t}{1+\nu} m_t + \left(\frac{1}{1+\nu}\right)\sum_f w_t^f x_t^f - \left(\frac{1}{1+\nu}\right)\sum_i p_t^i c_t^i \tag{A8}$$

With equation A3 we rewrite (A8) as

$$m_{t+1} = \frac{1+r_t}{1+\nu} m_t + \left(\frac{1}{1+\nu}\right)\sum_f w_t^f x_t^f - \left(\frac{1}{1+\nu}\right) c_t \prod_i \left(\frac{p_t^i}{\varphi^i}\right)^{\varphi^i} \tag{A9}$$

By applying A9 for *t*+2, *t*+3, etc. with the simplest household expectation, we obtain

$$m_{t+T} = \left(\frac{1+r_t}{1+\nu}\right)^T m_t + \left(\frac{1}{1+\nu}\right)\sum_f w_t^f x_t^f \times \sum_{k=1}^{T}\left(\frac{1+r_t}{1+\nu}\right)^{k-1}$$
$$-\left(\frac{1}{1+\nu}\right)\sum_{k=1}^{T}\left[\left(\frac{1+r_t}{1+\nu}\right)^{T-k}\left(\frac{1+r_t}{1+\rho}\right)^{(k-1)/\sigma}\right] \times c_t \prod_i \left(\frac{p_t^i}{\varphi^i}\right)^{\varphi^i} \tag{A10}$$

Dividing the both sides by $\left(\frac{1+r_t}{1+\nu}\right)^T$ we obtain

$$\left(\frac{1+\nu}{1+r_t}\right)^T m_{t+T} = m_t + \left(\frac{1}{1+\nu}\right)\sum_f w_t^f x_t^f \times \sum_{k=1}^{T}\left(\frac{1+\nu}{1+r_t}\right)^k -$$
$$\left(\frac{1}{1+\nu}\right)\left(\frac{1+\rho}{1+r_t}\right)^{1/\sigma}\sum_{k=1}^{T}\left[\left(\frac{1+\nu}{1+r_t}\right)\left(\frac{1+r_t}{1+\rho}\right)^{1/\sigma}\right]^k \times c_t \prod_i \left(\frac{p_t^i}{\varphi^i}\right)^{\varphi^i} \tag{A11}$$

From the transversality condition $\lambda_t \lim_{T\to\infty}\left[\left(\frac{1+\nu}{1+r_t}\right)^T m_{t+T}\right] = 0$ with $r_t > \nu$, the left hand side becomes zero, i.e.

$$\lim_{T\to\infty}\left(\frac{1+\nu}{1+r_t}\right)^T m_t = 0 \tag{A12}$$

Also, there are limit values of geometric progressions in the right hand side as follows:

$$\lim_{T\to\infty}\sum_{k=1}^{T}\left(\frac{1+\nu}{1+r_t}\right)^k = \frac{1+\nu}{r_t-\nu} \tag{A13}$$

$$\lim_{T\to\infty}\sum_{k=1}^{T}\left[\left(\frac{1+\nu}{1+r_t}\right)\left(\frac{1+r_t}{1+\rho}\right)^{1/\sigma}\right]^k = \frac{(1+\nu)(1+r_t)^{1/\sigma}}{(1+r_t)(1+\rho)^{1/\sigma}-(1+\nu)(1+r_t)^{1/\sigma}} \tag{A14}$$

By putting (A12) - (A14) into (A11), with algebraic manipulations, we obtain

$$c_t^* = \left[\prod_i\left(\frac{\varphi^i}{p_t^i}\right)^{\varphi^i}\right] \times \left[1+r_t-(1+\nu)\left(\frac{1+r_t}{1+\rho}\right)^{1/\sigma}\right] \times \left[m_t + \frac{1}{r_t-\nu}\sum_f w_t^f x_t^f\right]$$