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Regional Integration, Sectoral Adjustments and Natural Groupings in East Asia

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[Abstract] Although East Asian countries were relatively inactive in signing free trade agreements (FTAs) until the end of 1990s, a number of FTAs involving East Asian countries have been signed since the turn of the century. Because sectoral interests can exert significant influence on policy negotiations, the sectoral results would be particularly important for political economy considerations. The objective of this study is to compare welfare gains and sectoral adjustments resulting from various FTA scenarios in East Asia using a dynamic global computable general equilibrium (CGE) model. The RCA rankings of commodities with various FTA scenarios and those with the global trade liberalization are correlated to examine how "natural" each grouping would be. The results suggest that the ASEAN+3 FTA, with relatively large welfare gains and small structural adjustments, could be a facilitating intermediate step towards global free trade. Some of the smaller FTAs, such as the ASEAN-China and ASEAN-Korea FTAs, would result in large structural adjustments for ASEAN countries.

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1. Introduction

In the past decade the number of free trade agreements (FTAs) has proliferated rapidly. Other than ASEAN Free Trade Agreement (AFTA), East Asian countries were relatively inactive in signing FTAs until the end of 1990s. Since 2001, however, a number of FTAs involving East Asian countries have been implemented or signed, including Singapore-New Zealand (2001), Japan-Singapore (2002), Singapore-Australia (2003), Singapore-U.S. (2004), Korea-Chile (2004), ASEAN-China (2005), Japan-Mexico (2005), Thailand-Australia (2005), Korea-Singapore (2006), and ASEAN-Korea (2006).[1] Korea and the United Stated signed an FTA in June 2007, but it remains to be seen whether the U.S. Congress and the Korean National Assembly would ratify the bilateral pact. A large number of FTAs are currently being negotiated in East Asia, including ASEAN-Japan, China-Australia, and Japan-Korea. The ASEAN+3 group, consisting of the ASEAN countries, China, Japan, and Korea, has provided an effective mechanism for greater cooperation and gradual regional economic integration in East Asia. The trends in negotiating for new FTAs are likely to grow in East Asia.[2]

Whether the growth of FTAs has a positive or negative impact on multilateral trade liberalization under the World Trade Organization (WTO) has been debated intensely (e.g., Krueger, 1999; Panagariya, 2000; Lloyd and MacLaren, 2004).[3] Since the outcome depends upon the choice of the objective function (e.g. economic welfare versus political objective), the height and structure of initial trade barriers and other variables,[4] it would be helpful to examine the actual record. The earlier studies (e.g., World Trade Organization,

[1] The ASEAN-Korea FTA signed in May 2006 was initially limited to trade in goods, and some agricultural products including rice was left out. Thailand decided not to sign the FTA because of the exclusion of rice.

[2] See Kawai (2004), Feridhanusetyawan (2005), and Lee and Park (2005) for more detailed discussion on the proliferation of FTAs in East Asia.

[3] Proponents for regional integration argue that FTAs encourage member countries to liberalize beyond the level committed by multilateral negotiations and that they are an effective way to promote economic integration (e.g., Kahler, 1995; Dee, 2007). In addition, FTAs are likely to induce dynamic effects that might contribute to member countries' growth through the accumulation of physical and human capital, productivity growth, and accelerated domestic reforms (e.g., Ethier, 1998; Fukase and Winters, 2003). Opponents worry that the proliferation of FTAs is likely to undermine the multilateral trading system and that beneficiaries of FTAs might form a political lobby to deter further multilateral liberalization (e.g., Bhagwati, 1995; Srinivasan, 1998a, 1998b; Panagariya, 1999a).

[4] See, for example, Panagariya (1999b), Schiff and Winters (2003), and Lloyd and MacLaren (2004) for reviews on this issue.

1995; World Bank, 2000) suggest that the proliferation of regional integration agreements (RIAs) did not delay multilateral liberalization. However, Lloyd and MacLaren (2004) point out that after the WTO Ministerial Conference in Cancún in September 2003, the United States and the EU's priority has shifted to the completion of bilateral and regional trade negotiations. Thus, the relationship between the growth of RIAs and multilateral liberalization might have changed.

A number of studies have quantified the effects of various FTAs in East Asia using a computable general equilibrium (CGE) model (e.g., Brown et al., 2003; Dee, 2007; Lee et al., 2004; Park, 2006; Scollay and Gilbert, 2001; Urata and Kiyota, 2003; Zhai, 2006). These studies generally find: (1) most of the FTA members' real income increases while at least some of non-members' real income declines; (2) the larger the economic size of the FTA, the larger the aggregate gain to the members; (3) if FTAs are confined to only tariff liberalization for merchandize trade, the welfare gains are limited and some of the members are more likely to become worse off; (4) when FTAs include services trade liberalization and trade facilitation, the gain to each member increases and the aggregate loss to non-members decreases; (5) the impact of FTAs becomes greater when the model incorporates increasing returns to scale and imperfect competition in at least some of the industries; and (6) the effects of FTAs tend to become more beneficial with the model incorporating investment and growth effects.

While the aggregate welfare effect of FTAs is certainly important, the sectoral impact could be of an even greater concern to policy makers. This is because regional integration might lead to a sharp contraction of output and employment in highly protected sectors. For example, the agricultural sectors in Japan and Korea are highly subsidized and shielded against foreign imports by significant tariffs and nontariff barriers. In a number of developing members, tariffs, industrial policy, and other government policies protect certain manufacturing industries from foreign competition. Since trade policy is often formulated from the bottom up, a modern view of national interest, such as that based on trade reciprocity, might encounter conflicts with established domestic interests.

Using a dynamic global CGE model, we evaluate the effects of various free trade agreements involving East Asian countries, emphasizing sectoral adjustments and changes in the pattern of trade resulting from the formation of FTAs. The next section gives an overview of the model. Section 3 provides a brief description of the baseline and policy scenarios, followed by assessments of computational results in section 4. The final section summarizes the main policy conclusions.

2. Overview of the Model

The model used in this study, known as the LINKAGE model, is a dynamic global CGE model developed by van der Mensbrugghe (2005). It spans the period 2001-2015 and all sectors are assumed to be perfectly competitive and operate under constant returns to scale.[5] Production in each sector is modeled by a series of nested constant elasticity of substitution (CES) production functions, which are intended to represent the different substitution and complementarity relations across the various inputs in each sector. Labor can have three different skill levels: unskilled, skilled, and highly skilled. The first two are substitutable and combined in a CES aggregation function as a single labor bundle. Highly skilled labor is combined with capital to form a physical plus human capital bundle.

Dynamics in this model is recursive. Population and labor supply growth are exogenous. Capital accumulation is based on past savings and investment. In each period the supply of primary factors is generally predetermined. The supply of land is assumed to be sensitive to the contemporaneous price of land, however. Land is assumed to be partially mobile across agricultural sectors. Thus rates of return are sector-specific, but sectoral land supply reacts to changes in relative rates of return**.** Some of the natural resource sectors also have a sector-specific factor whose contemporaneous supply is price sensitive. The model incorporates a vintage structure for capital that allows for adjustment costs. New capital is assumed to be perfectly mobile across sectors, whereas installed capital is only partially mobile. All else equal, countries with higher savings rates will have more ‘flexible’ capital since it is assumed that substitution elasticities are higher with new capital than with installed capital. Labor within each skill category is perfectly mobile across sectors.

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[5] The assumption of constant returns to scale is a simplification and generally biases downwards the gains from trade reform because expansion of trade provides scale efficiencies. The introduction of scale economies raises a number of important issues, each of which could significantly modify the results, but we prefer to leave out of the current study. They include the lack of data on the minimum efficient scale and the specification of market structure (e.g., Cournot versus Bertrand competition), the number of firms, conjectural variations, and whether there is free entry and exit.

Factor income accrues to a single representative household, which finances government expenditures (through direct and indirect taxes) and investment (through domestic savings). Domestic savings may be augmented or diminished by a net capital flow. In the current version of the model, the latter is exogenous in any given time period for each region, thereby generating a fixed current account balance. Ex ante shocks to the current account—e.g., a reduction in trade barriers—induces a change in the real exchange rate. Government fiscal balances are also fixed in each time period, and the equilibrating mechanism is lump-sum taxes on the representative household. For example, a reduction in tariff revenue is compensated by an increase in household direct taxation.

The basic assumption on trade is that imports originating in different regions are imperfect substitutes (known as the Armington assumption). The model uses a nested demand structure. Aggregate domestic absorption by sector is allocated between domestic goods and a single composite import good. The latter is then allocated across region of origin to determine the bilateral trade flows on a sectoral basis. An analogous dual-nested structure is used to allocate domestic production between domestic and export markets using constant elasticity of transformation functions.

The model has four trade prices incorporating four separate instruments. First, producers receive price *PE* for exported goods. Second, the FOB price, *WPE*, includes domestic export taxes or subsidies. Third, the CIF price, *WPM*, includes the direct costs of port-to-port shipping, represented by the ad valorem wedge ζ, as well as a non-monetary or frictional cost,[6] represented by the iceberg parameter λ. Thus the relationship between the FOB price and the CIF price is given by

$$WPM_{r,r',i} = \left(1+\zeta_{r,r',i}\right)WPE_{r,r',i} \big/ \lambda_{r,r',i} \tag{1}$$

where subscripts *r*, *r*', and *i* denote exporting region/country, importing region/country, and commodity, respectively. Finally, the domestic price of imports, *PM*, is equal to the CIF price, *WPM*, plus the ad valorem tariff (or tariff-equivalent) rate. In our model, an increase in $\lambda_{r,r',i}$ represents a reduction in trade-related risk, lower administrative barriers

[6] This type of cost is referred to as 'iceberg' transport cost, developed by Samuelson (1952) based on a concept developed earlier by von Thünen. More recently, these have been used in work by Helpman and Krugman (1985) and Fujita, Krugman, and Venables (1999).

to trade (e.g., customs procedures) and/or a fall in technical barrier (e.g., mutual recognition of product standards). In other words, trade facilitation would increase the value of $\lambda_{r,r',i}$.

Foreign capital flows (e.g., foreign direct investment: FDI) are exogenous in the current version. We acknowledge that endogenous treatment of FDI is very important when we discuss the implications of FTAs because trade and FDI are closely linked. It has been shown that allowing for capital to flow to countries with relatively high rates of return could significantly raise the gains from trade reform. In our preliminary investigation on the impact of APEC trade and investment liberalization, Lee and van der Mensbrugghe (2005) find that an addition of FDI liberalization to trade liberalization would significantly boost the gains to most of the APEC economies.

Most of the data used in the model come from the GTAP database, version 6, which provides 2001 data on input-output, value added, final demand, bilateral trade, tax and subsidy data for 87 regions and 57 sectors.[7] For the purpose of the present study, the database is aggregated into 10 regions and 26 sectors as shown in Table 1.

Table 1
Regional and sectoral aggregation

A. Regional aggregation

Country/region	Corresponding economies/regions in the GTAP database
China	China and Hong Kong
Japan	Japan
Korea	Korea
Taiwan	Taiwan
ASEAN	Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, rest of Southeast Asia
Australasia	Australia and New Zealand
North America	United States, Canada, Mexico
Latin America	Central America and the Caribbean, South America
EU	Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, plus the new member countries since 2004
Rest of world	All the other economies/regions

[7] Dimaranan (2006) gives detailed descriptions of the GTAP database, version 6.

Table 1 (continued)

B. Sectoral aggregation

Sector	Corresponding commodities/sectors in the GTAP database
Rice	Paddy rice, processed rice
Other grains	Wheat, cereal grains n.e.s.
Vegetables and fruits	Vegetables and fruits
Other crops	Oil seeds, sugar cane and sugar beet, plant-based fibers, crops n.e.s.
Livestock	Bovine cattle, sheep and goats, animal products n.e.s.
Natural resources	forestry, minerals
Fossil fuel	Coal, oil, gas
Food products	Fishing, food products, beverages and tobacco products
Textiles	Textiles
Apparel	Wearing apparel
Leather	Leather products
Wood products	Wood products
Paper products	Paper products and publishing
Petroleum products	Petroleum and coal products
Chemical products	Chemical, rubber and plastic products
Mineral products	Non-metallic mineral products
Iron and steel	Iron and steel
Nonferrous metal	Nonferrous metal
Metal products	Fabricated metal products
Machinery	Machinery and equipment
Electronic equipment	Electronic equipment
Motor vehicles	Motor vehicles and parts
Other transport equip.	Other transportation equipment
Other manufactures	Manufactures n.e.s.
Trade and transport	Trade, sea transport, air transport, transport n.e.s.
Services	Construction, public utilities, communication, financial services, other services

Source: GTAP database, version 6.

3. The Baseline and Policy Scenarios

3.1 The Baseline Scenario

To evaluate alternative FTA scenarios in East Asia, we first establish a baseline, which shows the path of each economy in the absence of any FTAs over the period 2001-2015. In the baseline, several key variables, including GDP growth rates, population and labor supply, are predetermined by the exogenous assumptions. Projections of real GDP, population and labor supply are broadly consistent with the World Bank’s long-term forecast. We assume that the trade and transport margin declines by 1 percent per annum in every country. The dynamics are calibrated in each country/region by imposing the assumption of a balanced growth path. This implies that the ratio between labor and the capital/fixed-factor bundle (in efficiency units) is held constant over time.[8] When policy scenarios are simulated, the growth of capital is endogenously determined by the saving-investment relation.

Several assumptions underline the calibration of productivity. Agricultural productivity is fixed in the baseline using results from recent empirical studies. Sectoral productivity in non-agricultural sectors is composed of three components: a uniform economywide factor that is calibrated to achieve the given GDP target, a sector-specific factor related to openness, and a constant shifter. The sector-specific factor intended to capture openness-sensitive changes in productivity, $\chi_{i,t}$, is given by

$$\chi_{i,t} = \phi_{i,t}\left(\frac{E_{i,t}}{X_{i,t}}\right)^{\eta_i} \tag{2}$$

where $E_{i,t}$ is exports of commodity i, $X_{i,t}$ is output of commodity i, $\phi_{i,t}$ is a shift parameter, and η_i is the elasticity of productivity with respect to openness. $\phi_{i,t}$ is calibrated in the baseline scenario so that the trade-sensitive portion of sectoral productivity is some share of total productivity.[9]

There are four types of taxes in the model: commodity taxes, production taxes, income taxes and trade taxes (consisting of tariffs and export taxes). Commodity and production taxes are held constant throughout the simulation period. The marginal income tax rate adjusts to maintain a given government budget surplus or deficit. For the final implementation of the Uruguay Round, the tariff and export tax rates are lowered during the 2001-2005 period. The Agreement on Textiles and Clothing (ATC) that have phased out import quotas on textiles and apparel are also incorporated in the baseline. Finally, China and Taiwan's WTO accession and the resulting reductions in their tariff rates are also included.

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[8] This involves computing in each period a measure of Harrod-neutral technical progress in the capital/fixed-factor bundle as a residual, given that the growth of the labor force (in efficiency units) is pre-determined. This is a standard calibration procedure in dynamic CGE modeling.

[9] Three main channels have been identified linking openness with productivity: imports of technology-laden intermediate inputs (for example fertilizers in agriculture), imports of capital goods, and export market penetration (with the requirement to produce to a higher standard than at home to be able to penetrate new markets; expanding foreign markets can also lead to scale economies). Much empirical work is ongoing trying to identify the extent to which each one of these channels operates. At a macro level, there are to some extent observationally equivalent to the extent that current account balances are more or less exogenous. de Melo and Robinson (1990) and Dessus et al. (1999) take an approach similar to ours. Das et al. (2001) have explored some firm-level characteristics of export supply response.

3.2 Policy Scenarios

To evaluate sectoral adjustments and changes in the pattern of trade resulting from prospective free trade agreements in East Asia, the following seven policy scenarios are considered:

1) ASEAN-China FTA: Free trade among the ASEAN countries and China[10]
2) ASEAN-Japan FTA: Free trade among the ASEAN countries and Japan
3) ASEAN-Korea FTA: Free trade among the ASEAN countries and Korea
4) China-Japan-Korea FTA: Free trade among China, Japan and Korea
5) ASEAN+3: Free trade among the ASEAN countries, China, Japan and Korea
6) ASEAN-EU: Free trade among the ASEAN and EU member countries
7) Global trade liberalization (GTL): Complete abolition of import tariffs and export subsidies

While the likelihood of actually completing the above trade liberalization or FTAs within a reasonable time horizon differs significantly across scenarios, it is worth examining each of them. Scenario 1 is under implementation as ASEAN countries and China signed a framework agreement in 2002 to establish the FTA for trade in goods by 2010 for China and ASEAN-6 and by 2015 for newer ASEAN member states.[11] Scenario 2 that excludes sensitive sectors is likely to be realized as ASEAN and Japan signed an agreement on the Comprehensive Economic Partnership (CEP) in October 2003 and the negotiation is expected to be concluded by the end of 2007.[12] An FTA between ASEAN and Korea (scenario 3), initially limited to trade in goods and excluding some agricultural products such as rice, was signed in May 2006. The proposal for China-Japan-Korea FTA (scenario 4) has been considered by the governments of the three countries (Wong et al., 2004), and

[10] Throughout the paper Hong Kong is included in China, as indicated in Table 1.

[11] ASEAN-6 refers to the original ASEAN members; i.e., Brunei, Indonesia, Malaysia, Philippines, Singapore, and Thailand. Newer ASEAN member states are Cambodia, Lao PDR, Myanmar, and Vietnam.

[12] Yamazawa and Hiratsuka (2003) provides an overview of ASEAN-Japan Comprehensive Economic Partnership.

a joint research on economic cooperation among these countries has been undertaken by the Development Research Center of the State Council of China, the National Institute for Research Advancement of Japan, and the Korea Institute for International Economic Policy. Although negotiations for an FTA among the economies of ASEAN+3 have not yet begun, we include scenario 5 because a number of studies have examined the possible effects of such an arrangement (e.g., Brown et al., 2003; Lee and Park, 2005). In addition, in May 2007 the ASEAN countries and the EU agreed to start negotiations on a comprehensive trade agreement. Finally, we have the global trade liberalization (GTL) scenario so that the effects of the FTA scenarios can be compared with those of the global scenario.

In all FTA experiments, we gradually remove bilateral tariffs and export subsidies of the relevant sectors among the member countries over the 2007-2012 period. We set the elasticity of productivity with respect to openness, η_i, to 0.5 in agricultural sectors and to 1.0 in all other sectors. We assume that frictional trade costs (e.g. administrative barriers and trade-related risk) would be reduced by 2.5 percent in all FTA scenarios and the GTL scenario.[13]

4. Results

4.1 Effects on Welfare

The welfare results for the seven policy scenarios, as deviations in equivalent variations (EV) from the baseline in 2015, are summarized in Table 2. The GTL scenario (scenario 7) is the most attractive for all countries and regions. To be realistic, however, the WTO process is fraught with uncertainty about the scope, depth, and timeliness of multilateral commitments to abolish trade barriers. Although the Doha Round started in 2001, there have been disagreements between developed countries and developing countries on a number of issues, particularly on the extent of reductions in agricultural subsidies in the United States and the EU and tariff caps. As a result, the negotiations of

[13] Keuschnigg and Kohler (2000) and Madsen and Sorensen (2002) use a 5 percent reduction in real costs of trade between the EU-15 and Central and East European countries. We use a smaller reduction in these costs because the reductions in technical barriers are expected to be negligible for FTAs in East Asia as well as for GTL compared with EU enlargement.

the current round have been deadlocked a number of times.[14] This kind of uncertainty has been an important impetus to regional agreements, particularly those between small groups of nations who find consensus, implementation and monitoring easier.

Table 2
Effects on welfare (deviations in equivalent variations from the baseline in 2015)

Country/region	Scenario (1) ASEAN-China	(2) ASEAN-Japan	(3) ASEAN-Korea	(4) China-Japan-Korea	(5) ASEAN plus 3	(6) ASEAN-EU	(7) GTL
A. Absolute deviations (US$ billion in 2001 prices)							
China	26.8	-2.9	-2.5	58.7	64.9	-2.3	69.7
Japan	-1.7	19.7	-0.9	29.8	29.7	-0.5	48.2
Korea	-1.1	-0.6	9.1	16.8	16.2	-0.6	23.7
Taiwan	-1.1	-0.7	-0.4	-1.5	-2.6	-0.5	12.1
ASEAN	27.2	15.3	11.8	-3.8	23.5	9.9	22.6
Australia/New Zealand	-0.2	-0.3	-0.2	-0.5	-0.8	-0.2	11.4
North America	-0.3	-0.9	-0.4	-1.8	-2.8	-0.3	130.8
Latin America	0.0	-0.3	-0.6	-1.1	-1.3	-0.9	36.1
EU	-1.9	-0.8	-0.4	-0.7	-2.5	88.0	76.2
Rest of the world	-1.8	-1.6	-1.6	-2.0	-4.5	-7.1	108.1
East Asia total	50.0	30.8	17.1	100.0	131.7	6.0	176.3
World total	45.7	26.8	13.9	93.8	119.7	85.5	538.8
B. Percent deviations							
China	1.1	-0.1	-0.1	2.4	2.7	-0.1	2.9
Japan	0.0	0.5	0.0	0.7	0.7	0.0	1.2
Korea	-0.2	-0.1	1.4	2.5	2.4	-0.1	3.5
Taiwan	-0.3	-0.2	-0.1	-0.4	-0.6	-0.1	2.9
ASEAN	2.8	1.6	1.2	-0.4	2.5	1.0	2.4
Australia/New Zealand	0.0	-0.1	0.0	-0.1	-0.2	0.0	2.3
North America	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Latin America	0.0	0.0	0.0	-0.1	-0.1	-0.1	2.2
EU	0.0	0.0	0.0	0.0	0.0	1.1	1.0
Rest of the world	0.0	0.0	0.0	-0.1	-0.1	-0.2	2.8
East Asia total	0.6	0.4	0.2	1.2	1.6	0.1	2.1
World total	0.1	0.1	0.0	0.3	0.3	0.2	1.5

In the ASEAN-China FTA (scenario 1), EV of ASEAN increases by 2.8 percent, whereas EV of China increases by a smaller percentage (1.1%), compared with the baseline values in 2015. This largely results from two factors: (1) the share of ASEAN's

[14] See, for example, Langhammer (2004) for causes and triggers of the setback at the WTO Ministerial Conference in Cancún in September 2003.

exports to China is significantly larger than the share of China's exports to ASEAN, and (2) the exports to output ratio is substantially higher for ASEAN countries. The welfare effects on non-member countries are negligible except for Korea and Taiwan, which experience 0.2 and 0.3 percent declines in their EVs. When ASEAN and Japan form an FTA (scenario 2), ASEAN's EV increases by 1.6 percent while Japan's EV increases by just 0.5 percent in 2015. Welfare of other East Asian countries (China, Korea, and Taiwan) declines very slightly. In the ASEAN-Korea FTA (scenario 3), the corresponding changes for ASEAN and Korea's EV are 1.2 and 1.4 percent.

When a free trade area is formed among China, Japan, and Korea (scenario 4), China and Korea are expected to accrue relatively large welfare gains (2.4% and 2.5%, respectively) while Japan's welfare is expected to rise by 0.7 percent. This is largely because (1) China has relatively high pre-FTA tariffs,[15] and (2) Korea will have preferential accesses to the large Chinese and Japanese markets and its exports to China and Japan, which already constitute large shares of Korea's total exports, will increase dramatically. Under the trilateral FTA, China, Korea and Japan respectively obtain 84, 71 and 62 percent of the GTL's benefits. Thus, the China-Japan-Korea FTA could be a very attractive stepping stone to globalization for the three countries although large political obstacles must be surmounted to achieve such an FTA.

Under the ASEAN+3 FTA scenario (scenario 5), the welfare of all members increases although the welfare gain for Japan and Korea are somewhat smaller than under the trilateral FTA. These small losses are more than offset by the ASEAN and China's gains and East Asia as a whole is expected to gain $131.7 billion (1.6%) in 2015, compared with its $176.3 billion (2.1%) gain under the GTL. In other words, East Asia will be able to attain three-quarters of GTL's benefits from the ASEAN+3 FTA.

If free trade between ASEAN and the EU is realized (scenario 6), ASEAN is expected to realize a 1.0 percent gain in its welfare, which is surprisingly smaller than the gain expected from an FTA with China, Japan, or Korea. The EU's welfare is predicted to increase by 1.1 percent. One of the reasons for a relatively small welfare gain for ASEAN is that its trade with East Asian countries, particularly with China, is projected to grow

[15] The countries with high pre-FTA tariffs generally gain proportionally more than those with low tariffs because of larger gains to their consumers resulting from greater reductions in import prices.

significantly faster than that with the EU during the simulation period. For example, by 2015 ASEAN's exports are predicted to increase by $81 billion under the ASEAN-China FTA scenario, but they are predicted to increase by only $40 billion under the ASEAN-EU FTA scenario (compared with the baseline exports for ASEAN).

4.2 Effects on Sectoral Output

While the aggregate welfare and trade results are of interest in themselves, the most useful results are at the industry level, where structural adjustments and resource reallocations occur in response to policy changes. Because sectoral interests can exert significant influence on policy negotiations, the sectoral results would be most important for political economy considerations. In this section we examine the effects of alternative policy scenarios on sectoral output.

Tables 3-6 summarize output adjustments for the 26 sectors in China, Japan, Korea and ASEAN countries under the policy scenarios in which each country/region is a participant. Sectoral adjustments are expressed in percent deviations from the baseline for the year 2015. They are large in most of the agricultural and food sectors for East Asia in general and Japan and Korea in particular because of high trade barriers in these two countries.

China's agricultural and food sectors expand under the China-Japan-Korea FTA and ASEAN+3 FTA scenarios (Table 3). In particular, the percentage increases in output of other crops are over 150 percent relative to the baseline in 2015 under these two scenarios although in absolute values, these increases are smaller than rice, other grains, vegetables and fruits, and food products.

Among the manufacturing sectors, output of other transportation equipment increases 15-16 percent when the ASEAN countries are included in the FTA. Output of the apparel and leather sectors increases moderately when Japan is an FTA member, but the increase is small relative to the GTL scenario because China's exports of these products to North American and the EU are much larger. The motor vehicle sector contracts when Japan and Korea are FTA members, but the extent of contraction is relatively small compared with the GTL scenario.[16]

Table 3
China's sectoral output adjustments under alternative scenarios
(percent deviations from the baseline for the year 2015)

Commodity/sector	Scenario			
	(1) ASEAN-China	(4) China-Japan-Korea	(5) ASEAN plus 3	(7) GTL
Rice	0.4	26.7	19.8	17.1
Other grains	0.3	27.0	26.7	-50.9
Vegetables and fruits	0.2	5.5	5.3	4.9
Other crops	-0.2	156.9	157.6	2.4
Livestock	0.8	3.1	3.3	5.4
Natural resources	-0.4	-0.9	-1.1	-2.5
Fossil fuel	0.3	0.2	0.4	-4.4
Food products	1.4	7.0	7.3	3.9
Textiles	0.9	-0.6	-0.2	11.4
Apparel	-0.2	5.0	3.9	20.7
Leather	2.4	1.4	3.0	17.9
Wood products	-1.5	0.8	-0.7	1.9
Paper products	0.1	-0.3	-0.1	-0.1
Petroleum products	2.4	-1.0	1.2	-3.2
Chemical products	-2.2	-0.9	-2.7	-3.1
Mineral products	0.0	-0.5	-0.5	0.1
Iron and steel	0.7	-2.0	-1.4	-3.5
Nonferrous metal	0.1	-2.1	-2.0	-6.5
Metal products	0.3	-0.7	-0.5	1.8
Machinery	0.4	-1.2	-1.0	-2.6
Electronic equipment	2.0	1.2	1.9	0.9
Motor vehicles	2.0	-4.4	-4.8	-13.9
Other transport equip.	16.0	0.3	15.3	13.9
Other manufactures	-0.5	-0.5	-0.6	0.0
Trade and transport	0.0	0.1	0.1	0.3
Services	0.3	0.4	0.4	0.2

Japan's rice sector contracts significantly under all four scenarios (Table 4). The contractions of other agricultural and food products, particularly other grains, are much smaller under the three FTA scenarios than under the GTL scenario. Under the China-Japan-Korea FTA and ASEAN+3 FTA scenarios, Japan's textile sector expands by 19-21

[16] Under the China-Japan-Korea FTA and ASEAN+3 FTA scenarios, large increases in China's imports of motor vehicles from Japan and Korea are partially offset by reductions in its imports from North America and the EU.

percent, largely driven by sharp increases in its exports to China. By contrast, the apparel and leather sectors respectively contract by 7-8 percent and 13-15 percent, caused by large increases in its imports from China and to a much lesser extent from increases in its imports from other member countries. Under the ASEAN+3 FTA scenario, output of steel increases by 4 percent, about the same percentage increase as the GTL scenario largely because about three-quarters of Japan's steel exports are shipped to other East Asian countries.

Table 4
Japan's sectoral output adjustments under alternative scenarios
(percent deviations from the baseline for the year 2015)

	Scenario			
Commodity/sector	(2) ASEAN-Japan	(4) China-Japan-Korea	(5) ASEAN plus 3	(7) GTL
Rice	-53.2	-58.0	-58.5	-65.7
Other grains	0.8	-33.0	-34.1	-87.3
Vegetables and fruits	0.5	-0.1	-0.8	-5.6
Other crops	0.3	-2.1	-2.7	-5.8
Livestock	-0.9	2.5	0.8	-6.4
Natural resources	-0.2	-1.0	-0.2	-0.2
Fossil fuel	-2.2	-3.7	-3.8	-7.9
Food products	-2.4	-0.5	-2.9	-14.5
Textiles	2.9	20.6	18.8	10.2
Apparel	-0.7	-7.8	-7.4	-7.1
Leather	-3.8	-12.7	-14.8	-22.0
Wood products	-1.1	-2.6	-2.2	-0.9
Paper products	0.0	0.0	0.0	-0.6
Petroleum products	0.1	-0.3	-0.5	-3.5
Chemical products	0.6	1.9	1.4	1.1
Mineral products	0.5	2.3	2.5	2.3
Iron and steel	3.1	1.6	4.0	3.9
Nonferrous metal	1.3	1.8	2.9	-0.9
Metal products	1.1	0.3	1.2	1.8
Machinery	-0.1	2.5	2.2	0.9
Electronic equipment	-0.8	-1.4	-2.5	-0.7
Motor vehicles	4.4	-1.3	2.2	14.0
Other transport equip.	0.8	-3.5	-5.0	7.6
Other manufactures	0.7	-0.7	0.2	0.1
Trade and transport	0.0	-0.1	0.0	0.4
Services	0.2	0.2	0.2	0.4

A small contraction in Japan's motor vehicle industry under the China-Japan-Korea FTA scenario needs to be interpreted with caution. Large increases in its exports to China and Korea increase the price of Japanese automobiles in our model, reducing its exports to nonmember countries as well as the domestic demand. However, in practice the automakers are unlikely to raise the price at least in the short run because they usually try to maintain the market shares. Thus, output of motor vehicles in Japan is likely to increase even under this scenario.

Table 5
Korea's sectoral output adjustments under alternative scenarios
(percent deviations from the baseline for the year 2015)

Commodity/sector	Scenario			
	(3) ASEAN-Korea	(4) China-Japan-Korea	(5) ASEAN plus 3	(7) GTL
Rice	-41.0	-54.8	-55.1	-55.7
Other grains	-19.7	-47.3	-49.8	-91.9
Vegetables and fruits	4.5	-20.0	-19.7	-17.3
Other crops	7.5	-30.9	-30.2	-68.4
Livestock	20.0	36.7	35.0	31.1
Natural resources	-4.2	-8.1	-7.9	-14.8
Fossil fuel	-2.9	-0.3	-1.9	-14.4
Food products	14.6	22.5	20.8	16.1
Textiles	5.6	21.0	23.0	25.8
Apparel	-1.4	5.0	5.6	4.6
Leather	25.5	100.2	90.4	68.4
Wood products	-5.7	-3.3	-5.9	-4.3
Paper products	-2.0	1.6	0.6	-3.6
Petroleum products	2.8	17.0	14.0	17.6
Chemical products	-0.8	6.1	2.1	-1.8
Mineral products	-2.6	-1.4	-2.1	-7.5
Iron and steel	0.3	-3.7	-2.3	-5.7
Nonferrous metal	0.3	-1.4	0.6	-10.3
Metal products	-0.4	-1.8	-1.6	-2.4
Machinery	-3.3	-4.9	-5.1	-8.3
Electronic equipment	-3.8	-0.6	-2.7	-3.4
Motor vehicles	21.3	-1.1	11.7	30.0
Other transport equip.	6.4	-12.2	-15.5	22.3
Other manufactures	2.7	10.5	12.7	2.8
Trade and transport	0.7	1.0	1.1	3.0
Services	-0.2	-0.2	-0.3	-0.2

Like Japan, Korea will experience large output adjustments in the agricultural sectors under all four scenarios (Table 5). In particular, output of other gains (mainly wheat) is predicted to contract by almost 70 percent. Production of rice is also expected to fall by 41-56 percent, and output of vegetables and fruits and other crops will contract significantly under the China-Japan-Korea FTA, ASEAN+3 FTA, and GTL scenarios.[17]

Among the manufacturing sectors, output of textiles, leather, petroleum products, and other manufactures would increase. Although the motor vehicle industry would expand under the ASEAN-Korea FTA and GTL scenarios, it is expected to contract under the China-Japan-Korea FTA and ASEAN+3 FTA scenarios largely because Korea's imports of motor vehicles from Japan increase substantially.

Under the FTA scenarios in which ASEAN countries are members, the sectoral adjustments differ significantly across the scenarios (Table 6). For example, the textile, apparel, and leather industries expand by 13-29 percent under the ASEAN-EU FTA scenario, whereas these industries either increase only slightly or contract in the other four FTA scenarios. This is mainly because ASEAN countries have comparative advantage in these products over the EU, but not over China. In addition, the protection rates on these products in ASEAN were high relative to those in Japan and Korea in the base year (2001).

Output of chemicals and machinery expands substantially when China is a member of the FTA, and output of motor vehicles and parts contracts noticeably in all scenarios except the ASEAN-China FTA case.

[17] In practice, however, Japan and Korea are extremely unlikely to remove tariffs on imports of rice, wheat, and a number of other agricultural products. Thus, the magnitudes of sectoral adjustments are expected to be smaller than those reported in Tables 3-6. Lee et al. (2004) provide several FTA scenarios where trade barriers on agricultural products and processed food are assumed to remain fixed. They confirm that welfare gains to the FTA member countries become significantly smaller in the absence of agricultural liberalization.

Table 6
ASEAN's sectoral output adjustments under alternative scenarios
(percent deviations from the baseline for the year 2015)

Commodity/sector	Scenario					
	(1) ASEAN-China	(2) ASEAN-Japan	(3) ASEAN-Korea	(5) ASEAN plus 3	(6) ASEAN-EU	(7) GTL
Rice	-1.2	24.7	7.1	7.1	7.5	13.9
Other grains	-10.5	-0.5	30.1	-2.6	-5.4	-16.2
Vegetables and fruits	6.7	-3.5	-3.8	3.6	-3.1	3.6
Other crops	11.1	9.3	9.1	9.4	13.4	-2.2
Livestock	1.6	4.4	0.9	3.9	3.2	9.7
Natural resources	-5.0	-3.3	-2.3	-3.8	-4.7	-8.2
Fossil fuel	-3.7	-1.5	-0.2	-2.1	-3.5	-6.0
Food products	3.0	11.7	3.9	9.3	7.4	21.1
Textiles	-0.8	0.3	0.6	-4.8	13.0	6.5
Apparel	-1.1	3.3	1.9	2.3	15.3	24.3
Leather	-9.7	0.9	-2.8	-8.2	29.0	7.5
Wood products	-7.1	-1.6	-2.8	-2.2	-4.6	-5.0
Paper products	-1.3	-2.1	-0.6	-2.2	-3.2	-3.4
Petroleum products	2.0	0.9	0.5	-0.3	-0.5	-0.4
Chemical products	22.8	-0.8	2.1	17.7	0.2	12.0
Mineral products	0.8	-2.4	0.9	-0.8	-2.4	-1.7
Iron and steel	0.9	-7.4	-0.2	-7.2	-4.1	-10.8
Nonferrous metal	-3.2	-3.6	-1.4	-4.0	-7.0	-13.7
Metal products	0.4	-0.6	1.9	-1.6	-1.4	-3.8
Machinery	11.2	4.6	5.4	10.8	0.6	5.1
Electronic equipment	1.4	-0.5	-0.7	1.7	-4.1	-4.9
Motor vehicles	9.2	-13.7	-7.9	-18.4	-6.0	-20.4
Other transport equip.	-8.2	11.3	12.4	-6.0	12.0	-9.3
Other manufactures	-3.8	-1.4	-0.8	-3.2	-0.6	-7.8
Trade and transport	-0.5	-0.6	-0.6	-0.6	-0.5	-0.5
Services	-0.2	-0.3	-0.2	-0.3	-0.3	-0.7

4.3 Changes in the Pattern of Trade

In this section we examine the effects of alternative FTA scenarios on the pattern of East Asian trade. Specifically, we compute the indices of revealed comparative advantage (RCA), developed by Balassa (1965), and correlate RCA rankings of commodities with various FTA scenarios and those with the global trade liberalization scenario to examine how "natural" the groupings would be.

RCA is defined as

$$RCA = \frac{E_{r,i} \Big/ \sum_r E_{r,i}}{\sum_r E_{r,i} \Big/ \sum_r \sum_i E_{r,i}} \tag{3}$$

where $E_{r,i}$ is country (region) r's exports of commodity i. In other words, RCA is defined as the share of commodity i in country r's total exports relative to the commodity's share in total world exports. When the RCA index is greater than one, commodity i is more important in country r's exports than it is in total world exports, implying that the country has a comparative advantage in the commodity.

Table 7
Revealed comparative advantage indices for China, Japan, Korea and ASEAN in 2001

Commodity/sector	China	Japan	Korea	ASEAN
Rice	1.21	1.87	0.09	4.48
Other grains	0.37	0.00	0.00	0.06
Vegetables and fruits	0.65	0.01	0.23	0.66
Other crops	0.46	0.04	0.17	1.53
Livestock	1.05	0.09	0.08	0.35
Natural resources	0.35	0.05	0.04	1.39
Fossil fuel	0.18	0.00	0.00	0.87
Food products	0.44	0.12	0.26	1.18
Textiles	1.94	0.72	2.69	0.97
Apparel	3.77	0.05	0.84	1.49
Leather	5.20	0.05	0.99	1.44
Wood products	1.46	0.06	0.12	1.69
Paper products	0.40	0.27	0.57	0.64
Petroleum products	0.47	0.15	1.72	1.01
Chemical products	0.52	0.91	1.01	0.69
Mineral products	1.12	0.97	0.54	0.69
Iron and steel	0.32	1.58	1.61	0.27
Nonferrous metal	0.39	0.59	0.69	0.55
Metal products	1.37	0.75	0.98	0.45
Machinery	0.86	1.76	0.78	0.58
Electronic equipment	1.26	1.76	2.39	3.07
Motor vehicles	0.07	2.33	1.15	0.11
Other transport equip.	0.42	1.25	1.83	0.24
Other manufactures	3.43	0.71	0.58	0.75
Trade and transport	2.17	0.56	0.55	0.80
Services	0.46	0.43	0.56	0.77

Source: GTAP database, version 6.

Table 7 provides the RCA indices for the 26 sectors in China, Japan, Korea and ASEAN in 2001. In general, the larger the RCA index for a given commodity, the higher is the ranking of the product by comparative advantage (Kreinin and Plummer, 1994a,b).

However, the RCA index may be distorted by tariffs, nontariff barriers, subsidies and other policies. For example, RCA in Japan's rice sector is equal to 1.87, but this number is highly distorted because rice is one of the least competitive sectors in Japan.

In China the commodities/sectors with the five highest RCA index values in 2001 are leather (5.20), apparel (3.77), other manufactures (3.43), trade and transport (2.17), and textiles (1.94). In Japan they are motor vehicles (2.33), machinery (1.76), electronic equipment (1.76), iron and steel (1.58), and other transport equipment (1.25). In Korea the commodities with high RCA rankings are textiles (2.69), electronic equipment (2.39), other transport equipment (1.83), petroleum products (1.72), and iron and steel (1.61), whereas in ASEAN they are rice (4.48), electronic equipment (3.07), wood products (1.69), other crops (1.53), apparel (1.49), and leather (1.44).

To examine how "natural" each FTA grouping might be, we first compute the RCA indices under the GTL scenario for the year 2015. Second, we calculate the RCA indices for each member country of FTA with respect to the bloc it joins, rather than the world as a whole, for the six FTA scenarios in 2015. Third, we compute the Spearman rank correlation coefficients for China, Japan, Korea, ASEAN and the EU between each FTA scenario and the GTL scenario in 2015.[18] The results are summarized in Table 8. It should be noted that our definition of natural trading bloc is one where each member country has a relatively high Spearman rank correlation coefficient between the particular trading bloc and global trade liberalization. This should contrasted with a more conventional definition of natural trading partners where a pair of countries have similar size, GDP per capita, are neighboring, and share a common border and/or a common language (e.g., Frankel et al., 1995).

For China and ASEAN the correlation coefficients of RCA rankings between any particular FTA and GTL differ considerably across the FTA scenarios. On the contrary, for Japan and Korea the coefficients are 0.83-0.91 and 0.71-0.85, respectively, suggesting that RCA rankings between any given FTA and GTL are similar for the two countries. For example, for Japan motor vehicles, machinery, and iron and steel are ranked in the top 3,

[18] We also computed the Spearman rank correlation coefficients between each FTA scenario and the baseline scenario in 2015 for these countries, but the results were qualitatively similar. This is because we assume partial trade liberalization on imports of all products from all trading partners in the baseline.

while agricultural products and fossil fuel are ranked at or near the bottom of the rankings, under all three FTA scenarios in which Japan is a member as well as under GTL. By contrast, China has a very low coefficient between the China-Japan-Korea FTA and GTL. This is mainly caused by large increases in China's exports of other grains, other crops and fossil fuel to Japan and Korea, thereby significantly raising its RCA rankings of these commodities with respect to the trilateral bloc. However, China's RCA indices of these commodities under GTL are at the bottom of the rankings. Thus, for China large increases in exports of agricultural products and energy under the China-Japan-Korea FTA are undesirable because they result in sectoral adjustments that are quite different from those expected from GTL.

Table 8
Spearman rank correlation coefficients between each FTA scenario
and global trade liberalization in 2015

	Scenario					
Country/region	(1) ASEAN-China	(2) ASEAN-Japan	(3) ASEAN-Korea	(4) China-Japan-Korea	(5) ASEAN plus 3	(6) ASEAN-EU
China	0.60	–	–	0.04	0.54	–
Japan	–	0.91	–	0.83	0.86	–
Korea	–	–	0.85	0.71	0.82	–
ASEAN	0.24	0.45	0.21	–	0.41	0.77
EU	–	–	–	–	–	0.56

ASEAN has low Spearman correlation coefficients between the FTA with either China or Korea and GTL for two important reasons. First, electronic equipment has the highest RCA index among all commodity groups in ASEAN under GTL. However, its RCA ranking falls to 10-15th in the ASEAN-China and ASEAN-Korea FTA scenarios. Second, apparel and leather's RCA indices are near the top of the rankings under GTL, but their rankings fall significantly under the bilateral FTA with China or Korea.

Kreinin and Plummer (1994b) suggest that a natural FTA is one in which the Spearman correlation coefficients are high for all member countries. Among the six FTA scenarios considered in this study, the ASEAN-EU FTA may be considered relatively natural as the Spearman correlation coefficients are greater than 0.5 for both ASEAN and the EU. Among the five alternative East Asian FTAs, the ASEAN-Japan and the ASEAN+3 FTAs cause relatively small adjustments in the rankings of industries compared with the rankings of industries under GTL.

5. Concluding Remarks

In this paper, we have examined the effects of alternative FTA scenarios in East Asia on sectoral adjustments and the pattern of trade. Our findings indicate that the China-Japan-Korea FTA and the ASEAN+3 FTA would bring about relatively large welfare gains to all member countries. However, a tradeoff exists between welfare gains and costs associated with structural adjustments. For China, a low Spearman rank correlation coefficient between the China-Japan-Korea FTA and global trade liberalization suggests that it would need to undergo considerable structural adjustments under the trilateral FTA. The average correlation coefficient of the member countries' RCA rankings between a particular FTA and GTL is significantly greater for the ASEAN-Japan and the ASEAN+3 FTAs. Thus, it appears that the ASEAN+3 FTA would be the most attractive FTA among the alternative FTAs considered in this study, with relatively large welfare gains and small structural adjustments.

References

Balassa, B., 1965. Trade liberalization and 'revealed' comparative advantage. *Manchester School of Economics and Social Studies* 23, 99-123.

Bhagwati, J., 1995. U.S. trade policy: The infatuation with free trade areas. In: J. Bhagwati and A. O. Krueger (Eds.). *The Dangerous Drift to Preferential Trade Agreements*. Washington, DC: American Enterprise Institute for Public Policy Research.

Brown, D. K., A. V. Deardorff, and R. M. Stern, 2003. Multilateral, regional, and bilateral trade-policy options for the United States and Japan. *World Economy* 26, 803-828.

Das, S., M. J. Roberts, and J. R. Tybout, 2001. Market entry costs, producer heterogeneity, and export dynamics. NBER Working Paper No. 8629. Cambridge, MA: National Bureau of Economic Research.

de Melo, J. and S. Robinson, 1990. Productivity and externalities: Models of export-led growth. Policy Research Working Paper No. 387. Washington, DC: World Bank.

Dee, P., 2007. East Asian economic integration and its impact on future growth. *World Economy* 30, 405-423.

Dessus, S., K. Fukasaku, and R. Safadi, 1999. Multilateral tariff liberalization and the developing countries. *OECD Development Centre Policy Brief*, No. 18. Paris: OECD.

Dimaranan, B. V. (Ed.), 2006. *Global Trade, Assistance, and Production: The GTAP 6 Data Base*. West Lafayette: Center for Global Trade Analysis, Purdue University.

Ethier, W., 1998. The new regionalism. *Economic Journal* 108, 1149-1161.

Feridhanusetyawan, T., 2005. Preferential trade agreements in the Asia-Pacific region. IMF Working Paper WP/05/149. Washington, DC: International Monetary Fund.

Frankel, J. A., E. Stein, and S.-J. Wei, 1995. Trading blocs and the Americas: The natural, the unnatural, and the super-natural. *Journal of Development Economics* 47, 61-95.

Fujita, M., P. Krugman, and A. J. Venables, 1999. *The Spatial Economy: Cities, Regions, and International Trade*. Cambridge, MA: MIT Press.

Fukase, E. and L. A. Winters, 2003. Possible dynamic effects of AFTA for the new member countries. *World Economy* 26, 853-871.

Helpman, E. and P. R. Krugman, 1985. *Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy*. Cambridge, MA: MIT Press.

Kahler, M., 1995. *International Institutions and the Political Economy of Integration*. Washington DC: Brookings Institution.

Kawai, M., 2004. Regional economic integration and cooperation in East Asia. Paper presented at the Experts' Seminar on the Impact and Coherence of OECD Country Policies on Asian Developing Economies, OECD, Paris, 10-11 June.

Keuschnigg, C. and W. Kohler, 2002. Eastern enlargement of the EU: How much is it worth for Austria? *Review of International Economics* 10, 324-342.

Kreinin, M. E. and M. G. Plummer, 1994a. Structural change and regional integration in East Asia. *International Economic Journal* 8(2), 1-12.

Kreinin, M. E. and M. G. Plummer, 1994b. 'Natural' economic blocs: An alternative formulation. *International Trade Journal* 8, 193-205.

Krueger, A. O., 1999. Are preferential trading arrangements trade-liberalizing or protectionist? *Journal of Economic Perspectives* 13(4), 105-125.

Langhammer, R. J., 2004. China and the G-21: A new North-South divide in the WTO after Cancún. Kiel Working Paper No. 1194, Kiel Institute for World Economics (http://www.uni-kiel.de/ifw/pub/kap/2004/kap1194.pdf).

Lee, H., D. Roland-Holst, and D. van der Mensbrugghe, 2004. China's emergence in East Asia under alternative trading arrangements, *Journal of Asian Economics* 15, 697-712.

Lee, H. and D. van der Mensbrugghe, 2005. Interactions between foreign direct investment and trade in a general equilibrium framework. Paper presented at the ADB Experts' Meeting on Long-term Scenarios of Asia's Growth and Trade, Asian Development Bank, Manila, 10-11 November.

Lee, J.-W. and I. Park, 2005. Free trade areas in East Asia: Discriminatory or non-discriminatory? *World Economy* 28, 21-48.

Lloyd, P. J. and D. MacLaren, 2004. Gains and losses from regional trading agreements: A survey. *Economic Record* 80, 445-467.

Madsen, A. D. and M. L. Sorensen, 2002. Economic consequences for Denmark of EU enlargement. Paper presented at the International Conference on Policy Modeling, Brussels, 4-6 July (http://www.ecomod.net/conferences/ecomod2002/papers/due.pdf).

Panagariya, A., 1999a. *Regionalism in Trade Policy: Essays on Preferential Trading*. London: World Scientific.

Panagariya, A., 1999b. The regionalism debate: An overview. *World Economy* 22, 477-511.

Panagariya, A., 2000. Preferential trade liberalization: The traditional theory and new development. *Journal of Economic Literature* 38, 287-331.

Park, I., 2006. East Asian regional trade agreements: Do they promote global free trade? *Pacific Economic Review* 11, 547-568.

Samuelson, P. A., 1952. The transfer problem and transport costs: The terms of trade when impediments are absent. *Economic Journal* 62, 278-304.

Schiff, M. and A. Winters, 2003. *Regional Integration and Development*. New York/ Washington, DC: Oxford University Press/The World Bank.

Scollay, R. and J. Gilbert, 2001. *New Subregional Trading Arrangements in the Asia-Pacific*. Washington, DC: Institute for International Economics.

Srinivasan, T. N., 1998a. *Developing Countries and the Multilateral Trading System: From GATT to the Uruguay Round and the Future*. Boulder: Westview Press.

Srinivasan, T. N., 1998b. Regionalism and the WTO: Is nondiscrimination passé? In: A. O. Krueger (Ed.). *The WTO as an international organization*. Chicago: University of Chicago Press.

Urata, S. and K. Kiyota, 2003. The impacts of an East Asia FTA on foreign trade in East Asia. NBER Working Paper No. 10173. Cambridge, MA: National Bureau of Economic Research.

van der Mensbrugghe, D., 2005. LINKAGE Technical Reference Document: Version 6.0. Washington, DC: The World Bank. Available at http://siteresources.worldbank.org/ INTPROSPECTS/Resources/334934-1100792545130/LinkageTechNote.pdf.

Wong, K.-Y., T.-D. Yeo, Y. M. Yoon, and S. Yun, 2004. Northeast Asia economic integration: An analysis of the trade relations among China, Japan, and South Korea, mimeo, Department of Economics, University of Washington (http://faculty.washington.edu/karyiu/papers/NEA-FTA.pdf).

World Bank, 2000. *Trade Blocs*. New York/Washington, DC: Oxford University Press/ World Bank.

World Trade Organization, 1995. *Regionalism and the World Trading System*. Geneva: World Trade Organization.

Yamazawa, I., and D. Hiratsuka, eds., 2003. *Toward ASEAN-Japan Comprehensive Economic Partnership*. IDE Development Perspective Series No. 24. Tokyo: Institute of Developing Economies.

Zhai, F., 2006. Preferential trade agreements in Asia: Alternative scenarios of "hub and spoke." ERD Working Paper Series No. 83. Manila: Asian Development Bank.

Appendix: Model Equations

A.1. The Neo-Classical Model in Comparative Static Mode

In the equations describing the model specification, the following indices are frequently employed. In general, the regional and time indices are omitted unless needed for clarification. The base sectoral, labor and regional indices are specific to the GTAP data set. The other indices are specific to the model specification.

i Sectoral index ***j*** is used as an alias for ***i***.

ll Labor skill (representing skilled, unskilled, and highly skilled labor).

l A subset of *ll*, which excludes highly skilled labor.

f An index for other domestic final demand agents (government and investment).

r Regional index. ***r'*** is used as an alias for ***r***.

v Capital vintage.

t time index.

Other labels for important subsets of sectors are the following:

Index	*Subset label*	*Description*
i	*cr*	Crops sectors (user-determined)
i	*lv*	Livestock sectors (user-determined)
i	*ag*	Agricultural sectors (the union of the crop and livestock sectors)
i	*ip*	Non-agricultural products (user-determined)
i	*e*	Energy sectors (user-determined)
i	*ft*	Fertilizer sectors (user-determined)
i	*fd*	Feed sectors (user-determined)
i	*ik*	Sectors including in the calibrating productivity (user-determined)

Production Technology

Crop Production

(1) $$ND_{cr} = \sum_{v} \alpha^{nd}{}_{cr,v} \left(AT_{cr}\right)^{\sigma^{p}_{cr,v}-1} \left(\frac{PXv_{cr,v}}{PND_{cr}}\right)^{\sigma^{p}_{cr,v}} XPv_{cr,v}$$

(2) $$VA_{cr,v} = \alpha^{va}{}_{cr,v} \left(AT_{cr}\right)^{\sigma^{p}_{cr,v}-1} \left(\frac{PXv_{cr,v}}{PVA_{cr,v}}\right)^{\sigma^{p}_{cr,v}} XPv_{cr,v}$$

(3) $$PXv_{cr,v} = \frac{1}{AT_{cr}} \left[\alpha^{nd}{}_{cr,v} \left(PND_{cr} \right)^{1-\sigma^{p}_{cr,v}} + \alpha^{va}{}_{cr,v} \left(PVA_{cr,v} \right)^{1-\sigma^{p}_{cr,v}} \right]^{1/\left(1-\sigma^{p}_{cr,v}\right)}$$

(4) $$PX_{cr} = \sum_{v} \frac{XPv_{cr,v}}{XP_{cr}} PXv_{cr,v}$$

(5) $$AL_{cr} = \sum_{v} \alpha^{l}_{cr,v} \left(\frac{PVA_{cr,v}}{AW_{cr}} \right)^{\sigma^{v}_{cr,v}} VA_{cr,v}$$

(6) $$HKTEF_{cr,v} = \alpha^{hktef}_{cr,v} \left(\frac{PVA_{cr,v}}{PHKTEF_{cr,v}} \right)^{\sigma^{v}_{cr,v}} VA_{cr,v}$$

(7) $$PVA_{cr,v} = \left[\alpha^{l}_{cr,v} \left(AW_{cr} \right)^{1-\sigma^{v}_{cr,v}} + \alpha^{hktef}_{cr,v} \left(PHKTEF_{cr,v} \right)^{1-\sigma^{v}_{cr,v}} \right]^{1/\left(1-\sigma^{v}_{cr,v}\right)}$$

(8) $$L^{d}_{l,cr} = \alpha^{ld}_{l,cr} \left(\lambda^{l}_{l,cr} \right)^{\sigma^{l}_{cr}-1} \left(\frac{AW_{cr}}{W_{l,cr}} \right)^{\sigma^{l}_{cr}} AL_{cr}$$

(9) $$AW_{cr} = \sum_{l} \left[\alpha^{ld}_{l,cr} \left(\frac{W_{l,cr}}{\lambda^{l}_{l,cr}} \right)^{1-\sigma^{l}_{cr}} \right]^{1/\left(1-\sigma^{l}_{cr}\right)}$$

(10) $$fert_{cr} = \sum_{v} \alpha^{fert}_{cr,v} \left(\frac{PHKTEF_{cr,v}}{Pfert_{cr}} \right)^{\sigma^{f}_{cr,v}} HKTEF_{cr,v}$$

(11) $$HKTE_{cr,v} = \alpha^{hkte}_{cr,v} \left(\frac{PHKTEF_{cr,v}}{PHKTE_{cr,v}} \right)^{\sigma^{f}_{cr,v}} HKTEF_{cr,v}$$

(12) $$PHKTEF_{cr,v} = \left[\alpha^{fert}_{cr,v} \left(Pfert_{cr} \right)^{1-\sigma^{f}_{cr,v}} + \alpha^{hkte}_{cr,v} \left(PHKTE_{cr,v} \right)^{1-\sigma^{f}_{cr,v}} \right]^{1/\left(1-\sigma^{f}_{cr,v}\right)}$$

(13) $$XEp_{cr,v} = \alpha^{e}_{cr,v} \left(\frac{PHKTE_{cr,v}}{PEp_{cr,v}} \right)^{\sigma^{e}_{cr,v}} HKTE_{cr,v}$$

(14) $$HKT_{cr,v} = \alpha^{hkt}_{cr,v} \left(\frac{PHKTE_{cr,v}}{PHKT_{cr,v}} \right)^{\sigma^{e}_{cr,v}} HKTE_{cr,v}$$

(15) $$PHKTE_{cr,v} = \left[\alpha^{e}_{cr,v} \left(PEp_{cr,v} \right)^{1-\sigma^{e}_{cr,v}} + \alpha^{hkt}_{cr,v} \left(PHKT_{cr,v} \right)^{1-\sigma^{e}_{cr,v}} \right]^{1/\left(1-\sigma^{e}_{cr,v}\right)}$$

(16) $$L^{d}_{HSk,cr} = \sum_{v} \alpha^{h}_{cr,v} \left(\lambda^{l}_{HSk,cr} \right)^{\sigma^{h}_{cr,v}-1} \left(\frac{PHKT_{cr,v}}{W_{HSk,cr}} \right)^{\sigma^{h}_{cr,v}} HKT_{cr,v}$$

(17) $$KT_{cr,v} = \alpha^{kt}_{cr,v} \left(\frac{PHKT_{cr,v}}{PKT_{cr,v}} \right)^{\sigma^{e}_{cr,v}} HKT_{cr,v}$$

(18) $$PHKT_{cr,v} = \left[\alpha^{h}_{cr,v} \left(\frac{W_{HSk,cr}}{\lambda^{l}_{HSk,cr}} \right)^{1-\sigma^{h}_{cr,v}} + \alpha^{kt}_{cr,v} \left(PKT_{cr,v} \right)^{1-\sigma^{h}_{cr,v}} \right]^{1/\left(1-\sigma^{h}_{cr,v}\right)}$$

(19) $$Kv^{d}_{cr,v} = \alpha^{k}_{cr,v} \left(\lambda^{k}_{cr,v} \right)^{\sigma^{k}_{cr,v}-1} \left(\frac{PKT_{cr,v}}{R_{cr,v}} \right)^{\sigma^{k}_{cr,v}} KT_{cr,v}$$

(20) $$T^{d}_{cr} = \sum_{v} \alpha^{t}_{cr,v} \left(\lambda^{t}_{cr} \right)^{\sigma^{k}_{cr,v}-1} \left(\frac{PKT_{cr,v}}{PT_{cr}} \right)^{\sigma^{k}_{cr,v}} KT_{cr,v}$$

(21) $$F^{d}_{cr} = \sum_{v} \alpha^{f}_{cr,v} \left(\lambda^{f}_{cr} \right)^{\sigma^{k}_{cr,v}-1} \left(\frac{PKT_{cr,v}}{PF_{cr}} \right)^{\sigma^{k}_{cr,v}} KT_{cr,v}$$

(22) $$PKT_{cr,v} = \left[\alpha^{k}_{cr,v} \left(\frac{R_{cr,v}}{\lambda^{k}_{cr,v}} \right)^{1-\sigma^{k}_{cr,v}} + \alpha^{t}_{cr,v} \left(\frac{PT_{cr}}{\lambda^{t}_{cr}} \right)^{1-\sigma^{k}_{cr,v}} + \alpha^{f}_{cr,v} \left(\frac{PF_{cr}}{\lambda^{f}_{cr}} \right)^{1-\sigma^{k}_{cr,v}} \right]^{1/\left(1-\sigma^{k}_{cr,v}\right)}$$

(23) $$XAp_{ft,cr} = \alpha^{ft}_{ft,cr} \left(\lambda^{ft}_{ft,cr} \right)^{\left(\sigma^{ft}_{cr}-1\right)} \left(\frac{Pfert_{cr}}{\left(1+\tau^{Ap}_{ft,cr}\right) PA_{ft}} \right)^{\sigma^{ft}_{cr}} fert_{cr}$$

(24) $$Pfert_{cr} = \left[\sum_{ft} \alpha^{ft}_{ft,cr} \left[\frac{\left(1+\tau^{Ap}_{ft,cr}\right) PA_{ft}}{\lambda^{ft}_{ft,cr}} \right]^{1-\sigma^{ft}_{cr}} \right]^{1/\left(1-\sigma^{ft}_{cr}\right)}$$

(25) $$XAp_{e,cr} = \sum_{v} \alpha^{ep}_{e,cr,v} \left(\lambda^{ep}_{e,cr} \right)^{\sigma^{ep}_{cr,v}-1} \left(\frac{PEp_{cr,v}}{\left(1+\tau^{Ap}_{e,cr}\right) PA_{e}} \right)^{\sigma^{ep}_{cr,v}} XEp_{cr,v}$$

(26) $$PEp_{cr,v} = \left[\sum_{e} \alpha^{ep}_{e,cr,v} \left(\frac{\left(1+\tau^{Ap}_{e,cr}\right) PA_{e}}{\lambda^{ep}_{e,cr}} \right)^{1-\sigma^{ep}_{cr,v}} \right]^{1/\left(1-\sigma^{ep}_{cr,v}\right)}$$

(27) $$XAp_{nnft,cr} = a_{nnft,cr} ND_{cr}$$

(28) $$PND_{cr} = \sum_{nnft} a_{nnft,cr} \left(1+\tau^{Ap}_{nnft,cr}\right) PA_{nnft}$$

Livestock Production

(29) $$ND_{lv} = \sum_{v} \alpha^{nd}_{lv,v} \left(AT_{lv}\right)^{\sigma^{p}_{lv,v}-1} \left(\frac{PXv_{lv,v}}{PND_{lv}}\right)^{\sigma^{p}_{lv,v}} XPv_{lv,v}$$

(30) $$VA_{lv,v} = \alpha^{va}_{lv,v} \left(AT_{lv}\right)^{\sigma^{p}_{lv,v}-1} \left(\frac{PXv_{lv,v}}{PVA_{lv,v}}\right)^{\sigma^{p}_{lv,v}} XPv_{lv,v}$$

(31) $$PXv_{lv,v} = \frac{1}{AT_{lv}} \left[\alpha^{nd}_{lv,v} \left(PND_{lv}\right)^{1-\sigma^{p}_{lv,v}} + \alpha^{va}_{lv,v} \left(PVA_{lv,v}\right)^{1-\sigma^{p}_{lv,v}}\right]^{1/\left(1-\sigma^{p}_{lv,v}\right)}$$

(32) $$PX_{lv} = \sum_{v} \frac{XPv_{lv,v}}{XP_{lv}} PXv_{lv,v}$$

(33) $$KTEL_{lv,v} = \alpha^{ktel}_{lv,v} VA_{lv,v}$$

(34) $$TFD_{lv,v} = \alpha^{tfd}_{lv,v} VA_{lv,v}$$

(35) $$PVAf_{lv,v} = \alpha^{ktel}_{lv,v} PKTEL_{lv,v} + \alpha^{tfd}_{lv,v} PTFD_{lv,v}$$

(36) $$feed_{lv} = \sum_{v} \alpha^{feed}_{lv,v} \left(\frac{PTFD_{lv,v}}{Pfeed_{lv}}\right)^{\sigma^{f}_{lv,v}} TFD_{lv,v}$$

(37) $$T^{d}_{lv} = \sum_{v} \alpha^{t}_{lv,v} \left(\lambda^{t}_{lv}\right)^{\sigma^{f}_{lv,v}-1} \left(\frac{PTFD_{lv,v}}{PT_{lv}}\right)^{\sigma^{f}_{lv,v}} TFD_{lv,v}$$

(38) $$PTFD_{lv,v} = \left[\alpha^{feed}_{lv,v} \left(Pfeed_{lv}\right)^{1-\sigma^{f}_{lv,v}} + \alpha^{t}_{lv,v} \left(\frac{PT_{lv}}{\lambda^{t}_{lv}}\right)^{1-\sigma^{f}_{lv,v}}\right]^{1/\left(1-\sigma^{f}_{lv,v}\right)}$$

(39) $$AL_{lv} = \sum_{v} \alpha^{l}_{lv,v} \left(\frac{PKTEL_{lv,v}}{AW_{lv}}\right)^{\sigma^{v}_{lv,v}} KTEL_{lv,v}$$

(40) $$HKTE_{lv,v} = \alpha^{hkte}_{lv,v} \left(\frac{PKTEL_{lv,v}}{PHKTE_{lv,v}}\right)^{\sigma^{v}_{lv,v}} KTEL_{lv,v}$$

(41) $$PKTEL_{lv,v} = \left[\alpha^{l}_{lv,v} \left(AW_{lv}\right)^{1-\sigma^{v}_{lv,v}} + \alpha^{hkte}_{lv,v} \left(PHKTE_{lv}\right)^{1-\sigma^{v}_{lv,v}}\right]^{1/\left(1-\sigma^{v}_{lv,v}\right)}$$

(42) $$L^{d}_{l,lv} = \alpha^{ld}_{l,lv} \left(\lambda^{l}_{l,lv}\right)^{\sigma^{l}_{lv}-1} \left(\frac{AW_{lv}}{W_{l,lv}}\right)^{\sigma^{l}_{lv}} AL_{lv}$$

(43) $$AW_{cr} = \sum_{l}\left[\alpha_{l,cr}^{ld}\left(\frac{W_{l,cr}}{\lambda_{l,cr}^{l}}\right)^{1-\sigma_{cr}^{l}}\right]^{1/\left(1-\sigma_{cr}^{l}\right)}$$

(44) $$XEp_{lv,v} = \alpha_{lv,v}^{e}\left(\frac{PHKTE_{lv,v}}{PEp_{lv,v}}\right)^{\sigma_{lv,v}^{e}} HKTE_{lv,v}$$

(45) $$HKT_{lv,v} = \alpha_{lv,v}^{hkt}\left(\frac{PHKTE_{lv,v}}{PHKT_{lv,v}}\right)^{\sigma_{lv,v}^{e}} KTE_{lv,v}$$

(46) $$PKTE_{lv,v} = \left[\alpha_{lv,v}^{e}\left(PEp_{lv,v}\right)^{1-\sigma_{lv,v}^{e}} + \alpha_{lv,v}^{hkt}\left(PHKT_{lv,v}\right)^{1-\sigma_{lv,v}^{e}}\right]^{1/\left(1-\sigma_{lv,v}^{e}\right)}$$

(47) $$L_{HSk,lv}^{d} = \sum_{v}\alpha_{lv,v}^{h}\left(\lambda_{HSk,lv}^{l}\right)^{\sigma_{lv,v}^{h}-1}\left(\frac{PHKT_{lv,v}}{W_{HSk,lv}}\right)^{\sigma_{lv,v}^{h}} HKT_{lv,v}$$

(48) $$KT_{lv,v} = \alpha_{lv,v}^{kt}\left(\frac{PHKT_{lv,v}}{PKT_{lv,v}}\right)^{\sigma_{lv,v}^{h}} HKT_{lv,v}$$

(49) $$PHKT_{lv,v} = \left[\alpha_{lv,v}^{h}\left(\frac{W_{HSk,lv}}{\lambda_{HSk,lv}^{l}}\right)^{1-\sigma_{lv,v}^{h}} + \alpha_{lv,v}^{kt}\left(PKT_{lv,v}\right)^{1-\sigma_{lv,v}^{h}}\right]^{1/\left(1-\sigma_{lv,v}^{h}\right)}$$

(50) $$Kv_{lv,v}^{d} = \alpha_{lv,v}^{k}\left(\lambda_{lv,v}^{k}\right)^{\sigma_{lv,v}^{k}-1}\left(\frac{PKT_{lv,v}}{R_{lv,v}}\right)^{\sigma_{lv,v}^{k}} KT_{lv,v}$$

(51) $$F_{lv}^{d} = \sum_{v}\alpha_{lv,v}^{f}\left(\lambda_{lv}^{f}\right)^{\sigma_{lv,v}^{k}-1}\left(\frac{PKT_{lv,v}}{PF_{lv}}\right)^{\sigma_{lv,v}^{k}} KT_{lv,v}$$

(52) $$PKT_{lv,v} = \left[\alpha_{lv,v}^{k}\left(\frac{R_{lv,v}}{\lambda_{lv,v}^{k}}\right)^{1-\sigma_{lv,v}^{k}} + \alpha_{lv,v}^{f}\left(\frac{PF_{lv}}{\lambda_{lv}^{f}}\right)^{1-\sigma_{lv,v}^{k}}\right]^{1/\left(1-\sigma_{lv,v}^{k}\right)}$$

(53) $$XAp_{fd,lv} = \alpha_{fd,lv}^{fd}\left(\lambda_{fd,lv}^{fd}\right)^{\left(\sigma_{lv}^{fd}-1\right)}\left(\frac{Pfeed_{lv}}{\left(1+\tau_{fd,lv}^{Ap}\right)PA_{fd}}\right)^{\sigma_{lv}^{fd}} feed_{lv}$$

(54) $$Pfeed_{lv} = \left[\sum_{fd}\alpha_{fd,lv}^{fd}\left[\frac{\left(1+\tau_{fd,lv}^{Ap}\right)PA_{fd}}{\lambda_{fd,lv}^{fd}}\right]^{1-\sigma_{lv}^{fd}}\right]^{1/\left(1-\sigma_{lv}^{fd}\right)}$$

(55) $$XAp_{e,lv} = \sum_v \alpha^{ep}_{e,lv,v} \left(\lambda^{ep}_{e,lv}\right)^{\sigma^{ep}_{lv,v}-1} \left(\frac{PEp_{lv,v}}{\left(1+\tau^{Ap}_{e,lv}\right)PA_e}\right)^{\sigma^{ep}_{lv,v}} XEp_{lv,v}$$

(56) $$PEp_{lv,v} = \left[\sum_e \alpha^{ep}_{e,lv,v} \left(\frac{\left(1+\tau^{Ap}_{e,lv}\right)PA_e}{\lambda^{ep}_{ej}}\right)^{1-\sigma^{ep}_{lv,v}}\right]^{1/\left(1-\sigma^{ep}_{lv,v}\right)}$$

(57) $$XAp_{nnff,lv} = a_{nnfd,lv} ND_{lv}$$

(58) $$PND_{lv} = \sum_{nnfd} a_{nnfd,lv} \left(1+\tau^{Ap}_{nnfd,lv}\right) PA_{nnfd}$$

Non-Agricultural Production

(59) $$ND_{ip} = \sum_v \alpha^{nd}_{ip,v} \left(AT_{ip}\right)^{\left(\sigma^p_{ip,v}-1\right)} \left(\frac{PXv_{ip,v}}{PND_{ip}}\right)^{\sigma^p_{ip,v}} XPv_{ip,v}$$

(60) $$VA_{ip,v} = \alpha^{va}_{ip,v} \left(AT_{ip}\right)^{\left(\sigma^p_{ip,v}-1\right)} \left(\frac{PXv_{ip,v}}{PVA_{ip,v}}\right)^{\sigma^p_{ip,v}} XPv_{ip,v}$$

(61) $$PXv_{ip,v} = \frac{1}{AT_{ip}} \left[\alpha^{nd}_{ip,v} PND_{ip}^{1-\sigma^p_{ip,v}} + \alpha^{va}_{ip,v} PVA_{ip,v}^{1-\sigma^p_{ip,v}}\right]^{1/\left(1-\sigma^p_{ip,v}\right)}$$

(62) $$PX_{ip}\ XP_{ip} = \sum_v PXv_{ip,v} XPv_{ip,v}$$

(63) $$AL_{ip} = \sum_v \alpha^l_{ip,v} \left(\frac{PVA_{ip,v}}{AW_{ip}}\right)^{\sigma^v_{ip}} VA_{ip,v}$$

(64) $$HKTE_{ip,v} = \alpha^{hkte}_{ip,v} \left(\frac{PVA_{ip,v}}{PHKTE_{ip,v}}\right)^{\sigma^v_{ip,v}} VA_{ip,v}$$

(65) $$PVA_{ip,v} = \left[\alpha^{hkte}_{ip,v} PHKTE_{ip,v}^{1-\sigma^v_{jv}} + \alpha^l_{ip,v} \left(AW_{ip}\right)^{1-\sigma^v_{ip,v}}\right]^{1/\left(1-\sigma^v_{ip,v}\right)}$$

(66) $$L^d_{l,ip} = \alpha^{ld}_{l,ip} \left(\lambda^l_{l,ip}\right)^{\sigma^l_{ip}-1} \left(\frac{AW_{ip}}{W_{l,ip}}\right)^{\sigma^l_{ip}} AL_{ip}$$

(67) $$AW_{ip} = \sum_l \left[\alpha^{ld}_{l,ip} \left(\frac{W_{l,ip}}{\lambda^l_{l,ip}}\right)^{1-\sigma^l_{ip}}\right]^{1/\left(1-\sigma^l_{ip}\right)}$$

(68) $$XEp_{ip,v} = \alpha^{e}_{ip,v} \left(\frac{PHKTE_{ip,v}}{PEp_{ip,v}} \right)^{\sigma^{e}_{ip,v}} HKTE_{ip,v}$$

(69) $$HKT_{ip,v} = \alpha^{hkt}_{ip,v} \left(\frac{PHKTE_{ip,v}}{PHKT_{ip,v}} \right)^{\sigma^{e}_{ip,v}} HKTE_{ip,v}$$

(70) $$PHKTE_{ip,v} = \left[\alpha^{e}_{ip,v} \left(PEp_{ip,v} \right)^{1-\sigma^{e}_{ip,v}} + \alpha^{hkt}_{ip,v} \left(PHKT_{ip,v} \right)^{1-\sigma^{e}_{ip,v}} \right]^{1/\left(1-\sigma^{e}_{ip,v}\right)}$$

(71) $$L^{d}_{HSk,ip} = \sum_{v} \alpha^{h}_{ip,v} \left(\lambda^{l}_{HSk,ip} \right)^{\sigma^{h}_{ip,v}-1} \left(\frac{PHKT_{ip,v}}{W_{HSk,ip}} \right)^{\sigma^{h}_{ip,v}} HKT_{ip,v}$$

(72) $$KT_{ip,v} = \alpha^{kt}_{ip,v} \left(\frac{PHKT_{ip,v}}{PKT_{ip,v}} \right)^{\sigma^{h}_{ip,v}} HKT_{ip,v}$$

(73) $$PHKT_{ip,v} = \left[\alpha^{h}_{ip,v} \left(\frac{W_{HSk,ip}}{\lambda^{l}_{HSk,ip}} \right)^{1-\sigma^{h}_{ip,v}} + \alpha^{kt}_{ip,v} \left(PKT_{ip,v} \right)^{1-\sigma^{h}_{ip,v}} \right]^{1/\left(1-\sigma^{h}_{ip,v}\right)}$$

(74) $$F^{d}_{ip} = \sum_{v} \alpha^{f}_{ip,v} \left(\lambda^{f}_{ip} \right)^{\sigma^{k}_{ip,v}-1} \left(\frac{PKT_{ip,v}}{PF_{ip}} \right)^{\sigma^{k}_{ip,v}} KT_{ip,v}$$

(75) $$T^{d}_{ip} = \sum_{v} \alpha^{t}_{ip,v} \left(\lambda^{t}_{ip} \right)^{\sigma^{k}_{ip,v}-1} \left(\frac{PKT_{ip,v}}{PT_{ip}} \right)^{\sigma^{k}_{ip,v}} KT_{ip,v}$$

(76) $$Kv^{d}_{ip,v} = \alpha^{k}_{ip,v} \left(\lambda^{k}_{ip} \right)^{\sigma^{k}_{ip,v}-1} \left(\frac{PKT_{ip,v}}{R_{ip,v}} \right)^{\sigma^{k}_{ip,v}} KT_{ip,v}$$

(77) $$PKT_{ip,v} = \left[\alpha^{f}_{ip,v} \left(\frac{PF_{ip}}{\lambda^{f}_{ip}} \right)^{1-\sigma^{k}_{ip,v}} + \alpha^{t}_{ip,v} \left(\frac{PT_{ip}}{\lambda^{t}_{ip}} \right)^{1-\sigma^{k}_{ip,v}} + \alpha^{k}_{ip,v} \left(\frac{R_{ip,v}}{\lambda^{k}_{ip,v}} \right)^{1-\sigma^{k}_{ip,v}} \right]^{1/\left(1-\sigma^{k}_{ip,v}\right)}$$

(78) $$XAp_{nf,ip} = \alpha_{nf,ip} ND_{ip}$$

(79) $$PND_{ip} = \sum_{nf} a_{nf,ip} \left(1 + \tau^{Ap}_{nf,ip} \right) PA_{nf}$$

(80) $$XAp_{e,ip} = \sum_{v} \alpha^{ep}_{e,ip,v} \left(\lambda^{ep}_{e,ip} \right)^{\sigma^{ep}_{ip,v}-1} \left(\frac{PEp_{ip,v}}{\left(1 + \tau^{Ap}_{e,ip} \right) PA_{e}} \right)^{\sigma^{ep}_{ip,v}} XEp_{ip,v}$$

(81) $$PEp_{ip,v} = \left[\sum_e \alpha^{ep}_{e,ip,v} \left(\frac{\left(1+\tau^{Ap}_{e,ip}\right) PA_e}{\lambda^{ep}_{e,ip}}\right)^{1-\sigma^{ep}_{ip,v}}\right]^{1/\left(1-\sigma^{ep}_{ip,v}\right)}$$

Market structure

(82) $$PP_i = PX_i \left(1+\pi_i\right)\left(1+\tau^p_i\right)$$

Income Distribution

(83) $$TY = \sum_i NPT_i \; T^d_i$$

(84) $$FY = \sum_i PF_i \; F^d_i$$

(85) $$LY_{ll} = \sum_i NW_{ll,i} L^d_{ll,i}$$

(86) $$KY = \sum_v \sum_i NR_{i,v} \; Kv^d_{i,v} + \sum_i \pi_i PX_i XP_i$$

(87) $$YH_h = \varphi^t_h TY + \varphi^f_h FY + \sum_{ll} \varphi^l_{h,ll} LY_{ll} + \varphi^k_h KY - DeprY_h + PGDP \; TRG_h$$

(88) $$DeprY_h = \varphi^k_h \delta^f \; PGDP \; K$$

(89) $$Yd_h = \left(1-\chi^k \kappa^h_h\right) YH_h$$

Final Demand

(90) $$Y^*_h = Yd_h - \sum_j \left(1+\tau^{Ac}_{j,h}\right) PA_j \; Pop_h \; \theta_{j,h}$$

(91) $$XAc_{i,h} = Pop_h \; \theta_{i,h} + \frac{\mu_{i,h}}{\left(1+\tau^{Ac}_{i,h}\right) PA_i} Y^*_h$$

(92) $$S^h_h = Yd_h - \sum_i \left(1+\tau^{Ac}_{i,h}\right) PA_i XAc_{i,h}$$

(93) $$CPI_h = \frac{\sum_i \left(1+\tau^{Ac}_{i,h}\right) PA_i XAc_{i,h}}{\sum_i \left(1+\tau^{Ac}_{i,h,0}\right) PA_{i,0} XAc_{i,h}}$$

(94) $$XAf_{i,f} = a^f_{i,f} FD_f$$

(95) $$PFD_f = \sum_i a^f_{i,f} \left(1+\tau^{Af}_{i,f}\right) PA_i$$

Trade

Import Specification

(96) $$XA_i = \sum_j XAp_{i,j} + \sum_h XAc_{i,h} + \sum_f XAf_{i,f}$$

(97) $$\begin{cases} XD_i^d = \beta_i^d \left(\dfrac{PA_i}{PD_i} \right)^{\sigma_i^m} XA_i & \text{if} \quad \sigma^m < \infty \\ PD_i = PA_i & \text{if} \quad \sigma^m = \infty \end{cases}$$

(98) $$\begin{cases} XMT_i = \beta_i^m \left(\dfrac{PA_i}{PMT_i} \right)^{\sigma_i^m} XA_i & \text{if} \quad \sigma^m < \infty \\ PMT_i = PA_i & \text{if} \quad \sigma^m = \infty \end{cases}$$

(99) $$\begin{cases} PA_i = \left[\beta_i^d PD_i^{1-\sigma_i^m} + \beta_i^m PMT_i^{1-\sigma_i^m} \right]^{1/\left(1-\sigma_i^m\right)} & \text{if} \quad \sigma^m < \infty \\ XA_i = XD_i^d + XMT_i & \text{if} \quad \sigma^m = \infty \end{cases}$$

(100) $$\begin{cases} WTF_{r',r,i}^d = \beta_{r',r,i}^w \left(\dfrac{PMT_{r,i}}{PM_{r',r,i}} \right)^{\sigma_{r,i}^w} XMT_{r,i} & \text{if} \quad \sigma^w < \infty \\ PM_{r',r,i} = PMT_{r,i} & \text{if} \quad \sigma^w = \infty \end{cases}$$

(101) $$\begin{cases} PMT_{r,i} = \left[\sum_{r'} \beta_{r',r,i}^w \left(PM_{r',r,i} \right)^{1-\sigma_{r,i}^w} \right]^{1/\left(1-\sigma_{r,i}^w\right)} & \text{if} \quad \sigma^w < \infty \\ XMT_{r,i} = \sum WTF_{r',r,i}^d & \text{if} \quad \sigma^w = \infty \end{cases}$$

Export Specification

(102) $$\begin{cases} XD_i^s = \gamma_i^d \left(\dfrac{PD_i}{PP_i} \right)^{\sigma_i^x} \left(XP_i - XMg_i \right) & \text{if} \quad \sigma_i^x < \infty \\ PD_i = PP_i & \text{if} \quad \sigma_i^x = \infty \end{cases}$$

(103) $$\begin{cases} ES_i = \gamma_i^e \left(\dfrac{PPE_i}{PP_i}\right)^{\sigma_i^x} \left(XP_i - XMg_i\right) & \text{if} \quad \sigma_i^x < \infty \\ PPE_i = PP_i & \text{if} \quad \sigma_i^x = \infty \end{cases}$$

(104) $$\begin{cases} PP_i = \left[\gamma_i^d PD_i^{1+\sigma_i^x} + \gamma_i^e PPE_i^{1+\sigma_i^x}\right]^{1/\left(1+\sigma_i^x\right)} & \text{if} \quad \sigma_i^x < \infty \\ XP_i = XD_i^s + ES_i + XMg_i & \text{if} \quad \sigma_i^x = \infty \end{cases}$$

(105) $$\begin{cases} WTF_{r,r',i}^s = \gamma_{r,r',i}^w \left(\dfrac{PE_{r,r',i}}{PPE_{r,i}}\right)^{\sigma_{r,i}^z} ES_{r,i} & \text{if} \quad \sigma_i^z < \infty \\ PE_{r,r',i} = PPE_{r,i} & \text{if} \quad \sigma_i^z = \infty \end{cases}$$

(106) $$\begin{cases} PPE_{r,i} = \left[\sum_{r'} \gamma_{r,r',i}^w \left(PE_{r,r',i}\right)^{1+\sigma_{r,i}^z}\right]^{1/\left(1+\sigma_{r,i}^z\right)} & \text{if} \quad \sigma_i^z < \infty \\ ES_{r,i} = \sum_{r'} WTF_{r,r',i}^s & \text{if} \quad \sigma_i^z = \infty \end{cases}$$

Trade Prices

(107) $$WPE_{r,r',i} = \left(1 + \tau_{r,r',i}^e\right) PE_{r,r',i}$$

(108) $$WPM_{r,r',i} = \left(1 + \zeta_{r,r',i}^t\right) WPE_{r,r',i} / \lambda_{r,r',i}^w$$

(109) $$PM_{r,r',i} = \left(1 + \tau_{r,r',i}^m\right) WPM_{r,r',i}$$

Demand for International Trade and Transport Services

(110) $$WPMg\, WXMg = \sum_r \sum_{r'} \sum_i \zeta_{r,r',i}^t WPE_{r,r',i} WTF_{r,r',i}^d$$

Allocation of the Demand for International Trade and Transport Services across Regions

(111) $$AXMg_r = \alpha_r^{TT} \left(\frac{WPMg}{APMg_r}\right)^{\sigma^{TT}} WXMg$$

(112) $$WPMg = \left[\sum_r \alpha_r^{TT} APMg_r^{\,1-\sigma^{TT}}\right]^{1/\left(1-\sigma^{TT}\right)}$$

Local Supply for Trade and Transport Services

(113) $XMg_{r,i} = a_{r,i}^{Mg} AXMg_r$

(114) $APMg_r = \sum_i a_{r,i}^{Mg} PP_{r,i}$

Goods Market Equilibrium

(115) $XD_{r,i}^s = XD_{r,i}^d$

(116) $WTF_{r,r',i}^d = \lambda_{r,r',i}^w WTF_{r,r',i}^s$

Domestic Closure

(117)
$$\begin{aligned} YG_r = & \sum_i \tau_{r,i}^p \left(1+\pi_{r,i}\right) PX_{r,i} XP_{r,i} + \sum_h \chi_r^h \kappa_{r,h}^h YH_r \\ + & \sum_i \sum_j \tau_{r,i,j}^{Ap} PA_{r,i} XAp_{r,i,j} + \sum_h \sum_i \tau_{r,i,h}^{Ac} PA_{r,i} XAc_{r,i,h} + \sum_i \sum_f \tau_{r,i,f}^{Af} PA_{r,i} XAf_{r,i,f} \\ + & \sum_i \sum_{r'} \tau_{r',r,i}^m WPM_{r',r,i} WTF_{r',r,i}^d + \sum_i \sum_{r'} \tau_{r,r',i}^e PE_{r,r',i} WTF_{r,r',i}^s \\ + & \sum_i \sum_{ll} \tau_{r,ll,i}^l NW_{r,ll,i} L_{r,ll,i}^d + \sum_i \sum_v \tau_{r,i,vi}^k NR_{r,i,v} Kv_{r,i,v}^d + \sum \tau_{r,i}^t NPT_{r,i}\, T_{r,i}^d \end{aligned}$$

(118) $S^g = YG - PFD_{Gov} FD_{Gov} - \sum_h PGDP\, TRG_h$

(119) $RS^g = S^g / PGDP$

(120) $FD_{Gov} = \chi_{Gov} RGDPMP$

(121) $PFD_{Inv,r*} FD_{Inv,r*} = \sum_h \left[S_{h,r*}^h + DeprY_h^{r*} \right] + S_{r*}^g + P\, S_{r*}^f$

(122) $$P = \frac{\sum_{r \in OECD} \sum_{r'} \sum_{i \in Manu} WPE_{r,r',i} WTF_{r,r',i,0}}{\sum_{r \in OECD} \sum_{r'} \sum_{i \in Manu} WPE_{r,r',i,0} WTF_{r,r',i,0}}$$

Factor Markets

Labor Markets

(123)
$$\begin{cases} L_{ll}^s = \chi_{ll}^l \left(\dfrac{TW_{ll}}{PABS} \right)^{\omega_{ll}^L} & \text{if} \quad 0 \le \omega_{ll}^L < \infty \\ TW_{ll} = PABS\, TW_{ll,0} & \text{if} \quad \omega_{ll}^L = \infty \end{cases}$$

(124) $\sum_j L_{ll,j}^d = L_{ll}^s$

(125) $W_{ll,j} = \Phi_{ll,j} TW_{ll}$

(126) $W_{ll,j} = \left(1+\tau^{l}_{ll,j}\right) NW_{ll,j}$

Land Market

(127) $$\begin{cases} TLnd = \chi^{T}\left(\dfrac{PTLnd}{PABS}\right)^{\eta^{T}} & \text{if} \quad 0 \le \eta^{T} < \infty \\ PTLnd = PABS\ PTLnd_{0} & \text{if} \quad \eta^{T} = \infty \end{cases}$$

(128) $$\begin{cases} PTLnd = \left[\sum_{i} \gamma_{i}^{T} PT_{i}^{1+\omega^{t}}\right]^{1/\left(1+\omega^{T}\right)} & \text{if} \quad 0 \le \omega^{T} < \infty \\ TLnd = \sum_{i} T_{i}^{d} & \text{if} \quad \omega^{T} = \infty \end{cases}$$

(129) $$\begin{cases} T_{i}^{s} = \gamma_{i}^{T}\left(\dfrac{PT_{i}}{PTLnd}\right)^{\omega^{T}} TLnd & \text{if} \quad 0 \le \omega^{T} < \infty \\ PT_{i} = PTLnd & \text{if} \quad \omega^{T} = \infty \end{cases}$$

(130) $T_{i}^{d} = T_{i}^{s}$

(131) $PT_{i} = \left(1+\tau_{i}^{t}\right) NPT_{i}$

Sector-specific Factors

(132) $$\begin{cases} F_{i}^{s} = \chi_{i}^{F}\left(\dfrac{PF_{i}}{PABS}\right)^{\omega^{F}} & \text{if} \quad 0 \le \omega^{F} < \infty \\ PF_{i} = PABS\ PF_{i,0} & \text{if} \quad \omega^{F} = \infty \end{cases}$$

(133) $F_{i}^{s} = F_{i}^{d}$

Capital Market in a Single Vintage Framework

(134) $$\begin{cases} KS_{i}^{s} = \gamma_{i}^{k}\left(\dfrac{R_{i}}{TR}\right)^{\omega^{K}} K^{s} & \text{if} \quad 0 \le \omega^{K} < \infty \\ R_{i} = TR & \text{if} \quad \omega^{K} = \infty \end{cases}$$

(135) $$\begin{cases} TR = \left[\sum_i \gamma_i^k \left(R_i\right)^{1+\omega^K} \right]^{1/\left(1+\omega^K\right)} & \text{if} \quad 0 \le \omega^K < \infty \\ \sum_i K_i^d = K^s & \text{if} \quad \omega^K = \infty \end{cases}$$

(136) $$\sum_i K_i^d = KS_i^s$$

Capital Market Equilibrium in a Multiple Vintage Framework

(137) $$\chi_{i,v}^v = \frac{Kv_{i,v}^d}{XPv_{i,v}}$$

(138) $$K_{i,t}^0 \left(RR_{i,t}\right)^{\eta_i^k} \le \chi_{i,Old}^v XP_i \quad \text{and} \quad RR_{i,t} \le 1$$

(139) $$\sum_i \sum_v Kv_{i,v,t}^d = K_t^s$$

(140) $$NR_{i,Old,t} = RR_{i,t} TR_t$$

(141) $$NR_{i,New,t} = TR_t$$

(142) $$R_{i,v,t} = \left(1 + \tau_{i,v,t}^k\right) NR_{i,v,t}$$

Allocation of Output across Vintages

(143) $$XP_i = \sum_v XPv_{iv}$$

(144) $$XPv_{i,Old,t} = K_{i,t}^0 \left(RR_{i,t}\right)^{\eta_i^k} / \chi_{i,Old,t}^v$$

Aggregate Capital Stock in a Recursive Dynamic Framework

(145) $$FD_{Inv,t} = \left(1 + \gamma^I\right)^n FD_{Inv,t-n}$$

(146) $$K_t = \left(1 - \delta\right)^n K_{t-n} + \frac{\left(1 + \gamma^I\right)^n - \left(1 - \delta\right)^n}{\gamma^I + \delta} FD_{Inv,t-n}$$

(147) $$K_t^s = \frac{K_0^s}{K_0} K_t$$

Other Equations and Definitions

$$(148)\quad \begin{aligned} RGDPMP_r \;=\; & \sum_i \left[\sum_h \left(1+\tau^{Ac}_{r,i,h,0}\right) PA_{r,i,0} XAc_{r,i,h} + \sum_f \left(1+\tau^{Af}_{r,i,f,0}\right) PA_{r,i,0} XAf_{r,i,f} \right] \\ + \; & \sum_i \sum_{r'} \left(WPE_{r,r',i,0} WTF^s_{r,r',i} - WPM_{r',r,i,0} WTF^d_{r',r,i} \right) + APMg_{r,0} AXMg_r \end{aligned}$$

$$(149)\quad RGDP = \sum_i AT_i \left[\lambda^t_i NPT_{i,0} T^d_i + \lambda^f_i PF_{i,0} F^d_i + \sum_{ll} \lambda^l_{ll,i} NW_{ll,i,0} L^d_{ll,i} + \sum_v \lambda^k_{i,v} NR_{i,v,0} Kv^d_{i,v} \right]$$

$$(150)\quad PGDP\ RGDP = \sum_h \left[YH_h + DeprY_h - PGDP\ TRG_h \right] - \sum_i \pi_i PX_i XP_i$$

$$(151)\quad PABS = \frac{\sum_i PA_i XA_i}{\sum_i PA_{i,0} XA_i}$$

$$(152)\quad \sum_i \sum_{r'} WPE_{r,r',i} WTF^s_{r,r',i} + APMg_r AXMg_r + P\,S_f = \sum_i \sum_{r'} WPM_{r',r,i} WTF^d_{r',r,i}$$

A.2. Model Dynamics

Endogenous Dynamic Equations

$$(153)\quad RGDPMP_t = \left(1+g^y\right)^n RGDPMP_{t-n}$$

$$(154)\quad \lambda^l_{ll,ik,t} = \left(1+\gamma^l_t + \chi^p_{ik,t} + \pi_{ik,t}\right)^n \lambda^l_{ll,ik,t-n}$$

$$(155)\quad \chi^p_{i,t} = \phi^p_{i,t} \left(\frac{ES_{i,t}}{XP_{i,t}} \right)^{\eta^p_i}$$

$$(156)\quad \chi^p_{ik,t} = \alpha^p_{ik,t} \left(\gamma^l_t + \chi^p_{ik,t} + \pi_{ik,t} \right)$$

$$(157)\quad \lambda^l_{ll,ink,t} = \left[1 + \chi^p_{ink.t} + \left(1-\alpha^p_{ink.t}\right)\gamma^s_{ink.t} \right]^n \lambda^l_{ll,ink,t-n}$$

$$(158)\quad \lambda^k_{ink,v,t} = \left[1 + \chi^p_{ink,t} + \left(1-\alpha^p_{ink,t}\right)\gamma^s_{ink,t} \right]^n \lambda^l_{ink,v,t-n}$$

$$(159)\quad \lambda^t_{ink,t} = \left[1 + \chi^p_{ink,t} + \left(1-\alpha^p_{ink,t}\right)\gamma^s_{ink,t} \right]^n \lambda^t_{ink,t-n}$$

$$(160)\quad \lambda^f_{ink,t} = \left[1 + \chi^p_{ink,t} + \left(1-\alpha^p_{ink,t}\right)\gamma^s_{ink,t} \right]^n \lambda^f_{ink,t-n}$$

Exogenous Dynamic Equations

(161) $Pop_t = \left(1 + g^{Pop}\right)^n Pop_{t-n}$

(162) $\chi_t^L = \left(1 + g^L\right)^n \chi_{t-n}^L$

(163) $\chi_t^T = \left(1 + g^T\right)^n \chi_{t-n}^T$

(164) $\chi_{i,t}^F = \left(1 + g^F\right)^n \chi_{i,t-n}^F$

(165) $K_{i,t}^0 = \sum_v \left(1 - \delta\right)^n Kv_{i,v,t-n}^d$

(166) $\lambda_{ip,t}^t = \left(1 + \gamma_t^t\right)^n \lambda_{ip,t-n}^t$

(167) $\lambda_{ip,t}^f = \left(1 + \gamma_t^f\right)^n \lambda_{ip,t-n}^f$

(168) $\lambda_{e,j,t}^{ep} = \left(1 + \gamma_{e,j,t}^e\right)^n \lambda_{e,j,t}^{ep}$

A.3 Definitions of Variables

Production Variables

Crops

ND	Demand for aggregate non-energy non-fertilizer intermediate demand	*r* x *cr*
VA	Demand for value added+energy+ fertilizer bundle	*r* x *cr* x *v*
PXv	Unit cost of production by vintage	*r* x *cr* x *v*
PX	Average unit cost of production	*r* x *cr*
PP	Producer price	*r* x *cr*
AL	Demand for aggregate labor (x/ 'highly skilled')	*r* x *cr*
HKTEF	Demand for capital+energy+fertilizer+land bundle	*r* x *cr* x *v*
PVA	Price of value added+energy+fertilizer bundle	*r* x *cr* x *v*
L^d	Demand for labor (x/ 'highly skilled')	*r* x *cr* x *l*
AW	Aggregate sectoral wage (x/ 'highly skilled')	*r* x *cr*
HKTE	Demand for capital+energy+land bundle	*r* x *cr* x *v*
Fert	Demand for fertilizer	*r* x *cr*
PHKTEF	Price of capital+energy+fertilizer+land bundle	*r* x *cr* x *v*
XEp	Demand for aggregate energy bundle	*r* x *cr* x *v*
HKT	Demand for bundle of capital plus land	*r* x *cr* x *v*
PHKTE	Price of capital+energy+land bundle	*r* x *cr* x *v*
L_{Hsk}	Demand 'highly' skilled labor	*r* x *cr*
KT	Demand for bundle of capital plus land	*r* x *cr* x *v*
PHKT	Price of capital (human and physical)+land bundle	*r* x *cr* x *v*

T^d	Demand for land	*r* x *cr*
F^d	Demand for sector-specific factor	*r* x *cr*
Kv^d	Demand for capital (by vintage)	*r* x *cr* x *v*
PKT	Price for bundle of capital plus land	*r* x *cr* x *v*
XAp	Demand for (Armington) intermediate goods	*r* x *cr* x *j*
PND	Price of aggregate non-energy intermediate goods	*r* x *cr*
PEp	Price of aggregate energy bundle	*r* x *cr* x *v*
Pfert	Price for fertilizer	*r* x *cr*

Livestock

ND	Demand for aggregate non-energy non-feed intermediate demand	*r* x *lv*
VA	Demand for value added+energy+feed bundle	*r* x *lv* x *v*
PXv	Unit cost of production by vintage	*r* x *lv* x *v*
PX	Average unit cost of production	*r* x *lv*
PP	Producer price	*r* x *lv*
TFD	Demand for land-feed bundle	*r* x *lv* x *v*
KTEL	Demand for capital-energy-labor composite good	*r* x *lv* x *v*
PVA	Price of value added+energy+feed bundle	*r* x *lv* x *v*
T^d	Demand for land	*r* x *lv*
Feed	Demand for feed	*r* x *lv*
PTFD	Price of land feed bundle	*r* x *lv* x *v*
AL	Demand for aggregate labor (x/ ‘highly’ skilled)	*r* x *lv*
HKTE	Demand for capital-energy bundle	*r* x *lv* x *v*
PKTEL	Price of labor-capital-energy bundle	*r* x *lv* x *v*
L^d	Demand for labor by skill (x/ ‘highly’ skilled)	*r* x *lv* x *l*
AW	Aggregate sectoral wage (x/ ‘highly’ skilled)	*r* x *lv*
XEp	Demand for aggregate energy bundle	*r* x *lv* x *v*
HKT	Demand for bundle of capital and other factors	*r* x *lv* x *v*
PHKTE	Price of capital+energy bundle	*r* x *lv* x *v*
L_{Hsk}	Demand ‘highly’ skilled labor	*r* x *lv*
KT	Demand for bundle of capital plus other factors	*r* x *lv* x *v*
PHKT	Price of capital (human and physical)+other bundle	*r* x *lv* x *v*
F^d	Demand for sector-specific factor	*r* x *lv*
Kv^d	Demand for capital (by vintage)	*r* x *lv* x *v*
PKT	Price for bundle of capital plus land	*r* x *lv* x *v*
XAp	Demand for (Armington) intermediate goods	*r* x *lv* x *j*
PND	Price of aggregate non-energy intermediate goods	*r* x *lv*
PEp	Price of aggregate energy bundle	*r* x *lv* x *v*
Pfeed	Price of feed	*r* x *lv*

Non-agricultural sectors

ND	Demand for aggregate non-energy intermediate demand	*r* x *ip*
VA	Demand for value added+energy bundle	*r* x *ip* x *v*
PXv	Unit cost of production by vintage	*r* x *ip* x *v*
PX	Average unit cost of production	*r* x *ip*
PP	Producer price	*r* x *ip*

AL	Demand for aggregate labor (x/ ‘highly’ skilled)	*r* x *ip*
HKTE	Demand for capital+energy bundle	*r* x *ip* x *v*
PVA	Price of value added+energy bundle	*r* x *ip* x *v*
L^d	Demand for labor by skill (x/ ‘highly’ skilled)	*r* x *ip* x *l*
AW	Aggregate sectoral wage (x/ ‘highly’ skilled)	*r* x *ip*
XEp	Demand for aggregate energy bundle	*r* x *ip* x *v*
HKT	Demand for bundle of capital plus other resources	*r* x *ip* x *v*
PHKTE	Price of capital+energy bundle	*r* x *ip* x *v*
L_{Hsk}	Demand ‘highly’ skilled labor	*r* x *ip*
KT	Demand for bundle of capital plus other factors	*r* x *ip* x *v*
PHKT	Price of capital (human and physical)+other bundle	*r* x *ip* x *v*
T^d	Demand for land	*r* x *ip*
F^d	Demand for sector-specific resources	*r* x *ip*
Kv^d	Demand for capital (by vintage)	*r* x *ip* x *v*
PKT	Price for bundle of capital plus other resources	*r* x *ip* x *v*
XAp	Demand for (Armington) intermediate goods	*r* x *ip* x *j*
PND	Price of aggregate non-energy intermediate goods	*r* x *ip*
PEp	Price of aggregate energy bundle	*r* x *ip* x *v*

Income Variables

TY	Aggregate land remuneration	*r*
FY	Aggregate sector-specific factor remuneration	*r*
LY	Aggregate labor remuneration (by skill)	*r* x *ll*
KY	Aggregate capital remuneration	*r*
YH	Gross household income	*r* x *h*
DY	Depreciation allowance	*r* x *h*
Yd	Disposable household income	*r* x *h*

Final Demand Variables

Y^*	Supernumerary income	*r* x *h*
XAc	Household (Armington) demand for goods and services	*r* x *i* x *h*
S^h	Household saving	*r* x *h*
CPI	Consumer price index	*r* x *h*
XAf	Other final (Armington) demand for goods and services	*r* x *i* x *f*
PFD	Aggregate price index for other final demand	*r* x *f*

Trade Variables

XA	Aggregate Armington demand	*r* x *i*
XD	Domestic demand for domestic production[a]	*r* x *i*
XMT	Domestic demand for aggregate imports	*r* x *i*
PA	Armington price	*r* x *i*
WTF	Trade flow matrix[b]	*r* x *r* x *i*
PMT	Price of aggregate imports	*r* x *i*

PD	Price of domestic goods sold locally	*r* x *i*
ES	Aggregate supply of exports	*r* x *i*
XP	Aggregate domestic output	*r* x *i*
WPE	Determination of bilateral (world) export prices	*r* x *r* x *i*
PPE	Price of aggregate exports	*r* x *i*
WXMg	Volume of world demand for international trade and transport services	1
AXMg	Regional supply of international trade and transport services	*r*
WPMg	Aggregate world price of international trade and transport services	1
XMg	Regional sectoral demand for goods and services related to trade	*r* x *i*
APMg	Regional supply price of international trade and transport services	*r*

Domestic Closure Variables

YG	Aggregate government revenue	*r*
S^g	Government saving (or deficit)	*r*
RS^g	Real government saving (or deficit)	*r*
FD_{Gov}	Aggregate volume of government expenditures on goods and services	*r*
FD_{Inv}	Aggregate volume of investment expenditures on goods and services[c]	*r*-1
P	Price index of OECD exports	1

Factor Market Variables

L^s	Aggregate labor supply	*r* x *ll*
TW	Economy-wide equilibrium wage	*r* x *ll*
W	Sector-specific wage	*r* x *ll* x *i*
NW	After tax wage	*r* x *ll* x *i*
TLnd	Aggregate land supply	*r*
PTLnd	Economy-wide land price	*r*
T^s	Sectoral land supply	*r* x *i*
PT	Sectoral-specific land price	*r* x *i*
NPT	After tax land price	*r* x *i*
F^s	Supply of sector-specific factors	*r* x *i*
PF	Price of sector-specific factor	*r* x *i*
KS^s	Supply of sectoral capital[d]	*r* x *i*
TR	Economy-wide rental rate	*r*
R	Sector and vintage specific rental rate	*r* x *i* x *v*
NR	Sector and vintage specific rental rate after tax	*r* x *i* x *v*
RR	Relative price of *Old* to *New* capital[e]	*r* x *i*
χ^v	Capital-output ratio[f]	*r* x *i*
XPv	Output by vintage	*r* x *i* x *v*
γ^I	Rate of real investment growth	*r*
K	Aggregate capital stock (non-normalized)	*r*
K^s	Aggregate capital stock (normalized)	*r*

Other Variables

RGDPMP	Real GDP at market price	*r*
RGDP	Real GDP at factor cost	*r*
PGDP	GDP deflator (at factor cost)	*r*
PABS	Price index of aggregate domestic absorption	*r*
g^y	Growth rate of real GDP (at factor cost)[g]	*r*
λ^l	Labor productivity factor	*r* x *ll* x *ik*
χ^p	Trade-sensitive productivity shifter	*r* x *i*
ϕ^p	Productivity shifter calibration parameter[h]	*r* x *ik*
λ^l	Exogenous labor productivity factor	*r* x *ll* x *ink*
λ^k	Exogenous capital productivity factor	*r* x *ink* x *v*
λ^t	Exogenous land productivity factor	*r* x *ink*
λ^f	Exogenous sector-specific factor productivity factor	*r* x *ink*