China's Emergence and the Implications of Prospective Free Trade Agreements in East Asia

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Abstract

China's accelerated global emergence has changed trade patterns in the Asia-Pacific region and exerted important influence on its trilateral relationship with Japan and the United States. In this paper, we evaluate the effects of multilateral and regional trade policy scenarios that are particularly relevant to China, Japan, and the United States using a dynamic global computable general equilibrium (CGE) model. Our results suggest that the three countries would gain substantially from a trilateral free trade agreement and could realize large fractions of the residual gains from global trade liberalization. We contrast this with prospective free trade agreements (FTAs) in East Asia, and we find that these FTAs largely benefit smaller member economies (e.g., ASEAN countries).

JEL classifications: F13; F15

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1. Introduction

Over the last decade, a new landscape of economic relations has begun to emerge in the Pacific Basin. As conflicts and rivalries between the United States and Japan appear to have receded and the agenda of globalization has advanced, more countries are embracing outward economic orientation and open multilateralism as a means of accelerating domestic economic growth. Most prominent of the later entrants in the regional arena is China, whose domestic economic reforms have led it to record growth rates, dramatically accelerating export expansion and sharply raising living standards. Since its entry to the WTO in December 2001, China has speeded up its domestic and external liberalization.

The emergence of China as a major trading partner has important implications for the U.S.-Japan bilateral relationship in particular and the evolution of Asian Pacific trade patterns generally. Because of its size and stage of development, China will play two roles in the region with unusual prominence. First, it is likely to strengthen its export competitiveness in a wider range of products. Second, the size of China's growing internal market will make it the largest East Asian importer of East Asian goods. Thus China interposes itself between the rest of East Asia and the U.S.-Japan as an export and import competitor, respectively. Asia's newly industrialized economies (NIEs) have played such a role in the past, but none are comparable to China in size or scope of potential regional influence.

Clearly, the emergence of China into this new economic prominence will be most successful if it can be accommodated into a framework of regional cooperation, particularly with respect to the most influential economies, the United States and Japan. It is not enough to simply argue that all three should get along, however, since the evolution of domestic economic conditions and external trade patterns will exert important influences on policy in all three countries. A more realistic way to promote the smooth evolution of open multilateralism in the region would be to clearly elucidate the interests and potential rewards to participating countries.

In the past decade the number of regional integration agreements (RIAs) has proliferated rapidly. Japan and Singapore signed a New-Age Economic Partnership in

January 2002, Korea's National Assembly ratified Korea-Chile free trade agreement (FTA) in February 2004, and Japan and Mexico reached final accord on an FTA in March 2004. A large number of FTAs involving countries in the Asia-Pacific region are currently being negotiated, including ASEAN-China FTA, ASEAN-Japan FTA, and Japan-Korea FTA. The ASEAN+3 group, consisting of ASEAN countries, China, Japan, and Korea, has emerged primarily to provide a framework for establishing East Asian leadership and influence on regional and international affairs (Drysdale, 2002), and it has provided an effective mechanism for greater cooperation and gradual regional economic integration in East Asia. The trends in negotiating for new RIA are likely to continue.

Whether regional agreements are a facilitating intermediate step towards global free trade or a hindrance to greater global trade liberalization is a hotly debated issue (e.g., Krueger, 1999a; Laird, 1999; Panagariya, 2000). Proponents for regional integration argue that RIAs encourage member countries to liberalize beyond the level committed by multilateral negotiations and that they make tough negotiating issues easier to handle (e.g., Dutta, 2000; Kahler, 1995). In addition, RIAs 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).[1] Opponents worry that the proliferation of RIAs is likely to undermine the multilateral trading system and that beneficiaries of RIAs might form a political lobby to deter further multilateral liberalization (e.g., Bhagwati, 1995; Levy, 1997; Srinivasan, 1998ab; Panagariya, 1999).

Empirical evidence on benefits and costs of RIAs suggests that trade creation exceeds trade diversion in almost all RIAs (Robinson and Thierfelder, 1999). The positive effect on economic welfare resulting from the European Union (EU) and North American Free Trade Agreement (NAFTA) is supported by Brown, Deardorff, and Stern (1992), Harrison, Rutherford, and Tarr (1996), Lee and van der Mensbrugghe (2004), and Roland-Holst, Reinert, and Shiels (1992). However, Yeats (1998) finds that during 1988-94 Mercosur countries experienced significant trade diversion when their intra-Mercosur trade increased sharply.

[1] Ethier (1998) suggests that small-country members are induced to lock in their liberalized trade regimes and that RIAs are congruent with further multilateral liberalization.

Using a dynamic global computable general equilibrium (CGE) model, we evaluate the effects of prospective free trade agreements involving East Asian countries, including China-Japan-U.S. FTA. In addition, we examine the effects of China's unilateral trade liberalization and global trade liberalization. The next section provides the trends in trilateral trade among China, Japan, and the United States during the 1980-2002 period. An overview of the model is given in section 3, followed by a brief description of scenarios and assessments of computational results in section 4. The final section summarizes the main policy conclusions.

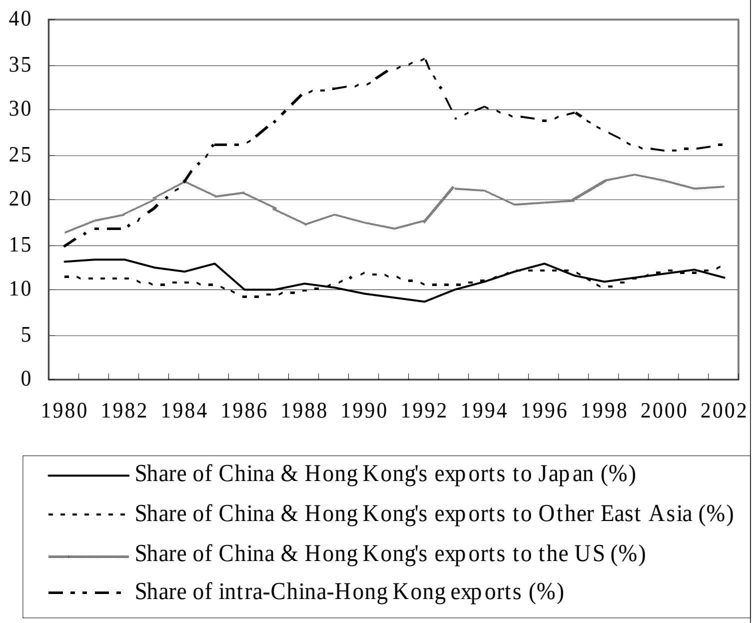
2. Trilateral Trade among China, Japan, and the United States, 1980-2002

Figures 1 and 2 provide trends in China and Hong Kong's shares of merchandise trade with Japan, other East Asia, the United States, and each other (i.e., intra-China-Hong Kong trade). Three arresting features are readily observed from these figures. First, trade between China and Hong Kong as the ratio of their total trade surged from 12-15 percent in 1980 to about one-third in 1991-92, before falling off to about one-fourth in the past several years. Significant portions of Hong Kong's trade with China are entrepôt trade or re-exports (Hong Kong, Census and Statistics Department, various years). Until the early 1990s, China-Hong Kong trade as the share of their total trade continued to rise as China's growing trade with East Asian countries, particularly with Korea and Taiwan, passed through Hong Kong.

Second, the United States has been the largest export destination country for China and Hong Kong, and the share of Chinese (including Hong Kong) exports to the United States has increased in the past decade. In contrast, the share of its imports from the United States has steadily declined over the 1980-2002 period, thereby widening China's trade surplus with the United States in recent years.

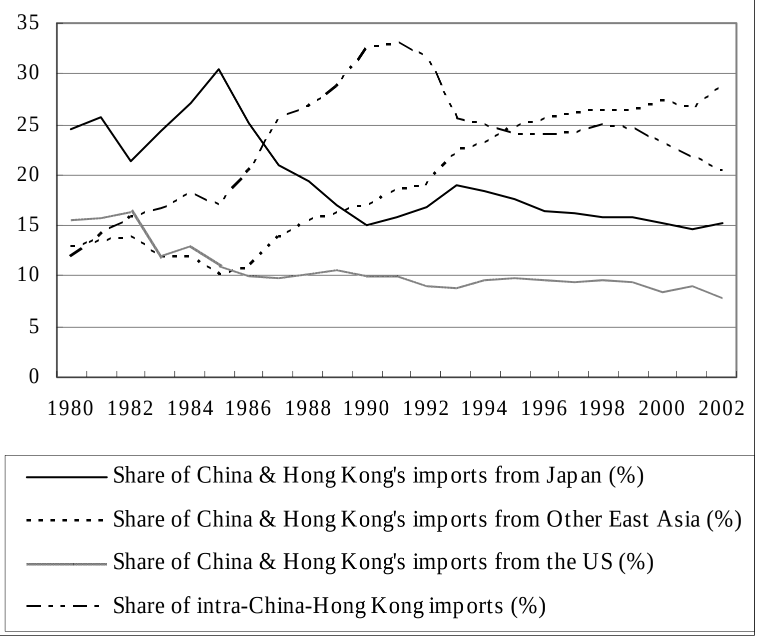
Third, the share of Chinese imports from Japan has also declined from the mid-1980s although Japan still remains the largest single exporter to China. However, a group of other East Asian countries' exports to China surpassed Japanese exports in 1990 and continued to grow very rapidly in the past decade. The shares of Chinese exports to both Japan and other East Asia have remained relatively stable since 1980.

Figure 1. Trends in China & Hong Kong's Exports to Japan, Other East Asia, and the United States



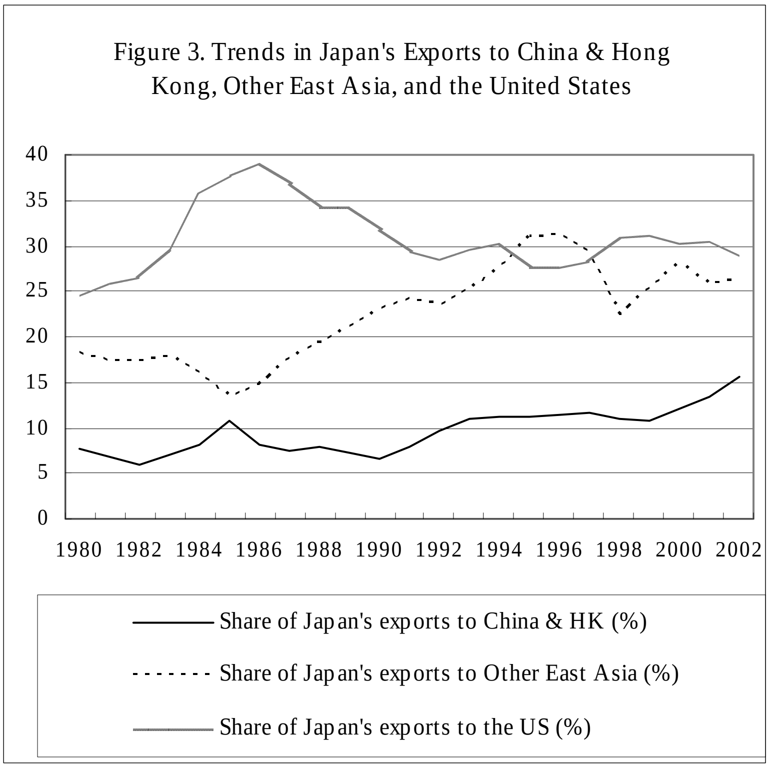
Sources: International Centre for the Study of East Asian Development (2004); International Monetary Fund, *Direction of Trade Statistics Yearbook*, various years.

Figure 2. Trends in China & Hong Kong's Imports from Japan, Other East Asia, and the United States



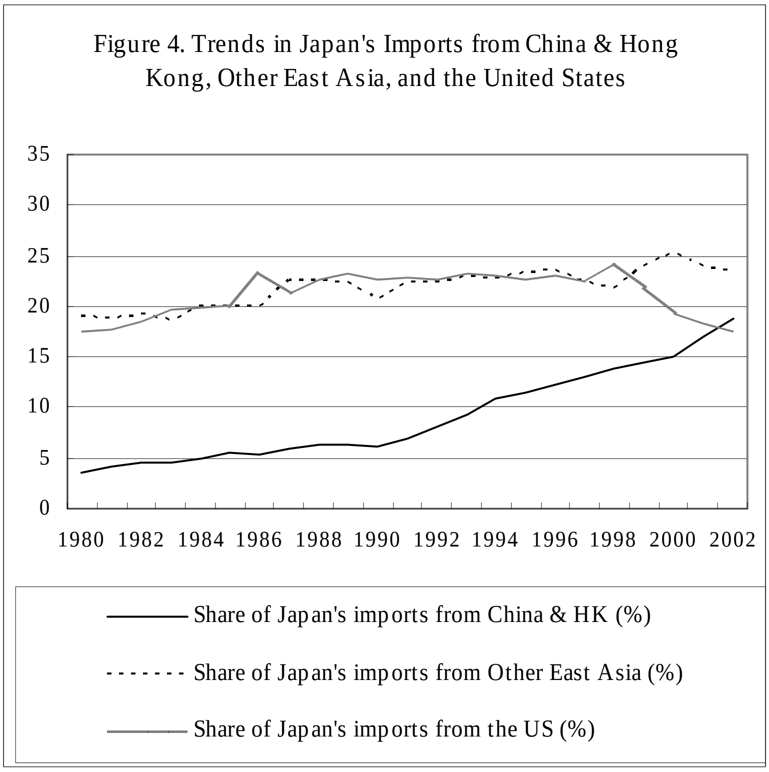
Sources: Same as Figure 1.

Figures 3 and 4 provide trends in Japan's shares of merchandise trade with China and Hong Kong, other East Asia, and the United States during the period 1980-2002. Similar to China, the largest share of Japanese exports is destined to the United States, peaking at 39 percent in 1986 and hovering around 30 percent since 1990. During the 1985-1996 period, the share of Japanese exports to other East Asia surged from 13 percent to 31 percent. Its exports to crisis-hit Asian countries fell drastically in 1997 and 1998 before recovering in 1999 and 2000. Since 1990, the share of Japanese exports to China has steadily increased.[2]



Sources: Same as Figure 1.

[2] The fact that Japan's exports to China and other East Asia has increased trade during the 1985-96 period might be explained by the rapid average growth of the importing countries (Frankel, 1993; Frankel, Stein, and Wei, 1998). Bilateral trade would be affected by the partner country's growth rate of real GDP and changes in relative openness.



Sources: Same as Figure 1.

On the import side, the share of Japanese imports from China increased dramatically from 6 percent in 1990 to 19 percent in 2002. The shares of imports from other East Asia and the United States remained relatively stable until 1998. During 1998-2002, the imports from other East Asia increased while those from the United States stagnated. Comparisons of the trend in the shares of Chinese exports to Japan in Figure 1 and that of Japanese imports from China (including Hong Kong) in Figure 4, as well as comparisons of the trend in the shares of Chinese imports from Japan in Figures 2 and that of Japanese exports to China in Figure 3, make evident that China (including Hong Kong)'s trade grew much more rapidly than Japan's during the 1980-2002 period.

Since trends in the U.S. share of merchandise trade with China (including Hong Kong) and Japan may be deduced from Figures 1-4, we omit corresponding graphs for the United States. Japan is the second largest trading partner for the United States after Canada, whereas China is the third largest supplier of U.S. imports. Both countries have been running extremely large trade surpluses with the United States, accounting for 36-70 percent of U.S. merchandise trade deficits during the 1990-2002 period (International Monetary Fund, *Direction of Trade Statistics Yearbook*, various years). Until 1999 Japan was the largest bilateral deficit partner-country for the United States, but since 2000 China has become the largest deficit partner-country, accounting for 22 percent of U.S. merchandise trade deficits of $509 billion in 2002.

3. 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 (2003).[3] It spans the period 1997-2015 and is a relatively standard neoclassical CGE, with constant returns to scale in all sectors, perfect competition and price-clearing behavior in all markets. The model incorporates three types of production structure—crops, livestock, and manufacturing and services. The first distinguishes intensive (chemical- and labor-based) farming versus extensive (land-based) farming. Livestock production is characterized by ranch- versus range-fed cattle. All other sectors conform to the more standard labor-capital substitution effects, albeit with sufficient structure to capture the complex interactions across various inputs and factors of production (see Figure 5).[4]

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.

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[3] See the Appendix for the model equations. To some extent, this section replicates Lee and van der Mensbrugghe (2004, section 2).

[4] At the top nest, production is formed by the combination of aggregate intermediate demand other than energy (*ND*) and value added plus energy (*VA*). The second nest consists of two nodes. The first node decomposes aggregate intermediate demand into sectoral demand for goods and services. The second node decomposes *VA* between demand for aggregate labor (*L*) and demand for human capital, physical capital, energy, and sector-specific factor bundle (*HKTE*). The third and subsequent nodes are decomposed by a similar fashion, as illustrated in Figure 5.

Figure 5. Production Nesting in the Manufacturing and Services Sectors

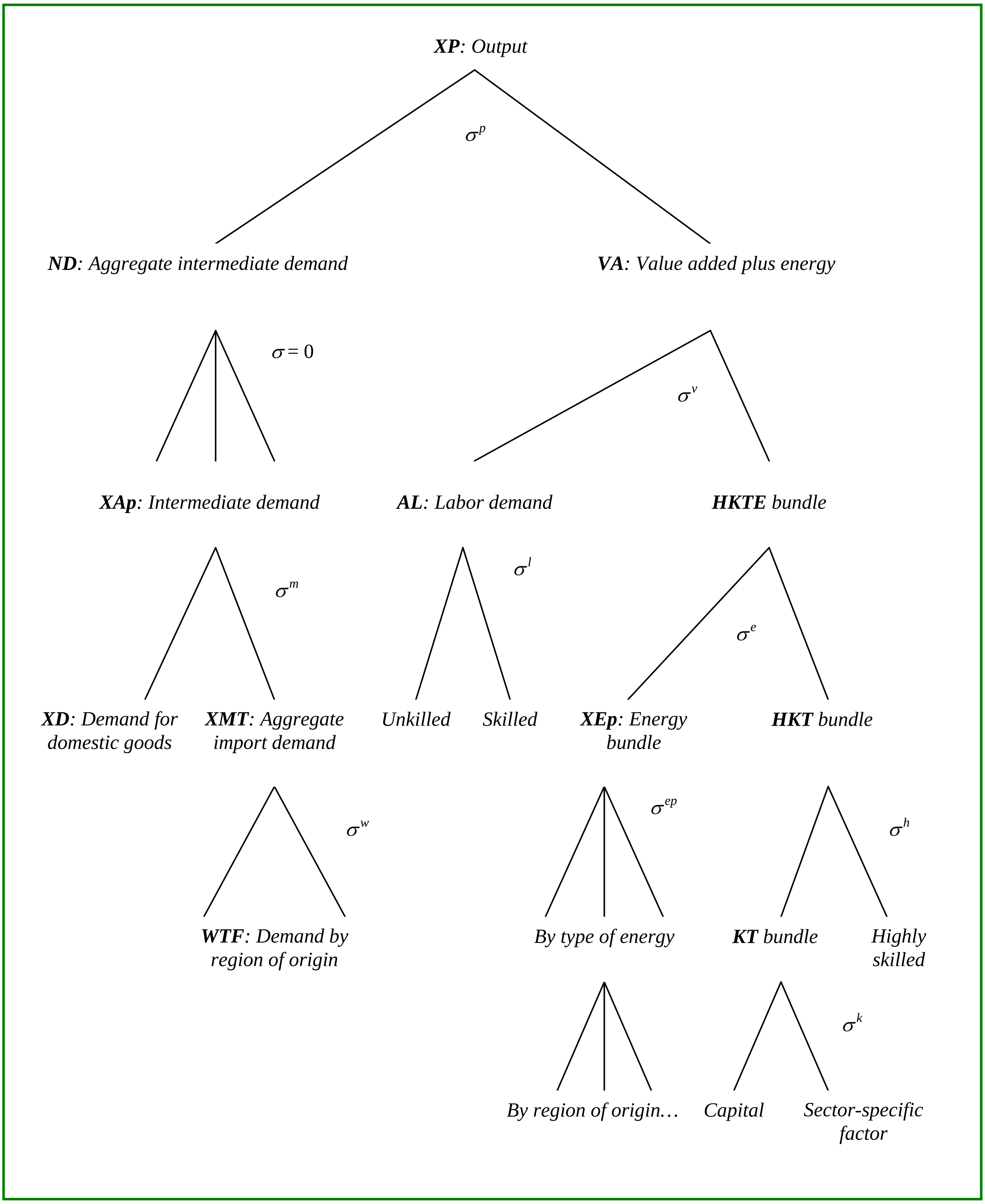

Figure 5 (continued)

Definition of variables and parameters:

XP:	Output (by vintage)
ND:	Demand for aggregate non-energy intermediate demand
VA:	Demand for labor, capital, energy, and sector-specific factor bundle
XAp:	Demand for (Armington) intermediate goods (excluding energy)
XD:	Demand for domestically produced intermediate goods
XMT:	Aggregate import demand for intermediate goods
WTF:	Demand for imported intermediate goods by region of origin
AL:	Demand for aggregate labor (excluding 'highly' skilled)
HKTE:	Demand for human and physical capital, energy, and sector-specific factor bundle
XEp:	Demand for aggregate energy bundle
HKT:	Demand for human capital, physical capital, and sector-specific factor bundle
KT:	Demand for physical capital and sector-specific factor bundle
σ^p:	Elasticity of substitution between *ND* and *VA*
σ^v:	Elasticity of substitution between *AL* and *HKTE*
σ^l:	Elasticity of substitution between unskilled and skilled labor
σ^e:	Elasticity of substitution between *XEp* and *HKT*
σ^{ep}:	Elasticity of substitution between different type of energy
σ^h:	Elasticity of substitution between *KT* and highly skilled labor
σ^k:	Elasticity of substitution between physical capital and sector-specific factor

Note: The sector-specific factor includes land in agricultural sectors and the resource base in the coal, crude oil, natural gas, and mining sectors.

Trade is modeled using the ubiquitous Armington assumption of imperfect substitution, i.e., goods are differentiated by region of origin. 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,[5] represented by the iceberg parameter λ.[6] Thus the relationship between the FOB price and the CIF price is given by

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

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.

Dynamics in this model is recursive. Population and labor supply growth are exogenous. Land and (sector-specific) natural resources supply curves are price-sensitive within period, but land is only partially mobile across agricultural sectors. Capital accumulation is based on past savings and investment. 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.

The final important ingredient in the dynamic behavior of the model regards the productivity assumptions. Agricultural productivity is given in the baseline. Productivity in manufacturing and services is calibrated in order to achieve some target for real per capita GDP growth.[7] In these sectors, productivity is the sum of three components. There is a sector-specific component, a component linked to the sectoral export-output ratio (the ‘openness’ component), and an economywide component. The latter is the calibration component (i.e., one target-one instrument). The sector-specific component is based on an aggregate assumption, typically that productivity is some percentage point higher in manufacturing than in services (e.g., 2 percentage points). The openness component is calibrated in the baseline so that it explains a specified share of total sectoral productivity.

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[5] 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).

[6] A rise in λ represents an improvement in trade ‘efficiency’ and thus a reduction in trade cost. This could correspond to a reduction in administrative barriers to trade (e.g., customs procedures) and/or a lower technical barrier (e.g., mutual recognition of technical standards in production, packaging and marketing).

[7] Productivity is assumed to be labor-augmenting.

In policy reforms scenario, this component ($\chi_{i,t}$) is assumed to be endogenous, i.e., it changes with the ratio of exports to output:

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

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. For example, if manufacturing productivity in the baseline is 4 percent in some year, the openness component explains 50 percent of total sectoral productivity, and the export-output ratio increases by 10 percent, then productivity would increase by 5 percent (to 4.2 percent) assuming the openness elasticity is one.[8]

Previous studies have shown that two additional factors that are not incorporated in the present model would significantly boost the gains from trade. First, Harris (1984), Brown and Stern (1989), and Francois and Roland-Holst (1997), among others, have demonstrated that incorporation of increasing returns to scale and imperfect competition could lead to multiple changes in the aggregate results. Second, foreign capital flows (e.g., foreign direct investment and portfolio investment) are exogenous in the current version of the model, but 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.[9]

Most of the data used in the model come from the GTAP database, version 5.2, which provides 1997 data on input-output, value added, final demand, bilateral trade, tax

[8] Note that if the export-output ratio increases by 10 percent, then assuming $\eta_i = 1$ the openness component of productivity, $\chi_{i,t}$, increases by 10 percent. Since the other two components of productivity are exogenous, an increase in sectoral productivity is calculated as

$$[\theta_\chi (1 + g_\chi) + (1 - \theta_\chi)] - 1 = [0.5*(1 + 0.10) + (1 - 0.5)] - 1 = 0.05$$

where θ_χ is the share of sectoral productivity explained by the openness component and g_χ is the rate at which $\chi_{i,t}$ increases.

[9] See, for example, Petri (1997) and Lee and van der Mensbrugghe (2001).

and subsidy data for 76 regions and 57 sectors.[10] For the purpose of the present study, the database is aggregated into 9 regions and 18 sectors.[11]

4. Scenarios and Results

4.1 Policy Scenarios

To evaluate prospective free trade agreements in the wake of China's emergence, the following seven policy scenarios are considered:

1) China's unilateral trade liberalization

2) ASEAN-China FTA: Free trade among the ASEAN countries and China/Hong Kong

3) ASEAN-Japan FTA: Free trade among the ASEAN countries and Japan

4) ASEAN+3: Free trade among the ASEAN countries, China/Hong Kong, Japan, and Korea

5) ASEAN-China-EU: Free trade among the three regions

6) China-Japan-U.S. FTA: Trilateral trade liberalization among the emergent Pacific economies

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 plausible because China is in the process of unilaterally reducing its tariff rates and Chinese growth in part is being led by trade. Scenario 2 is expected to be

[10] Dimaranan and McDougall (2002) give detailed descriptions of the GTAP database, version 5.0. The number of regions is increased from 66 to 76 in Version 5.2, which disaggregates the Central and Eastern European regions into single countries.

[11] The 9 regions are (1) China and Hong Kong, (2) Japan, (3) Korea, (4) Taiwan, (5) ASEAN, (6) United States, (7) Canada, Australia, and New Zealand, (8) EU-15, and (9) the rest of the world. The 18 sectors are (1) rice, (2) other grains, (3) oil seeds, (4) sugar, (5) other crops, (6) livestock, (7) energy, (8) processed food, (9) textiles, (10) wearing apparel, (11) leather, (12) basic manufactures, (13) motor vehicles, (14) other transportation equipment, (15) electronic equipment, (16) other manufactures, (17) construction, and (18) services.

realized as ASEAN countries and China signed a framework agreement in 2002 to establish an FTA within 10 years. Scenario 3 that excludes sensitive sectors has also become a real possibility after ASEAN and Japan signed an agreement on the Comprehensive Economic Partnership (CEP) in November 2003.[12] Although negotiations for an FTA among the economies of ASEAN+3 have not yet begun, we include scenario 4 because a number of studies have examined the possible effects of such an arrangement (e.g., Brown, Deardorff, and Stern, 2003; Tran, 2003). In addition, as the EU is becoming more conscious of the role of China in the global economy and its potential implications, it is unlikely to remain idle. Given that it has established a cooperative relationship with ASEAN, it would be natural to consider scenario 5 in which ASEAN, China, and the EU form an FTA. The China-Japan-U.S. FTA scenario is considered because China is expected to gain a great deal if it can establish an FTA with its two largest trading partners. Finally, we have the global trade liberalization (GTL) or full WTO scenario so that the effects of the unilateral and regional scenarios may be discussed relative to the global scenario.

As observed in a number of recent FTA negotiations, some countries and regions, Japan and the EU in particular, are likely to resist liberalizing their agricultural markets. Given the continued political sensitivities associated with agricultural protection, we also run alternative versions of scenarios 2-6 in which trade barriers on agricultural products and processed food remain fixed. Altogether, we conduct 12 experiments. It should be noted that in reality trade barriers on agricultural products are lowered to some extent in many FTAs. Thus, the results of the scenarios with no reductions in trade barriers on agricultural products are likely to provide the lower bound of welfare changes.

In all 12 experiments, we gradually remove bilateral tariffs and export subsidies of the relevant sectors among the member countries over the 2005-2010 period. We set the elasticity of productivity with respect to openness, η_i, to 0.75 in agricultural sectors and to 1.0 in all other sectors. We assume that non-monetary trade costs would be reduced by 2

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

percent in all FTA scenarios, but they remain unchanged in the unilateral and global scenarios (scenarios 1 and 7).[13]

4.2 Effects on Welfare

Aggregate income gains and/or losses summarize the extent trade distortions are hindering growth prospects and the ability of economies to use the gains to help those whose income could potentially decline. We compared the four counterfactual scenarios with the baseline situation in the terminal year, 2015, using a measure of compensated or equivalent variation aggregate national income. Real income is summarized by Hicksian equivalent variation (EV). This represents the income consumers would be willing to forego to achieve post-reform well-being (u^p) compared to baseline well-being (u^b) at baseline prices (p^b):

$$EV = E\left(p^b, u^p\right) - E\left(p^b, u^b\right) \tag{3}$$

where E represents the expenditure function to achieve utility level u given a vector of prices p (superscript b represents baseline levels, and p the post-reform levels). The model uses the extended linear expenditure system (ELES), which incorporates savings in the consumer's utility function (Lluch, 1973; Howe, 1975). The ELES expenditure function is easy to evaluate at each point in time.

Table 1 summarizes the welfare results for the seven policy scenarios as deviations in EVs from the baseline in 2015. The GTL or full WTO scenario is the most attractive for almost 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.[14] This kind of uncertainty has been an important impetus to regional

[13] Smith and Venables (1988) use a 2.5 percent reduction in intra-EU trade costs in their study of the Single Market program's possible pro-competitive effects, whereas Keuschnigg and Kohler (2000) and Madsen and Sorensen (2002) use a 5 percent reduction in real costs of trade between the EU and Central and East European countries. We use a smaller reduction in these costs among the members of FTAs in scenarios 2-6 because the reductions in technical barriers are expected to be smaller in these cases than in the EU case.

[14] For example, the Fifth WTO Ministerial Conference in Cancún in September 2003 ended with no concrete agreement for the future course of the negotiations.

agreements, particularly those between small groups of nations who find consensus, implementation, and monitoring easier.

Table 1
Effects on welfare (deviations in equivalent variations from the baseline in 2015)

Region	Senarios[a]						
	(1) China Unilat	(2) ASEAN-China	(3) ASEAN-Japan	(4) ASEAN plus 3	(5) ASEAN-China-EU	(6) China-Japan-US	(7) GTL
(A) Absolute deviations (US$ billion in 1997 prices)							
China & Hong Kong	73.3	34.8	-3.0	102.3	74.1	105.3	134.8
Japan	13.5	1.4	18.2	66.3	4.8	77.3	116.1
Korea	5.0	-0.4	-1.2	30.1	-1.9	-4.3	29.1
Taiwan	5.6	-1.5	-0.7	-5.4	-2.8	-5.5	12.7
ASEAN[b]	5.4	26.0	28.4	41.8	43.0	-16.5	38.1
United States	13.8	0.8	-1.4	-0.9	-2.9	60.6	70.9
Canada & ANZ[c]	1.2	0.2	-0.4	-0.2	-0.6	-2.9	17.3
EU-15	16.9	3.9	0.2	6.8	127.9	-0.3	165.9
Rest of the world	7.9	-3.6	-2.4	-9.8	-18.4	-15.5	147.4
World	142.4	61.8	37.7	231.1	223.4	198.1	732.2
(B) Percent deviations							
China & Hong Kong	2.9	1.4	-0.1	4.0	2.9	4.1	5.3
Japan	0.3	0.0	0.4	1.6	0.1	1.9	2.8
Korea	0.6	-0.1	-0.1	3.7	-0.2	-0.5	3.6
Taiwan	1.0	-0.3	-0.1	-1.0	-0.5	-1.0	2.4
ASEAN	0.5	2.5	2.7	4.0	4.2	-1.6	3.7
United States	0.1	0.0	0.0	0.0	0.0	0.6	0.7
Canada & ANZ	0.1	0.0	0.0	0.0	0.0	-0.2	1.4
EU-15	0.2	0.0	0.0	0.1	1.5	0.0	2.0
Rest of the world	0.1	-0.1	0.0	-0.2	-0.3	-0.3	2.4
World	0.4	0.2	0.1	0.7	0.6	0.6	2.1

[a] Scenarios: (1) China's unilateral trade liberalization; (2) ASEAN-China FTA; (3) ASEAN-Japan FTA; (4) ASEAN+3 FTA: free trade among ASEAN, Japan, China/Hong Kong, and Korea; (5) ASEAN-China-EU: free trade among the three regions; (6) China-Japan-U.S. FTA; (7) global trade liberalization.

[b] Only Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam are included in ASEAN. In the GTAP database, Brunei, Cambodia, Laos, and Myanmar are aggregated into the rest of the world.

[c] Canada, Australia, and New Zealand.

When China removes its trade barriers unilaterally (scenario 1), its economic welfare is predicted to increase by $73 billion (2.9 percent) in 2015, or by more than a half of the gains it can accrue from the GTL. All the trading partners also benefit, and the gains to Taiwan, Korea, and ASEAN countries are relatively large in percentage terms. These results suggest that Chinese trade policy is not only important for the future growth of China but for the future performance of East Asian trading partners.

In the ASEAN-China FTA scenario (scenario 2), in 2015 EV of ASEAN increases by 2.5%, whereas EV of China increases by a smaller percentage (1.4%). This largely results from two factors: (1) the share of ASEAN's exports to China is significantly larger than the share of China's exports to ASEAN; (2) the exports to output ratio is substantially higher for ASEAN countries. The welfare effects on non-member countries are extremely small. When ASEAN and Japan form an FTA (scenario 3), ASEAN's EV increases by 2.7 percent, whereas the increase in Japan's EV is relatively small. Welfare of other East Asian countries (China, Korea, and Taiwan) declines slightly.

Under the ASEAN+3 FTA scenario (scenario 4), the welfare of all members increases.[15] ASEAN and Korea are expected to accrue greater welfare gains under this scenario than under the GTL primarily because they will have preferential accesses to the Chinese and Japanese markets. In particular, their exports to China increase dramatically as China is predicted to become East Asia's largest importing country after 2006. China's welfare is expected to increase by 4.0 percent compared with a 5.3 percent gain under the GTL.

If free trade among ASEAN, China, and the EU is realized (scenario 5), ASEAN is expected to capture even greater gains (4.2 percent) than under the ASEAN+3 FTA. EVs of China and the EU is predicted to increase by 2.9 percent and 1.5 percent, respectively.

The United States would clearly prefer global liberalization to any of the regional arrangements under consideration, but the China-Japan-U.S. FTA (scenario 6) could be a very attractive stepping stone to globalization. In this scenario, about 85 percent of the GTL's benefits would be obtained in exchange for liberalizing only two components of U.S. bilateral trade. The arrangement would also be incentive compatible for the other two countries. China enjoys about 78 percent of the GTL's benefits under the trilateral FTA, whereas Japan obtains two-thirds of the benefits. For these three countries, China-Japan-U.S. FTA dominates the other FTA scenarios.

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[15] When productivity does not depend upon trade, China's welfare is virtually unchanged because the deterioration in its terms of trade offsets real output gains (Lee, Roland-Holst, and van der Mensbrugghe, 2002).

Table 2

Effects on welfare when trade barriers on food and agricultural products remain fixed (deviations in equivalent variations from the baseline in 2015)

Region	Senarios				
	(8) ASEAN-China	(9) ASEAN-Japan	(10) ASEAN plus 3	(11) ASEAN-China-EU	(12) China-Japan-US
(A) Absolute deviations (US$ billion in 1997 prices)					
China & Hong Kong	21.5	-1.2	45.8	44.7	62.9
Japan	2.3	4.7	28.7	6.6	35.8
Korea	-0.5	-0.7	12.4	-1.6	-2.9
Taiwan	-1.4	-0.6	-5.2	-2.7	-5.1
ASEAN	17.2	12.3	25.9	27.4	-14.5
United States	0.7	-0.4	1.0	-2.7	45.4
Canada & ANZ	0.3	-0.1	0.2	-0.4	-1.8
EU-15	3.4	0.3	6.8	105.9	-0.2
Rest of the world	-1.9	-1.1	-4.4	-14.7	-9.4
World	41.6	13.1	111.2	162.5	110.2
(B) Percent deviations					
China & Hong Kong	0.9	-0.1	1.9	1.8	2.6
Japan	0.1	0.1	0.7	0.2	0.9
Korea	-0.1	-0.1	1.5	-0.2	-0.4
Taiwan	-0.3	-0.1	-1.0	-0.5	-1.0
ASEAN	1.7	1.2	2.6	2.7	-1.4
United States	0.0	0.0	0.0	0.0	0.5
Canada & ANZ	0.0	0.0	0.0	0.0	-0.1
EU-15	0.0	0.0	0.1	1.3	0.0
Rest of the world	0.0	0.0	-0.1	-0.2	-0.2
World	0.1	0.0	0.3	0.5	0.3

Scenarios (8)-(12) are same as scenarios (2)-(6), respectively, except that trade barriers on food and agricultural products remain fixed.

Table 2 provides the welfare results for the five FTA scenarios when trade barriers on food and agricultural products remain fixed. In the absence of agricultural liberalization, welfare gains to the member countries of prospective FTAs become significantly smaller. For example, Japan’s welfare gains from the ASEAN-Japan, ASEAN+3, and China-Japan-U.S. FTAs would be reduced by 54-74 percent when agricultural and food products are excluded from the agreements. China’s gains from the ASEAN-China, ASEAN+3, ASEAN-China-EU, and China-Japan-U.S. FTAs would be reduced by 38-55 percent. By not liberalizing agricultural trade among the member countries, a very large proportion of distortions remain, particularly in trade with Japan and the EU. In this case, economic incentives to form FTAs are greatly lessened. Because strong resistances to agricultural liberalization are likely to persist in most of the prospective FTAs considered in this study, only small concessions are expected.

4.3 Effects on Bilateral and World Trade Flows

Before examining the effects of selected regional arrangements on trade flows, we first present the world trade matrix in the baseline for the year 2015 in Table 3. We observe a number of large asymmetries in bilateral trade. For example, China's exports to other East Asian economies (Japan, Korea, Taiwan, and ASEAN) are significantly smaller than its imports from these economies, whereas its exports to the United States and the EU are almost double its imports from these regions. By contrast, Japan runs large trade surpluses with other East Asian economies. This might create greater incentives for the rest of East Asia to form an FTA with China than with Japan, particularly if the Japanese government is reluctant to open its agricultural market. For China and Japan, the United States is a very important trading partner as both countries send about one-quarter of their exports to the largest country in the world.

Tables 4 and 5 present world trade flow adjustments resulting from free trade among the ASEAN+3 countries and China-Japan-U.S. FTA, respectively. Figures are given in deviations from the baseline scenario in 2015 in billions of 1997 U.S. dollars. These tables provide the extent of trade creation and trade diversion at the aggregate level.[16] Under the ASEAN+3 FTA, China would suffer relatively large import diversion because the large increases in imports from the member countries results in reductions in imports from the non-member countries/regions. The extent of import diversion is much

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[16] We intend to examine trade creation and trade diversion at the commodity level in the future. Krueger (1999b) suggests that if reductions in imports from non-member countries are associated with increases in imports from the member countries, there would a strong presumption of trade diversion. Alternatively, as suggested by Kreinin and Plummer (1994), one could compute indices of revealed comparative advantage (RCA) and correlate RCA rankings of commodities with various FTA scenarios and those with the GTL scenario to examine how "natural" the groupings would be.

Table 3
World trade matrix in the baseline, 2015 (US$ billion in 1997 prices)

Exporting region	Importing region									
	China & HK	Japan	Korea	Taiwan	ASEAN	United States	Canada & ANZ	EU-15	ROW	World
China/Hong Kong	49.1	106.5	32.3	22.2	66.8	209.3	28.8	182.4	129.1	826.4
Japan	123.9		46.5	51.5	112.7	192.4	29.6	142.6	89.1	788.4
Korea	74.4	25.2		11.1	42.2	46.4	10.6	49.3	64.4	323.8
Taiwan	86.3	19.4	5.2		31.1	58.1	8.5	42.1	17.4	268.2
ASEAN	96.8	77.0	24.9	32.0	164.4	144.1	28.5	164.8	91.3	823.8
United States	107.1	149.8	70.8	53.3	121.5		281.1	435.6	414.2	1,633.3
Canada & ANZ	31.5	40.5	20.8	10.5	27.1	305.9	16.9	68.4	46.9	568.6
EU-15	108.5	160.6	65.9	39.7	152.4	392.8	100.3	2,177.2	713.4	3,910.9
Rest of world	91.9	117.0	62.0	17.0	101.2	415.4	43.4	631.0	514.3	1,993.2
World	769.6	696.0	328.5	237.3	819.5	1,764.5	547.8	3,893.3	2,080.1	11,136.6

Table 4
Effects on trade flows resulting from free trade among ASEAN+3 countries (deviations from the baseline in 2015 in US$ billion in 1997 prices)

Exporting region	Importing region									
	China & HK	Japan	Korea	Taiwan	ASEAN	United States	Canada & ANZ	EU-15	ROW	World
China/Hong Kong	33.5	60.7	40.6	0.7	49.9	10.9	1.5	12.0	5.0	214.8
Japan	118.6		28.8	-7.2	44.2	-31.5	-4.6	-19.8	-11.5	117.1
Korea	66.7	28.0		-2.2	18.1	-8.5	-2.1	-9.3	-13.1	77.6
Taiwan	-21.7	1.2	-0.5		-4.4	5.4	0.8	4.1	1.7	-13.4
ASEAN	69.1	37.8	13.4	-1.4	54.7	-4.6	-2.0	-5.7	-8.6	152.8
United States	-20.3	-8.5	-6.1	-0.2	-8.7		3.3	8.0	4.2	-28.2
Canada & ANZ	-5.1	-0.9	-0.8	-0.2	-1.9	2.4	0.3	1.1	0.7	-4.5
EU-15	-17.3	2.0	0.7	-1.6	-6.5	-2.4	-0.9	-11.4	-1.5	-38.9
Rest of world	-22.5	-7.1	-0.5	-0.8	1.5	2.5	0.1	-2.0	0.9	-27.9
World	200.9	113.3	75.6	-12.8	146.9	-25.7	-3.6	-23.0	-22.2	449.3

Table 5
Effects on trade flows resulting from China-Japan-U.S. FTA (deviations from the baseline in 2015 in US$ billion in 1997 prices)

Exporting region	Importing region									
	China & HK	Japan	Korea	Taiwan	ASEAN	United States	Canada & ANZ	EU-15	ROW	World
China/Hong Kong	40.0	65.8	1.0	0.3	0.5	138.0	0.9	7.2	-1.9	252.0
Japan	162.4		-7.1	-8.4	-18.6	62.5	-4.3	-21.2	-13.5	151.9
Korea	-16.5	-1.3		0.2	0.5	-3.3	0.6	2.3	3.2	-14.3
Taiwan	-20.4	0.2	0.4		1.8	-2.0	0.8	3.6	1.5	-14.1
ASEAN	-11.5	-6.5	0.4	0.1	0.5	-15.9	0.4	3.8	1.2	-27.6
United States	130.0	98.0	-4.7	-4.0	-8.5		-17.3	-26.4	-28.7	138.4
Canada & ANZ	-6.4	-2.2	0.4	-0.1	0.4	-15.2	0.4	2.0	1.1	-19.7
EU-15	-19.7	-0.7	-1.3	-1.2	-1.8	-16.0	-0.6	-8.9	-4.9	-55.1
Rest of world	-21.4	-8.4	-0.4	-0.4	-0.1	-21.9	0.6	2.6	2.6	-46.9
World	236.5	145.0	-11.5	-13.4	-25.3	126.1	-18.5	-34.9	-39.4	364.6

smaller for Japan, Korea, and ASEAN, but these countries would experience relatively large export diversion, shown by significant reductions in their exports to the non-member countries/regions.

The trade flow tables reward closer inspection, particularly to obtain deeper insights about bilateral interactions and incentive properties. China’s significant trade surplus with the United States and a substantial deficit with East Asia would result in a transitive surplus for its regional partners. While this might be a desirable property from the East Asian perspective, it puts China in a difficult position as a member of less inclusive East Asian arrangements. This is because, to join such an arrangement, China is implicitly expected to expand exports outside the region by significantly reducing extra-regional imports. This might complicate bilateral relations, particularly with respect to the OECD countries, for a newly emergent WTO member.

Of great interest to this paper is the trilateral scenario, the trade flow results of which are given in Table 5. Here we see compositional adjustments that include substantial trade creation among the three principals, as well as significant trade diversion. While the former outweighs the latter, the incidence of trade diversion is such that we might expect vigorous challenges to emergent Trilateralism in the Asian Pacific. While trade growth is about three times the total amount of trade diversion, every country and region outside the agreement experiences an absolute decline in aggregate exports. This strong and uniform diversion is again a result of the relatively high prior protection in China and Japan. For this reason, it is reasonable to expect mitigation of this effect over time, at least from the Chinese side, as WTO conformity levels the playing field for countries outside the trilateral agreement.

Why does Trilateralism look better to China than other regional arrangements? The answer, as suggested already, is partly market size. Another important aspect, however, is economic diversity. By joining with the United States and Japan, China gets access to more diversified import demand and export supply than is available in ASEAN and the EU. This kind of diversification completes international networks of comparative advantages and is one of the primary attractions of North-South regionalism.[17]

[17] The case for North-South regionalism has been strenuously argued along these lines in, among others, World Bank (2000).

Even with strong trade diversion, does Pacific Trilateralism provide a solid stepping stone to global free trade? To the extent that it accelerates trade between the three largest economies in the region, such an agreement can advance the case for greater global interdependence although the exclusion of agricultural liberalization would considerably reduce potential economic gains. Whether or not Trilateralism is really on the path to globalization, however, depends upon the nature of the structural adjustments ensuing from both trade regimes. A key question is whether the composition of sectoral output, factor use, and trade arising from Trilateralism are structurally consistent with patterns of comparative advantage that would emerge in the same countries under long-run WTO implementation. This question can only be answered conclusively by detailed analysis of sectoral information, the next stage of our work in progress.

For the present, an important lesson drawn from our work is that the largest economies in the region have a strong incentive to take the lead in any regional liberalization initiatives. For China, Japan, and the United States, trilateral liberalization dominates other FTAs examined in this paper. Other economies in the region, particularly the ASEAN countries, have strong incentive to enlist them in less inclusive arrangements, and they are making progress in their negotiations with China and Japan.

5. Concluding Remarks

China’s accession to the WTO portends dramatic evolution for the East Asian and Pacific economic regions. Over the last two decades, China has established new standards for sustained growth and dynamic resource allocation by a large economy, and further Chinese domestic and external liberalization will redefine trade relations in ways that are only beginning to be understood. Initial reactions of regional partners, who perceive China as a strong export competitor and magnet for FDI, have been rather defensive. These sentiments could undermine multilateralism and retard the dramatic historical progress of regional trade and growth.

In this paper, we have examined how regional trade might evolve under a variety of alternative trade regimes, including free trade among the ASEAN+3 countries and a trilateral FTA between the largest regional economies, China, Japan, and the United States. We have also experimented with FTA scenarios in the absence of agricultural liberalization. Our general findings indicate that China has made the right decision to move directly toward globalization, but that Trilateralism might be a convenient stepping stone in that direction, particularly if food and agricultural products are liberalized to a great extent. We find that a trilateral FTA will bring about very large fractions of the GTL's aggregate benefits to China, Japan, and the United States, although these benefits are likely to come at the expense of extra-regional bilateral relations.[18]

In contrast to an FTA that diverts China's trade into smaller regional markets (e.g., ASEAN-China FTA), a trilateral arrangement would provide both the market depth and diversity necessary to absorb China's burgeoning export capacity and meet its complex import needs. China's diversity and scale are also apparently sufficient to meet the needs of the Pacific giants, the United States and Japan. Thus we estimate that more efficient allocation of comparative advantage between these three economies would realize substantial gains from trade, especially when this arrangement includes agricultural liberalization. Exactly how this relationship would evolve in terms of structural adjustment, however, will not be clear until we conduct more detailed sectoral analysis. This extension of the present work is non-trivial to its policy implications because adversely affected industry lobbies are likely to strongly oppose new trade agreements. Suffice for the present to say that Trilateralism appears to offer relatively large potential gains for China, Japan, and the United States, but that this potential will be realized only if the implied sectoral and extra-FTA trade adjustments are politically feasible. As we have seen from recent actions by the United States in the steel and agricultural sectors, one cannot even take for granted the political feasibility of prior commitments to the WTO, let alone a hypothetical FTA. There may be many microeconomic obstacles to a Pacific Trilateral FTA, but the stakes do seem high enough to justify closer examination of this prospect.

[18] It should be noted that the magnitudes of welfare gains reported in section 3 are likely to be underestimated because the present version of the model does not incorporate increasing returns to scale or allow foreign capital to move in response to a change in relative rates of return.

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Appendix: Model Equations

A.1. The Neoclassical 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) $$ND_{lv} = \sum_{v} \alpha_{lv,v}^{nd} \left(AT_{lv}\right)^{\sigma_{lv,v}^{p}-1} \left(\frac{PXv_{lv,v}}{PND_{lv}}\right)^{\sigma_{lv,v}^{p}} XPv_{lv,v}$$

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

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

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

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

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

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

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

(37) $$T_{lv}^{d} = \sum_{v} \alpha_{lv,v}^{t} \left(\lambda_{lv}^{t}\right)^{\sigma_{lv,v}^{f}-1} \left(\frac{PTFD_{lv,v}}{PT_{lv}}\right)^{\sigma_{lv,v}^{f}} TFD_{lv,v}$$

(38) $$PTFD_{lv,v} = \left[\alpha_{lv,v}^{feed} \left(Pfeed_{lv}\right)^{1-\sigma_{lv,v}^{f}} + \alpha_{lv,v}^{t} \left(\frac{PT_{lv}}{\lambda_{lv}^{t}}\right)^{1-\sigma_{lv,v}^{f}}\right]^{1/\left(1-\sigma_{lv,v}^{f}\right)}$$

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

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

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

(42) $$L_{l,lv}^{d} = \alpha_{l,lv}^{ld} \left(\lambda_{l,lv}^{l}\right)^{\sigma_{lv}^{l}-1} \left(\frac{AW_{lv}}{W_{l,lv}}\right)^{\sigma_{lv}^{l}} AL_{lv}$$

(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) $$PXv_{ip,v} = \frac{1}{AT_{ip}} \left[\alpha^{nd}_{ip,v} PND^{1-\sigma^{p}_{ip,v}}_{ip} + \alpha^{va}_{ip,v} PVA^{1-\sigma^{p}_{ip,v}}_{ip,v} \right]^{1/\left(1-\sigma^{p}_{ip,v}\right)}$$

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

(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) $$PEp_{ip,v} = \left[\sum_{e} \alpha_{e,ip,v}^{ep} \left(\frac{\left(1+\tau_{e,ip}^{Ap}\right) PA_e}{\lambda_{e,ip}^{ep}} \right)^{1-\sigma_{ip,v}^{ep}} \right]^{1/\left(1-\sigma_{ip,v}^{ep}\right)}$$

Market structure

(82) $$PP_i = PX_i \left(1+\pi_i\right)\left(1+\tau_i^p\right)$$

Income Distribution

(83) $$TY = \sum_i NPT_i \; T_i^d$$

(84) $$FY = \sum_i PF_i \; F_i^d$$

(85) $$LY_{ll} = \sum_i NW_{ll,i} L_{ll,i}^d$$

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

(87) $$YH_h = \varphi_h^t TY + \varphi_h^f FY + \sum_{ll} \varphi_{h,ll}^l LY_{ll} + \varphi_h^k KY - DeprY_h + PGDP \; TRG_h$$

(88) $$DeprY_h = \varphi_h^k \delta^f \; PGDP \; K$$

(89) $$Yd_h = \left(1-\chi^k \kappa_h^h\right) YH_h$$

Final Demand

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

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

(92) $$S_h^h = Yd_h - \sum_i \left(1+\tau_{i,h}^{Ac}\right) PA_i XAc_{i,h}$$

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

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

(95) $$PFD_f = \sum_i a_{i,f}^f \left(1+\tau_{i,f}^{Af}\right) PA_i$$

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

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

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

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

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

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

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

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

A.2. Model Dynamics

Endogenous Dynamic Equations

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

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

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

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

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

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

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

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

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*

Notes:

a. The implementation of the model incorporates the equilibrium condition for the variable *XD*, therefore, the Armington demand condition can be thought of determining *XD*, and the CET supply condition can be thought of determining the price of *XD*, i.e. *PD*.
b. Similar to the explanation in note a., the model incorporates the equilibrium condition for the variable *WTF*.
c. The investment equation for one region is dropped due to the global Walras' Law.
d. Variable only included for models with a single capital vintage.
e. Variable only included for model with *old* and *new* capital vintages.
f. The capital-output ratio is only calculated for *old* capital.
g. In the baseline scenario, the variable g^y is exogenous, and the labor productivity parameter, γ^l is endogenous. In all other scenarios, the reverse holds.
h. The calibration parameter is only calibrated in the baseline scenario.