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Welfare Effects of Trade Liberalization and Port Efficiency in China

by

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Abstract

After nearly 15 years of negotiations with the World Trade Organization and a series of tariff rate reductions, on the November 10, 2001 China became a full member of the organization. With WTO membership, China would be required to reduce its tariffs further and eliminate non-tariff barriers. Earlier studies have ignored the domestic structural rigidities in the Chinese economy. One of the most important characteristics of Chinese economy is the restriction on the labor mobility from the rural to urban areas. This has influenced the wage structure in the rural and urban sectors of the economy. This paper models the labor market rigidities, by an exogenous wage differential specification and tries to estimate the welfare gains due to trade liberalization. Another factor that influences trade is the efficiency at the ports. China is developing its port and shipping infrastructure at a phenomenal pace. The efficiency of ports has significant influence on the cost structure of various sectors. This paper further analyzes the welfare effect of port sector efficiency on the Chinese economy. The results indicate that Chinese economy gains substantially due to tariff reforms and increasing port efficiency further strengthens this.

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1. Introduction

Since the introduction of Reforms and Open-up Policy in 1978, multi facet liberalization of the economy has generated significant growth in China. The annual average growth rate of GNP is over 10 percent and external trade has expanded by more than 15 percent a year from 1980 to 1995. Foreign direct investment in the signed agreements and contracts, total amount of foreign direct investment to be utilized and actually used has maintained 260 thousand cases, 396 billion dollars and 135 billion dollars in total, respectively, till 1995. The share of agriculture goods sold at an administered price reduced from 94.3 percent in 1978 to 10.2 percent in 1993 and of consumption goods from 97.4 percent to 12.2 percent (Cao, Fan, Woo, 1996).

On the November 10th, 2001 China formally became a full member of World Trade Organization after negotiations which lasted for nearly 15 years with WTO and its predecessor General Agreement on Tariffs and Trade (GATT). Since 1990, Chinese government has taken a series of important steps to actively promote its trade liberalization in order to respond to the globalization trend of world economy and participate in international competition on the basis of WTO rules. These steps are composed mainly of tariff reduction and elimination of non-tariff barriers. Accession to WTO would have significant impact on the external trade patterns in China. Zhai and Li (2000) showed that Chinese economy would gain with the accession to WTO, but the gains are not evenly distributed among either sectors or income groups. Especially, protected sectors like agriculture would be the losers and rural households will suffer

since the dominant role of agriculture is minimized. Fan and Zheng (2000) showed that tariff cuts induced by trade liberalization have minor but positive effects on macro-economy in terms of gains in GDP.

Besides the tariff reforms, development of port and shipping in China are continuing at a phenomenal pace. Frankel (1998) states, "China's ports and shipping are now being rationalized in terms of inland infrastructure and inter-modal networks, optimum trade flows, foreign alliances, and physical forms or consolidation of cargo". These developments would certainly enhance the efficiency and trade would benefit further. This paper has two objectives (i) to estimate the welfare gains due to tariff reforms and (ii) to estimate the additional benefit that port efficiency would generate.

Earlier papers using computable general equilibrium models have estimated the welfare effects of tariff reforms without giving much attention to the domestic labor market institutional arrangements. These studies assume that the labor is free to move between sectors and in the equilibrium state a uniform wage rate exists. Rural China had 323 million farmers in its labor force for 1995, according to official statistics (National Bureau of Statistics, 1996), of a total of 860 million official rural residents. However, with only 1/3 hectare of cultivated land per farmer, Chinese countryside does not actually support so many fully employed farmers. The average labor productivity in agriculture is less than one fifth that of industry and less than one third that in the service sector; farmers officially account for over half of the national labor force, but produce only 20% of the GDP (Bhattacharya et al., 1999). Bhattacharya et al. (1999) estimates that there is an apparent surplus of between 35 to 40% of the agricultural labor force.

The incentive to migrate has always been present in rural China, even though the opportunity was not previously available before economic reform transformed Chinese economy. The migration from rural area to urban in China is one of the largest flows in the world. This has been occurring since mid-1980's and tens of millions of rural migrants are working and residing in urban areas (Zhao, 1999a). Almost all of that, however, is the so-called "floating population" (*liudong renkou*), which means migrants without official permanent urban registration. Most of these migrants from rural areas find employment in the informal sector. This is primarily because these migrants from rural areas do not have legal documents for stay in the urban areas. Formal sectors in urban areas are unable to employ this labor and they have to pay higher wages to retain the labor with legal documents. China has an immense wage differential because of this "*hukou*" system of household registration by which the migration from rural to urban has been restricted. Under the *hukou* system, rural registered labor is not granted opportunities of employment equal to urban registered labor in the urban areas and their children don't have equal educational opportunities (Yang, 1997; Zhao, 1999b), to add to some other reasons such as lack of information of urban and safety during transportation, the psychological cost derived from separation (Zhao, 1999a).

In this paper, we explicitly model the restrictions on the labor movements by assuming that the wage differentials present between the sectors is due to restriction on the labor movement and retain the initial wage rate differential for subsequent experiments. We try to analyze the welfare impact of tariff and port efficiency in China.

Rest of the paper is structured as follows: Section 2 briefly overview the trade liberalization process in China. Section 3 discussed the role of port sector and

developments in the port sector. Section 4 presents our stylized CGE model. In the section 5, we present the results of our counterfactual scenarios and section 6 concludes.

2. Trade liberalization in China

Until 1992, China's trade barriers were still very high with a simple average nominal tariff rate as high as 43.2 percent and a variety of non-tariff measures including licensing, quotas, tendering and other controls (Fan and Zheng, 2000). Since then, China has taken steps to greatly reduce tariffs and remove non-tariff measures pursuant to its bilateral commitments and to support its WTO accession bid.

Chinese tariff rates operate as part of an industrial policy to protect its specific industry sectors and build its international competitiveness. Since 1992, China has speeded up its tariff liberalization. By 1998, China reduced six times its simple average tariff from 43.2 percent to 17.0 percent. On January 1999, the Ministry of Finance announced tariff reductions for 1014 commodities in the forestry, textile and toy sectors. On January 2000, China adjusted tariff schedule to increase the number of import tax codes from previous 6940 to 7062 and partially reduced further tariff rates. A total of 819 textile commodities have undergone tax rate reductions (Fan and Zheng, 2000).

However, the actual tariff collection rate is far lower than the nominal tariff rate both because of legal tariff exemptions and illegal smuggling and corruption. Table 1 illustrates the profile of China's trade pattern and actual tariff collection rates in 1995 (and partially in 1997). The simple average actual tariff rate of 3 sectors is only 2.3 percent while simple average nominal tariff rate is as high as 19.6 percent. Hence, the

official tariff rates should be scaled down to accommodate the tariff exemptions and smuggling so that China's tariff barriers won't be overestimated.

Table 1: Tariff rates and non-tariff barriers in China

(%)

	Nominal tariff rate	Actual tariff rate	Non tariff barriers
Agriculture	27.20	1.54	0.00
Material Industry	11.57	1.52	19.23
Manufacturing	27.77	3.29	12.68
Other Manufacturing	3.00	0.53	0.00
Port and Shipper	0.00	0.00	0.00
Other Services	0.00	0.00	0.00

Source: Computed from Fan and Zheng (2000)、Zhai and Li (2000)

In the Sino-U.S. WTO Deal signed on 15 November 1999 for China's accession to WTO membership, China agreed to reduce its tariff rates on agricultural product to 14.5～15 percent, decreasing about by 12 percent from its 1997 tariff base. China pledged to cut its tariff rates on wood and paper to 5～7.5 percent by 2005, decreasing by about 55 percent for wood products and 49 percent for paper products; lower its industrial tariffs to an overall average of 9.4 percent by 2005, a decrease of about 53.7 percent from its 1997 tariff base for other industrial products on average.

China's non-tariff barriers (afterward, NTBs) to trade usually include a broad array of licenses, quotas, tendering, state trading and other controls. Combined with high tariff, Chinese NTBs overlap and serve as a web of protection for its specific domestic industries. As a result, the removal of NTBs is also required for its accession to the WTO membership. In fact, China has removed over 1000 quotas and licenses on a wide range of commodities since 1992. The number of products requiring licenses and quotas is said to be so far only 395 (Fan and Zheng, 2000).

Despite the removal of quotas and license requirements during the period 1992-1998, China is required to remove further NTBs for its WTO accession. Among them include the elimination of China's WTO-inconsistent licensing, quotas and tendering requirements, the elimination of China's trade-related investment measures and market openings in specified Chinese serviced sectors, etc. Given the significance of NTBs in China's trade policy regime, it is any event meaningful to quantify the probable economic impact of the removal of NTBs in the context of China's WTO accession.

We calibrate our model to actual tariff rates and tariff equivalent of non-tariff barriers. The tariff equivalents of NTBs are taken from Fan and Zheng (2000). The experimentation that we have carried out is (1) what are the welfare implications of China's accession to WTO in the presence of factor rate differentials, and (2) what are the welfare implications of trade reforms when there are no factor rate differentials.

3. Port Sector in China

As a component of the overall economy, the port sector is only 0.13% of the GDP. Share of this sector in total employment is 0.09% and capital stock is 0.09%. The share of intermediate inputs in the gross output of the port sector is around 64.3%. Factor income constitutes 35.7% of the gross output.

Table 2: Cost Structure of Port Sector

Sectors	Percentage share in total cost
Labor	15.50%
Capital	5.88%
Agriculture	0.00%
Material manufacturing	25.14%
Manufacturing	17.80%
Other Manufacturing (Non Tradable)	0.31%
Port and Shipper	0.59%
Other Services	20.43%

Source: Computed based on our SAM.

Table 2 presents the cost structure of the port sector. The cost structure indicates that labor payments constitute around 16% of the total cost. Port is a service sector that deals with incoming and outgoing cargo. Ports require an extensive set of both water and land infrastructure to handle various types of cargo. Shippers and shipping lines as well as many other related port users require various administrative and related financial and other services[1].

The efficiency of port operations is dependent on the design and maintenance of berths, channels, navigation aids, other water-side facilities, stacking areas, cargo handling equipment, warehouses, container freight stations, accessibility, and other land-side facilities. Port management, particularly the type of port ownership and administration, stevedoring labor, and the existence of competition in port network determine the operating efficiency of port facilities. Information technology helps make their operating performances better.

[1] See, for example, Alderton (1999), for the introduction of port systems.

In turn, port efficiency can be increased by improvements in port design, maintenance, operations, redevelopment, management, labor management, or by inter-port network reform or by a mixture of such approaches.

4. A Stylized CGE Model

This analysis uses a stylized CGE model to focus on the effect of labor market behavior in response to a policy shock. The basic structure of the model is a modified version of the classic Jones model (1971) used in trade theory as presented in Thierfelder and Shiells (1997). There are two factors, labor and capital, used to produce three commodities, agriculture, manufacture good and services. Both factors are mobile across the sectors. Output is produced according to a constant elasticity of substitution (CES) production function over labor and capital.

Departing from the standard theoretical trade model, this model assumes imports and domestic commodities are not perfect substitutes. Instead, this uses the Armington assumption and distinguishes commodities by country of origin. Consumers purchase a composite good that is a CES aggregate of the imported and the domestic variety. Likewise, on the output side, the model assumes that output for the domestic market is different from output sold on the export market. There is a constant elasticity of transformation (CET) function describing the relationship between exports and goods for domestic consumption. The Armington specification dampens the price transmission following a trade policy shock. When tariffs are eliminated, for example, domestic prices do not experience the full price change –the changes depend on the degree of substitutability between the imported and the domestic good.

The model develops a single country model in which one country trades with the rest of the world at constant prices. The trade balance is held constant and both the relative price of imports to the domestic competing variety and the relative price of exports to the domestic competing variety adjust. The domestic price index is numeraire. Consistent with theoretical trade models, all tariff revenue is redistributed to the consumer in a lump sum fashion.

The stylized model is summarized in the Appendix 1 and 2. The Appendix 1 identifies the variables and the parameters for the model, and the model equations appear in the Appendix 2.

Let us rethink about the efficiency improvement of the port services. In the model that we have used, the capital stock is fixed, though it is free to move between the sectors. Reducing the domestic supply price of port services shifts the demand away from domestic supply to exports. Exports increase, however, are determined by foreign export demand function price elasticities. Domestic price of composite sales good of port services declines (this is a function of domestic supply and domestic export prices). Since the intermediate input coefficient to the port sector is fixed, the value added price of port sector also declines. Labor and capital adjust to this change and move out of this sector. At the same time with the decrease in the domestic sales price and since the domestic import price does not change the consumer price of port services to other sectors decreases. This increases the value added price in other sectors as input cost of port services has reduced. Increased value added price adjusts the wage and capital returns. Through consumption effect, the demand for composite good in various sectors increases. Balance of payment equation ensures that foreign exchange balance is maintained.

Foreign savings are fixed, increased exports of port services require that imports also increase. Imports in various sectors increase. Output would shift to those sectors that would benefit most from the reduction in the price of port services.

5. Results

We have calibrated the base case to the 1995 social accounting matrix for China (Doi *et al.*, 2002). The base case is presented in Table 3.

Table 3: Base case (1995)

	Agriculture	Material Industry	Manufacturing	Other Manufacturing	Port and Shipper	Other Services	Total
Output (billion yuan)	2034.10	3794.24	5104.77	1633.58	21.49	3069.30	15657.48
Domestic Consumption (billion yuan)	2084.25	4009.67	5339.38	1703.32	14.62	3163.64	16314.89
Domestic Good Consumption (billion yuan)	2053.54	3650.98	4776.80	1699.04	14.63	3085.88	15280.86
Intermediate Demand (billion yuan)	805.64	2386.68	3351.15	1099.51	13.81	1338.09	8994.87
GDP (billion yuan)	1228.46	1407.56	1753.62	534.08	7.68	1731.22	6662.61
Export (billion yuan)	14.89	340.41	632.11	6.15	7.19	87.77	1088.52
Import (billion yuan)	31.52	357.66	563.92	3.96	—	77.16	1034.22
Labor (million person)	342.90	46.66	59.57	37.03	0.53	120.99	607.68
Capital (billion yuan)	435.80	2801.00	2964.80	846.20	10.81	4657.69	11716.30
Wage (thousand yuan)	3.20	16.04	13.85	8.36	10.51	8.34	3995.13
Return to Capital (yuan)	0.30	0.23	0.31	0.27	0.20	0.16	2671.60

As mentioned earlier, 64.3% of the gross output is the intermediate inputs and rest is the factor payments. Of the total factor payments, the share of labor is around 43.40% while that of capital is 16.46%. The share of labor employed in port sector is only 0.09% of the total labor and port employs only 0.09% of the total capital. The rate of return to the labor is very high. Improvements like introduction of information technology, design and maintenance of land-side facilities, improved port management, particularly the type of port ownership and administration, stevedoring labor, and the existence of competition in port network can improve the operating efficiency of port facilities. A number of port policy changes could be discussed which introduce efficiency in this sector. It is not easy to introduce these impediments in the CGE framework. To show the implications of gains in total efficiency in the port sector, we introduce a total factor productivity gain by 20% in the coefficient $A3_{port}$ of the port sector production function.

$$X_{port} = A3_{port} \cdot \left(\sum_{f} \delta_{port,f} \cdot FDSC_{port,f}^{-\rho_{p,port}} \right)^{-1/\rho_{p,port}}$$

The notations for the production function are shown in Appendix 1. As discussed earlier, increase in total factor efficiency would produce the same output with less labor and capital and reduce the cost of production. This would reduce the cost of port services and would make trade cheaper. The output would shift towards exports and imports and various linkages within the economy would determine the impact of this change. We exogenously increase the total factor efficiency by 20% from its current level (base case). The percentage changes in various macroeconomic and sectoral variables are presented in Table 4 and Table 5. Table 4 indicates that when the tariffs and non-tariff barriers are removed, the GDP increases by 2.31%. Output increases by 0.08%, which is mainly

driven by manufacturing sector where output increases by 1.6%. Output of all other sectors except ports decline. The growth in the output of port sector is caused by increase in trade. With tariffs being reduced exports and imports increase substantially. Exports grow by 26% and imports grow by 13%. The overall domestic consumption declines slightly by 0.9%. The average wage and capital rate increases and exchange rate depreciate by 5.1%.

When we superimpose port efficiency on the tariff reduction scenario, the GDP increases by 2.5% compared to the base case (Table 5). The output grows by 0.16%. With ports becoming more efficient, material manufacturing and other services also grow besides manufacturing and port sectors. The growth in the material manufacturing and other services is due to relatively high share of intermediate input from these sectors to the port sector. The trade grows further and exports grow by 28% and imports grow by 15%. The domestic consumption declines but relative to tariff reduction scenario the decline is marginally less. The exchange rate depreciates by 7.1%.

The results indicate that with tariffs and non-tariff barrier reduction, Chinese economy would gain substantially. Increasing port efficiency would further substantiate the growth.

Table 4: The effects of trade liberalization (Percentage changes in real values over the base case)

	Agriculture	Material Industry	Manufacturing	Other Manufacturing	Port and Shipper	Other Services	Total
Output	-0.69	-1.18	1.60	-0.80	14.91	-0.04	0.08
Domestic Consumption	-0.87	-0.87	-0.88	-0.89	-0.87	-0.95	-0.89
Domestic Good Consumption	-0.85	-3.58	-1.97	-0.89	-0.91	-0.76	-1.84
Intermediate Demand	-0.47	-5.35	-0.17	-0.77	14.93	0.13	-1.58
GDP	-0.82	5.91	4.98	-0.86	14.86	-0.17	2.31
Export	27.98	24.14	27.08	24.98	46.25	25.95	26.20
Import	-5.07	26.97	7.98	-4.91	-	-4.63	13.16
Producer Price	-0.10	0.50	0.50	0.40	0.20	0.40	
Domestic Goods Price	0.00	-1.40	-1.20	0.40	-2.70	0.30	
Domestic Price of domestic variety	-0.10	0.00	-0.19	0.38	-2.74	0.29	
Domestic Price of exported good	5.10	5.10	5.10	5.10	5.10	5.10	
Domestic Price of imported good	3.50	-12.90	-9.30	4.60	-	4.60	
Labor	-0.54	2.93	1.65	-0.90	8.87	-0.18	0.00
Capital	-1.65	2.07	0.79	-1.73	7.59	-1.29	0.00
Wage	-0.11	3.37	2.08	-0.48	9.33	0.25	1.07
Return to Capital	-0.36	3.41	2.12	-0.44	9.01	0.00	1.53
Exchange Rate	5.10						

Table 5: The effect of trade liberalization and port efficiency (Percentage changes in real values over the base case)

	Agriculture	Material Industry	Manufacturing	Other Manufacturing	Port and Shipper	Other Services	Total
Output	-0.47	0.35	0.29	-0.75	38.86	0.33	0.16
Domestic Consumption	-0.87	-0.85	-0.82	-0.88	-0.81	-0.82	-0.84
Domestic Good Consumption	-0.80	-3.15	-2.58	-0.78	-0.92	-0.75	-1.91
Intermediate Demand	-0.31	-3.05	-2.19	-0.70	38.98	0.71	-1.57
GDP	-0.57	6.11	5.05	-0.83	38.64	0.03	2.50
Export	39.40	37.13	20.60	37.24	118.07	37.52	28.13
Import	-6.88	22.89	13.66	-6.41	-	-6.02	14.68
Producer Price	0.10	0.60	0.70	0.50	-2.20	0.50	
Domestic Goods Price	0.10	-1.30	-1.10	0.50	-8.50	0.50	
Domestic Price of domestic variety	0.00	-0.09	-0.28	0.57	-8.60	0.29	
Domestic Price of exported good	7.10	7.10	7.10	7.10	7.10	7.10	
Domestic Price of imported good	5.40	-11.30	-7.70	6.50	-	6.50	
Labor	-0.55	2.96	1.39	-0.97	3.77	0.01	0.00
Capital	-1.67	2.09	0.54	-1.81	2.62	-1.12	0.00
Wage	0.01	3.54	1.96	-0.41	4.36	0.57	1.19
Return to Capital	-0.38	3.44	1.86	-0.52	3.97	0.18	1.48
Exchange Rate	7.10						

6. Conclusion

After fifteen years of negotiations and concerted effort of stepwise reduction in the tariff rates, China became full member of the World Trade Organization on the 10th November 2001. With the accession to the WTO, China would be required to further reduce its tariff and non-tariff barriers. Chinese government policy of labor registration and the availability of employment opportunities by the place of domicile have restricted the opportunities for labor employment and the employers as well. Most of earlier studies using computable general equilibrium model to estimate the welfare possibilities due to trade reforms have assumed free movement of labor between the sectors of production. They have assumed that in the equilibrium, same wage rate would exist among the sectors. However, observing the base data for China, there are substantial wage differences between the rural (agriculture) and other sectors of the economy. This paper assumes that these wage differences are due to the restriction on the labor movements. We have estimated the impact of tariffs and non-tariff barriers reduction on the Chinese economy keeping the wage differentials as in the base case.

Another issue related to the trade in China is of improving port infrastructure. Since 1985, China has invested heavily on improving the port infrastructure. The improved infrastructure would lead to enhanced efficiency of the port sector. We analyze, in a counterfactual scenario, the further gains that increased port efficiency would cause in addition to the tariffs reduction.

The results indicate that Chinese GDP grows by 2.3% when tariffs and non-tariff barrier is removed completely. Increasing port efficiency further substantiates the GDP growth

rate gain to 2.5%. The productive sectors of economy (manufacturing) gain in both scenarios.

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Appendix 1: Factor Market Model in China: Notation of the System (based on Thierfelder and Shiells (1997), pp.473-475.)

Price Variables

PX_i*: Producer price

PQ_i: Composite good price

PWE_i: World export price

PWM_i: World import price

PED_i: Domestic price of exported good

PMD_i: Domestic price of imported good

PDT_i: Domestic price of domestic variety including tax

PD_i: Domestic price of domestic variety net of tax

Quantity Variables

E_i: Exports

DD_i: Domestic demand

DD_i0: Initial quantity of domestic demand

M_i: Imports

X_i: Production of the composite good

Q_i: Composite consumption good

$INTD_i$: Intermediate input

a_{ij}: Intermediate input coefficient

Sector Tax Variables

td_i: Domestic good tax

te_i: Export subsidy

tm_i: Import tariff

Welfare Variables

$CLIV$: Cost of living index in current prices

$UTIL$: Utility

YN: New income in equivalent variation calculation

EV: Equivalent variation

Macroeconomic Variables

$PINDEX$: Domestic price index

Y : Gross domestic product

GR : Government net revenue

ER : Exchange rate

$FSAV$: Foreign savings

Factor Variables

$FDSC_{i,f}$: Factor demand

$FCTRY_{i,f}$: Factor income

WF_f : Economy-wide average wage

$WFDIST_{i,f}$: Factor payment differential

Functional Parameters

σ_i : CES trade substitution elasticity

Ω_i : CET export transformation elasticity

Γ_i : CES production substitution elasticity

$\rho_{c,i}$: CES import aggregation parameter

$\rho_{t,i}$: CET export transformation parameter

$\rho_{p,i}$: CES production function parameter

β_i : CES trade share parameter

α_i : CET export share parameter

$\delta_{i,f}$: CES production factor share parameter

$A1_i$: CES trade constant

$A2_i$: CET export constant

$A3_i$: CES production constant

cs_i : Consumption expenditure share

$pwts_i$: Weight for the domestic goods price index

*: Subscript i and f show the sector and factor, respectively

Appendix 2: Factor Market Model in China: System of Equations (based on Thierfelder and Shiells (1997), pp.473-475.)

Price Equations

$$PX_i \cdot X_i = PED_i \cdot E_i + PD_i \cdot DD_i$$

$$PMD_i = PWM_i \cdot ER \cdot (1 + tm_i)$$

$$PED_i = PWE_i \cdot ER \cdot (1 + te_i)$$

$$PQ_i \cdot Q_i = PDT_i \cdot DD_i + PMD_i \cdot M_i$$

$$PDT_i = PD_i \cdot (1 + td_i)$$

$$PINDEX = \sum_i pwts_i \cdot PD_i, \quad where\ pwts_i = \frac{DD_i 0}{\sum_i DD_i 0}$$

$$PX_i \cdot X_i = \sum_f WF_f \cdot WFDIST_{i,f} \cdot FDSC_{i,f} + PDD_i INTD_i$$

Elasticity Equations

$$\Gamma_i = \frac{1}{(1 + \rho_{p,i})}$$

$$\sigma_i = \frac{1}{(1 + \rho_{c,i})}$$

$$\Omega_i = \frac{1}{(1 + \rho_{t,i})}$$

Production, Factor Demand and Final Demand Equations

$$X_i = A3_i \cdot \left(\sum_f \delta_{i,f} \cdot FDSC_{i,f}^{-\rho_{p,i}} \right)^{-1/\rho_{p,i}}$$

$$INTD_i = \sum_j a_{ij} X_i$$

$$WF_f \cdot WFDIST_{i,f} = PX_i A3_i \cdot \left(\sum_f \delta_{i,f} \cdot FDSC_{i,f}^{-\rho_{p,i}} \right)^{\left[\left(-1/\rho_{p,i}\right)-1\right]} \cdot FDSC_{i,f}^{\left(-\rho_{p,i}-1\right)}$$

$$X_i = A2_i \cdot \left(\alpha_i \cdot E_i^{-\rho_{t,i}} + (1 - \alpha_i) \cdot DD_i^{-\rho_{t,i}} \right)^{-1/\rho_{t,i}}$$

$$Q_i = A1_i \cdot \left(\beta_i \cdot M_i^{-\rho_{c,i}} + (1 - \beta_i) \cdot DD_i^{-\rho_{c,i}} \right)^{-1/\rho_{c,i}}$$

$$PQ_i \cdot Q_i = cs_i \cdot \sum_i PQ_i \cdot Q_i$$

Trade Equations

$$E_i = DD_i \cdot \left(\frac{PD_i}{PED_i} \cdot \frac{\alpha_i}{(1-\alpha_i)} \right)^{1/(1+\rho_{t,i})}$$

$$M_i = DD_i \cdot \left(\frac{PDT_i}{PMD_i} \cdot \frac{\beta_i}{(1-\beta_i)} \right)^{1/(1+\rho_{c,i})}$$

$$FSAV = \sum_i PWM_i \cdot M_i - \sum_i PWE_i \cdot E_i$$

Welfare Equations

$$CLIV = \prod_i PQ_i^{cs_i}$$

$$UTIL = \prod_i (Q_i - INTD_i)^{cs_i}$$

$$EV = YN - Y0$$

Income and Objective Equations

$$GR = \sum_i tm_i \cdot ER \cdot PWM_i \cdot M_i + \sum_i td_i \cdot PD_i \cdot DD_i - \sum_i te_i \cdot ER \cdot PWE_i \cdot E_i$$

$$FCTRY_f = \sum_i WF_f \cdot WFDIST_{i,f} \cdot FDSC_{i,f}$$

$$\sum_i (PQ_i \cdot Q_i) = \sum_i PX_i \cdot X_i + ER \cdot FSAV + GR$$

Market Clearing Equations

$$\overline{FS_f} = \sum_i FDSC_{i,f}$$