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Welfare Effect of Exporting the High-tech Intermediate Products for a Newly Industrialized Country

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Abstract

One of the main concerns for the newly industrialized countries toward trade liberalization is that technology spillover from exporting the high-tech intermediate goods will benefit the final goods production in other developing countries. Furthermore, those developing countries will then compete with the newly industrialized countries in exporting the final goods to other countries. This paper builds a three-country theoretical model that has considered those "side effects" to simulate the effects of trade liberalization on a newly industrialized country, which has the comparative advantage in producing high-tech intermediate goods.

The model shows that when the newly industrialized country liberalizes the export of the high-tech intermediate goods to the developing country, the latter's export of the final good to the third country becomes more competitive and the global welfare level goes up. However, the welfare level for the former might go down since its export of the final good is hampered. To partially internalize the benefit from specialization, the newly industrialized country can liberalize the import of the final good from the developing country in the meantime.

The model also shows that when both countries play a simultaneous move game on their respective trade policies, there are many possible policy combinations that are welfare-improving for both countries compared to the Nash equilibrium outcome. This suggests that instead of letting both countries interact strategically without negotiation, the role of some trade agreements would be crucial.

Keywords: Trade; Technology spillover; General equilibrium model

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1 Introduction

The increasing level of trade liberalization has raised concerns about the welfare changes for different countries. Firms in newly industrialized countries (NICs) may export their high-tech intermediate goods to other developing countries as input for downstream final goods, and then import the final goods back to the home country or even export them to other countries.[1] For example, Taiwan, one of the four Asian NICs, exports many intermediate goods to China, the world's largest developing economy, especially integrated circuits, micro-assemblies, and other electronic parts.[2] These commodities constitute around 19% of total exports from Taiwan to China in 1998 and even rise to 38% in 2006 as shown in Figure 1-1.[3]

With its abundant labor, China is becoming the production site for many countries. Many Taiwanese firms are urging their government to further liberalizing the regulations on trade, FDI, or outsourcing activities to China. From the developing countries' perspectives, many studies have shown that technology spillover from abroad has positive effects on their productivity growth. These effects are even stronger when they are more open to foreign trade (Coe and Helpman (1995), Coe, Helpman, and Hoffmaister (1997), Hejazi and Safarian (1999), and Keller (2002)).

However, for the NICs, among the main concerns regarding trade liberalization are: first, whether or not outward technology spillover would harm them while benefiting the developing countries.[4] For example, recent research by Markusen, Rutherford and Tarr (2005) shows that inward FDI into the host countries, which is also a channel of technology spillover, might cause the reverse of the comparative advantage. Second, whether or not exporting the high-tech intermediate goods from the

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[1] While outpacing other developing countries, the NICs are still less-developed than the developed countries.

[2] According to U.S. Census Bureau, the Asian NICs include Hong Kong, Korea, Singapore, and Taiwan. See: http://www.census.gov/foreign-trade/guide/sec5.html.

[3] Source: Bureau of Foreign Trade, Taiwan: http://cweb.trade.gov.tw/kmDoit.asp?CAT322&CtNode=594.

[4] In addition to outward technology spillover, from a small country's perspective, Ekholm and Hakkala (2003) investigate the location of high-tech production. They show that hosting an agglomeration of R&D activities does not necessarily lead to welfare gains.

NICs enhances the developing countries' competitiveness in exporting the final goods worldwide.[5]

Technology spillovers can be classified into two types. The first is through trade in intermediate goods. In this case, using foreign high-tech intermediate goods as input for final good production involves an implicit usage of foreign technology. The second is in the form of international R&D spillover. In this case, the spillover may happen through many different ways other than trade (Keller, 2004). Since the main purpose of this paper is to analyze the welfare effect from trade liberalization, technology spillover from trade in intermediate goods will be considered. More specifically, in this paper, technology in the form of product design is transmitted to domestic and foreign downstream final goods production sector through their usage of differentiated intermediate goods as discussed in Keller (2002).

The research questions in this paper are: first, given the existence of technology spillover from trade in intermediate goods, what would be the effects on a NIC when exporting the high-tech intermediate goods to a developing country? Second, what would be the effects on the NIC of importing the final goods that use those previously exported intermediate goods as input? Finally, when considering the strategic interactions on trade policies between the NIC and the developing country, what will be the possible changes in welfare level for each country? Is there any policy combination that would make both parties better off?

Historically, these issues are important as the problems happened between England and India in the 19th Century, between Japan and Asian NICs in 1970s and 1980s, and are happening between the Asian NICs and China. A similar pattern for these examples is that the firms in more developed countries export the intermediate goods to less developed countries and utilize the cheaper foreign labor in assembling the final products.[6]

To investigate these issues, this paper builds a three-country theoretical general equilibrium model

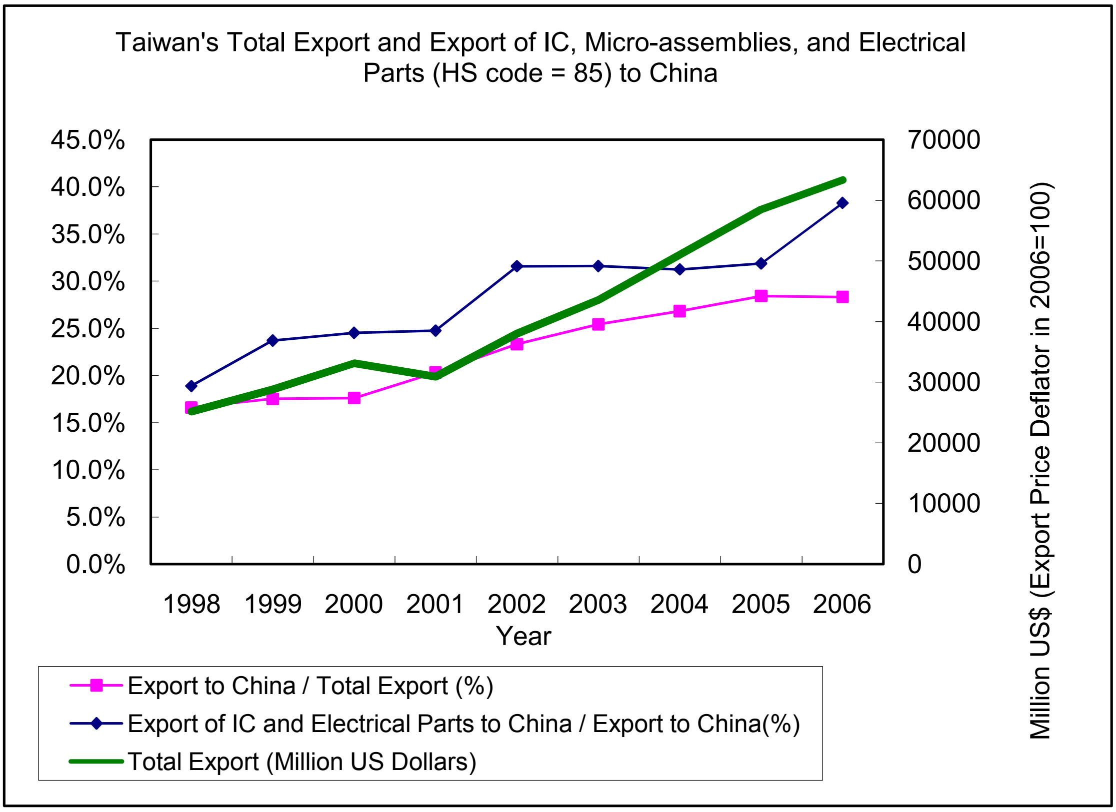
5 Some main concern regarding FDI are: whether inward FDI affects employment and economic growth and whether outward FDI is simply 'job exporting', with the firms moving to low-cost, labor abundant locations (Barrell and Pain, 1997; OECD, 1995).

6 I would like to thank Frank Hsiao for this helpful comment.

to study the trade liberalization effects. The three countries are: a newly industrialized country T, a developing country C, and the rest of the world R. T exports the high-tech intermediate goods to C for processing and imports the processed final good from C for consumption. At the same time, both T and C compete in exporting the final goods to R. Since at this level of complexity, the model becomes analytically difficult to solve, numerical simulations will be applied instead.

With a two-country scheme, trade liberalization simulations often generate more optimistic results. This is because a two-country model cannot take into account the competition in exporting the final goods to the third country. Unfortunately, this is of course far from the reality. In contrast, by adopting a three-country scheme, this paper considers the competition in exporting the final goods to the third country explicitly. This makes the welfare analysis for the NIC becoming more realistic. The detailed model settings will be presented in the next section. The simulation will be presented in section 3 while section 4 concludes.

Figure 1-1 Taiwan's Total Export and Export of IC and Electrical Parts to China



Sources: Bureau of Foreign Trade and the databank of Taiwan Economic Journal

2 Model

This paper assumes a three-country, three-sector, and three-factor model to analyze the effects of trade liberalization for a newly industrialized country. The specifications of the model are illustrated below.

2.1 Framework

There are three countries: a newly industrialized country T, a developing country C, and the rest of the world R. In the benchmark, both T and C produce the differentiated high-tech intermediates D, the final good X, and the final good Y, respectively (D, X, and Y denote both the production sectors and their corresponding outputs). R only produces the final good Y.

There are three different primary factors: skilled labor S, unskilled labor L, and capital K. The production of D uses S and K. Each firm in sector D has some market power in producing the differentiated intermediate good.[7] Under the symmetric assumption, every firm's markup is the same. For simplicity, the mark up in producing D is also assumed to be the same across countries. The production of X uses the composite of D, and all three kinds of primary factors, while the production of Y uses only L and K. T and C have all the three primary factors as endowments while R only has L and K. All goods are tradable but the primary factors are not. Final good X is homogeneous only if being produced by the same country. Final good Y is homogenous among different countries.

Several key assumptions for the benchmark are: first, T, C, and R have the comparative advantages in producing D, X, and Y, respectively. For example, T has the comparative advantage in producing D since its marginal production cost in terms of the other goods is the lowest among the three countries (i.e., the opportunity cost in producing D in country T is the lowest among the three countries), as presented in Table 2-2. Also, C uses the primary factors more intensively than T in

[7] The theoretical background for the monopolistic competition and scale economies can be found in Dixit and Stiglitz (1977), Krugman (1979), Krugman (1980), Markusen (1990), and Markusen (2006).

producing X, and R has already specialized in producing Y.[8] Since each country's comparative advantage will not be changed under the considered simulations, the direction of trade will not be altered.

Second, in the benchmark, T exports D and X to C and R, respectively, and imports X from C (X is heterogenous if being produced by different countries). C exports X both to T and R, and import D from T. R exports Y to both T and C, and imports X from both T and C. These settings are summarized in Figure 2-1. Thus, country T and C compete in exporting the final good X to R. Trade balance is assumed to hold for each country all the time.

Third, the model assumes that in the benchmark, T imposes the export quota constraint on D and the import tariff on X. C imposes the import tariff on D. R does not impose any trade barrier. The implication of this assumption is that although trade between T and C can be terminated by the above policy variables, trade between T and R and between C and R will never be halted.

Finally, this paper assumes that the GDP for each country is the same since the different size of the economies is not the focus of this paper.

[8] Note that the intermediate good D is more expensive in C. Under the same cost structure in producing X, C uses less physical quantities of D and more those of primary factors, as presented in Appendix A-01.

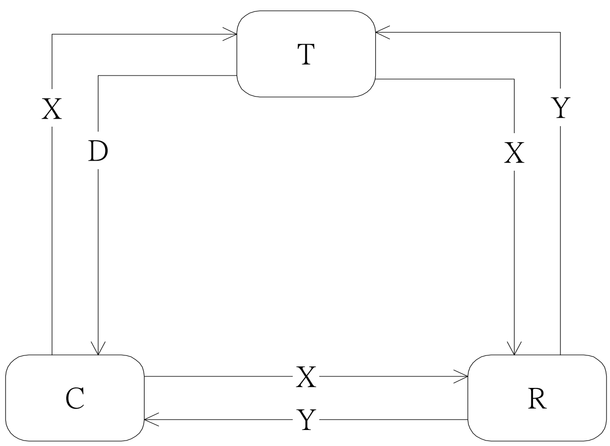
Table 2-1 Model Framework

Country	T	C	R
Production sector	{D, X, Y}	{D, X, Y}	{Y}
Comparative advantage	D	X	Y
Export	D, X	X	Y
Import	X, Y	Y	X
Factor endowment	{S, L, K}	{S, L, K}	{L, K}
Production technology	$D=f_{DT}(S,K)$ $X=f_{XT}(S,L,K)$ $Y=f_{YT}(L,K)$	$D=f_{DC}(S,K)$ $X=f_{XC}(S,L,K)$ $Y=f_{YC}(L,K)$	$Y=f_{YR}(L,K)$
Trade barriers (Policy tools)	1. Export quota constraint on D 2. Tariff on X	Tariff on D	None

Table 2-2 The Marginal Cost for Producing Each Good

	Marginal Cost ($)			Marginal Cost (in terms of other goods)		
Country / Good	D	X	Y	D	X	Y
T	1	1	1	**1X or 1Y**	1D or 1Y	1D or 1X
C	$\frac{3}{2}$	$\frac{4}{5}$	1	$\frac{15}{8}$X or $\frac{3}{2}$Y	**$\frac{8}{15}$D or $\frac{4}{5}$Y**	$\frac{2}{3}$D or $\frac{5}{4}$X
R	m	n	1	m/n X or m Y	n/m D or n Y	**1/m D or 1/n Y**
m and n are large enough such that R will always specialize in producing Y.						

Figure 2-1 Trade relationships among three countries



2.2 Model Setting

This section presents the key features for the model settings. The complete model and details are presented in Appendix A-02 and A-03.

2.2.1 Production technology and spillover

Here are several key assumptions about the production technologies. First, the production technologies for the firms are constant return to scale as equations (1), (2), and (3) below (i, j, k are indices for the individual firm in sector D, X, and Y, respectively). Note that for different countries, although the firm's production function in each sector has the same functional form, the parameters are not the same since the production technologies are different.

$$D_i = AD \cdot S_{D_i}^{\alpha} \cdot K_{D_i}^{1-\alpha}, \ for\ T\ and\ C \tag{1}$$

$$X_j = AX \cdot min\left(\delta \cdot CD_j\ ;\ S_{X_j}^{\beta_1} \cdot L_{X_j}^{\beta_2} \cdot K_{X_j}^{1-\beta_1-\beta_2}\right), \qquad for\ T\ and\ C \tag{2}$$

$$Y_k = AY \cdot L_{Y_k}^{\gamma} \cdot K_{Y_k}^{1-\gamma}\ , \ for\ T, C, and\ R \tag{3}$$

Since X produced within the same country are homogeneous and Y is homogeneous internationally, in these two sectors, each firm's production function can be summed up directly to get the industrial level production function as shown in equations (4) and (5).

$$X = AX \cdot min\left(\delta \cdot CD\ ;\ S_X^{\beta_1} \cdot L_X^{\beta_2} \cdot K_X^{1-\beta_1-\beta_2}\right), \qquad for\ T\ and\ C \tag{4}$$

$$Y = AY \cdot L_Y^{\gamma} \cdot K_Y^{1-\gamma}, \ for\ T, C, and\ R \tag{5}$$

Second, the firms in sector D are symmetric and produce the same amount of differentiated intermediate goods. They exhibit the Dixit-Stiglitz type of "large-group" monopolistic competition such that the demand elasticity and mark-up for D_i are $\sigma_D = 1/1 + \rho_D$ and $1/\sigma_D$, respectively, where ρ_D is the coefficient presented in the exponent of the CES aggregation for the industrial level composite intermediate good CD. Note that CD will be larger than summing up each firm's output D_i directly. This captures the technology spillover, which will be explained later.

Third, sector X uses composite intermediate good CD produced by sector D in a fixed proportion. More specifically, according to the trade relationship presented in 2.1, in T, CD used by sector X in T only comes from part of the composite intermediate produced in T while in C, CD is composed of both its domestic composite intermediate and the imported composite intermediate from T. As a result, CD will be a two-level CES aggregation in C, as shown in equation (6), where N_T and N_C are the number of firms in sector D in country T and C, respectively.

$$CD = \begin{cases} \left(\sum_{i=1}^{N_T} D_i^{-\rho_D}\right)^{\frac{-1}{\rho_D}} = \left(N_T \cdot D_i^{-\rho_D}\right)^{\frac{-1}{\rho_D}} = N_T^{\frac{-1}{\rho_D}} D_i,\ \rho_D \in (-1,0),\ for\ T \\ ADC \cdot \left(\theta_{DC} \cdot (N_C^{\frac{-1}{\rho_D}} D_i)^{-\rho_D} + (N_T^{\frac{-1}{\rho_D}} D_i)^{-\rho_D}\right)^{-1/\rho_D},\ for\ C \end{cases} \quad (6)$$

Fourth, establishing a firm in sector D needs the fixed cost $F(PS, PK)$, where PS and PK are the unit factor prices for the skilled labor and the capital, respectively (the notations for the different countries are temporarily dropped to simplify the expression).[9] This paper assumes that the firms in sector X and Y do not incur any fixed cost. The number of firms N in sector D is determined endogenously by the free entry condition as equation (7), where PD_i and $C(PS, PK)$ are the unit price and the marginal cost for D_i, respectively. N can be interpreted as the range of the differentiated intermediate inputs. The numbers of firms in sector X and Y are not important since they are not the interest of this paper.

$$PD_i \cdot D_i - C(PS, PK) \cdot D_i = F(PS, PK), \qquad for\ T\ and\ C \quad (7)$$

Finally, to capture the contribution of technology spillover from sector D to sector X, this paper borrows the idea from Keller (2002). He assumes that the cumulative resources devoted to R&D are proportional to the range of the differentiated intermediate inputs, which is just the number of firms. Furthermore, the more the variety of intermediate inputs, the higher the productivity of the industry that uses those intermediate inputs. This idea is embedded in the CES aggregation in (6). When

9 Since factor prices could be different among countries, this paper uses PST, PLT, PKT, and PSC, PLC, PYC to denote the factor prices for the skilled labor, unskilled labor, and capital in T and C, respectively. Also, PLR and PKR are the factor prices for the unskilled labor and capital in R. The situations are similar for other variables. See Appendix A-02.

$\rho_D \in (-1,0)$, the composite output CD is homogeneous of degree $\frac{-1}{\rho_D} > 1$ in N_T or N_C, which is an "augmented output" that has already included the spillover effect.[10]

2.2.2 Profit maximization

The cost function for each good can be derived from the firm's cost minimization problem, which is the necessary condition for maximizing the profit. The sufficient condition for the profit maximization is the "zero profit condition" where the firm equalizes the marginal benefit and marginal cost, providing that the second order condition is met, which is true since the profit function is concave. The output for the individual firm D_i is determined by the firm's optimization behavior as equation (8), where $C_D(PS, PK)$ denotes the marginal cost of producing one unit of D_i.

$$PD_i \cdot (1 - 1/\sigma_D) = C_D(PS, PK),\ for\ T\ and\ C \quad (8)$$

Note that when plugging PD_i in equation (8) into equation (7), the output per firm in sector D becomes:

$$D_i = \frac{(\sigma_D - 1)F(PS,PK)}{C_D(PS,PK)} \quad (9)$$

This paper assumes that the functional form for the fixed cost $F(PS, PK)$ in equation (7) is the exactly the same as that for $C_D(PS, PK)$ in equation (8). Under this assumption, the output per firm D_i in sector D will be constant. The change in the total output of sector D comes solely from the change in the number of firms in that sector.[11] Also, equation (7) implies that at equilibrium, each firm in sector D has its price that equals the marginal cost, which means that each firm's markup is totally used in financing the fixed cost for its establishment.

The price index for the composite good CD, denoted by PCD, is presented in equation (10) below. Similar to equation (6), in T, PCD is just a CES aggregation of PD_i while in C, PCD is composed

[10] When $\rho_D = -1$, there is no spillover. When $-1 < \rho_D < 0$, there is positive spillover.

[11] As mentioned in Markusen (2006), assuming the functional form for the fixed cost to be the same as that for the marginal cost of production is typically made in the literature implicitly.

of the price indices for its domestic composite intermediate and the imported composite intermediate from T. TEVTD is the shadow export duty from the export quota constraint imposed by T, while TIPCD is the import tariff imposed by C.

$$PCD = \begin{cases} \left(\sum_{i=1}^{N_T} PD_i^{1-\sigma_D}\right)^{\frac{1}{1-\sigma_D}} = N_T^{\frac{1}{1-\sigma_D}} PD_i, \; for\ T \\ \left(\frac{1}{ADC}\right) \cdot \left(\delta^{\sigma_{DC}} \cdot (N_C^{\frac{1}{1-\sigma_D}} PD_i)^{1-\delta^{\sigma_{DC}}} + PDTC^{1-\delta^{\sigma_{DC}}}\right)^{\frac{1}{1-\delta^{\sigma_{DC}}}}, \; for\ C \end{cases} \quad (10)$$

$$where\ PDTC = (N_T^{\frac{1}{1-\sigma_D}} PD_i) \cdot (1 + TEVTD) \cdot (1 + TIPCD)$$

Since no mark-ups are presented for the firms producing homogeneous goods in sector X or Y, their optimization behaviors can be simplified to equations (11) and (12) below, while PX and PY are the unit prices for X and Y, and $C_X(PCD; PS, PL, PK)$ and $C_Y(PL, PK)$ are the unit cost for producing X and Y, respectively.

$$PX = C_X(PCD; PS, PL, PK), \qquad for\ T\ and\ C \quad (11)$$

$$PY = C_Y(PL, PK), \; for\ T, C, and\ R \quad (12)$$

2.2.3 Consumer preference

The consumers in each country demand two types of final good from sector X and Y, denoted by CX and CY, respectively. The preference is characterized by a Cobb-Douglas utility function as equation (13). Note that X produced in T and in C are differentiated. From the assumption for the trade relations presented in Section 2.1, in country T, the composite final good CX is a CES aggregation of XTT (X produced in T and consumed in T) and XCT (X produced in C and consumed in T). The case for the rest of the world R (CES aggregation of XTR and XCR) is similar. However, in country C, CX comes only from XCC (X produced in C and consumed in C). These settings are shown in equation (14). Since Y is assumed to be homogeneous internationally, the composite final good CY in T is just the sum of YT (Y produced in T) and YRT (Y produced in R and consumed in T). The case for C is similar, while in R, CY comes only from YRR (Y produced in R and consumed in R). These settings are shown in equation (15).

$$W = CX^{\mu} \cdot CY^{1-\mu} \tag{13}$$

$$CX = \begin{cases} AXT \cdot (\theta_{XT} \cdot XTT^{-\rho_{XT}} + XCT^{-\rho_{XT}})^{-1/\rho_{XT}}, & \rho_{XT} \in (-1,0)\ ;\ for\ T \\ AXR \cdot (\theta_{XR} \cdot XTR^{-\rho_{XR}} + XCR^{-\rho_{XR}})^{-1/\rho_{XR}}, & \rho_{XR} \in (-1,0)\ ;\ for\ R \\ XCC, \quad for\ C & \end{cases} \tag{14}$$

$$CY = \begin{cases} YT + YRT,\ for\ T \\ YC + YRC,\ for\ C \\ YRR,\ for\ R \end{cases} \tag{15}$$

2.2.4 Utility Maximization

The optimization behavior for a consumer is similar to that for a firm. The expenditure function can be derived from the consumer's cost minimization problem, which is the necessary condition for maximizing the utility. The sufficient condition is the "zero profit condition" where the consumer equalizes the cost (derived from the expenditure function) and the benefit (measured by the shadow price for one unit of utility, denoted by PW) of buying the utility, providing that the second order condition is met, which is true since the utility function is strictly quasiconcave. This optimized behavior is shown in equation (16), where PCX and PCY are the price indices for CX and CY, respectively, as presented in equations (17) and (18). In equation (17), TIPTX is the tariff rate imposed by T on importing X from C.

$$PW = e_W(PCX, PCY)\ ;\ for\ T, C, and\ R \tag{16}$$

$$PCX = \begin{cases} \left(\frac{1}{AXT}\right) \cdot \left(\gamma^{\sigma_{XT}} \cdot {PX_T}^{1-\sigma_{XT}} + \left(PX_C \cdot (1 + TIPTX)\right)^{1-\sigma_{XT}}\right)^{\frac{1}{1-\sigma_{XT}}}\ ;\ for\ T \\ PX_C\ ;\ for\ C \\ \left(\frac{1}{AXR}\right) \cdot \left(\gamma^{\sigma_{XR}} \cdot {PX_T}^{1-\sigma_{XR}} + {PX_C}^{1-\sigma_{XR}}\right)^{\frac{1}{1-\sigma_{XR}}}\ ;\ for\ R \end{cases} \tag{17}$$

$$PCY = PY\ ;\ for\ T, C, and\ R \tag{18}$$

2.2.5 Equilibrium conditions and Model Closure

The equilibrium is determined by three types of equations: zero profit conditions, market clearing conditions, and income balance equations. Each zero profit condition determines a corresponding output or "activity level". The market clearing conditions characterize the price and output allocation that clears the markets, while the income balance equations are the accounting identities that balance income and expenditure.

The complete model is presented in Appendix A-03, where equations (A1) to (A21) are zero profit conditions, (A22) to (A26) are income balance conditions, and (A32) to (A58) are market clearing conditions. (A27) to (A31) are auxiliary equations for policy simulation. There are 58 equations and 58 corresponding variables. For these 58 equations, one of them is not independent of the others by Walras law. As a result, the shadow price for one unit of the utility in T, denoted by PWT, is chosen to be the numeraire. All prices are measured in terms of it. The model is solved by MPS/GE.

3 Simulation

The following three simulations answer the research questions presented in Section 1. The first one studies the effect of changing T's export quota constraint on the high tech intermediates D. The second one investigates the effects of changing both T's export quota constraint on D and the import tariff on the final good X. The last simulation analyzes the strategic interactions on trade polices between country T and C.

Several key assumptions are, first, while the model assumes zero substitution elasticity between the composite intermediate input from D and other primary inputs (S, L, and K), the elasticities of substitution between the primary inputs for a given production function are assumed to be 1. Second, the model assumes that the elasticities of substitution between the heterogeneous intermediates D produced by the same country are 5. Under the assumption of monopolistic competition, the demand elasticity for D will also be 5, which implies the markup for D is 20%. Finally, the elasticities of substitution between the composite D produced by different countries are assumed to be 2. A Similar assumption applies to X produced by different countries.

In a theoretical general equilibrium model, since the benchmark is only used to calibrate the model, it is only a relative position. As a result, any comprehensive simulation should consider the entire range of the policy variables as presented below.

3.1 Liberalizing the Export of the High-tech Intermediates

Figure3-1 shows that when liberalizing the export quota constraint on the intermediate goods D from the most restrictive scenario (zero-quota scenario), the global welfare level (i.e., the weighted average of the welfare level in T, C, R) goes up until the export quota constraint does not bind.[12] This is just because of the comparative advantage effect. The resources are reallocated in a way such

[12] In calculating the global welfare level, the weight of each country is just the share of its GDP to world GDP in the benchmark. Since all countries have the same GDP in the benchmark, the weight for each country is 1/3.

that T and C produce and export more goods with lower opportunity costs.

Note that R only has sector Y and its output is constant. This is because of the full employment assumption and the fact that there is no reallocation of its production factors. However, in R, the price index for the imported composite final good CX goes down (since R imports more low-priced X from C and less high-priced X from T), while the price index for its exported good Y goes up (since the world output of Y goes down). This implies the welfare level in R goes up all the way when T liberalizes its export quota constraint on D.

In C, the lower price for the composite D imported from T helps the expansion of its sector X. This explains the growth of its export as shown in Figure 3-2. Note that the composite D imported from T has already included the technology spillover that "inflates" the effective intermediate input to sector X in C.

This paper focuses on the welfare change of T. While T exports more D to C and imports more X from C, however, T's export of X to R will be hurt since C's export of X to R becomes more competitive, as shown in Figure 3-3. The implication is that T cannot internalize all the benefit from lowering the export quota constraint on D. This kind of unfavorable effect on T will be denoted as the "leakage effect". Figure 3-1 and 3-4 show that when liberalizing the export quota constraint on D, the welfare level of T goes up first. However, when the leakage effect dominates the comparative advantage effect, the welfare level for T finally goes down. Figure 3-5 shows that since in T, the resources are reallocated in favor of the expansion of sector D, which uses more skilled labor S and capital K, the factor prices for S and K go up while the factor price for the unskilled labor L will eventually go down, as shown in Figure 3-6.

Figure 3-1 Simulation 1: Welfare Levels in T, C, R, and the Weighted Average of the Three

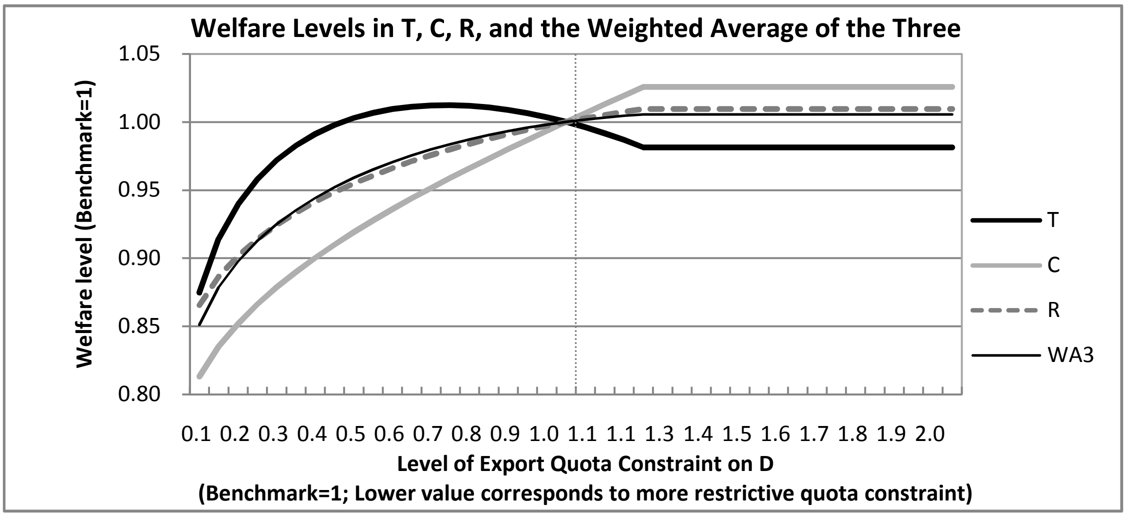


Figure 3-2 Simulation 1: Export and Import in Country C

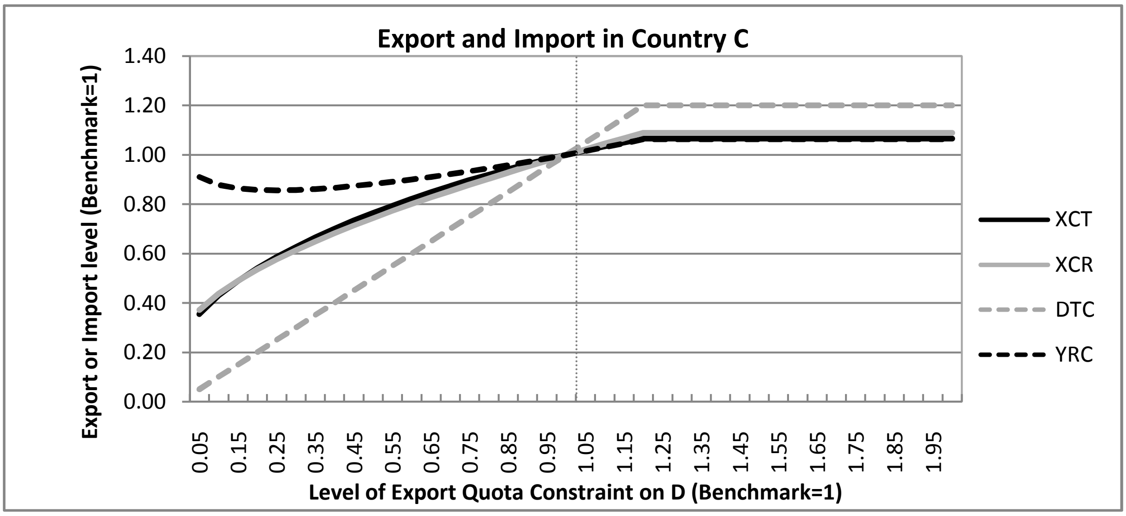


Figure 3-3 Simulation 1: Export and Import in Country T

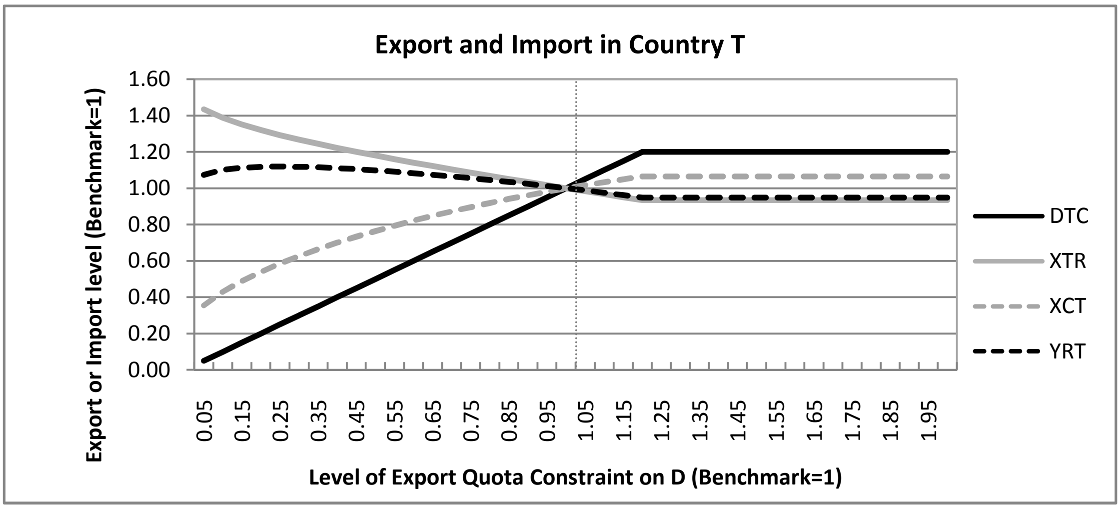


Figure 3-4 Simulation 1: Final Goods Consumptions and Welfare Level in Country T

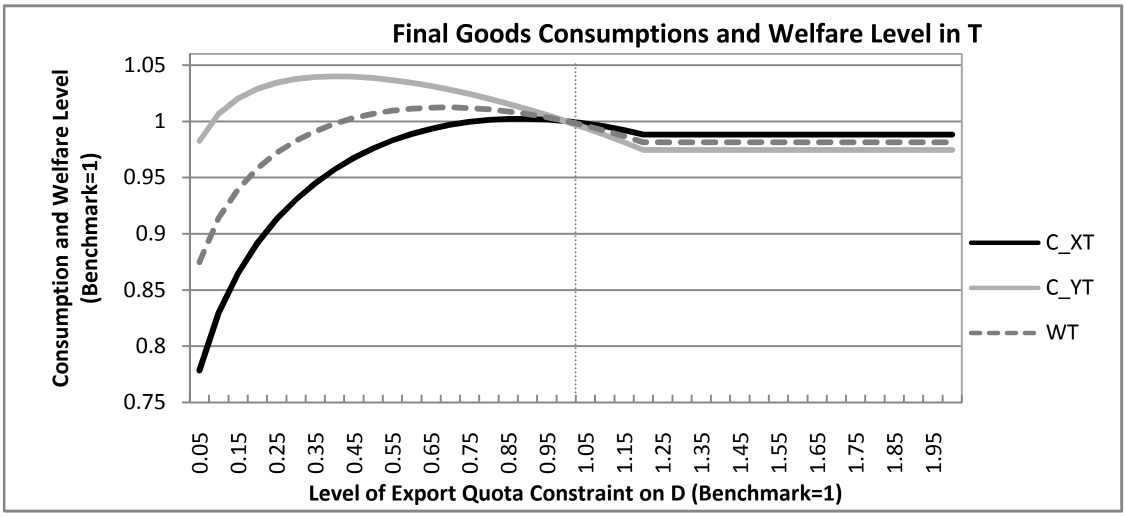


Figure 3-5 Simulation 1: Sectoral Output in Country T

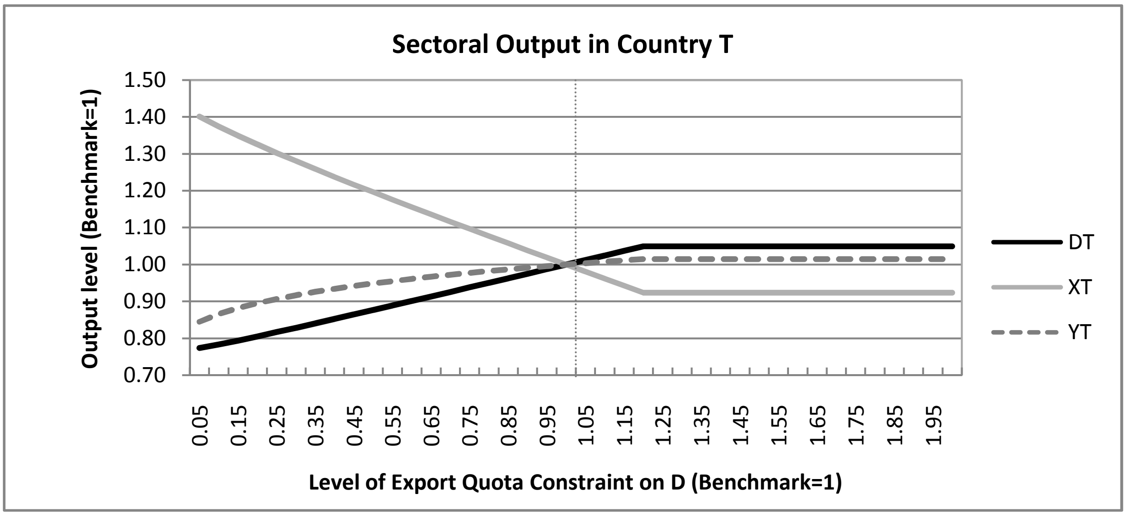
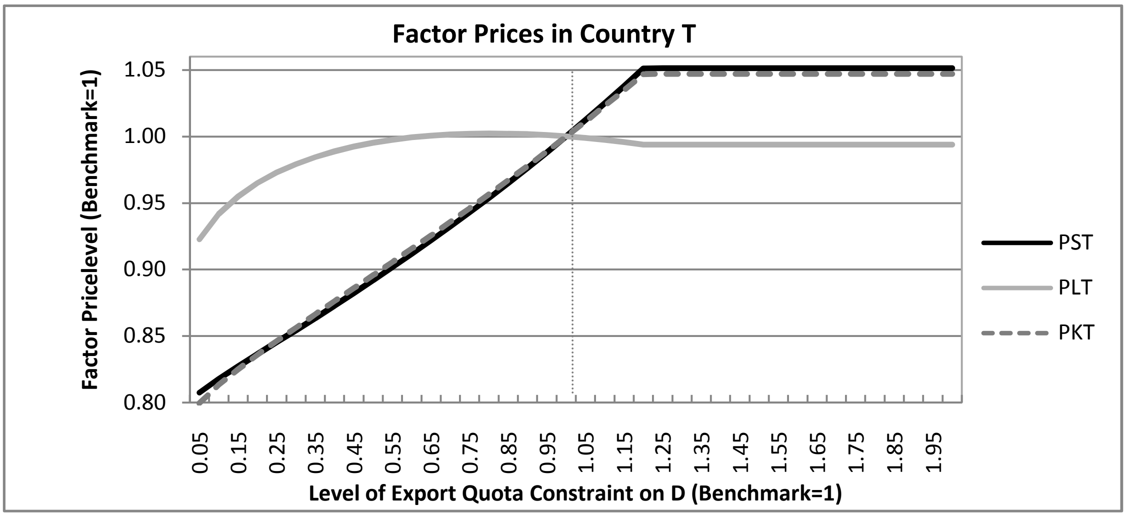


Figure 3-6 Simulation 1: Factor Prices in Country T



3.2 Liberalizing the Export of the Intermediate Goods and the Import of the Final Product

The simulation presented in Section III.1 shows that due to the leakage effect, T cannot internalize all the benefit from lowering the export quota constraint on D. One might suggest that T should also lower the import tariff to internalize part of the above benefit. This possibility is presented below.

Figure 3-7 considers the case where T liberalizes both the export quota constraint on the intermediate goods D and lower the tariff on the import of the final good X. Let us start from the most restrictive policy combination from the upper left corner of Figure 3-7. The general pattern is that when liberalizing the export quota constraint on D, lowering the tariff rate on the import of X can increase the welfare level. This is because lowering the tariff rate results in a lower price index for the composite X (composed of domestic and imported X goods) in T. Furthermore, for C, since exporting X to T becomes more attractive now, exporting X to R will decrease. This helps T's export of X to R as demonstrated in Figure 3-8, i.e., the leakage effect becomes less severe from T's point of view.

Figure 3-7 also shows that if C's policy (tariff rate on the import of D from T) remains unchanged, then if T would like to maximize its welfare level, the best policy combination would be to keep a moderate level of export quota constraint on D while significantly liberalizing the import of X. A moderate level of export quota constraint on D helps to mitigate the outward technology spillover and the leakage effect, while lowering the import tariff on X helps to internalize the benefit from lowering the quota constraint on D, and thus lessens the leakage effect further.

Figure 3-7 Simulation 2: The Welfare Level in Country T

Tariff rate on XCT / Quota on DTC	125%	100%	87.5%	75%	62.5%	50%	37.5%	25%	12.5%	0%
0.05	0.85	0.86	0.86	0.86	0.87	0.87	0.87	0.87	0.87	0.87
0.24	0.93	0.94	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97
0.43	0.96	0.96	0.97	0.98	0.98	0.99	1.00	1.00	1.00	1.00
0.62	0.96	0.97	0.98	0.99	0.99	1.00	1.01	1.01	1.02	1.02
0.81	0.96	0.97	0.97	0.98	0.99	1.00	1.00	1.01	1.01	1.02
1.00	0.95	0.95	0.96	0.97	0.98	0.99	0.99	1.00	1.00	1.01
1.19	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.99	0.99
1.38	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98
1.57	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98
1.76	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98
1.95	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.98

Note: Each table entry represents the welfare level under the given trade policies (the benchmark welfare level is normalized to unity). The benchmark export quota constraint on D and the import tariff on X are unity and 25%, respectively. DTC and XCT denote D going from T to C, and X going from C to T, respectively.

Figure 3-8 Simulation 2: T's Export of X to R

Tariff rate on XCT / Quota on DTC	125%	100%	87.5%	75%	62.5%	50%	37.5%	25%	12.5%	0%
0.05	1.31	1.32	1.34	1.35	1.37	1.39	1.41	1.43	1.46	1.50
0.24	1.17	1.18	1.19	1.21	1.23	1.25	1.27	1.30	1.33	1.37
0.43	1.08	1.09	1.10	1.12	1.14	1.16	1.18	1.21	1.24	1.28
0.62	1.00	1.02	1.03	1.05	1.06	1.08	1.11	1.13	1.16	1.20
0.81	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.06	1.09	1.13
1.00	0.88	0.89	0.90	0.92	0.93	0.95	0.98	1.00	1.03	1.06
1.19	0.87	0.88	0.89	0.89	0.90	0.91	0.92	0.94	0.96	1.00
1.38	0.87	0.88	0.89	0.89	0.90	0.91	0.92	0.93	0.95	0.96
1.57	0.87	0.88	0.89	0.89	0.90	0.91	0.92	0.93	0.95	0.96
1.76	0.87	0.88	0.89	0.89	0.90	0.91	0.92	0.93	0.95	0.96
1.95	0.87	0.88	0.89	0.89	0.90	0.91	0.92	0.93	0.95	0.96

Note: Each table entry represents the level of X's export by T under the given trade policies (the benchmark export level is normalized to unity). The benchmark export quota constraint on D and the import tariff on X are unity and 25%, respectively. DTC and XCT denote D going from T to C, and X going from C to T, respectively.

3.3 Strategic Interactions on Trade Policies

Another interesting issue would be to consider the strategic interaction of the trade policies. Since the main focus of this paper is about the interaction between country T and C, for simplicity, it assumes that R will not implement any trade policy. On the other hand, the policy tools for T are the export quota constraint (DTCQ) on D and the tariff rate (TIPTX) on the import of X, while the only policy tool for C is the tariff rate (TIPCD) on the import of D.

Let us denote the combination of the trade policies by [(DTCQ, TIPTX); TIPCD], where (DTCQ, TIPTX) are controlled by T and TIPCD are controlled by C. The benchmark combination of those polices is characterized by [(1, 25%); 20%], and this is only used to calibrate the model. To make sure the simulation is comprehensive, this paper begins from the most restrictive case [(0, ∞%); ∞%] to the fully liberalized scenario [(∞, 0%); 0%].[13]

Figure 3-9 considers the simultaneous move game for the two countries T and C. The results are as follows. First, any policy combination other than $\text{TIPTX} = \infty\%$ and $\text{TIPCD} = \infty\%$ (denoted as the area with crosses) is welfare-improving for both countries. This suggests that both T and C have the incentives to liberalize their respective trade barriers from the most restrictive scenario.

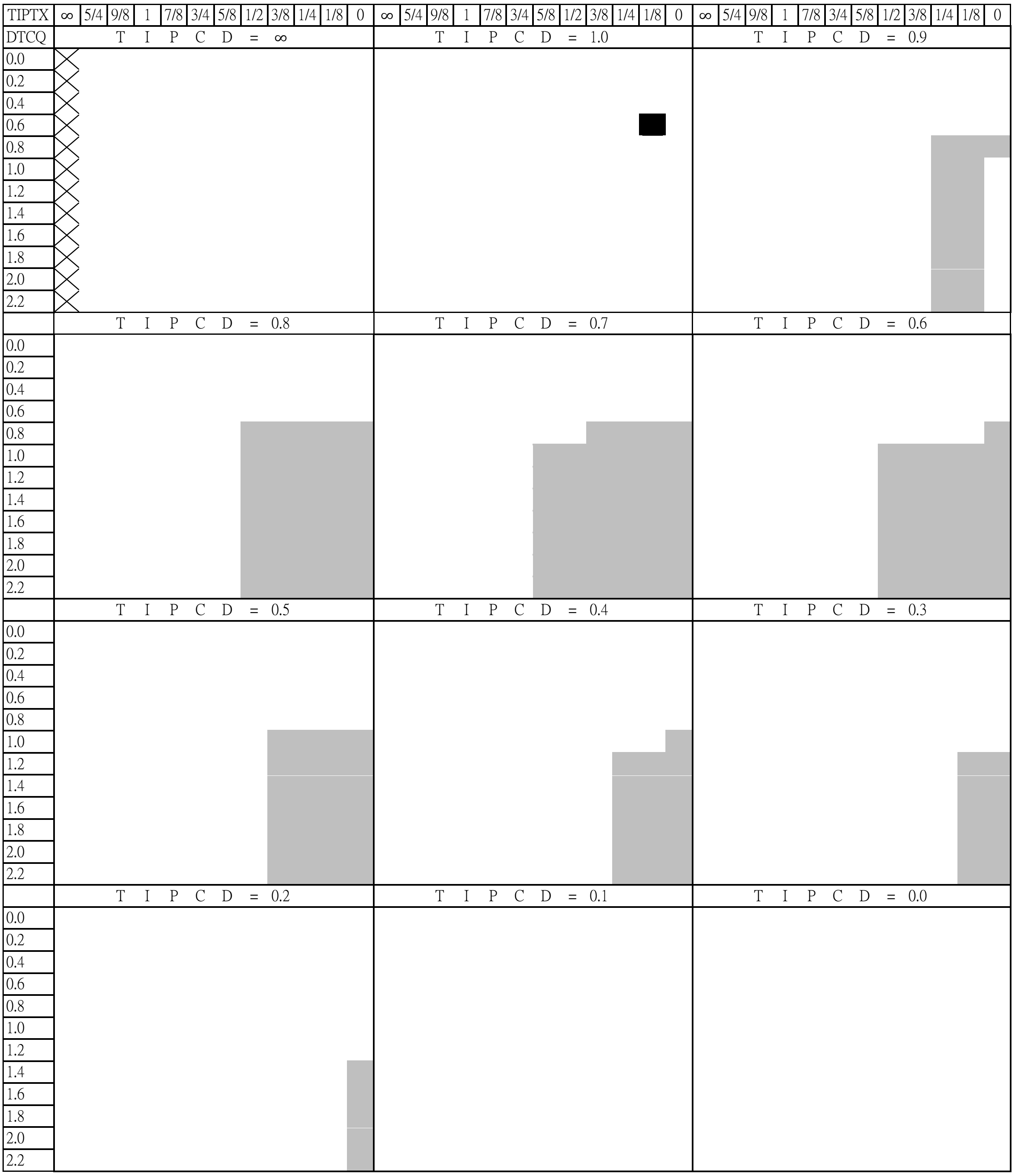
Second, the Nash equilibrium for this simultaneous move game (denoted as the area with black color) is characterized by [(0.5, 12.5%); 100%], which means that T will implement a moderate level of the quota constraint on the export of D to C, while significantly lowering the tariff rate on the import of X from C. At the same time, C will still implement a pretty high tariff rate on the import of D from T.

Third, Figure 3-9 also shows that compared to the Nash equilibrium outcome, there are still many possible policy combinations that yield even higher welfare levels for both countries (denoted as the area with gray color). This suggests that instead of just letting both countries interact strategically without any negotiation, the role of some trade agreements would be crucial. For example, T can

[13] Under the most restrictive case, the trade barriers between T and C are high enough such that there will be no trade between them. Note that even under this situation, there are still some trade activities between T and R, and C and R, respectively.

propose the policy combination [(1.4, 0%); 20%], i.e., T significantly liberalizes its trade barriers and also asks C to do so. If both countries can reach this agreement, then compared to the Nash equilibrium scenario, T's and C's welfare levels go up by 7.92% and 0.11%, respectively.

Figure 3-9 Simulation 3: The outcome of the Simultaneous Move Game



Crosses: Policy combinations that are not welfare-improving for both T and C compared to the most restrictive scenario. **Black:** The Nash equilibrium. **Gray:** Welfare-improving region for both T and C compared to the Nash equilibrium outcome.

4 Conclusion

This paper establishes a theoretical general equilibrium model to simulate the effect of trade liberalization on a NIC. The main conclusions are, first, when country T, the NIC, liberalizes the export quota constraint on the high-tech intermediate goods D from the most restrictive scenario, the global welfare level goes up until the constraint does not bind. However, the distribution of the benefit is quite different. The export of the final good X by country C, the developing country, becomes more competitive from adopting more composite D produced by T. Since both T and C compete in exporting X to the third country R, this implies that T cannot internalize all the benefit from this liberalization policy.

Second, for country T, lowering the tariff rate on the import of X from C can partially internalize the benefit created from exporting D to C. Also, for a given tariff rate imposed by C on the import of D, the welfare maximizing policy for T would be to adopt a moderate level of export quota constraint on D while significantly lowering the tariff rate on X. This is because a moderate level of export quota constraint can control the extent of the outward technology spillover and the leakage effect, while lowering the tariff rate can mitigate the leakage effect.

Finally, when both T and C play a simultaneous move game with their respective trade policy tools, there are still many possible policy combinations which yield even higher welfare levels for both countries compared to the Nash equilibrium outcome. This suggests that instead of just letting both countries interact strategically without any negotiation, the role of some trade agreements would be crucial.

Further studies could be considered. For example, while the firms might choose to export the high-tech intermediate goods, under some circumstances, they might also choose to establish plants in foreign countries directly (outward FDI) or adopt the outsourcing strategy.[14] These are not

[14] There are many studies about Multinational firms (FDI) and outsourcing. For example, Markusen (1984), Grossman and Helpman (2002), Antràs (2003), and Grossman and Helpman (2005).

considered in this paper. Investigating the welfare effects on the NIC from these activities would be an interesting extension for the future research.

Appendix A-01: Social Accounting Matrix for the Benchmark

	DT	XT	YT	DC	XC	YC	YR	DTC	XTR	XCT	YRT	XCR	YRC	NT	NC	WT	WC	WR	COT	ETT	COC	ETC	COR
PDT	80	-40						-40															
PXT		100							-50	50						-100							
PYT			40								60					-100							
PDC				20	-80			60															
PXC					200					-40		-60					-100						
PYC						50							50				-100						
PXRA									50			60						-110					
PYR							200				-60		-50					-90					
PWT																200			-200				
PWC																	200				-200		
PWR																		200					-200
PST	-32	-20												-8					60				
PLT		-20	-30																50				
PKT	-32	-20	-10											-8					70				
PSC				-8	-40										-2						50		
PLC					-40	-40															80		
PKC				-8	-40	-10									-2						60		
PLR							-150																150
PKR							-50																50
PFT														16						-16			
PFC															4							-4	
TTX										-10									10				
QTD								-10											10				
TCD								-10													10		
MKT	-16																			16			
MKC				-4																		4	

Appendix A-02: Definition of the Variables

1	DT	Sector D's composite output in T	30	DPADC	Output subsidy rate in MPS/GE for the IRS production in sector D in C
2	XT	Sector X's total output in T	31	DQADC	Difference b/w the output from IRS production and CRS production in C
3	YT	Sector Y's total output in T	32	PDT	User's price for DT in T
4	DC	Sector D's composite output in C	33	PDTC	User's price for DTC (DT export from T to C) in C
5	XC	Sector X's total output in C	34	PXT	Consumer's price for XT in T
6	YC	Sector Y's total output in C	35	PXTR	Consumer's price for XTR in R
7	YR	Sector Y's total output in R	36	PXTA	Consumer's price for XTA in T
8	DTC	Sector D's composite output from T to C	37	PYT	Consumer's price for YT in T
9	XCT	Sector X's output from C to T	38	PDC	User's price for DC in C
10	XTR	Sector X's output from T to R	39	PDCA	User's price for DCA in C
11	YRT	Sector Y's output from R to T	40	PXC	Consumer's price for XC in C
12	XCR	Export of sector X's output from C to R	41	PXCR	Consumer's price for XCR in R
13	YRC	Sector Y's output from R to C	42	PXCT	Consumer's price for XCT in T
14	XTA	Composite X in T (CES aggregation of "XT−XTR" and "XCT")	43	PYC	Consumer's price for YC in C
15	DCA	Composite D in C (CES aggregation of "DC" and "DTC")	44	PXRA	Consumer's price for XRA in R
16	XRA	Composite X in R (CES aggregation of "XTR" and "XCR")	45	PYR	Consumer's price for YR in R
17	NT	Activity level for number of firms in T	46	PWT	Shadow price for a unit utility in T (Chosen to be the numeraire)
18	NC	Activity level for number of firms in C	47	PWC	Shadow price for a unit utility in C
19	WT	Activity level for utility level in T	48	PWR	Shadow price for a unit utility in R
20	WC	Activity level for utility level in C	49	PST	Price for a unit skilled labor in T
21	WR	Activity level for utility level in R	50	PLT	Price for a unit unskilled labor in T
22	COT	Consumer's total income in T	51	PKT	Price for a unit capital in T
23	COC	Consumer's total income in C	52	PSC	Price for a unit skilled labor in C
24	COR	Consumer's total income in R	53	PLC	Price for a unit unskilled labor in C
25	ETT	Enterprises' total income in T (D sector's value added times mark-up in T)	54	PKC	Price for a unit capital in C
26	ETC	Enterprises' total income in C (D sector's value added times mark-up in C)	55	PLR	Price for a unit unskilled labor in R
27	TEVTD	Shadow export duty on DTC from imposing the export quota constraint	56	PKR	Price for a unit capital in R
28	DPADT	Output subsidy rate in MPS/GE for the IRS production in sector D in T	57	PFT	Price for a unit fixed cost in T
29	DQADT	Difference b/w the output from IRS production and CRS production in T	58	PFC	Price for a unit fixed cost in C

Appendix A-03: Model Specification

	Inequalities	Complementary variables	
Equation (1)-(31) can be generated by setting the data fields in MPS-GE (1)-(21): Zero-Profit conditions, (22)-(26): Income Balance conditions, and (27)-(31): Auxiliary equations		Activity level	Benchmark quantity
(A1)[15]	$PST^{0.5}PKT^{0.5} \geq PDT \cdot (1 + DPADT) \cdot (1 - 1/EDT)$	DT	QDT0=80/1.25
(A2)	$0.6 \cdot PST^{\frac{1}{3}}PLT^{\frac{1}{3}}PKT^{\frac{1}{3}} + 0.4 \cdot \frac{PDT}{1.25} \geq PXT$	XT	QXT0=100
(A3)	$PLT^{0.75}PKT^{0.25} \geq PYT$	YT	QYT0=40
(A4)[16]	$\frac{3}{2} \cdot (PSC^{0.5}PKC^{0.5}) \geq PDC \cdot (1 + DPADC) \cdot (1 - 1/EDC)$	DC	QDC0=20/1.875
(A5)	$\frac{4}{5} \cdot (0.6 \cdot PSC^{\frac{1}{3}}PLC^{\frac{1}{3}}PKC^{\frac{1}{3}} + 0.4 \cdot \frac{PDCA}{1.875}) \geq PXC$	XC	QXC0=200/0.8
(A6)	$PLC^{0.8}PKC^{0.2} \geq PYC$	YC	QYC0=50
(A7)	$PLR^{0.75}PKR^{0.25} \geq PYR$	YR	QYR0=200
(A8)	$PDT \cdot (1 + TEVTD) \cdot (1 + TIPCD) \geq PDTC$	DTC	QDTC0: 40
(A9)	$PXC \cdot (1 + TIPTX) \geq PXCT$	XCT	QXCT0=40/0.8
(A10)	$PXT \geq PXTR$	XTR	QXTR0=50
(A11)	$PYR \geq PYT$	YRT	QYRT0: 60
(A12)	$PXC \geq PXCR$	XCR	QXCR0=60/0.8

[15] In MPSGE program, the author breaks this single equation into two parts:
(1) $PCDT \geq PDT \cdot (1 + DPADT)$ with complementary variable DT. PCDT is the producer's price while PDT is the user's price in T.
(2) $PST^{0.5}PKT^{0.5} \geq PCDT \cdot (1 - 1/EDT)$ with complementary variable CDT

```
$PROD:DT
O:PDT      Q:QDT0     P:PDT0     A:COT     N:DPADT    M:-1
I:PCDT     Q:QDT0     P:PCDT0

$PROD:CDT  s:1.0
O:PCDT     Q:QDT0     P:PCDT0    A:ETT     T(1/EDT)
I:PST      Q:QSDT0    P:PST0
I:PKT      Q:QKDT0    P:PKT0
```

PCDT is the producer price for producing CDT (Composite DT), which is in fact the same as DT. I have CDT and DT here only because I have two equations here. This block says that when DPADT > 0, the production of DT will be encouraged. Since the producer's price PCDT will be higher than the user's price PDT.

[16] Similar to the above case, in MPSGE program, we have: (1) $PCDC \geq PDC \cdot (1 + DPADC)$ with complementary variable DC, and (2) $\frac{3}{2} \cdot PSC^{0.5}PKC^{0.5} \geq PCDC \cdot (1 - 1/EDC)$ with complementary variable CDC.

(A13)	$PYR \geq PYC$	YRC	QYRC0=50
(A14)[17]	$\left(\frac{1}{0.5}\right) \cdot (1^{\sigma} \cdot PXT^{1-\sigma} + 1^{\sigma} \cdot PXCT^{1-\sigma})^{\frac{1}{1-\sigma}} \geq PXTA\ ;\ \sigma = 2$	XTA	QXTA0=100
(A15)	$\left(\frac{1}{0.75}\right) \cdot (0.5774^{\sigma} \cdot PDC^{1-\sigma} + 1^{\sigma} \cdot PDTC^{1-\sigma})^{\frac{1}{1-\sigma}} \geq PDCA\ ;\ \sigma = 2$	DCA	QDCA0=80/1.875
(A16)	$\left(\frac{1}{0.4364}\right) \cdot (1.0206^{\sigma} \cdot PXTR^{1-\sigma} + 1^{\sigma} \cdot PXCR^{1-\sigma})^{\frac{1}{1-\sigma}} \geq PXRA\ ;\ \sigma = 2$	XRA	QXRA0=110
(A17)	$PST^{0.5}PKT^{0.5} \geq PFT$	NT	QFT0=16
(A18)	$PSC^{0.5}PKC^{0.5} \geq PFC$	NC	QFC0=4
(A19)	$PXTA^{0.5}PYT^{0.5} \geq PWT$	WT	QWT0=200
(A20)	$\left(\frac{PXC}{0.80}\right)^{0.5}PYC^{0.5} \geq PWC$	WC	QWC0=200
(A21)	$PXRA^{0.55}PYR^{0.45} \geq PWR$	WR	QWR0=200
(A22)	$COT = PST \cdot (QSDT0 + QSXT0 + QSFT0) + PLT \cdot (QLXT0 + QLYT0) + PKT \cdot (QKDT0 + QKXT0 + QKYT0 + QKFT0) + TEVTD \cdot PDT \cdot DTC \cdot QDTC0 + TIPTX \cdot PXC \cdot XCT \cdot QXCT0 + PDT \cdot DQADT \cdot QDT0$	COT	200
(A23)	$COC = PSC \cdot (QSDC0 + QSXC0 + QSFC0) + PLC \cdot (QLXC0 + QLYC0) + PKC \cdot (QKDC0 + QKXC0 + QKYC0 + QKFC0) + PDT \cdot (1 + TEVTD) \cdot TIPCD \cdot QDTC0 \cdot DT + PDC \cdot DQADC \cdot QDC0$	COC	200
(A24)	$COR = PLR \cdot QLYR0 + PKR \cdot QKYR0$	COR	200
(A25)	$ETT = \frac{PDT \cdot (1 + DPADT)}{EDT} \cdot QDT0 \cdot DT$	ETT	16
(A26)	$ETC = \frac{PDC \cdot (1 + DPADC)}{EDC} \cdot QDC0 \cdot DC$	ETC	4
(A27)	$DTCQ \geq DTC$	TEVTD	TEVTD0=0.25
(A28)	$DPADT = NT^{1/(EDT-1)} - 1$	DPADT	0
(A29)	$DQADT = DPADT \cdot DT$	DQADT	0
(A30)	$DPADC = NC^{1/(EDC-1)} - 1$	DPADC	0
(A31)	$DQADC = DPADC \cdot DC$	DQADC	0
	The following equations (Market Clearing conditions) are generated automatically by MPS-GE in the background. They are in the form: Supply ≥ Demand with the corresponding price as the complementary variable.	Activity level	Initial value

[17] In fact, this can be treated as an equation since XTA = 0 will never happen (If XTA = 0, then country T's utility will be zero).

(A32)[18]	$QDT0 \cdot DT \geq 0.32 \cdot QXT0 \cdot XT + \left(\frac{4}{3}\right) \cdot (0.5774^{\sigma} \cdot PDC^{1-\sigma} + PDTC^{1-\sigma})^{\sigma/1-\sigma} \cdot PDTC^{-\sigma} \cdot QDCA0 \cdot DCA$	PDT	PDT0=1.25
(A33)[19]	$PDTC = PDT \cdot (1 + TEVTD) \cdot (1 + TIPCD)$	PDTC	PDTC0=1.875
(A34)[20]	$QXT0 \cdot XT - QXTR0 \cdot XTR \geq 0.5 \cdot \left[\left(\frac{1}{0.5}\right) \cdot (1^{\sigma} \cdot PXT^{1-\sigma} + 1^{\sigma} \cdot PXCT^{1-\sigma})^{\frac{1}{1-\sigma}}\right]^{-0.5} \cdot PYT^{0.5} \cdot QWT0 \cdot WT \cdot \left[\frac{1}{0.5} \cdot (PXT^{1-\sigma} + PXCT^{1-\sigma})^{\frac{\sigma}{1-\sigma}} \cdot PXT^{-\sigma}\right]$	PXT	PXT0=1
(A35)	$PXTR = PXT$	PXTR	PXTR0=1
(A36)	$0.5 \cdot [1 \cdot (QXT0 \cdot XT - QXTC0 \cdot XTC)^{0.5} + 1 \cdot (QXCT0 \cdot XCT)^{0.5}]^2 \geq 0.5 \cdot PXTA^{-0.5} PYT^{0.5} \cdot QWT0 \cdot WT$	PXTA	PXTA0=1
(A37)	$QYT0 \cdot YT + QYRT0 \cdot YRT \geq 0.5 \cdot \left[\left(\frac{1}{0.5}\right) \cdot (1^{\sigma} \cdot PXT^{1-\sigma} + 1^{\sigma} \cdot PXCT^{1-\sigma})^{\frac{1}{1-\sigma}}\right]^{0.5} \cdot PYT^{-0.5} \cdot QWT0 \cdot WT$	PYT	PYT0=1
(A38)[21]	$QDC0 \cdot DC \geq \left(\frac{64}{375} \cdot QXC0 \cdot XC\right) \cdot \left[\left(\frac{4}{3}\right) \cdot 0.5774^{\sigma} \cdot PDC^{-\sigma} \cdot (0.5774^{\sigma} \cdot PDC^{1-\sigma} + PDTC^{1-\sigma})^{\sigma/(1-\sigma)}\right]$	PDC	PDC0=1.875
(A39)	$0.75 \cdot [0.5774 \cdot (QDC0 \cdot DC)^{0.5} + 1 \cdot (QDTC0 \cdot DTC)^{0.5}]^2 \geq (\frac{64}{375}) \cdot QXC0 \cdot XC$	PDCA	PDCA0=1.875
(A40)	$QXC0 \cdot XC - QXCT0 \cdot XCT - QXCR0 \cdot XCR \geq 0.5 \cdot (5/4) \cdot (PXC/0.80)^{-0.5} \cdot PYC^{0.5} \cdot QWC0 \cdot WC$	PXC	PXC0=0.80

[18] By Shepard's Lemma, the Hicksian demand for DTT is derived from taking the partial derivative of $e(PST, PLT, PKT, PDT; QXT0 \cdot XT)$ with respect to PDT, where $e(PST, PLT, PKT, PDT; QXT0 \cdot XT) = 0.6 \cdot PST^{\frac{1}{3}} PLT^{\frac{1}{3}} PKT^{\frac{1}{3}} + 0.4 \cdot \frac{PDT}{1.25}$ as presented in the left hand side of (A2).
Similarly, the Hicksian demand for DTC is derived from taking the partial derivative of $e(PDC, PDTC; QDCA0 \cdot DCA)$ with respect to PDTC, where $e(PDC, PDTC; QDCA0 \cdot DCA) = \left(\frac{1}{0.75}\right) \cdot (0.5774^{\sigma} \cdot PDC^{1-\sigma} + 1^{\sigma} \cdot PDTC^{1-\sigma})^{\frac{1}{1-\sigma}}$ as presented in the left hand side of (A15).

[19] This is determines PDTC (price of DT in country C) under the trade barriers imposed by both countries. TEVTD is the shadow export duty generated from T's export quota constraint, where TIPCD is the import tariff imposed by C.

[20] Country T's Hicksian demand for XT is derived from $\frac{\partial e(PXTA, PYT, QWT0 \cdot WT)}{\partial PXTA} \cdot \frac{\partial PXTA}{\partial PXT}$. We have country T's expenditure function as shown in the left hand side of (19): $e(PXTA, PYT, QWT0 \cdot WT) = e(PXT, PXCT, PYT, QWT0 \cdot WT) = PXTA^{0.5} PYT^{0.5}$ where $PXTA = \left(\frac{1}{0.5}\right) \cdot (1^{\sigma} \cdot PXT^{1-\sigma} + 1^{\sigma} \cdot PXCT^{1-\sigma})^{\frac{1}{1-\sigma}}$ when (14) is non-binding, which is in fact always true in this model.

[21] From (5), $e(PSC, PLC, PYC, PDCA; QXC0 \cdot XC) = \frac{4}{5} \cdot (0.6 \cdot PSC^{\frac{1}{3}} PLC^{\frac{1}{3}} PKC^{\frac{1}{3}} + 0.4 \cdot \frac{PDCA}{1.875}) \cdot QXC0 \cdot XC$, or equivalently: $e(PSC, PLC, PYC, PDC, PDTC; QXC0 \cdot XC) = \frac{4}{5} \cdot (0.6 \cdot PSC^{\frac{1}{3}} PLC^{\frac{1}{3}} PKC^{\frac{1}{3}} + 0.4 \cdot \frac{\left(\frac{1}{0.75}\right) \cdot (0.5774^{\sigma} \cdot PDC^{1-\sigma} + 1^{\sigma} \cdot PDTC^{1-\sigma})^{\frac{1}{1-\sigma}}}{1.875}) \cdot QXC0 \cdot XC$. As a result, we have: $\frac{\partial e}{\partial PDC} = \frac{\partial e}{\partial PDCA} \cdot \frac{\partial PDCA}{\partial PDC} = \left(\frac{64}{375} \cdot QXC0 \cdot XC\right) \cdot \left(\frac{4}{3}\right) \cdot 0.5774^{\sigma} \cdot PDC^{-\sigma} \cdot (0.5774^{\sigma} \cdot PDC^{1-\sigma} + PDTC^{1-\sigma})^{\sigma/(1-\sigma)}$.

(A41)	$PXCR = PXC$	PXCR	PXCR0=0.80
(A42)	$PXCT = PXC \cdot (1 + TIPTX)$	PXCT	PXCT0=1
(A43)	$QYC0 \cdot YC + QYRC0 \cdot YRC \geq 0.5 \cdot \left(\frac{PXC}{0.80}\right)^{0.5} \cdot PYT^{-0.5} \cdot QWC0 \cdot WC$	PYC	PYC0=1
(A44)	$0.4364 \cdot (1.0206 \cdot (QXTR0 \cdot XTR)^{0.5} + 1 \cdot (QXCR0 \cdot XCR)^{0.5})^2 \geq \frac{11}{20} \cdot PXRA^{-9/20} \cdot PYR^{9/20} \cdot QWR0 \cdot WR$	PXRA	PXRA0=1
(A45)	$QYR0 \cdot YR - QYRT0 \cdot YRT - QYRC0 \cdot YRC \geq \frac{9}{20} \cdot PXRA^{11/20} \cdot PYR^{-11/20} \cdot QWR0 \cdot WR$	PYR	PYR0=1
(A46)	$QWT0 \cdot WT \geq \frac{COT}{PWT}$	**PWT.fx**	PWT0=1
(A47)	$QWC0 \cdot WC \geq \frac{COC}{PWC}$	PWC	PWC0=1
(A48)	$QWR0 \cdot WR \geq \frac{COR}{PWR}$	PWR	PWR0=1
(A49)	$QST0 \geq 0.5 \cdot PST^{-0.5}PKT^{0.5} \cdot QDT0 \cdot DT + 0.6 \cdot \frac{1}{3} \cdot PST^{-\frac{2}{3}}PLT^{\frac{1}{3}}PKT^{\frac{1}{3}} \cdot QXT0 \cdot XT$ $+0.5 \cdot PST^{-0.5}PKT^{0.5} \cdot QNT0 \cdot NT$	PST	PST0=1
(A50)	$QLT0 \geq 0.6 \cdot \frac{1}{3} \cdot PST^{\frac{1}{3}}PLT^{-\frac{2}{3}}PKT^{\frac{1}{3}} \cdot QXT0 \cdot XT + \frac{3}{4} \cdot PLT^{-\frac{1}{4}}PKT^{\frac{1}{4}} \cdot QYT0 \cdot YT$	PLT	PLT0=1
(A51)	$QKT0 \geq 0.5 \cdot PST^{0.5}PKT^{-0.5} \cdot QDT0 \cdot DT + 0.6 \cdot \frac{1}{3} \cdot PST^{\frac{1}{3}}PLT^{\frac{1}{3}}PKT^{-\frac{2}{3}} \cdot QXT0 \cdot XT$ $+\frac{1}{4} \cdot PLT^{\frac{3}{4}}PKT^{-\frac{3}{4}} \cdot QYT0 \cdot YT + 0.5 \cdot PST^{0.5}PKT^{-0.5} \cdot QNT0 \cdot NT$	PKT	PKT0=1
(A52)	$QSC0 \geq 0.5 \cdot \frac{3}{2} \cdot PSC^{-0.5}PKC^{0.5} \cdot QDC0 \cdot DC + 0.6 \cdot \frac{1}{3} \cdot \frac{4}{5} \cdot PSC^{-\frac{2}{3}}PLC^{\frac{1}{3}}PKC^{\frac{1}{3}} \cdot QXC0 \cdot XC$ $+0.5 \cdot PSC^{-0.5}PKC^{0.5} \cdot QNC0 \cdot NC$	PSC	PSC0=1
(A53)	$QLC0 \geq 0.6 \cdot \frac{1}{3} \cdot \frac{4}{5} \cdot PSC^{\frac{1}{3}}PLC^{-\frac{2}{3}}PKC^{\frac{1}{3}} \cdot QXC0 \cdot XC + \frac{4}{5} \cdot PLC^{-\frac{1}{5}}PKC^{\frac{4}{5}} \cdot QYC0 \cdot YC$	PLC	PLC0=1
(A54)	$QKC0 \geq 0.5 \cdot \frac{3}{2} \cdot PSC^{0.5}PKC^{-0.5} \cdot QDC0 \cdot DC + 0.6 \cdot \frac{1}{3} \cdot \frac{4}{5} \cdot PSC^{\frac{1}{3}}PLC^{\frac{1}{3}}PKC^{-\frac{2}{3}} \cdot QXC0 \cdot XC$ $+\frac{1}{5} \cdot PLC^{\frac{4}{5}}PKC^{-\frac{4}{5}} \cdot QYC0 \cdot YC + 0.5 \cdot PSC^{0.5}PKC^{-0.5} \cdot QNC0 \cdot NC$	PKC	PKC0=1
(A55)	$QLR0 \geq \frac{3}{4} \cdot PLR^{-\frac{1}{4}}PKR^{\frac{1}{4}} \cdot QYR0 \cdot YR$	PLR	PLR0=1

(A56)	$QKR0 \geq \frac{1}{4} \cdot PLT^{\frac{3}{4}} PKT^{-\frac{3}{4}} \cdot QYR0 \cdot YR$	PKR	PKR0=1
(A57)	$QNT0 \cdot NT \geq \frac{ETT}{PFT}$	PFT	PFT0=1
(A58)	$QNC0 \cdot NC \geq \frac{ETC}{PFC}$	PFC	PFC0=1

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