

Reflecting upon the impact of the gate-price system under perfect and imperfect competition

-Introducing a spatial equilibrium model under consideration of a realistic, differential tariff system to the Japanese pork import market-

Abstract:

Key words: international pork market, spatial equilibrium model, imperfect market competition, Japanese gate-price system

Introduction

Albeit an increasing health awareness and the possibility to obtain a variety of meat products, due to improved trade conditions, pork remains the main meat consumed in most developed countries. In addition, pork consumption grows in transition countries where supplementary available income is primarily spent on food products. All the same, the international pork market is a rather narrow market according to participating trading regions and traded volume. Only about nine percent of the world pork production is internationally traded. Key exporters include the United States, Canada, and the European Union. Key importers constitute Japan and Russia. The latter also produce pork themselves at high production costs. This is only possible because of a remaining heavy protection rate in these countries. Although the international pork market when compared to other markets seems to be de-regulated this is not true for each single market in particular. In other words, protection remains high in countries such as Japan and Russia.

In this context, the Japanese gate-price system is especially being targeted by key exporters. The gate-price system is, thus, subject to revision in the current WTO negotiation round on agricultural trade. However, the gate-price system as it has been negotiated during the Uruguay round is a specific variable tariff which has not been endogenously computed in most of the existing trade models.

This study aims at introducing a partial equilibrium model of international trade as it has been first developed by SHONO and KAWAGUCHI (1999A). It has been extended by BERGEN, KAWAGUCHI and KANO (2004) to include the gate-price system, in order to apply it to the international pork market. Following a brief explanation of the Japanese gate-price system, the model will be presented and applied under perfect and imperfect market conditions.

The Japanese gate-price system for pork imports

Japan's pork market illustrates the role of both, import and domestic measures for protecting commodity markets, and also the rapid restructuring of agriculture following a market price decline. Japan's agricultural policies in the pork sector pursue to support producers' income while keeping market prices stable. The specific domestic protection instrument to implement government policies in the pork sector applies a price stabilisation band.

The midpoint price of the band is set to meet the objective of maintaining a standard of living in rural areas, while the floor and ceiling prices are set to constrain excess upward price movements. The Livestock Industry Promotion Corporation (LIPC)¹ intervenes in the market through its purchase or storage subsidies granted to producers and selling activities to ensure that market price always moves within the limits of the band.²

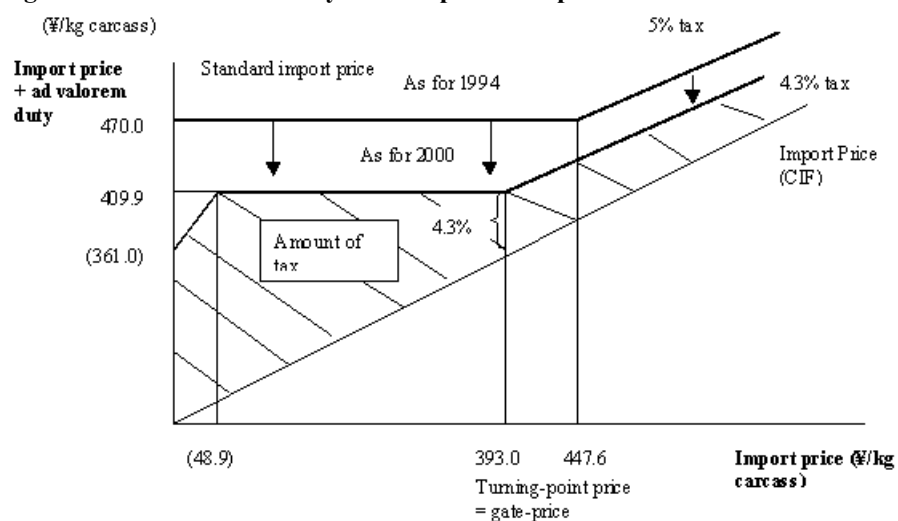
Moreover, the price band is supported at the border by requiring that all imports enter at a minimum import price, the so-called gate-price, which used to be linked directly to the midpoint of the stabilisation band (stabilisation price = administrative price). Before the GATT Uruguay round agreement (URRA) a variable levy was used to implement the gate price policy. Imports with CIF values above the gate-price were charged an ad valorem tariff of five percent. Since then, these rules have altered due to an agreement between Japan and the United States. Although the gate-price was maintained, it is now (officially) decoupled from the stabilisation price band (see Figure 1).

Concluding, the Japanese pork market is now protected in two ways, which are still interlined. While subsidies are being paid through prefectural governments according to a complicated system, which has to be individually traced, a differential tariff system based on the concept of the gate-price system provides the basis for these payments. Accordingly, the gate-price is annually set, although it was subject to gradual reduction commitment until 2000. Since then it remains at 393 ¥/kg of carcass meat until the end of the next WTO round agreement. The variable levy has been converted into a specific tax, and together with the ad valorem tariff of currently 4.3 percent, it was also subject to reduction commitments.

¹ Agriculture & Livestock Industry Corporation (ALIC) was established in October, 1996 as a quasi-government institution by the integration of the LIPC and the Japan Raw Silk & Sugar Price Stabilisation Agency. Its object is to contribute to the sound development of the agricultural and livestock industries, along with their related industries, by stabilising and adjusting the prices of major livestock products, raw silk and sugar, and by promoting the agricultural and livestock industries.

² Applicable Law: Law concerning the Stabilisation of Livestock Prices.

Figure 1: Differential tariff system for pork in Japan

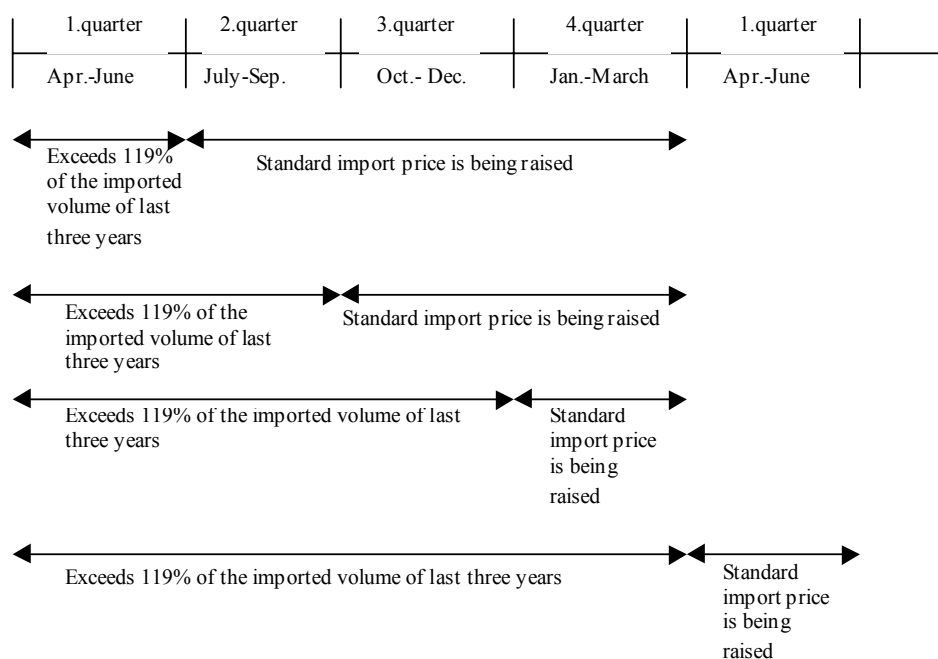


In other words, the Japanese differential tariff system for pork- or more precisely meat of swine- constitutes of a relatively low ad valorem tariff of 4.3 percent and the gate-price system which

confronts imports at the border. It imposes a minimum import price on pork shipments. For shipments valued below the minimum price, importers have to pay the difference between the shipment's value and the minimum price. Hence, the system taxes the importation of lower-valued pork cuts.

In addition, related to the gate-price system the so-called emergency import safeguard measures are automatically invoked whenever the import volume for a particular fiscal quarter exceeds the average for the same quarter of the past three years by more than 19 percent (see Figure 2). The safeguard then raises the gate-price from 393 ¥/kg to 489 ¥/kg for carcass meat of swine. This has been the case for the last five years.

Figure 2: Emergency safeguard for pork in Japan



The effect of the gate-price system, particularly in case the safeguard is triggered, is a thorn especially in the side of the major pork exporters to Japan. Major pork exporters to Japan include the United States, Canada, the European Union mainly represented by Denmark, and recently also Mexico.

Table 1: Export of pork to Japan (in 10 Mio. US\$, in 10'000 tons cut base)

	1998		1999		2000		2001		2002	
	volume	value	volume	value	volume	value	volume	value	volume	value
United States	16.02	7.33	16.77	8.15	18.91	10.25	24.49	14.47	24.89	15.08
Canada	6.18	2.71	9.09	4.35	11.09	5.91	15.28	8.87	17.89	10.84
EU 15	15.09	5.63	21.41	8.52	27.41	14.48	23.64	13.43	25.73	15.42
Denmark	12.47	5.26	17.19	8.03	21.22	11.22	21.35	10.05	23.99	14.40
Mexico	3.06	1.32	3.98	1.75	3.98	2.12	4.22	2.48	4.06	2.54
Chile	0.50	n.a.	0.47	n.a.	0.84	n.a.	1.01	0.56	2.16	1.25
Others	12.25	n.a.	12.80	n.a.	9.05	n.a.	4.50	2.55	4.75	2.83

Source: Agro trade handbook, JETRO.

Although opinions on the gate-price system may differ among exporters it has been stated clearly by the US and Canada that an amendment shall be necessary in order to do justice to an agricultural market liberalisation. An elimination of the gate-price system- or alternatively of the safeguard is called for.

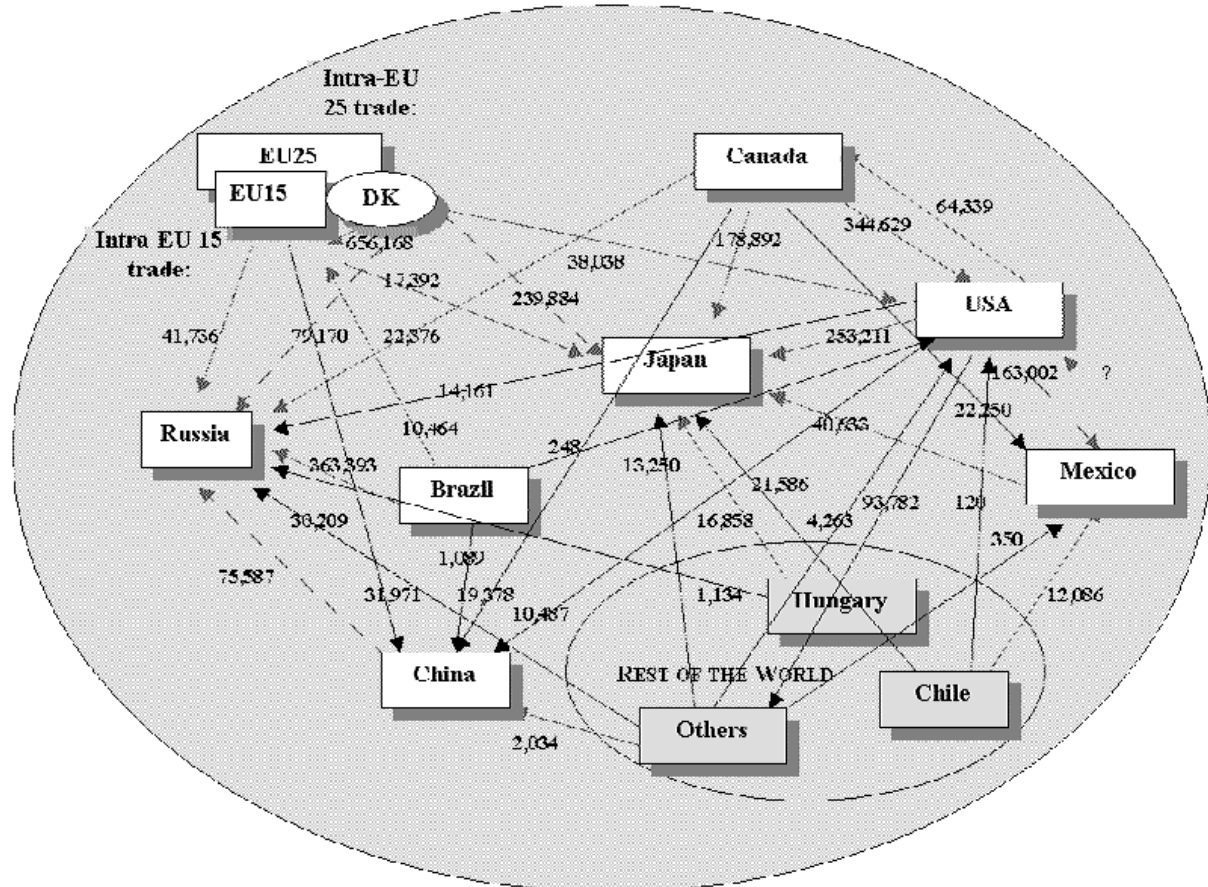
Hence, the objective of this research is to analyse future pork trade flows among nine major pork importers and exporters, along the following hypotheses:

1. The gate-price system including the safeguard will be abolished by 2011, while import tariff remains at 4.3 percent.
2. The gate-price system will remain, while import tariff will be reduced or abolished.
3. The gate-price system and the import tariff will be abolished by 2011.
4. The safeguard will be abolished, however gate-price and import tariff remain.

This research aims at forecasting a future prognosis for the year 2011 under the assumption of a mid-term analysis following a possible outcome of the present WTO negotiations on agriculture by 2006. Therefore, effects of the EU enlargement as well as the increasing production and consumption capacity in pork producing and consuming regions such as Brazil, China and Russia also need to be taken into account. Hence, this research includes

nine regions constituting Japan, the US, Canada, the EU, Mexico, Brazil, Russia, China and the rest-of-the-world (ROW), in order to close the model. The following figure shows basic trade flows between these regions in volume terms (metric tons unit).

Figure 3: Participating regions in international pork trade



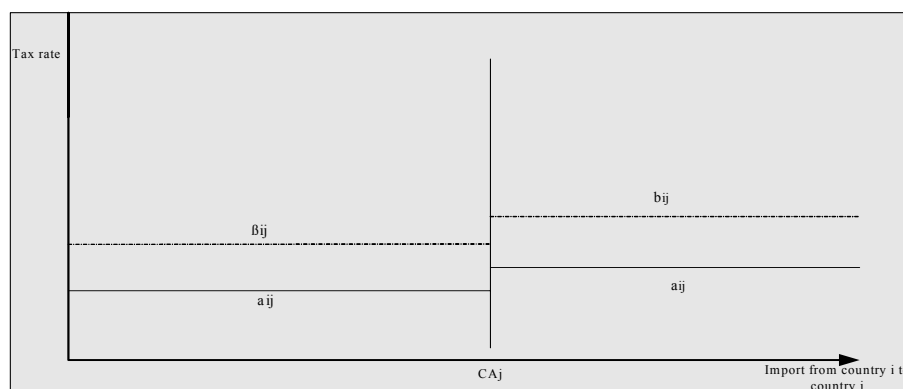
Source: Own composition taken from various statistical yearbooks.

Theoretical Model and its application

Following the above introduction to the problem at hand, this research applies a spatial equilibrium model under differing imperfect market competition, which is of partial, comparative-static nature. Moreover, it emphasises the significant characteristics of the Japanese pork market underlying the exceptional position of the gate-price, which proves to be influential to the world pork market. Yet, despite the model's originality, its explanatory power remains limited due to its constraints as a partial, one-product model. Thus, results of this model have to be linked to the circumstances as a whole, including national policies, international circumstances, environmental issues, farm level etc.

In order to apply the model, its conceptual framework shall be briefly explained. The SHONO and KAWAGUCHI (1998) spatial equilibrium model for international trade, introduces realistic tariffs in that it emphasises the existence of a tariff-quota system, which was not considered in previous models. In reality, although of homogenous quality, merchandised goods are divided into a primary and a secondary market. At the primary market goods can be imported at a low-level tax rate up to a fixed quantity (current access quantity). Exceeding this quantity level, goods have to be imported at a high-level tax rate to the secondary market. In addition, apart from the existing quantity-based specific tariff, one also finds a price-based ad valorem tariff, which are often combined to a third compound tariff.

Figure 4: Compound tariff in two separately regarded markets



Remark: the tax rate level shown in the solid as well as the perforate line exist in various pairs of countries, and in general the relation $\alpha_{ij} < \alpha_{ji}$, $\beta_{ii} < \beta_{ii}$ is solely to be found. In this figure there is no special meaning to the larger or smaller size relation of α and β (or a and b).

The above figure presents a subdivision of imports to country j into a primary and secondary market separated from each other by a fixed current access quantity. Accordingly, α_{ij} and β_{ii}

represent the ad valorem and specific tariff of the primary market, whereas a_{ij} and b_{ij} present the secondary market.³

At first, in order to understand and finally apply the spatial equilibrium model of international trade among n ($n \geq 2$) countries the following notations are used. If there is no specific definition, i, j refers to any integer from 1 to n .

In correspondence to the tariff-quota system mentioned above, we consider the markets of all countries as two different tariff markets, the primary and secondary market with a corresponding primary and secondary tariff rate.

Table 2: Compound tariff system of country j for imports from country i

	Primary market	Secondary market
Price-based tariff rate	α_{ij}	a_{ij}
Quantity-based tariff rate	β_{ij}	b_{ij}

Source: SHONO, KAWAGUCHI (1998)

- a) CA_j represents the current access quantity in the primary market of country j . With regard to exports from country i to country j the compound tariff composition of the importing country j is shown in Table 2. In addition, the compound tariff rates as shown in the above Figure 4 generally result in the following relation $\alpha_{ij} \leq a_{ij}$ (Price), $\beta_{ij} \leq b_{ij}$ (Quantity), with α, β representing the primary market, and a, b the secondary market. As a formality, domestic supply within country i is also considered to be an export to the primary market of country i . Hence, $\alpha_{ii} = \beta_{ii} = 0$. However, domestic supply is not considered to be part of the general import quantity. As a formal prerequisite a_{ii} and b_{ii} for imports are adjusted to prohibitive values at a high level by which an import to the secondary market becomes impossible.
- b) Quantity is marked for all trading countries as shown below in Table 3. For formality reasons the quantity traded from country i to country i in the secondary market is market by X_{sii} , but its value equals 0. Further $D_j = D_{1j} + D_{2j}$ introduces total demand in country j , whereas in country i , S_i defines the supply quantity, and in country j , D_j marks the demand quantity.

³ SHONO and KAWAGUCHI have further extended the model by introducing export quota and minimum export prices, and later export subsidies under perfect competition as well as under imperfectly competitive conditions. The gate-price system, however, had not yet been explicitly integrated into this model. Arguably, the gate-price was taken into consideration by various other models such as the ERS model of the USDA. The ERS model, however, used a range of tariffs instead of endogenously computing the gate-price. Tariffs substituted for the gate-price (and the current 4.3 percent ad valorem tariff) were 15 percent and 25 percent.

Table 3: Traded quantity and supply and demand quantity for all countries (n)

Importing country	1	2	...	n	1	2	...	n	Sum
Exporting country	Primary market				Secondary market				
1	X ₁₁	X ₁₂	...	X _{1n}	X _{s11}	X _{s12}	...	X _{s1n}	S ₁
2	X ₂₁	X ₂₂	...	X _{2n}	X _{s21}	X _{s22}	...	X _{s2n}	S ₂
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
n	X _{n1}	X _{n2}	...	X _{nn}	X _{sn1}	X _{sn2}	...	X _{snn}	S _n
Sum	D ₁₁	D ₁₂	...	D _{1n}	D ₂₁	D ₂₂	...	D _{2n}	

c) We use PS_i to refer to the production price in country i , and PD_j to represent the market price in country j , respectively. T_{ij} reflect the transportation costs (more generally transaction costs) per unit traded good from country i to country j . Insurance premium per unit for export from country i to j is defined as I_{ij} .

The following function shows the resulting log-linear supply function in country i .

$$\log S_i = \log \mu_i + \eta_i \log(PS_i) \quad (\text{generally } \eta_i > 0)$$

Its adverse function is given as:

$$\log PS_i = (\log \mu_i / \eta_i) + (1 / \eta_i) \log S_i$$

In addition, in country j the log-linear demand function is as follows:

$$\log D_j = \log \gamma_j - \lambda_j \log(PD_j) \quad (\text{generally } \gamma_j > 0, \lambda_j > 0)$$

Its adverse function is given as:

$$\log PD_j = (\log \gamma_j / \lambda_j) - (1 / \lambda_j) \log D_j$$

Altogether, the model applied would also allow for the implementation of exponential or linear functions, but finally applies log-linear functions, only. For simplicity reason though, equilibrium conditions are presented in the following as linear functional forms. They are converted and applied in the model according to the following concept:

Box 1: Log-linear supply and demand function

This research applies log-linear supply and demand functions for application reason.

$$\log S_i = \log \mu_i + \eta_i \log(PS_i) \quad (\text{generally } \eta_i > 0)$$

The converted function ascribed to a linear approximation is given as:

$$S_i = OS_i (1 - \eta_i) + [\eta_i (OS_i / OPS_i)] PS_i \quad (OPS_i = \text{old constant } PS_i, OS_i = \text{old constant } S_i, \eta_i = \text{elasticity of demand})$$

In addition, in country j the non-linear, exponential demand function is as follows:

$$\log D_j = \log \gamma_j - \lambda_j \log(PD_j) \quad (\text{generally } \varepsilon_j \geq 0, \theta \leq 0)$$

The converted function ascribed to the linear function is given as:

$$D_j = OD_j (1 - \lambda_j) + \lambda_j (OD_j / OPD_j) PD_j \quad (OPD_j = \text{old constant } PD_j, OD_j = \text{old constant } S_i, \lambda_j = \text{elasticity of demand})$$

Subsequently, equilibrium conditions for the case of perfect market competition are defined.

a) Equilibrium conditions of markets

Demand quantity in country j does not exceed the sum of the shipped quantity from all countries including country j to country j, and the both are equal if the market price PD_j is positive. They can differ if and only if PD_j equals 0.

$$\gamma_j - \lambda_j PD_j \leq X_{1j} + X_{2j} + X_{3j} + X_{s1j} + X_{s2j} + X_{s3j} \quad (j=1,2,3)$$

$$(-\gamma_j + \lambda_j PD_j + X_{1j} + X_{2j} + X_{3j} + X_{s1j} + X_{s2j} + X_{s3j}) PD_j = 0$$

b) Equilibrium conditions of producers

The sum of the shipped quantity from country i to all countries does not exceed the supply quantity in country i, both are equal if the production price PS_i is positive. They can differ if and only if PS_i equals 0.

$$X_{i1} + X_{i2} + X_{i3} + X_{s1i} + X_{s2i} + X_{s3i} \leq -\mu_i + \eta_i PS_i \quad (i=1,2,3)$$

$$(-\mu_i + \eta_i PS_i - X_{i1} - X_{i2} - X_{i3} - X_{s1i} - X_{s2i} - X_{s3i}) PS_i = 0$$

c) Equilibrium conditions of X_{ij}

Deducting the sum of the compound tariff of the primary market $\beta_{ij} + \alpha_{ij} (PS_i + T_{ij} + I_{ij})$, the unit transportation costs T_{ij}, unit insurance costs I_{ij} and the shadow price SP_j from the market price

PD_j in country j , one calculates *the value of marginal revenue* (MR) of the traded good in the producing country i in case of shipment to the concerned market j . This *MR value does not exceed the production price* PS_i ,⁴ which means the marginal income per unit is smaller than or equal to the production price, and if smaller, then X_{ij} equals 0. X_{ij} can be positive if and only if this MR is equal to PS_i . After a simple transformation this relation is expressed by the following formula (in case of $j = j$, the term $SP_j/(1+\alpha_{ij})$ should be deleted.)

$$PD_j / (1 + \alpha_{ij}) - PS_i - SP_j / (1 + \alpha_{ij}) \leq T_{ij} + I_{ij} + \beta_{ij} / (1 + \alpha_{ij}) \quad (j = 1,2,3 \quad i = 1,2,3)$$

$$[T_{ij} + I_{ij} + \beta_{ij} / (1 + \alpha_{ij}) - PD_j / (1 + \alpha_{ij}) + PS_i + SP_j / (1 + \alpha_{ij})] X_{ij} = 0$$

d) Equilibrium conditions of X_{sij}

The marginal revenue (MR), in country i in the case of shipping to the relevant market j , is calculated by deducting the compound tariff $b_{ij} + a_{ij}$ ($PS_i + T_{ij} + I_{ij}$), unit transportation costs T_{ij} and unit insurance costs I_{ij} from country j 's market price PD_j . It does not exceed the production prices PS_i , and if MR is smaller than the production price PS_i , then X_{sij} equals 0. X_{sij} can be positive if and only if these two are equal.

This is expressed in the following way:

$$PD_j / (1 + \alpha_{ij}) - PS_i \leq T_{ij} + I_{ij} + b_{ij} / (1 + \alpha_{ij}) \quad (j = 1,2,3 \quad i = 1,2,3)$$

$$[T_{ij} + I_{ij} + b_{ij} / (1 + \alpha_{ij}) - PD_j / (1 + \alpha_{ij}) + PS_i] X_{sij} = 0$$

e) Equilibrium condition of SP_j

The total import quantity to the primary market of country j does not exceed the current access quantity CA_j of the relevant market. In case the total import quantity is lower than the current access quantity, the shadow price SP_j of the relevant market equals 0.

The shadow price SP_j can be positive if and only if these two are equal.

$$X_{1j} + X_{2j} + X_{3j} - X_{sij} \leq CA_j \quad (j = 1,2,3)$$

$$(CA_j - X_{1j} - X_{2j} - X_{3j} + X_{sij}) SP_j = 0$$

The above explanation of equilibrium conditions for perfect market competition can be expressed in 27 steps of equations and inequalities. First, slack variables are introduced in each of these 27 inequalities, and then the equilibrium conditions are transformed in the way as are given in Appendix 1. Note, all variables including slack variables are assumed to be non-negative. The equations are subject to $n=3$, as an example.

⁴ Condition of perfect competition

Further, because taxation regulations usually do not count for domestic supply X_{11} , X_{22} , X_{33} tariff rates $\alpha_{11} = \alpha_{22} = \alpha_{33}$, $\beta_{11} = \beta_{22} = \beta_{33}$ generally become 0. Also, if at the primary market of country j a tariff, as it is the case for the markets of Japan, only exists as *ad valorem* tariff, β_{ij} becomes 0.

Further, if the requirements of the 27 mathematical expressions⁵ are presented in a matrix and vector symbols, it is clear that the problem can be specified as the problem to find the value of vectors P and W that meet the requirements of $W = AP + B$ and $WT P = 0$, as suggested by the particular LCP problem. In other words, the problem can be specified as a linear complementarity problem.⁶ Therefore, if the linear complementarity problem can be solved, the equilibrium solution can be found. The table in Appendix 2 according to KAWAGUCHI and SHONO (1999a) stresses the formulation of these specific equilibrium conditions as a complementarity problem for the case of perfect market competition.

Box 4: Introducing the basic idea of the linear complementarity problem (LCP) in few words

Complementarity problems belong to the general problem formulation of the variational inequality theory which also encompasses various mathematical problems such as non-linear equations, optimisation problems. Variational inequality theory, however, is utilised as a fundamental methodology in synthesising economic equilibrium models including spatial equilibrium models under a spectrum of behavioural mechanism (NAGURNEY 1993, pp. 1-12). In this context, it is relevant to differentiate between the ‘equilibrium’ modelling approach following a complementarity problem and an ‘optimisation’ approach where one derives necessary conditions from an optimisation model (MATHIESEN. 1985, p. 114). In a LCP there is no objective function to be optimised. The problem is: find $w = (w_1, \dots, w_n)$, $z = (z_1, \dots, z_n)^T$ satisfying:

$$(1.1) \quad w - Mz = q \quad w \geq 0, z \geq 0 \text{ and } w_i z_i = 0 \text{ for all } i$$

The only data in this problem is the column vector q and the square matrix M . The LCP is denoted by finding $w \in \mathfrak{R}_n$, $z \in \mathfrak{R}_n$ satisfying (1.1) by the symbol (q, M) . It is said to be a LCP of order n .

Summarizing, the LCP can be applied as a modelling format. An equilibrium is then computed by either solving the particular LCP via various existent pivoting algorithms or by iterative methods.

For the given problem, the so-called symmetric parametric principal pivoting method processes this specific LCP as the solving algorithm.⁷ Each of the algorithmic rules are then translated into the Visual Basic computer language and executed by machine.

For the case of imperfect market competition as it is finally applied in this research, the above equilibrium conditions are amended according to the following Cournot-Nash theorem for oligopolistic market behaviour:

⁵ In the case of $n = 9$ there are 189.

⁶ For further information on the mathematical background of the linear complementarity problem (LCP) please refer to COTTLE ET AL. (1992).

⁷ See COTTLE ET AL. (1992; pp. 293-296).

Box 2: The Cournot-Nash theorem for oligopolistic market behaviour, in brief

- 1) Consumers in each country act as price takers, while producing areas in each country do not form alliances but act independently as one country-one producing area in terms of the Cournot-Nash theorem.
- 2) In other words, consumers' demand in each country are set to be linear (or non-linear), while production costs of producers in each country constitute fixed costs and a linear (or non-linear) marginal cost function.
- 3) The connecting transportation network between producing area and market of each country is assumed a simplified direct route from the centre of the producing area to the market of each country, where each route's unit transportation cost is fixed based on ad-valorem tax.
- 4) In each producing country, producers know about demand functions prevailing in each market. Following this, in case the difference between marginal costs and marginal income is greater than unit transaction costs of the connecting exporting route, exporting countries' producers will increase exporting quantity along these routes. Contrary, if this difference is smaller than unit transaction costs, there will be no transport along this route.

In each country forwarding between markets does not take place.

Based on the same principle as introduced above, the main difference in the case of imperfect market competition refers to the difference between the prevailing market price PD_j and the marginal revenue. In other words, the revenue from selling export goods from country i to the market of country j can be denoted by R_{ij} and further expressed by using $D_j = x_{ij} + x_{Sij} + E_{ij}$ where:

$$R_{ij} = PD_{ij} (x_{ij} + x_{Sij}) = [\gamma_1/\lambda_j - (1/\lambda_j) D_j] (x_{ij} + x_{Sij}) = [\gamma_1/\lambda_j - (1/\lambda_j) x_{ij} + x_{Sij} + E_{ij}] (x_{ij} + x_{Sij}),$$

and where E_{ij} denotes supplied quantity to country j after excluding country i from all countries. Therefore, seeking the marginal revenue $\delta R_{ij}/\delta x_{ij} = \delta R_{ij}/\delta x_{Sij} = \gamma_1/\lambda_j - (1/\lambda_j) D_j - (1/\lambda_j) (x_{ij} + x_{Sij}) = PD_{ij} - (1/\lambda_j) (x_{ij} + x_{Sij})$, the difference to the market price PD_j is shown by the term $(1/\lambda_j) (x_{ij} + x_{Sij})$.

Accordingly, in case export increases by one unit, price declines by $(1/\lambda_j)$ only, since the effect of the price decrease is trickled down to the whole export quantity from country i to country j .

To make it more apparent, in case country i additionally exports one unit to the market of country j , other countries as a whole will react by exporting additional r_{ij} units to the market of country j . Country i will therefore speculate a total of $(1 + r_{ij})$ units of additional exports to country j , with only a $(1/\lambda_j) (1 + r_{ij})$ price decrease for itself. Country i 's own marginal income will speculatively be $[PD_{ij} - (1/\lambda_j) (1 + r_{ij}) (x_{ij} + x_{Sij})]$. In this case, the difference becomes $(1/\lambda_j) (1 + r_{ij}) (x_{ij} + x_{Sij})$.

Still, r_{ij} is called country i^{th} conjectural variation, expressing country i^{th} purely subjective speculations. Therefore, for simplicity reason $r_{ij} = 0$ is presumed, which implies that all countries behave according to the Nash theorem. Hence, the equilibrium conditions as they deviate from the case of perfect competition change as follows.

Equilibrium condition of x_{ij}

Referring to the exported quantity x_{ij} of the primary market from country i to country j one receives the pure marginal income by deducting the sum of the compound tariff $\beta_{ij} + \alpha_{ij}$ ($PS_i + T_{ij} + I_{ij}$) of the primary market, the unit transportation cost T_{ij} , the unit insurance cost and the shadow price from the marginal revenue $PD_{ij} - (1/\lambda_j)(1 + r_{ij})$. In other words, the pure marginal revenue of country i in case of export to the relevant market of country j (marginal revenue = unit transportation cost) does not exceed marginal cost PS_i . If pure marginal income is smaller than this marginal cost PS_i , x_{ij} equals zero. x_{ij} can be positive if and only if the two are equal. This relation is expressed in the following formula. Only if $i = j$ SP_j can be omitted.

$$PD_j / (1 + \alpha_{ij}) - PS_i - SP_j / (1 + \alpha_{ij}) - (x_{ij} + x_{sij}) / [\lambda_j (1 + \alpha_{ij})] \leq T_{ij} + I_{ij} + b_{ij} / (1 + \alpha_{ij})$$

$$T_{ij} + I_{ij} + b_{ij} / (1 + \alpha_{ij}) - PD_j / (1 + \alpha_{ij}) + PS_i + (x_{ij} + x_{sij}) / [\lambda_j (1 + \alpha_{ij})] \quad X_{ij} = 0$$

Etc.

Equilibrium conditions of X_{sij}

Accordingly, for shipped quantity from country i to the secondary market of country j the following relation is applied:

$$PD_j / (1 + \alpha_{ij}) - PS_i - (x_{ij} + x_{sij}) / [\lambda_j (1 + \alpha_{ij})] \leq T_{ij} + I_{ij} + b_{ij} / (1 + \alpha_{ij})$$

$$T_{ij} + I_{ij} + b_{ij} / (1 + \alpha_{ij}) - PD_j / (1 + \alpha_{ij}) + PS_i + (x_{ij} + x_{sij}) / [\lambda_j (1 + \alpha_{ij})] \quad X_{sij} = 0$$

Etc.

Summarizing, the following 27 equations of equilibrium conditions slightly deviate from the above introduced basic model so that equations 7-24 change as following:

Equilibrium conditions of X_{ij}

$$Y_{11} = T_{11} + I_{11} + \beta_{11}/(1 + \alpha_{11}) - PD_1/(1 + \alpha_{11}) + PS_1 + (x_{ij} + x_{sij})/ [\lambda_j (1 + \alpha_{ij})] \quad X_{11} Y_{11} = 0$$

$$Y_{21} = T_{21} + I_{21} + \beta_{21}/(1 + \alpha_{21}) - PD_1/(1 + \alpha_{21}) + PS_2 + SP_1/(1 + \alpha_{21}) + (x_{21} + x_{s21})/ [\lambda_j (1 + \alpha_{21})] \quad X_{21} Y_{21} = 0$$

Etc.

Equilibrium conditions of X_{sij}

$$Y_{11} = T_{11} + I_{11} + b_{11}/(1 + a_{11}) - PD_1/(1 + a_{11}) + PS_1 + (x_{ij} + x_{sij})/ [\lambda_j (1 + a_{ij})] \quad X_{11} Y_{11} = 0$$

$$Y_{21} = T_{21} + I_{21} + b_{21}/(1 + a_{21}) - PD_1/(1 + a_{21}) + PS_2 + (x_{21} + x_{s21})/ [\lambda_j (1 + a_{21})] \quad X_{21} Y_{21} = 0$$

Etc.

These equations 1-27 can also be transformed to be expressed as a LCP. The problem is then also solved by symmetric parametric principal pivoting method algorithm.

Further, the applied model presumes that depending on the exporting region the pork market is either an oligopoly or else of more polypolistic nature. In other words, using the simple model as presented above where the oligopolistic behaviour refers to the country itself is rather unrealistic. In other words, the simple assumption of a strongly oligopolistic country where N_i (export) companies equals one, implies that in a country i all export companies are exactly the same and behave identically. This is especially not lifelike when considering the “rest of the world” as one additional region. Hence, the idea of an oligopolistic market structure has to be revised such that it integrates different competitiveness into one model.

In other words, the marginal revenue of the exporting country i in case of a strongly oligopolistic market structure in country j (MR_{ij}) is given by $MR_{ij} = PD_j - (1/\lambda_j)(X_{ij} + X_{sij})$ where λ_j is the slope of the demand curve in country j and $X_{ij} + X_{sij}$ is the exporting quantity from i^{th} country to j^{th} country. PD_j is the market price in country j .

Revising, the marginal revenue can then be expressed by $MR_{ij} = PD_j - (1/\lambda_j)([X_{ij} + X_{sij}] / N_i)$ where N_i is the number of the same companies assumed in country i . However, a fixed number for each N_i does not necessarily reflect on actual competitiveness in each country for companies do not adhere to their market power essentially. Hence, in the first step of this research when fixing a reference set N_i was chosen by parameterization.

Equilibrium conditions of X_{ij}

$$Y_{11} = T_{11} + I_{11} + \beta_{11}/(1 + \alpha_{11}) - PD_1/(1 + \alpha_{11}) + PS_1 + (x_{ij} + xs_{ij})/[\lambda_j N_i(1 + \alpha_{ij})] \quad X_{11} Y_{11} = 0$$

$$Y_{21} = T_{21} + I_{21} + \beta_{21}/(1 + \alpha_{21}) - PD_1/(1 + \alpha_{21}) + PS_2 + SP_1/(1 + \alpha_{21}) + (x_{21} + xs_{21})/[\lambda_j N_i(1 + \alpha_{21})] \quad X_{21} Y_{21} = 0$$

Etc.

Equilibrium conditions of XS_{ij}

$$Y_{11} = T_{11} + I_{11} + b_{11}/(1 + a_{11}) - PD_1/(1 + a_{11}) + PS_1 + (x_{ij} + xs_{ij})/[\lambda_j N_i(1 + a_{ij})] \quad X_{11} Y_{11} = 0$$

$$Y_{21} = T_{21} + I_{21} + b_{21}/(1 + a_{21}) - PD_1/(1 + a_{21}) + PS_2 + (x_{21} + xs_{21})/[\lambda_j N_i(1 + a_{21})] \quad X_{21} Y_{21} = 0$$

Etc.

Based on the model as it has been developed by our research team (Professor KAWAGUCHI and Mr. H. KANO, Kyushu University, Japan, M. BERGEN, University of Hohenheim, Germany) the gate-price is finally integrated as a further restriction by converting it into an ad-valorem equivalent rate following the mathematical interrelation.

$$f_j(PC_i) = \begin{cases} (\overline{PDj} - PC_i) / PC_i & (1 + \delta_j) PC_i \leq \overline{PDj} \Leftrightarrow (\overline{PDj} - PC_i) / PC_i \geq \delta_j \\ \delta_j & (1 + \delta_j) PC_i > \overline{PDj} \Leftrightarrow (\overline{PDj} - PC_i) / PC_i < \delta_j \end{cases}$$

To begin with, as became clear, the gate-price system takes different taxation forms depending on whether the CIF import price levied by the “usual” ad valorem tariff exceeds or is less than the standard import price (gate-price).

In detail, the import CIF price from country i is denoted by PC_i . The gate-price as it is applied in country j is expressed as \overline{PDj} , while the equivalent ad valorem tariff rate is set as δ_j . Here, in case the price levied by the ad valorem tax rate on the CIF import price is less than the gate-price, country j directly pays $\overline{PDj} - PC_i$ and then divides this tax by PC_i . In other words, in case it is less than the gate-price it can be evaluated as ad valorem equivalent rate (EQR). In case the EQR δ_j exceeds the gate-price only the usual ad valorem tariff rate is applied.

Replacing the “usual” ad valorem tariff for the country applying the gate-price system (in case of Japan 4.3%) by an ad valorem equivalent rate levied on the gate-price all tariffs are treated uniformly as an ad valorem tariff depending on the import CIF price. For country j applying the gate-price system it seems realistic not to implement a tariff-quota-system with a secondary market. Hence, seeking equilibrium the current access quantity is extremely high, prohibitively disregarding the secondary market. In addition, for country j the general

meaning of a specific tariff does not exist. Besides, as explained above, imports at low prices are levied by a tax exceptional specific tariff. But, in reality it is difficult to imagine imports at such low a price so that this research does not consider that specific case.

Moreover, the above formula integrates the CIF price, which can also be written as $PC_i = PS_i + T_{ij} + I_{ij}$. Hitherto, the occurring ad valorem tariff rate α_{ij} is replaced by the term of $f_j(PC_i)$. This means, by introducing the gate-price to the basic model, the matrix M (alternatively denoted A) and the fixed variable column vector z (alternatively denoted B) of the LCP are now constituting a further element depending on the CIF price. The problem cannot be solved as a LCP anymore but as a non-linear complementarity problem (NLCP). Finding a solution to this NLCP leads to solution of the equilibrium conditions. Accordingly, one way to solve this particular NLCP is by applying the same *Symmetric Parametric Principal Pivoting Method (Symmetric PPPM)* combined with *Newton's Method*.⁸ This methodology has already been presented in detail by two members of our research team.⁹

Once, the model is amended to meet the above requirements a solution can be found when computing these equations and solving the equilibrium conditions, provided accurate data are imputed.

⁸ The Newton method solves nonlinear equations by step by step approximating nonlinear curve with a tangent linear line. See COTTLE ET AL. (1992, pp.87-95).

⁹ See KAWAGUCHI and KANO (2004, completely). Not yet published.

Data applied and preliminary base year results

Applying the above model to the international pork market secondary statistical data sources were referred to. However, differing categories, denomination and definitions can be found for the product of pork. Hence, a consistent definition is set and deviating data values are adjusted accordingly.

Referring to the World Customs Organisation Harmonised System *meat of swine* can be subdivided into fresh or chilled and frozen pork (often referred to simply as *pork*) on the one hand (HS 0203), and into *pork variety meats* on the other hand (HS 0206). In addition, *prepared meat products* also include pork-based products. However, this research neglects the class of prepared meat products.

Further, while quantities are given in cut base for traded pork national statistics often present production volume as carcass weight equivalent (CWE) using a country specific conversion factor. The average CWE to cut base in the case of Japan is 0.73.¹⁰

Although national statistics such as from the MAFF (農林水産省) and ALIC (農畜産業振興機構) in case of Japan, and Dansk Slagterier in case of Denmark were reviewed also, for conformation reason most data were taken from the FAOstat database, the EUROstat database, the USDA, FAPRI and the OECD.

Despite the availability of most of the data required some crucial parameters are not obtainable. This is especially the case with elasticities. Alternatively, these exogenous parameters were estimated by parameterization. Doing so, initial estimates of elasticities are referred to from outside sources and adjusted to arrive at an initial estimating point.

Table 5: Parameterized own price elasticities of demand and supply for pork

Country	Elasticity of Demand	Elasticity of Supply
Japan	-0.290	+0.432
Canada	-0.100	+1.290
EU15	-0.100	+0.200
United States	-0.495	+0.910
Mexico	-0.250	+0.550
Brazil	-0.470	+0.200
China	-0.410	+0.400
Russia	-0.540	+0.250
ROW	-0.210	+0.200

¹⁰ United States = 0.7484; EU15 = 0.74; Canada = 0.74; Mexico = 0.7614; Brazil = 0.74, Russia = 0.78437, China = 0.74, ROW = 0.74.

Assuming that the demand for pork is weakly separable from demands for other goods including other meat products such as beef, chicken and turkey and also including marine products this assumption allows to model meat demand conditional only on meat prices. According to HAHN¹¹ the assumption of separability is common in the analysis of meat demand. In addition, the purpose and hypotheses of this research allow for an isolated observation of the pork sector rather than the need for integrating cross-price elasticities with other meat products.

Wholesale prices on a CWE basis are used as market prices for calculating the demand functions. Producer prices, deflating by implicit deflators, are used as marginal costs in each country. However, in the case of Mexico the supply function needed to be adjusted. Currency exchange rate fluctuations and the impact of the NAFTA had to be taken into further consideration.

In the case of Japan ministerial order (省令) prices are used as representative prices. The ministerial ordinance is not necessarily related to the price stabilisation band but it moves within it. It describes the mean value between the high quality and the good quality price for pork meat. In general, an average is taken for the separately defined markets (Tokyo and Oosaka). The ministerial ordinance is regarded as the mean domestic pork price for carcass, and is close to the actual annual average price of pork.

For a future scenario, this research assumes that transportation costs for staple goods being transported by vessel are slightly increasing within the near future. Backed up by rising crude oil prices transportation costs in general are forecasted to increase by 5 percent within the next five to ten years.¹²

This may also include an introduced taxation for international goods traffic justified by environmental issues, which has not been applied so far. Since technical progress cannot be presumed in the near future transportation costs are not likely to decrease, respectively.

In a first step, the so-called FEFC Tariff System gives some detailed information on freight costs, which are referred to in the first place. Reverting to the Maersk Sealand-¹³, Evergreen Marine Cooperation-, Orient Overseas Container Line Limited- and Hapag Lloyd shipment rates then completes the required data. According to these sources the following transportation costs per container of 20000 tons of pork can be expected.

¹¹ See HAHN (1994, pp. 22).

¹² Based on information from various articles on increasing transportation costs and after conferring with experts from various freight companies etc.

¹³ <http://www.maersksealand.com> provides rates via the internet (20.05.04).

Table 6: Transportation cost US \$ per ton of pork (0203); cut base by sea freight, includes base freight only; 2002

	Japan	US	Canada	Denmark	Mexico	Brazil	Russia	China	ROW
Japan	0	63.750	63.75	71.25	82.50	82.50	67.50	22.50	78.75
US	59.66	0	40.50	63.75	45.25	33.13	64.05	62.99	52.50
Canada	57.95	40.50	0	63.75	49.75	54.25	65.00	63.75	56.25
EU15	76.03	54.54	63.75	0	67.50	67.50	15.00	67.50	5.00
Mexico	75.00	45.75	50.00	75.00	0	45.00	60.00	90.00	75.00
Brazil	75.45	45.50	49.00	67.50	45.0	0	60.00	90.00	67.00
Russia	63.75	45.00	63.75	18.75	60.0	60.0	0	60.00	60.00
China	20.45	63.75	63.75	67.50	90.0	90.0	60.00	0	67.50
ROW	62.85	48.55	49.08	60.00	50.45	58.90	50.25	65.25	0.00

Source: Maersk Sealand, Ocean Rate Bulletin (USDA), TAAFC, WTSA, FEEC, 2005.

Further, insurance costs may play a role, especially in the case of perishable goods. However, since pork comes in frozen or chilled, insurance costs in the first place are neglected, also due to lack of data available. Insurance premium is mainly negotiated on between importers and insurance companies in the exporting country, which makes it rather difficult to get access to these data. According to experts however, in general insurance premium are approximately 0.8 percent of the CIF price when landing.

Finally, the benchmark and scenarios are defined by the tariffs and other border measurements. The following table outlines the actual situation for the year 2002, while the second table lists up expected changes for tariffs and quotas according to countries for the future scenario.

Table 7: Trade Policies in each country and area for the base year 2002

Unit: NC per mt carcass weight equivalent, %, '000mt

Country and Area	Trade Policies Instruments								
	In-quota import Market				Over-quota Import Market		Specific Export Subsidy	Upper limit of subsidized Exports	Percentage PSE
	Specific Duty	<i>Ad valorem</i> Tariff	Differential Tariff	Tariff-Rate Quota	Specific Duty	<i>Ad valorem</i> Tariff			
Japan (Yen)	NO	4.3	(393000-CIF)/CIF	NO	NO	NO	NO	NO	57
U.S. (\$)	NO	NO	NO	NO	NO	NO	NO	NO	4
EU 15 (Euro)	467-867 (536.3)	NO	NO	133.1	NO	NO	In special cases	444	21
EU 25	-	-	-	-	-	-	-	-	-
Canada	NO	NO	NO	NO	NO	NO	NO	NO	6
Mexico	NO	20	NO	NO	NO	NO	NO	NO	22
Brazil	NO	11.5 (12.7)	NO	NO	NO	NO	NO	NO	n.a.
Russia	NO	15	NO	YES	NO	NO	NO	NO	n.a.
China	NO	12 (17.3)	NO	NO	NO	NO	NO	NO	n.a.
ROW	NO	NO	NO	NO	NO	NO	NO	NO	n.a.

Note: Mexico: Bound tariff lowered from 50% to 45%, 1995-2004. Applied Tariff was 20% in 2002. Tariff for imports from U.S. and Canada is zero as from January 1st, 2003. Until then, pig meat NAFTA tariff is set at 6%. Special safeguard provisions were put in place to limit import surges. Quota for fresh and frozen pork from Canada to Mexico was 8865 tonnes, In-Quota tariff 2%, Out-of-Quota tariff was 20 %.

Japan: Tariff lowered from 5% to 4.3%, 1995-2000. Gate-price lowered from 612 to 524 Yen/kg for cut meat, 460 to 393 Yen/kg for carcasses, and 1038 to 898Yen/kg for processed products, 1995-2000. Special safeguard provisions were put in place to limit import surges.

EU15: Duty is sum of ad valorem and specific tariffs. Ad valorem tariff ceiling on meat lowered from 3% to zero, 1995-2000. Additional specific tariffs lowered from range of 728-1358 ECU/ton in 1995 to range of 467-869 ECU/ton, 2000. Tariff rate quota of 7,000 tons for loins and bellies. Preferential tariff with EU accession countries.

Brazil:

China:

ROW:

United States: Tariffs on cuts specially prepared for retail lowered from 2.2 cents/kg to 1.4 cents/kg, 1995-2000. Aside from these cuts, tariffs are zero. *Canada:* zero

Russia: Introduction of a quota-system in

Feeding the model with the above data created the following preliminary results for the reference year 2002. Parameters were adjusted as to generate least possible deviation. Units are given in thousand tons and US\$ per ton carcass weight equivalent.

Result 1: Gate-price = 5211,49, ad valorem tariff= 0 0,43 for reference year 2002

```

EQR(2)= 3,667988; EQR(3)= 3,713746; EQR(4)= 3,462668; EQR(5)= 3,356593; EQR(6)= 3,664742;
EQR(7)= 2,980469; EQR(8)= 3,110608; EQR(9)= 3,620001;

PD (1) -PD (NC)
5267,8538 1110,5010 1176,9116 1451,6688 1185,0538 1088,0590 1282,8613 1295,3404
1110,9360

PS (1) -PS (NC)
3178,4950 1056,7719 1047,6442 1091,7670 1121,2308 1041,7586 1245,5152 1247,3648
1065,1779

SP (1) -SP (NC)
,0000, 0000, 0000, 207,9587, 0000, 0000, 0000, 0000, 0000

matrix [Xij]
1251,9765 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
270,1925 8280,0563 219,4429 ,0000 193,1054 ,0000 ,0000 ,0000 94,5335
270,1925 363,1985 475,6362 ,0000 249,1202 ,0000 112,9716 ,0000 400,0155
270,1925 ,0000 78,7207 15885,8831 ,0000 ,0000 342,9238 ,0000 776,4770
38,1327 ,0000 26,1279 ,0000 911,0079 ,0000 ,0000 ,0000 ,0000
,0000 ,0000 166,2799 ,0000 ,0000 1731,1321 673,6041 ,0000 119,1071
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 1588,2726 ,0000 ,0000
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 43184,6539 ,0000
76,2655 ,0000 116,3970 133,1000 ,0000 ,0000 10,1381 ,0000 6498,2992

matrix [XSij]
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
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,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000
,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000 ,0000

supply S (1) -S (NC)
1251,9765 9057,3305 1871,1344 17354,1971 975,2686 2690,1232 1588,2726 43184,6539
6834,1998

demand D (1) -D (NC)

```

As for comparative reason an elimination of each the gate-price, the safeguard and the ad valorem tariff of Japan are computed. From these three calculation it becomes clear that the impact of the gate-price system is by far higher than the ad valorem tariff. In fact the elimination of the 4.3 percent tariff rate does not impact the reference state at all. A cut-back of the safeguard clearly benefits pork exporters to Japan and results in higher producer prices in these regions. On the contrary, Japanese pork producers only loose about six percent of their production in volume terms. Trade flows between the remaining regions do not change significantly. A total elimination of the gate-price, however, would result in cut back of Japanese pork production to less than half of the original production volume. Producer and market prices in all regions would increase whereas they would clearly decrease in Japan. Mexico would not provide any pork to Japan, respectively.

The following tables shall reflect on preliminary results for 2011 under the above conditions but changing border measurements. Since these results have not been reviewed yet, they are not yet available at present but will be submitted shortly.

Conclusion and future outlook

The above results demonstrates that the model does realistically reflect on the actual market situation in international pork trade. Although the benchmark scenario deviates slightly from statistical reference it does converge to the real word situation. Validation still has to be conducted in order to justify future prognoses, though. This shall be done in the very near future by an ex-post forecast test for 2004, as soon as a consistent data base is available. For the time being, the given reference scenario is applied as the initial point for further computation to reflect on a possible outcome in 2011. Provided there was an increase of five percent in transportation costs, no extreme impact of the EU enlargement on international pork trade and no deciding change in exchange rates¹⁴, future projection of international pork trade flows basically accrues to a liberalisation of international border measurements. An elimination of the Japanese gate-price system is assumed.

This model shall not appear to be completed. Various ways to improve on its informational values are being considered. The acknowledgement of diversified marketing routes, as KAWAGUCHI (2003) suggests, being one of it. In order to apply it to up-to-date policy recommendation it also needs to allow for the integration of not yet existing border measurements. In addition, national policy measurements such as direct payments also need to be taken into account.

Nonetheless, this model may serve as a basis for further application and may have contributed to a detailed equilibrium modelling in international pork trade.

¹⁴ Exchange rate fluctuations will be taken into consideration in a forthcoming paper.

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Appendices

Appendix 1:

Equilibrium conditions of markets

1. $V_1 = -\gamma_1 + \lambda_1 PD_1 + X_{11} + X_{21} + X_{31} + X_{S11} + X_{S21} + X_{S31}$ $PD_1 V_1 = 0$
2. $V_2 = -\gamma_2 + \lambda_2 PD_2 + X_{12} + X_{22} + X_{32} + X_{S12} + X_{S22} + X_{S32}$ $PD_2 V_2 = 0$
3. $V_3 = -\gamma_3 + \lambda_3 PD_3 + X_{13} + X_{23} + X_{33} + X_{S13} + X_{S23} + X_{S33}$ $PD_3 V_3 = 0$

Equilibrium conditions of producers

4. $v_1 = -\mu_1 + \eta_1 PS_1 - X_{11} - X_{12} - X_{13} - X_{S11} - X_{S12} - X_{S13}$ $PS_1 v_1 = 0$
5. $v_2 = -\mu_2 + \eta_2 PS_2 - X_{21} - X_{22} - X_{23} - X_{S21} - X_{S22} - X_{S23}$ $PS_2 v_2 = 0$
6. $v_3 = -\mu_3 + \eta_3 PS_3 - X_{31} - X_{32} - X_{33} - X_{S31} - X_{S32} - X_{S33}$ $PS_3 v_3 = 0$

Equilibrium conditions of X_{ij}

7. $Y_{11} = T_{11} + I_{11} + \beta_{11}/(1 + \alpha_{11}) - PD_1/(1 + \alpha_{11}) + PS_1$ $X_{11} Y_{11} = 0$
8. $Y_{21} = T_{21} + I_{21} + \beta_{21}/(1 + \alpha_{21}) - PD_1/(1 + \alpha_{21}) + PS_2 + SP_1/(1 + \alpha_{21})$ $X_{21} Y_{21} = 0$
9. $Y_{31} = T_{31} + I_{31} + \beta_{31}/(1 + \alpha_{31}) - PD_1/(1 + \alpha_{31}) + PS_3 + SP_1/(1 + \alpha_{31})$ $X_{31} Y_{31} = 0$
10. $Y_{12} = T_{12} + I_{12} + \beta_{12}/(1 + \alpha_{12}) - PD_2/(1 + \alpha_{12}) + PS_1 + SP_2/(1 + \alpha_{12})$ $X_{12} Y_{12} = 0$
11. $Y_{22} = T_{22} + I_{22} + \beta_{22}/(1 + \alpha_{22}) - PD_2/(1 + \alpha_{22}) + PS_2$ $X_{22} Y_{22} = 0$
12. $Y_{32} = T_{32} + I_{32} + \beta_{32}/(1 + \alpha_{32}) - PD_2/(1 + \alpha_{32}) + PS_3 + SP_2/(1 + \alpha_{32})$ $X_{32} Y_{32} = 0$
13. $Y_{13} = T_{13} + I_{13} + \beta_{13}/(1 + \alpha_{13}) - PD_3/(1 + \alpha_{13}) + PS_1 + SP_3/(1 + \alpha_{13})$ $X_{13} Y_{13} = 0$
14. $Y_{23} = T_{23} + I_{23} + \beta_{23}/(1 + \alpha_{23}) - PD_3/(1 + \alpha_{23}) + PS_2 + SP_3/(1 + \alpha_{23})$ $X_{23} Y_{23} = 0$
15. $Y_{33} = T_{33} + I_{33} + \beta_{33}/(1 + \alpha_{33}) - PD_3/(1 + \alpha_{33}) + PS_3$ $X_{33} Y_{33} = 0$

Equilibrium conditions of X_{Sij}

16. $Y_{S11} = T_{11} + I_{11} + b_{11}/(1 + a_{11}) - PD_1/(1 + a_{11}) + PS_1$ $X_{S11} Y_{S11} = 0$
17. $Y_{S21} = T_{21} + I_{21} + b_{21}/(1 + a_{21}) - PD_1/(1 + a_{21}) + PS_2$ $X_{S21} Y_{S21} = 0$
18. $Y_{S31} = T_{31} + I_{31} + b_{31}/(1 + a_{31}) - PD_1/(1 + a_{31}) + PS_3$ $X_{S31} Y_{S31} = 0$
19. $Y_{S12} = T_{12} + I_{12} + b_{12}/(1 + a_{12}) - PD_2/(1 + a_{12}) + PS_1$ $X_{S12} Y_{S12} = 0$
20. $Y_{S22} = T_{22} + I_{22} + b_{22}/(1 + a_{22}) - PD_2/(1 + a_{22}) + PS_2$ $X_{S22} Y_{S22} = 0$
21. $Y_{S32} = T_{32} + I_{32} + b_{32}/(1 + a_{32}) - PD_2/(1 + a_{32}) + PS_3$ $X_{S32} Y_{S32} = 0$
22. $Y_{S13} = T_{13} + I_{13} + b_{13}/(1 + a_{13}) - PD_3/(1 + a_{13}) + PS_1$ $X_{S13} Y_{S13} = 0$
23. $Y_{S23} = T_{23} + I_{23} + b_{23}/(1 + a_{23}) - PD_3/(1 + a_{23}) + PS_2$ $X_{S23} Y_{S23} = 0$
24. $Y_{S33} = T_{33} + I_{33} + b_{33}/(1 + a_{33}) - PD_3/(1 + a_{33}) + PS_3$ $X_{S33} Y_{S33} = 0$

Equilibrium conditions of SP_i

25. $Z_1 = CA_1 - X_{21} - X_{31}$ $SP_1 Z_1 = 0$
26. $Z_2 = CA_2 - X_{12} - X_{32}$ $SP_2 Z_2 = 0$
27. $Z_3 = CA_3 - X_{13} - X_{23}$ $SP_3 Z_3 = 0$

Appendix 2:

Equilibrium condition equation no.	slack variable column vector W	27x27 matrix A																											variable column vector P	constant column vector B							
		PD1	PD2	PD3	PS1	PS2	PS3	SP1	SP2	SP3	X11	X21	X31	X12	X22	X32	X13	X23	X33	Xs11	Xs21	Xs31	Xs12	Xs22	Xs32	Xs13	Xs23	Xs33									
(1) -->	V1	λ_1									1	1	1							1	1	1										PD1	$-\gamma_1$				
(2) -->	V2		λ_2											1	1	1							1	1	1								PD2	$-\gamma_2$			
(3) -->	V3			λ_3													1	1	1							1	1	1					PD3	$-\gamma_3$			
(4) -->	v1				η_1						-1									-1													PS1	$-\mu_1$			
(5) -->	v2					η_2						-1									-1													PS2	$-\mu_2$		
(6) -->	v3						η_3						-1									-1												PS3	$-\mu_3$		
(25) -->	Z1							0					-1																					SP1	CA1		
(26) -->	Z2								0																										SP2	CA2	
(27) -->	Z3									0																									SP3	CA3	
(7) -->	Y11	$-1/(1+\alpha_{11})$			1																													X11	$T_{11}+I_{11}+\beta_{11}/(1+\alpha_{11})$		
(8) -->	Y21	$-1/(1+\alpha_{21})$				1		$1/(1+\alpha_{21})$																											X21	$T_{21}+I_{21}+\beta_{21}/(1+\alpha_{21})$	
(9) -->	Y31	$-1/(1+\alpha_{31})$					1	$1/(1+\alpha_{31})$																											X31	$T_{31}+I_{31}+\beta_{31}/(1+\alpha_{31})$	
(10) -->	Y12		$-1/(1+\alpha_{12})$		1				$1/(1+\alpha_{12})$																										X12	$T_{12}+I_{12}+\beta_{12}/(1+\alpha_{12})$	
(11) -->	Y22		$-1/(1+\alpha_{22})$			1				$1/(1+\alpha_{22})$																									X22	$T_{22}+I_{22}+\beta_{22}/(1+\alpha_{22})$	
(12) -->	Y32		$-1/(1+\alpha_{32})$				1																												X32	$T_{32}+I_{32}+\beta_{32}/(1+\alpha_{32})$	
(13) -->	Y13			$-1/(1+\alpha_{13})$	1						$1/(1+\alpha_{13})$																								X13	$T_{13}+I_{13}+\beta_{13}/(1+\alpha_{13})$	
(14) -->	Y23			$-1/(1+\alpha_{23})$		1						$1/(1+\alpha_{23})$																							X23	$T_{23}+I_{23}+\beta_{23}/(1+\alpha_{23})$	
(15) -->	Y33			$-1/(1+\alpha_{33})$			1																												X33	$T_{33}+I_{33}+\beta_{33}/(1+\alpha_{33})$	
(16) -->	Ys11	$-1/(1+\alpha_{11})$			1																														Xs11	$T_{11}+I_{11}+b_{11}/(1+\alpha_{11})$	
(17) -->	Ys21	$-1/(1+\alpha_{21})$				1																														Xs21	$T_{21}+I_{21}+b_{21}/(1+\alpha_{21})$
(18) -->	Ys31	$-1/(1+\alpha_{31})$					1																													Xs31	$T_{31}+I_{31}+b_{31}/(1+\alpha_{31})$
(19) -->	Ys12		$-1/(1+\alpha_{12})$		1																															Xs12	$T_{12}+I_{12}+b_{12}/(1+\alpha_{12})$
(20) -->	Ys22		$-1/(1+\alpha_{22})$			1																														Xs22	$T_{22}+I_{22}+b_{22}/(1+\alpha_{22})$
(21) -->	Ys32		$-1/(1+\alpha_{32})$				1																													Xs32	$T_{32}+I_{32}+b_{32}/(1+\alpha_{32})$
(22) -->	Ys13			$-1/(1+\alpha_{13})$	1																															Xs13	$T_{13}+I_{13}+b_{13}/(1+\alpha_{13})$
(23) -->	Ys23			$-1/(1+\alpha_{23})$		1																														Xs23	$T_{23}+I_{23}+b_{23}/(1+\alpha_{23})$
(24) -->	Ys33			$-1/(1+\alpha_{33})$			1																													Xs33	$T_{33}+I_{33}+b_{33}/(1+\alpha_{33})$