Chicken Supreme:
How the Indonesian Poultry Sector can Survive Avian Influenza

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Abstract

Avian influenza is a deadly disease that can spread rapidly through poultry. There are many documented cases of transmission from birds to people, but as yet only rare instances of human to human transmission. Nonetheless, public health officials are concerned about the possibility of a human pandemic, and many countries have policies of banning imports of live birds and poultry meat from infected regions. The potential impacts on Indonesia of a production shock, a shift in consumption or a trade ban are assessed using a heterogeneous product model where imports are differentiated by source. Empirical results suggest the likely trade impacts in Indonesia are minimal because its trade is a small share of production.

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Introduction

Public health officials are concerned that avian influenza (AI) may mutate and enter the human population. There is no cure for viruses, and an epidemic could spread rapidly through the population. Similar global influenza epidemics in 1918, 1957 and 1968 caused significant loss of life. AI is caused by the virus H5N1. The disease is spread across countries by migratory birds and imports of livestock and, perhaps, poultry meat. Therefore, one policy response is to ban imports from infected regions.

Indonesia is a major producer of poultry and has had numerous outbreaks of AI, even in the dry season. This suggests the disease is endemic. The initial outbreak is thought to have resulted from imports of live birds as breeding stock. Thailand, a major exporter, China and Vietnam have also experienced significant outbreaks. Isolated instances of the disease have been recorded in Turkey and several countries in Europe, where migratory birds may have had a more significant role. There have been no recorded cases in Australia or New Zealand. The purpose of this paper is to assess the likely impacts on Indonesia if it or other countries experience an outbreak that leads to a fall in production, a panic among consumers, or a ban on exports. Indonesia would suffer if its exports were banned, but on the other hand it may gain if exports from its competitors were reduced.

First, the characteristics of the disease and the poultry sector in the region are described, and potential control measures listed. A bilateral trade model is outlined and, using trade and production data from 2005, then used to simulate the potential impacts of various scenarios. Results are presented and analysed, and policy implications, limitations and possible extensions draw the paper to a close.

In this article there is no attempt to speculate on the probability of an AI outbreak, nor is there consideration given to a human pandemic.[2] The purpose here is to show the poultry trade impacts of a specific policy response. We also ignore the impacts on the feed sector and the substitutes in consumption, other meats.

[2] The World Health Organisation (WHO 2005) considers the risk of a pandemic as 'serious', because two of three necessary conditions are met: (i) a new virus has emerged; and (ii) it effects humans. As yet, however, there has been no sustained human to human transmission. There is no consensus on the likelihood of an outcome, except that the probability is no-zero.

Characteristics of avian influenza

AI can occur in fowls, pigs and humans. The virus is transmitted in faeces and other secretions from the body, and is therefore readily transmitted between animals, especially those housed together, such as caged birds or pigs. The virus is not present in fresh meat, and if contaminated, cooking kills the virus. The disease can move from domestic to wild animals and from animals to people.[3] Transmission across species, i.e. to humans, is difficult but seems most likely to occur during cleaning of the animal rather than consumption of the flesh. As yet there are few documented cases of human to human transmission, although small clusters of blood-relatives appear to have infected each other in Indonesia.[4] One cause of international transmission is migratory birds, such as ducks, geese and swans, but in the case of Indonesia the disease is more likely to have been introduced by imports of livestock from China. Among livestock the disease is quite contagious, meaning whole flocks can be infected within 48 hours. The virus is quite persistent, and new flocks can be re-infected if disinfection is inadequate. This occurred in the Pitchit Province in Thailand in August 2006, where the virus was the same strain as one previously thought to be eradicated.

Initial outbreaks of AI in Indonesia were in the large scale commercial sector, but now (2006) the disease appears to be endemic in the small-scale backyard sector, where control is much more difficult.

Control

Control measures involve either vaccination or culling, known as 'stamping out'. Current thinking favours so-called 'focal culling' of the affected birds, plus 'ring vaccination' of those birds within a reasonable distance. Culling implies a producer must remove all animals, disinfect the premises and restock after a period. FAO guidelines specify no restocking until at least three weeks after cleaning and disinfection. Vaccination is not very effective, providing limited protection and requiring repeated treatments. Successful control involves rapid identification and containment of the outbreaks by limiting the movement of livestock and personnel. Identification requires surveillance and subsequent laboratory diagnosis. Part of the control program is teaching producers and vets how to recognise the symptoms.

From an international perspective, little can be done about migratory birds, but one control measure is banning imports of live birds and poultry meat from the affected countries. This is

[3] To date 74 cases of AI in the human population in Indonesian have been confirmed, and 57 have proved fatal (WHO 2006).

[4] WHO (2005) reports that there have been rare instances of apparent human to human transmission, among close family members. However, since all family members are likely to have contact with the source of infection, it is difficult to determine if human to human transmission has in fact occurred.

aimed at preventing the spread from one country to another. As a result of this policy, countries have an incentive not to report an outbreak. Both China and Thailand appear to have delayed reporting outbreaks for several months.[5]

So far, annual production losses from isolated AI outbreaks in Indonesia are relatively minor. The production cycle for commercial chickens is eight weeks, so producers can get back into production relatively quickly. This is in contrast to foot and mouth disease and BSE, where the production lag is significant. Small scale producers may be selling their infected stock onto the market regardless, with little loss of production. Compensation of Rp1500 per bird is available, but this policy is difficult to administer in the backyard sector.

The poultry sector in Indonesia

Chicken is the most popular meat in Indonesia.[6] Consumption in 2005 was around 1000 kt or 4.45 kg per capita per year, followed by beef at 2.4 kg per capita. There is relatively high pork consumption, 2.6 kg per capita, given Indonesia is predominantly a Muslim country. Chicken demand is income elastic, but lack of refrigeration limits an increase in consumption. The main substitute is fish.

Chicken meat production was also around 1000 kt in 2005, similar to consumption. Production is essentially for the domestic market. There were no exports of significance. Much of the feed (maize, soybeans) is imported, and the industry is not competitive with Thailand and other Asian chicken producers.

Although not currently an exporter, Indonesia has been so in the past and could do so once again if a ban on exports from countries such as Thailand were implemented. Exports over the previous ten years are shown in table 1, along with production, imports and consumption. In 2003 exports were worth US$6.6 million, or $1,658 per tonne. Japan was the major market. In that year the 700 tonne of imports were valued at $1,321 per tonne. The USA, Australia and Brazil were the primary sources of supply of chicken meat.

[5] Strangely, AI is not listed as a notifiable disease by the Office International des Epizooties (World Organisation for Animal Health).

[6] A detailed description of the poultry sector in East Java can be found in Simmons (2006).

Table 1 Indonesian poultry meat production and trade

	Production kt	Imports kt	Exports kt	Domestic utilization kt	Utilization per capita kg
1997	899	0.9	0.1	899	4.43
1998	621	0.8	3.0	618	3.00
1999	620	9.1	2.9	626	3.00
2000	818	14.7	0.8	832	3.93
2001	924	1.8	1.9	923	4.31
2002	1105	1.2	3.3	1103	5.08
2003	1139	0.7	4.0	1136	5.17
2004	975	1.6	0.1	976	4.39
2005	1000	2.0	0.0	1002	4.45

Source: FAOSTAT.

The global poultry sector

The major producers of chicken meat are the United States (16.0 mmt in 2005), China (10.1 mmt), Brazil (8.7 mmt) and the European Union (8.9 mmt). Indonesia, at 1.0 mmt, is a larger producer than Thailand (0.9 mmt). Major exporters are Brazil, the United States, China and Thailand. The trade is segmented into light and dark meat, with Americans preferring light (breast) meat, while many other countries favour dark meat such as drumsticks. For this reason the United States exports dark meat while the Asian countries tend to export light meat for which there is a premium. As a result the unit values for Indonesian exports ($1,658 per tonne) exceed the value of their imports ($1,321 per tonne).

A model of the global poultry meat market

There have been few attempts to model the economic impacts of disease outbreaks. Paarlberg et al. (2004) provide a review of the modelling issues. Petersen and Orden (2005) model the global poultry sector by dividing the market into light and dark meat. Salin et al. (2003) develop a four region mathematical programming model in which product is divided into four types. The distinction between light and dark meat presents a problem when modelling international trade flows. Clearly, the two shades of meat are not perfect substitutes. The approach used here is to differentiate the imports by source using an Armington structure. This implies that imports into Japan from Brazil are not the same quality as those from Indonesia. However, the imports from alternative sources are somewhat substitutable, and the degree of substitution is determined by the Armington elasticity, a parameter estimated or imposed by the user. This approach gets around the problem of differentiated products, but it does imply that where both types of meat are exported to one destination, the export shares are held constant.

A comparative static, deterministic, bilateral trade model, GSIM, is used to assess the impacts of various production, consumption and trade shocks.[7] The data required are annual bilateral trade flows, production for domestic consumption, and elasticities of demand, supply and the substitution between imports of different source, the so-called Armington elasticity. For this application the world is divided into ten regions, one of which is a residual 'rest of world'. Bilateral data are necessary because the import bans are likely to be bilateral. Trade flows are measured in values to account for the different values of meats of differing quality. Also include the existing tariff restrictions, as these indicate the tariff revenue collected or forgone. There are no changes in stocks. To assess the impact of a policy change a likely shock, such as a ten per cent decrease in production in one country, is specified and the model is simulated to find a new set of market clearing prices. Comparing the initial and final outcomes provides an indication of the likely impacts. Outputs include changes in prices, production, consumption, and bilateral trade flows. Also reported are changes in welfare measures such as consumer and producer surplus, and government revenues. The base data used in the model are shown in table 2. Bilateral trade data are shown in the Appendix.

Table 2 Regional poultry meat production and trade, 2004

Region	Production kt	Imports kt	Exports kt
EU (25)	10944	750	949
USA	18008	50	2652
Japan	1224	738	1
China	13460	329	467
Brazil	8895	3	2628
Russian Fed.	1152	1149	1
Thailand	964	9	319
Indonesia	975	5	0
Australia	732	1	21
RoW	21416	4412	406

Source: Derived from data provided by FAO.

Tariffs on Indonesian imports are calculated at 22 per cent. On its exports Indonesia faces tariffs of 26 per cent in the European Union, 18 per cent in the United States, 46 per cent in Japan and 39 per cent in China. These tariffs are not varied in the modelling, although tariff revenues change with trade flows.

[7] Details of the model can be found in the appendix.

Perhaps a key parameter is the substitutability between imports from Indonesian and other suppliers. Indonesia does not have the sanitary standards that the European Union and Japan require on imports from Thailand. Further, if Thai exports where stopped because of concerns about AI, importers are unlikely to turn to Indonesia where the disease is considered endemic, at least within the small-scale sector. These factors suggest the Armington parameter for imports from Indonesia should be relatively low. However, in the medium term these factors can change if Indonesia improves its standards. Initially, an Armington elasticity of 5 is used for all countries, but sensitivity analysis on this parameter is undertaken.[8]

Table 3 Parameter values

Region	Elasticity of demand	Elasticity of supply	Armington elasticity
EU (25)	-0.30	0.32	5
USA	-0.30	0.31	5
Japan	-0.11	0.68	5
China	-0.81	0.32	5
Brazil	-0.30	0.45	5
Russian Fed.	-0.12	0.31	5
Thailand	-0.30	0.30	5
Indonesia	-0.64	0.28	5
Australia	-0.30	0.70	5
RoW	-0.30	0.30	5

Source: ATPSM.

One modelling issue that needs addressing concerns the small shares problem. Indonesia's export share in the base period is negligible. Since the Armington type models work by applying a percentage change to the base period levels, no trade flows can be generated when there are none initially. This is because the prices to which agents respond are volume weighted. [9]

This means, for example, that reducing a prohibitive tariff leads to no increase in imports. Kuiper and van Tongeren (2006) tackle this problem by reweighting the price index using trade share estimate based on gravity equations. Here, previous exports are used. In 2003 Indonesian poultry exports were 4 kt (table 1), including 1.3 kt to China, , 0.7 kt to the

[8] The model permits the Armington elasticity to vary by importing country, but not by exporters. This implies that all imports into the European Union for example are equally substitutable, whether they come from the United States, Brazil or Indonesia. Within the confines of the current model, it is not possible to set a low Armington elasticity for Indonesian exports.

[9] Consider the constant elasticity of substitution import demand specification $X_i/X=\alpha_i(P_i/P)^{-\sigma}$, where X_i is the quantity of imports demanded, P_i is the price of imports i, α_i is a share parameter and σ is the constant elasticity of substitution. Imports are determined by relative prices. However, the composite price, P, is $P=(\Sigma_i \alpha_i P_i^{(1-\sigma)})^{(1/(1-\sigma))}$. If the initial shares α_i are low or zero, the relevant price P_i has little or no influence.

European Union, 0.6 kt to United States, 0.2 kt to Malaysia and 0.1 kt to Switzerland. This compares with zero in the base period. The 2003 data are used to determine the initial weights.

Scenarios

The trade effects of an AI outbreak are likely to include three mechanisms: a decrease in productions; a fall in consumption as consumers shift away from chicken; and a policy response that may include a ban on imports or exports, imposed by the affected country or its trading partners. The direct effect will be a cut in production, but the indirect effects may be greater, particularly if the policy response is disproportionate, as has been the case with previous animal disease outbreaks. To separate out the various impacts, we specify five scenarios:

(i) Production shortfall: a ten per cent fall in production in Indonesian poultry output;

(ii) Foreign production shock: a ten per cent fall in poultry production in Thailand;

(iii) Consumer panic: a ten per cent fall in Indonesian poultry consumption;

(iv) Global panic: a ten per cent fall in global poultry consumption; and

(v) Bilateral ban: a ban on Thai exports to Europe and Japan.

Ten per cent is a rather large fall in production. East Java farmers surveyed by Simmons (2006) believed any likely fall in production would be manageable, and a greater problem would be the consumer response. Nonetheless, ten per cent provides a useful benchmark. The second scenario looks at a fall in production in Thailand, the major exporter in Asia and a country that has had significant AI outbreaks in the past. A fall in Thai output would be expected to have trade implications for other countries. The third and fourth scenarios look at consumption effects. In the past consumers have demonstrated their concern about AI by moving away from chicken for several months, although demand has returned after the initial scare has abated. The fall in consumption is modelled as a shift in preferences, not a movement along the demand curve in response to price movements. The final scenario reflects a policy response by major importers. The objective here is to see how external events affect the Indonesian market.

Results

Results for the five scenarios are shown in table 4. These results apply to Indonesia with the exception of the last row, global welfare. The first scenario, a ten per cent annual production shortfall in Indonesia, leads to a 15 per cent rise in domestic prices, a $4m fall in exports, and an offsetting increase in imports (not shown) which leads to an increase in tariff revenue.[10] In spite of the fall in output, producers are better off (by $247m) because the 15 per cent increase in price more than offsets the ten per cent fall in production. However, consumers are worse off (by $253m), and the net effect is also negative. There are also additional global losses because Indonesian exports have become more expensive. The observation that producers are better off is based on the implicit assumption that producers have cut back on production for a time. In other words, they have not invested in inputs such as feed. In reality, some birds may need to be culled at some stage through the production process, which means the inputs are lost. Although producers may be compensated for these, there is a net loss to the government that is not taken into account here.

The second scenario, a fall in production in a major exporting country, Thailand, has little impact on Indonesia because of its small trade share. Indonesian domestic prices rise marginally, but exports and imports are barely affected. There is a significant global welfare loss.

The third scenario is a shift in consumer preferences in Indonesia, perhaps in response to a food scare. The exogenous shift is sufficient to bring about a ten per cent fall in consumption. In response domestic prices fall by an estimated 32 per cent. Producers are worse of by $488m, and although those consumers not worried by the panic get to enjoy cheaper poultry, consumer surplus also falls. What is not captured here is the impact on other meat markets, such as beef, pork and fish. Consumers concerned about the safety of chicken would eat more of these substitutes. With the collapse of the domestic market, some of the surplus is exported, but this is only a small fraction of production because Indonesia currently has limited access to established markets. This response seems realistic. In the light of a panic by Indonesian consumers, foreign consumers are unlikely to be enthusiastic about buying cheap Indonesian poultry meat.

The fourth scenario is a global panic, in which consumers in all countries, including Indonesia, shift away from chicken, both domestically and foreign produced. The additional impact on Indonesia is small, and derives from a fall in exports. The negative welfare impacts are slightly larger. The main effect is on global welfare, which falls by a massive $92 billion. This is mainly a price effect.

[10] Note here that domestic prices are not determined by world prices plus a constant markup for transport or tariffs. This follows from the assumption that imported and domestically produced chickens are differentiated products. Hence, the production shortfall means that domestic prices rise although import prices are virtually unchanged.

Table 4: Impacts on Indonesian poultry sector

		Scenario 1 Production shortfall	Scenario 2 Foreign production shock	Scenario 3 Consumer panic	Scenario 4 Global panic	Scenario 5 Bilateral ban
Change in domestic prices	%	14.97	0.01	-31.63	-35.83	0.02
Change in output*	%	-10.01	0.00	-10.12	-11.46	0.01
Change in value of exports	$m	-4	0	4	-1	0
Producer surplus	$m	247	0	-488	-550	0
Consumer surplus	$m	-253	0	-275	-314	0
Tariff revenue	$m	1	0	1	-1	0
Net welfare effect	$m	-5	0	-763	-864	0
Global welfare	$m	-8	-61	-761	-91599	-587

Source: GSIM simulations. * The change in output is exogenous in scenarios 1, 3 and 4.

The final scenario, a hypothetical ban by the Europe Union and Japan on imports from Thailand, has very little impact on Indonesia because of the low initial value of Indonesia exports. The Thai domestic price falls by 43 per cent and output by 14 per cent. The loss in exports to the countries imposing the ban amounts to $610m. Some $50m in exports is diverted to the Rest of World and China, but this in no way compensates for the loss.[11] The Thai welfare loss is $176m. The countries imposing the ban, the Europe Union and Japan, also lose in welfare terms, $112m and $161m respectively. The major beneficiary is Brazil, $30m. Not taken into account are gains to suppliers of alternative meats.

Sensitivity analysis

The key parameters in this analysis are the elasticity of demand and the Armington elasticity. Doubling the Indonesian elasticity of demand from -0.64 to -1.28 reduces the producer gains following a 10 per cent production shock (scenario 1) from $247m to $149m, and reduces consumer surplus losses proportionately from $253m to $155m. On the other hand, halving the elasticity of demand increased the transfers to around $368m.

The Armington elasticity determines the changes in trade flows. In this study a common elasticity has been used across all countries. Changing this elasticity has little impact on

[11] The redirection of imports is determined by the Armington elasticities. In reality, a ban by one country may also encourage other importers to do likewise.

Indonesia because of its small trade share. Reducing the elasticity from 5 to 1 in all countries lessens the trade switching in scenario 5, a bilateral ban on Thai exports. Global welfare losses double from $587m to $1235m. The European Union and Japan have more difficulty obtaining supply from alternative sources, and Thailand finds it more difficult to find alternative markets. The results in this scenario seem sensitive to the value of the Armington elasticity, but only up to a point. Increasing the value from 5 to 10 has little impact on welfare and trade flows.[12]

Implications and conclusions

Perhaps the most striking observation that can be drawn from these results is that in a domestically oriented market, any decrease in supply following an AI outbreak will lead to an offsetting rise in domestic prices. Indeed, the rise in prices may more than offset the fall in production, leading to increasing producer revenues. Of course, the major beneficiaries are those producers that are not affected by AI and hence do not have to cull their flock. However, those producers that are affected are likely to receive some compensation from the government. This is almost necessary to encourage producers to report disease outbreaks. Compensation payments are not calculated here, but they merely represent a transfer from taxpayers to producers. This raises the interesting issue as to who should pay for the compensation. Since unaffected producers gain, there is an argument that a compensation scheme should be industry financed. The major losers are consumers who must pay higher prices for a reduced supply.

At present in Indonesia, large scale commercial producers appear to have AI under control, and thus the likelihood of a significant production loss is reduced. However, perhaps a greater threat is a panic by consumers. If this occurs domestically, this will have a negative impact on producers. History shows that consumers are prepared to move back to poultry meat within a few months of a scare. If consumer confidence is eroded in international markets, such as Europe, Japan and the United States, the effects on Indonesia will be limited. On the other hand, AI outbreaks in exporting countries such as Thailand and Brazil seem unlikely to provide Indonesia with an export opportunity.

The policy implications for Indonesia differ from those of a major exporting country such as Thailand. Indonesia need not be too concerned about a ban on its exports. It should be concerned about a domestic slide in consumer confidence. The most the government can do here is inform consumers of the need to prepare chicken meat appropriately. On the

[12] This is consistent with the finding of Zhang (2006) who shows that as the Armington value is increased, the terms of trade effects tend to stabilize.

production side imports of live chickens might be reconsidered. Chickens are imported as breeding stock but the imports represent a potential source of infection. The government might also do more to ensure producers are aware of the symptoms, and perhaps provide more laboratories to assist monitoring the disease. Given the externalities associated with the disease, there is a role for foreign governments to assist in monitoring and controlling outbreaks.

One issue assumed away here is whether Indonesia could become a major exporter in the medium term. The argument against this is that Indonesia relies on imported feed, which makes it uncompetitive. A second concern is the need to meet high sanitary standards. However, these are not insurmountable problems, as raising poultry does not require specific climatic or agronomic conditions. An international company, from an exporter like Thailand or an importer such as Japan, could set up a vertically integrated system that produces poultry meat to satisfy the requirements of a particular market.

Not looked at here are the links to other sectors, such as feedstuffs on the supply side and other meats on the demand side. Including substitutes, such as beef, in the model would lessen the gains and losses. A shift towards beef would partially offset losses to the poultry sector. On the supply side, chicken production losses would most likely have a negative impact on feed suppliers. At present most of the production losses appear to be occurring in the small-scale sector, where poultry scavenge for feed, so the measurable effects are likely to be minimal.

Another issue that needs further thought is the size of the production and consumption shocks modelled here. The ten per cent shifts assumed here are purely arbitrary, albeit within the realm of possibilities.

Another useful refinement may be to look at the localised impacts within Indonesia. Here Indonesia is treated as one entity, producing one good at one price. In reality the different localities are not well linked, with significant price differences between them. The localised price changes might be greater than those modelled here if the production losses or supply shifts are also localised.

Finally, we haven't considered the potential impact of a pandemic that involves human to human transmission. Unless this happens, it seems likely that the Indonesian poultry sector will survive ongoing but low-level outbreaks of avian influenza. This is because the disease is largely confined to the small-scale sector, consumer will likely switch back to poultry meat after a scare, and the share of trade is small, implying a ban on exports would be of little consequence.

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Appendix
GSIM

GSIM is static, deterministic, single commodity bilateral trade model driven by export supply and bilateral import demand equations.[13] Exports and imports are a function of the world price plus or minus the relevant bilateral trade tax or subsidy. Because taxes are bilateral, and possibly different from country to country, the change in tariffs or a quota lead to a change in relative prices that drive differential changes in imports from various sources. This is essential where bans are imposed on some countries but not others. An elasticity of substitution determines the extent to which changes in relative prices lead to a switch in the source of imports. The model solves numerically to a specified tolerance using Excel's Solver to find a market clearing price such that global imports equals global exports.

The crux of the model is the import demand equations. Import demand in country *v* for commodity *i* from country *r* is a function of prices and total expenditure on the commodity:

(1) $M_{(i,v),r} = f(P_{(i,v),r}, P_{(i,v),s\ r}, Y_{(i,v)})$

where $M_{(i,v),r}$ is imports, $P_{(i,v),r}$ internal prices, $P_{(i,v),s\ r}$ external prices and $Y_{(i,v)}$ expenditure on imports *i* in country *v*.

The response of imports to changes in relative prices depends on an expenditure share weighted sum of the composite demand elasticity, E_m, and the supply elasticity, E_s:

(2) $N_{(i,v),r,s} = \theta_{(i,v),s} (E_m + E_s)$, and

(3) $N_{(i,v),r,r} = \theta_{(i,v),r} E_m - \Sigma_{sr} \theta_{(i,v),s} E_s = \theta_{(i,v),r} E_m - (1-\theta_{(i,v),r} E_s)$.

The price linkage equations relate internal prices to exports prices:

(4) $P_{(i,v),r} = (1-t_{(i,v),r})P^*_{i,r} = T_{(i,v),r}P^*_{i,r}$

where T = (1+*t*), the power of the tariff. Quotas, or outright bans, can be expressed as a tariff equivalent. On the export side, exports are a function of world prices:

(5) $X_{(i,v),r} = f(_rP^*_{i,r})$.

These equations are in levels. By differentiating the import, export and price equations, it is possible to obtain expressions for the change in imports and exports according to changes in tariffs and world prices:

[13] GSIM was developed by Joseph Francois of the Tinbergen Institute and H. Keith Hall of the U.S. International Trade Commission. The model is documented in a memo by these authors entitled 'Global Simulation Analysis of Industry-Level Trade Policy', October 2002. See also Francois, J.F. and H.K. Hall, "Partial Equilibrium Modeling," in J.F. Francois and K. Reinert, eds., *Applied Methods for Trade Policy Analysis*: A Handbook, Cambridge University Press: Cambridge, 1997.

(6) $M'_{i,r} = \Sigma_v M'_{(i,v),r} = \Sigma_v N_{(i,v),r,r} P'_{(i,v),r} + \Sigma_v \Sigma_{sr} N_{(i,v),r,s} P'_{(i,v),s}$

$= \Sigma_v N_{(i,v),r,r} [P^*_r + T'_{(i,v),r}] + \Sigma_v \Sigma_{sr} N_{(i,v),r,s} [P^{*\prime}_s + T'_{(i,v),s}]$.

The model is solved numerically by finding a set of prices such that the change in global imports (equation 6) equals the change in global exports (the derivative of equation 5).

Once we have solved for world prices, it is possible to work backwards to solve for export quantities and import quantities. Changes in government revenues are simply determined by the trade flows times the tariff rates. Producer and consumer surplus effects can then be determined from changes in prices and quantities:

(7) $\Delta PS_{i,r} = R^0_{i,r} P'_{i,r} + 0.5 R^0_{i,r} P'_{i,r} X_{i,r}$

where $R^0_{i,r}$ is the initial export revenue.

Consumer surplus is more complex because consumption is a composite of imports from different sources.

(7) $\Delta CS_{i,r} = (\Sigma_v R^0_{(i,v),r} T^0_{(i,v),r}) * (0.5 E_{m(i,v)} P'^{2}_{i,v} * \text{sign}(P'_{i,v}) - P'_{i,v})$

Where $P'_{i,v} = \Sigma_r \theta_{(i,v),r} P^{*\prime}_r + T'_{(i,v),r.}$

$P'_{i,v}$ represents the price for composite imports, and $R^0 T^0$ the initial expenditure.

Total welfare is the sum of producer and consumer surplus and the change in government revenue.

Data required for the model are bilateral trade flows (in values), bilateral trade taxes, and elasticities of supply, demand and substitution between imports (the so-called Armington elasticities).

Limitations of the model include the (log) linear demand and supply relationship. Linearity implies that large shocks to the model may induce some errors in the size of the quantity changes. For example, it is reasonable to expect that as prices rise consumers become less responsive. A second limitation is the lack of substitution between products on the demand side, such as chicken and beef. Empirically, the cross effects tend to be rather small, depending on how the commodities are defined. A further consideration is the absence of upstream and downstream linkages, between chicken and feed for example.[14] There is no

[14] It is relatively trivial to add cross effects on the supply side, given the data on trade flows and cross elasticities are available. In this instance it was considered this refinement would not significantly contribute to the analysis.

storage in the model, nor time related effects or uncertainty. These limitations need to be kept in mind when interpreting the results.

Table A1 Bilateral trade flows 2004, kt

From\to	EU (25)	USA	Japan	China	Brazil	Russian Fed.	Thailand	Indonesia	Australia	RoW	WORLD
EU (25)	9995	1	5	6	0	174	0		0	763	949
USA	144	15356	33	91	0	733	8	4	0	1640	2652
Japan	0	0	1223	0			1			0	1
China	2	2	200	12993		2		0		147	467
Brazil	406	1	328	61	6267	202		0		1630	2628
Russian Fed.	0			0		1151				1	1
Thailand	129		161	1			645			28	319
Indonesia	0		0	0				975		0	0
Australia	0		0	1		0			711	21	21
RoW	69	46	12	55	2	38	1	1	0	21011	406
Total	750	50	738	329	3	1149	9	5	1	4412	7444

Source, FAOSTAT. Own trade, on the diagonal, refers to production for domestic consumption.