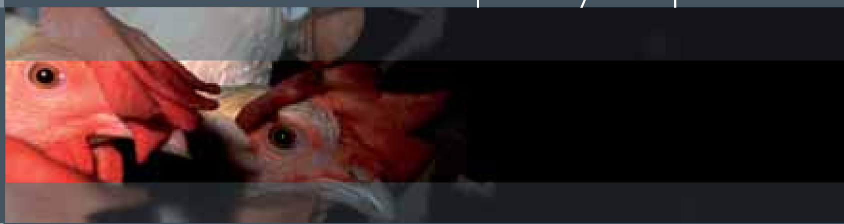
barriers to ASEAN meat exports

economic impacts of disease outbreaks and policy responses



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foreword

Livestock industries in the ASEAN region have grown markedly over the past 25 years, with total meat production tripling. Thailand is a large producer and exporter of poultry meat globally. Other ASEAN countries, such as Viet Nam, Malaysia and Myanmar, have the potential to increase their meat exports. However, livestock diseases are a major impediment to maintaining and expanding ASEAN meat exports. For example, the first wave of avian influenza outbreaks in Cambodia, Indonesia, Lao PDR, Thailand and Viet Nam during late 2003 and early 2004 had severe impacts on poultry producers in these economies. Significant costs were suffered from stock losses and from loss of export markets when importing countries imposed trade bans in an effort to minimise the risk of the disease spreading.

The objective in this report is to provide an assessment of the economic impacts of disease outbreaks, and the associated sanitary and phytosanitary restrictions on ASEAN meat exports. This report also provides an overview of developments in ASEAN livestock industries, and a discussion on export strategies that have worked and constraints that have impeded the development of ASEAN meat marketing opportunities.

A simplified version of the report, outlining the main findings of the analysis, has also been produced and is available on ABARE’s website (**abare**conomics.com).

Phillip Glyde
Executive Director

November 2007

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Dr Suon Sothoeun, Cambodia; Dr Phouth Inthavong, Lao PDR; Dr A. Rasyid Kisman, Indonesia; Dr Hardiman, Indonesia; Dr Etty Wuryaningsih, Indonesia; Dr P. Loganathan, Malaysia; Dr Ohn Kyaw, Myanmar; Mr Pedro Ocampo, Phillipines; Dr Bhanupong Nidhiprabah, Thailand; Dr Wimolporn Thitisak, Thailand; Mr Nguyen Do Anh Tuan, Viet Nam; Mr Hoang Dinh Quoc, Viet Nam; Ms Bui Thi Cuc, Viet Nam; Dr Le Thanh Hoa, Viet Nam.

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summary

- » Gains from trade promote economic growth. It is for this reason that countries in ASEAN, with a comparative advantage in labour intensive livestock production and meat processing systems, seek access to markets principally in developed economies.
- » In this study the role of ASEAN livestock disease as a constraint on the development of ASEAN meat exports is explored qualitatively and quantitatively. More generally, the study illustrates the economic impacts of livestock disease outbreaks on ASEAN countries, highlighting the direct costs of disease, including those from biosecurity barriers to export trade.
- » ASEAN livestock industries have developed strongly in recent decades, largely keeping pace with strong growth in local meat consumption. Rapid economic development of the region as a whole has been, and is expected to remain into the foreseeable future, the key driver of this growth in meat consumption. Thailand currently is the major meat exporter in the region.
- » Two lessons from the growth in regional exports are particularly noteworthy:
  - First, Thai chicken is sourced mainly from large scale commercial operations that can more readily meet international biosecurity standards in a cost effective manner than backyard operations. The granting of market access requires that meat from production systems is biosecure and poses no unacceptable risk from disease to importing countries. Product must be disease free. It must also be cost competitive for trade to occur. A structural shift is therefore under way in various ASEAN countries toward commercial operations.
  - Second, Thai chicken producers have also responded flexibly by reorienting their export operations away from less biosecure processing procedures to avoid loss of markets following the first outbreak of avian influenza that began in late 2003.
- » In this study a dynamic simulation model is used to illustrate the direct economic impacts through time of livestock disease outbreaks in key meat sectors of ASEAN economies, and to illustrate how to assess the economic merits of alternative domestic policy responses to disease management.

- An unanticipated livestock disease outbreak that reduces the stock of animals markedly, costs producers dearly. Ignoring any temporary taste change, the effect on consumers depends on the extent to which producers are able to raise prices and so pass on costs to consumers. This, in turn, depends on the sector's international trade exposure. Exposure to international markets is a discipline on costs. Under free trade, consumers pay no more than the world import parity price for meat and producers receive no less than the world export parity price. The direct effect on total welfare of a disease outbreak is negative overall because disease acts like a production tax, raising the price of the product.
- Livestock is a capital asset and investment decisions affecting the stock are based on assessing current and future opportunities to earn profit. Where future profitability falls below what it would otherwise be because of the cost of a disease outbreak, producers will reduce their stocking rates as soon as possible to maximise the stream of discounted profits over time. For example, in the case of the Thai poultry industry, with its strong exposure to the international export market, the simulated effects from an indefinite export ban caused greater initial destocking than that caused from the disease outbreak alone.
- The results further illustrate that any meat producer with a strong export exposure to the world market has much to gain from the export market, and therefore much to lose under an export ban imposed by importers in response to the threat of the spread of livestock disease. An export ban harms local livestock producers, lowers domestic prices and reduces social welfare overall.
- In a second illustrative analysis, a world chicken trade model is used to highlight the net benefits to Thailand from importers allowing access to cooked Thai product in order to avoid a full trade ban from a disease outbreak. Under the World Trade Organisation's Sanitary and Phytosanitary Agreement it is possible that a sanitary trade ban by an importer may be partial (conditional).
- Such conditional provisions have the potential to greatly lower the costs of trade when managing livestock disease risks. These provisions are zoning and compartmentalisation. Disease free status is granted to zones of a geographic region that are disease free (zoning) or to production systems that impose an acceptably low risk of a disease incursion (compartmentalisation). Large gains from trade in the absence of disease provide a strong incentive to find such least cost biosecurity solutions that preserve part of the net gains from meat trade.

- While potential importers want potential exporters to undertake cost effective disease management, regional cooperation is also critical in controlling and eradicating livestock diseases in adjoining countries. Many ASEAN countries have long borders and it is simply not cost effective, and may be impractical particularly where wildlife carry disease, to police all of them.
- Further, where prices are higher as a result of stock losses from disease in some regions, producers in neighbouring regions have strong incentives to break quarantine and potentially spread disease. As a consequence, if disease management is to be efficient and effective, neighbouring countries must face the same incentives to control and eradicate the disease. This is why the governments of Malaysia, Thailand and Myanmar have combined to develop a foot and mouth disease free zone in a designated area of their Peninsula. This is also why the governments of Thailand, Cambodia, Lao LDR, Viet Nam and Myanmar have drafted a cooperative plan to tackle avian influenza outbreaks and to strengthen their cross border network in controlling the disease.
- Locating high risk farm operations at considerable distance from both urban centres and from low risk farm operations may also help to reduce the risk of disease spread. But again, whatever scale is used for zoning, producers need to face common incentives in disease management, such as common rewards for vaccinating, reporting and culling animals that test positive over time, if livestock disease is to be effectively managed at least cost.

1

introduction

A key objective in this report is to explore the role of livestock diseases as a major barrier to the development of a substantial ASEAN meat export trade that could further promote ASEAN economic growth. While ASEAN meat production has tripled over the past twenty-five years, aside from Thailand's poultry meat trade, meat production systems in most ASEAN countries have focused on the domestic market. As a result, export marketing has been minor, with revenues highly volatile and affected by livestock disease outbreaks that close export markets.

It is not just the policy response of importers imposing a ban on export from countries affected by a livestock disease outbreak that is of concern to ASEAN livestock producers. These importing countries also want to prevent the introduction of livestock disease to their industries and environment. Policy responses may include the use of trade sanctions where the importer judges that the expected costs from a disease outbreak exceed the expected benefits from trade. Highly contagious livestock diseases also require appropriate domestic policies to manage local disease risks and damage costs from disease outbreaks throughout the ASEAN region. During the first wave of the avian influenza outbreaks between late 2003 and early 2004, disease and damage costs spread rapidly through Cambodia, Indonesia, Lao PDR, Thailand and Viet Nam, with the largest bird losses in Thailand.

The optimal mix of domestic livestock management policies in ASEAN economies is that which maximises the total expected benefits from preventing and controlling livestock damage costs, net of the total expected costs of implementing the policies.

Disease interventions can be 'ex ante' – that is, made before a disease incursion. These are preventative measures. Alternatively, interventions can be 'ex post' – that is, they can involve control or adaptation measures made after a disease incursion. A basic question behind this distinction is: when is prevention cheaper than the cure?

Depending on the environment and on the disease, a country might never have experienced a disease, or one disease incursion might result in the disease becoming endemic. Alternatively, the disease status of a country could involve irregular outbreaks concentrated in time and in location. In this case, disease free status could be regained in some zones of a country through early action that results in disease containment. Another basic question to ask in livestock disease management is: once a disease is contracted, is the cure simply not worth the cost and would the country be better off in terms of costs avoided by adapting to endemic livestock diseases?

With these basic questions in mind, this report is structured as follows. Chapters 2 and 3 provide the contextual setting for the quantitative analysis presented in chapter 4. In chapter 2, lessons in ASEAN meat marketing export success are reviewed – with an emphasis on Thailand's experience in the face of disease threats – and other impediments to gaining access to export markets are discussed more broadly.

In chapter 3, the main livestock diseases in ASEAN economies are noted and policy options used to manage livestock disease are outlined.

The main purpose in chapter 4 is to illustrate the direct economic impacts of a livestock disease outbreak on the meat sectors of ASEAN economies and to illustrate how damage cost estimates, including from trade bans imposed by importing countries, may be used to assess the relative merits of different domestic policy responses in prevention, control and adaptation. Additional modelling work is presented that confirms the importance of innovative policy responses to prevent market closures by developing more biosecure processed meat products, allowing some importers to accept these more biosecure products rather than imposing an overall trade ban.

2

lessons for ASEAN meat export success

ASEAN meat production has increased by 4.6 per cent a year over the past twenty-five years. Domestic production has largely kept pace with the strong local growth in domestic meat consumption that has been driven by rapid income growth of 7 per cent a year (in real terms) in the region. Details on ASEAN meat production and consumption trends are provided in appendixes A and B.

Most countries in ASEAN are small net importers or exporters of meat. However, Thailand stands out as an exception – it is a major exporter of chicken meat. This raises some pertinent questions for other ASEAN economies:

- Why has Thailand been so successful as an exporter?
- Could other members of ASEAN do as well?
- How important is livestock disease management to Thailand's export success?
- How can the biosecurity and cost competitiveness of ASEAN meat industries be improved to encourage exports?
- Which ASEAN economies have the greatest potential to gain from export trade?

To explore these questions, in this chapter the resilience of ASEAN export trade is discussed and the ASEAN experience in adopting commercial production systems as a means of lowering costs of production and gaining export market access is described. In addition, protection of domestic feedgrain industries against imports in some ASEAN countries is identified as one government policy that raises live-stock production costs.

ASEAN meat export trends and disease threats

ASEAN exports of meat – predominantly chicken meat and pig meat – grew steadily between 1990 and 2001, before plateauing at around 800 000 tonnes a year between 2001 and 2003 (figure A). Exports then fell significantly in 2004, following an outbreak of avian influenza in the region. In 2005, exports started to recover in most ASEAN countries.

ASEAN exports are dominated by chicken meat, which accounted for more than 70 per cent of total exports in 2005. Pig meat and beef exports accounted for only 16 per cent and 8 per cent respectively in the same year. Thailand is the largest exporter in the region, followed by Malaysia, Viet Nam and Indonesia.

Thai chicken meat exports accounted for around 80 per cent of ASEAN's total chicken meat exports in 2005. Relatively low production costs, high quality and Thailand's ability to tackle sanitary problems have contributed to a rapid expansion of Thai chicken exports (Preechajarn 2002a). Japan and the European Union are the major export markets for Thai chicken meat. Developed economies are expected to remain the main markets for ASEAN meat exports in the future, reflecting the cost competitiveness of ASEAN countries in labour intensive, high quality processed meat products that may be produced mainly from intensive livestock industries.

fig A **ASEAN meat exports, by country**

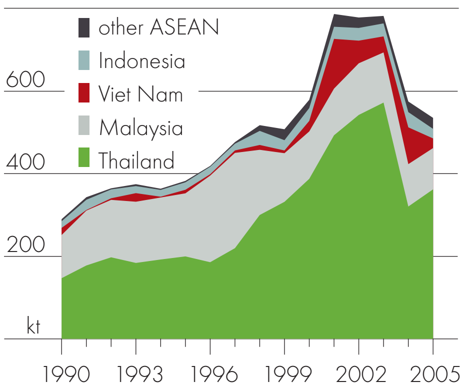
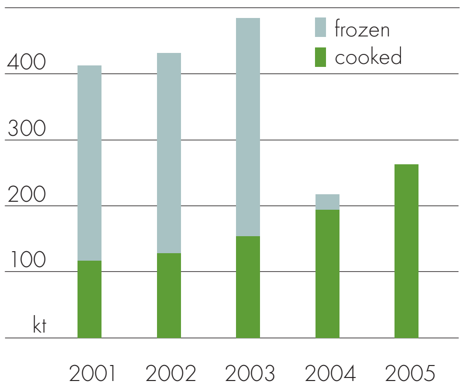


fig B **Thai chicken meat exports**



Between late 2003 and early 2004 the first wave of the avian influenza spread rapidly through five countries of ASEAN, including Thailand, causing massive stock losses and leading to trade bans on ASEAN exports. Just after the outbreak was thought to be under control, another outbreak occurred in mid-2004. Information sharing is particularly important once an outbreak occurs so that surveillance campaigns can be intensified in at-risk livestock populations. Early diagnosis and reporting of a disease outbreak in turn facilitate coordinated early action that allows the rapid stamping out of local outbreaks and that stops the disease from spreading.

It is not surprising that chicken meat exports fell sharply in 2004 and 2005, with exports falling below 300 000 tonnes in those years. However, while Thailand's exports of uncooked chicken meat fell, exports of cooked chicken meat continued to increase strongly (figure B). The value of exports of cooked chicken meat was around US$1 billion in 2005, compared with around US$500 million in 2003, and with US$700 million for frozen chicken meat in 2003. This reflected Thailand's success in marketing more biosecure cooked product, enabling some importers to switch some of their demand to cooked Thai product rather than ban all Thai chicken exports.

In some cases, the risk of disease transmission can be reduced where product has been cooked at an appropriately high temperature. Importing remains contingent on the level of risk, and associated costs from a disease outbreak, that an importer will accept. Thailand's actions following the outbreak of the first wave of avian influenza have reinforced Thailand's efforts in recent years to increase market share in profitable niche markets for highly processed products. As a result, Thailand now focuses more on cooked chicken exports.

Hygiene and animal diseases such as foot and mouth disease and classical swine fever are important factors that limit pig meat exports from ASEAN. In the region, pig meat is the main meat type produced (45 per cent), followed by chicken meat (37 per cent) and bovine meat (12 per cent). However, only small amounts of pig meat and beef are exported. Viet Nam and Thailand are the largest pig meat exporters. In 2005, pig meat exports from Viet Nam and Thailand were only 62 000 tonnes. The major markets for Viet Nam pig meat have been Hong Kong and the Russian Federation. However, Viet Nam has lost the Russian market to other competitors in recent years owing to foot and mouth disease. The major markets for Thai pig meat are Hong Kong and Japan. These are the world's largest and third largest importers of pig meat but Thailand's shares of imports are low. Hence, if Viet Nam and Thailand were able to overcome problems of hygiene and animal diseases, while strengthening their overall cost competitiveness, there would be potential for them to increase exports to these markets.

Myanmar is the region's major exporter of bovine meat, exporting around 23 000 tonnes and accounting for around 55 per cent of ASEAN bovine meat exports in 2005. Foot and mouth disease currently limits Myanmar's export trade but this constraint may be lifted in the medium term if efforts to establish disease free zones succeed (see chapter 3).

structural change in livestock production systems

Livestock production systems vary among countries and types of meat. These systems include backyard operations, commercial operations and state owned farm enterprises. The Thai chicken export industry was the first ASEAN livestock industry to adopt world class large scale commercial production systems as opposed to backyard operations.

Historically, backyard operations have dominated meat production in most ASEAN countries. In backyard farms, small numbers of animals are kept in household yards to provide household nutritional needs and supplementary income for families. However, animals are fed mainly on crop byproducts and residues that have poor nutrition. Hygiene and veterinary practices are poor, while the technologies used in animal raising and breeding are limited. Consequently, it is difficult to achieve productivity gains and a high level of biosecurity in backyard production systems. For these reasons, backyard operations are not cost competitive in livestock marketing for the meat export trade.

Backyard operations have been declining in ASEAN countries, while integrated commercial operations have been increasing. For example, the share of backyard pig operations in the Philippines fell from 82 per cent in 1994 to 74 per cent in 2006 (Ocampo 2006). Commercial operations are developing and expanding in many ASEAN countries. Chicken and pig meat production in Thailand, and chicken production in Malaysia are now largely carried out by integrated commercial operations.

The large integrated commercial firms manage breeding stock, feed supplies and veterinary services, and carry out slaughtering and processing. Integrated commercial operations provide a number of advantages over other types of operations, including introducing modern breeds, and using more advanced technologies and equipment in raising and slaughtering animals. Large integrated companies also benefit from economies of scale. For example, economies of scale allow large scale operators to buy inputs such as storage, transport, marketing and distribution services at a lower prices than is possible for small scale operators (Hoffmann et al. 2003). Consequently, the expansion of commercial operations, particularly those that provide integrated services, has the potential to improve productivity and sanitary standards in ASEAN livestock industries, so that least cost meat producers may compete in export markets.

In some countries, such as Viet Nam and Lao PDR, integrated operations have recently been set up by foreign companies. This foreign investment brings capital and new technology to local producers. Commercial operations have been encouraged in some ASEAN countries. In Viet Nam, for example, the government reduced or eliminated land rents and granted preferential tax rates for commercial farms and large scale slaughter facilities (Nguyen 2006).

costs in intensive livestock production

In intensive livestock production systems, major costs of production include feed, breeding stock, labour and capital costs. Preechajarn (2002a,b) suggested that Thailand's rapid expansion of chicken meat exports has been achieved through its low unit cost of production. Thai producers have successfully reduced their costs of production through improvements in farm management, breeding and relatively low labour costs. While other ASEAN livestock industries have been less internationally competitive, comparative advantage within the region is changing as relative labour costs rise in Thailand and commercial operators seek trade gains from new operations in other ASEAN economies, including in Viet Nam and Lao PDR.

Importantly, feed costs account for a large share (70–80 per cent) of the total costs of intensive livestock production systems. Many ASEAN countries, including Viet Nam, Thailand, Malaysia, Indonesia and the Philippines, are heavily dependent on imported feed, reflecting the relatively high cost of land.

The domestic feed industry is highly protected in some ASEAN countries. Import tariffs and tariff rate quotas on feed raise the cost of livestock, and hence meat production. Protection of feed producers is a tax on meat production. If ASEAN intensive livestock producers are to be cost competitive on the international market, feed production costs need to be at parity with the import price not higher than it.

Further, export opportunities are also constrained where importing countries use import tariffs, including tariff rate quotas, to artificially raise the cost of imports to subsidise their local producers at the expense of consumers. This is despite the evidence that import tariffs reduce the gains from trade to importing countries.

Japan, for example, is a major importer of pig meat but imposes very high tariffs. The highest tariff rates are on edible offal – around 180–340 per cent (WTO 2006). However, very high tariffs of around 118–240 per cent are also imposed on imports of fresh, chilled and frozen pig meat into Japan.

For chicken meat imports, high tariffs are imposed by the European Union on products such as boneless cuts and offal from both frozen (88 per cent on an *ad valorem* equivalent basis) and fresh, chilled chicken (63 per cent). Some types of chicken meat are subject to tariff rate quotas. For example, under an agreement between the European Union and Thailand in November 2006, Thailand received in-quota allocations of 92 000 tonnes for salted poultry meat exports and 160 000 tonnes for cooked poultry meat. Above-quota tariffs for salted and cooked poultry meat are €1300 and €1024 a tonne respectively. With continued expansion of Thai cooked chicken exports, it is possible that the tariff quota volume limit, and the above-quota tariff rate will constrain Thai exports in the future.

3

ASEAN livestock diseases and control measures

The purpose in this chapter is to describe the livestock diseases and consequent damages that are typically experienced in ASEAN countries and to discuss policy options that are being used to manage livestock disease.

ASEAN livestock diseases

In the ASEAN region, the major diseases of concern for international trade in animals and animal products are those with the greatest potential for very rapid spread and that cause or have the potential to cause the greatest damage costs. Direct damage costs arising from livestock disease outbreaks include lower incomes on household farms, and lower profits in integrated livestock and meat processing systems. Livestock diseases result in stock losses, can lower rates of feed conversion and reduce the quality of livestock products (Abdalla, Rodriguez and Heaney 2000). Upstream industries that provide inputs such as feedgrains are also affected by livestock disease outbreaks, as are downstream systems that process livestock products. Some livestock diseases may pose a threat to human health and may cause consumer taste changes in response to known or unknown risks. In some cases, disease in one livestock industry may spread to other industries. Loss of disease free status may eliminate international market access or remove a premium for disease free status.

Many diseases that are notifiable to the World Organisation of Animal Health (OIE) are found in ASEAN countries. Avian influenza, foot and mouth disease and classical swine fever are just some examples of highly contagious notifiable diseases that pose serious animal health threats. Despite the fact that vaccines are available for each of these diseases, intermittent outbreaks persist around the world and some of the highest rates of outbreak are in the ASEAN region. Among the commonly cited reasons for the high incidence of livestock disease in many ASEAN countries is lack of financial resources, which results in poor animal health practices. Hence, it is particularly important that resources are well targeted to provide the most cost effective means of reducing disease damages.

Recurring livestock disease outbreaks limit ASEAN export opportunities for poultry and pig meat products, particularly for trade in uncooked products. Export opportunities for beef cattle have also been affected by livestock disease. In recent years, avian influenza has been reported in Thailand, Indonesia, Viet Nam, Cambodia, Lao PDR, Myanmar and Malaysia (see the discussion in chapter 2). Avian influenza is absent from the Philippines. Foot and mouth disease, which seriously affects pigs and cattle, and classical swine fever are often reported in Myanmar, Thailand, Lao PDR, Cambodia and Viet Nam. Foot and mouth disease is declared absent in Indonesia, and some parts of the Philippines and Malaysia.

livestock disease control measures

Governments of ASEAN countries have implemented a number of measures to manage livestock disease. These include early detection by monitoring symptoms and testing for disease, vaccination to prevent infection or limit disease spread, border control to prevent illegal movement of animals, local movement bans from outbreak zones and pre-emptive slaughter to contain a disease outbreak, biosecurity improvement in farms and slaughterhouses, and increasing farmers' education and training. The choice of policies to manage livestock disease will depend on their relative costs and effectiveness, which in turn will vary with the features of the disease. For example, in assessing the scope required for vaccination, the number and frequency of vaccinations for herds or flocks is clearly disease dependent. Greater use of testing is likely to pay off in cases where a disease is known to spread before symptoms appear.

Elbakidze and McCarl (2006) argue in favour of relatively greater investment in pre as opposed to post outbreak measures when:

- an outbreak is more likely
- an investment in anticipatory measures has ancillary benefits
- early action is more cost effective than late action
- early action is cheaper than late action in disease control
- the disease is fast spreading.

Individual farmers have private incentives to care for their animals because these animals are sources of income and wealth (capital assets). Yet livestock disease persists. This is because animal health is partly a 'public good'.

Like public health, animal health involves unpriced spillover or 'free rider' effects. These effects cause private incentives to depart from the public good and necessitate government intervention to ensure that the appropriate level of animal health care is provided to maximise community welfare. For example, if many herds are already vaccinated then a farmer may feel that there is no need to undertake vaccination, free riding on the benefits from others' vaccination efforts and avoiding the cost of vaccination. In this situation, private vaccination will be underprovided. However, the cooperative solution involves greater vaccination levels and has higher welfare for all. Similarly local movement bans and pre-emptive culling that prevent the disease from spreading have public good features as they provide sanitary defence to all consumers and all other producers in the locality. In these cases, where there are spillover benefits, governments need to provide the required public animal health measures.

Problems with a mismatch of private and social incentives in livestock disease management are evident in illegal livestock trade that breaks a quarantine ban. In particular, the expected benefits of an illegal sale could outweigh the expected costs of detection despite the damage caused to communities if the disease spread further as a consequence. For these very reasons, it is important that private incentives are made to align with social incentives (policy responses) for disease management to be efficient and cost effective. For example, it may be significantly more costly in the long run not to provide compensation to farmers for reporting sick animals than to do so, if early action prevents the disease from rapidly spreading.

Eight members of ASEAN are committed to reducing foot and mouth disease through progressive zoning as part of the long term Southeast Asian Foot and Mouth Disease Campaign. This harmonised approach to foot and mouth disease control is an important example of cooperative action that is being taken to control a transboundary disease problem that calls for a cross-country solution. Centring on Thailand, joint efforts between several ASEAN neighbours to fight avian influenza is an example of well targeted effort in livestock disease management. Harmonising private with social incentives to improve animal health and slaughtering practices is required at local, national and regional levels, for efficient and cost effective management of transboundary diseases.

4

modelling the economic impacts of a livestock disease outbreak and policy responses

The purpose in this chapter is to quantitatively illustrate some key economic effects of livestock disease outbreaks in ASEAN countries, and to indicate in summary form the total welfare effect of domestic and international policy responses to the threat of a livestock disease on the meat sector directly involved. A dynamic mathematical programming model was constructed for this purpose using General Algebraic Modelling System (GAMS) software (see Brooke et al.1998 and www.gams.com). These types of models are useful for studying the economic optimising behaviour of producers, subject to natural resource constraints (see, for example, Conrad 1999 for the theory and Excel Solver applications). They are particularly useful for analysing issues in disease management (see, for example, the comprehensive review of terrestrial invasive species by Olson 2006).

Livestock diseases have direct impacts on production in the affected farm enterprises, and flow-on effects to product users and input suppliers, as well as to the wider economy through income effects on consumers. However, the focus here is on partial equilibrium analysis of livestock and livestock product markets only. The purpose is to illustrate the key first order or direct effects on the national meat market experiencing the disease outbreak, where the impacts on production, consumption and trade are expected to be the largest.

The critical question for disease management is to find the animal health policy or policy mix that maximises the direct total welfare benefits from the livestock sector. Disease management is modelled here under conditions of certainty and the policy responses to domestic disease concerns that are analysed are prevention, control and adaptation (in the form of no policy action). The main policy response by other countries to the threat of the disease being spread through imports that is analysed here is the use of a trade ban.

dynamic model features

Livestock disease outbreaks can affect both producers and consumers in ASEAN countries. The total welfare effect for the livestock sector is the sum of producer and consumer discounted net benefits over time from livestock production and consumption. It is this total welfare effect that is measured from the results of the programming model, under specific assumptions about the presence of a disease threat, and policy responses to that threat.

The model used is an analytical tool for projecting the annual meat outlook for any ASEAN member country. It has a generic theoretical structure that pertains to a single livestock type and country, and it is the user's selection that dictates the particular livestock and ASEAN country application. The livestock types chosen for the analysis reported here are pigs, poultry and beef cattle. The countries used in the illustrations are Viet Nam and Thailand.

The intensive pig and poultry industries were chosen because these industries in ASEAN have strong long term growth potential, and disease management needs to be optimised to maximise the net welfare benefits from these industries. Beef cattle were also included to reflect market opportunities for feedlot fattening, to compare and contrast impacts of disease outbreaks for slower maturing animals, and because some diseases, such as foot and mouth disease, pose a common threat to all animals with cloven hooves.

Foot and mouth disease, Newcastle disease and avian influenza are examples of highly infectious livestock diseases that represent a transboundary livestock disease problem for many ASEAN countries. Such diseases require a coordinated policy response for efficient and cost effective disease management. Viet Nam and Thailand were chosen for the illustrative analysis of disease outbreak impacts because of the dominance of large scale commercial operations for pig meat or poultry in their economies. Results for each of the other ASEAN economies, except for Singapore, are given in appendix C.

In these illustrative applications, a disease outbreak is assumed to involve an unanticipated shock that reduces the number of livestock and leads to trade restrictions. In the model, the time path for recovery from the stock reduction depends on both the natural rate at which stocks can rebuild and the economic incentives to rebuild. A disease outbreak initially kills animals, but it may also lower feed efficiency and change consumer tastes at least temporarily. The model can be used to analyse these phenomena as well by changing relevant variables.

While full details of the model used are contained in appendix D, a summary of the model's main assumptions and core features is discussed next. Most notably, the small country and small industry assumptions are adopted to measure the main direct impacts of a livestock disease shock on the meat sector experiencing it. These assumptions imply that world meat prices and many input costs are determined outside the model. Variables determined inside the model include the local meat price, the livestock price, stock numbers in the national herd or flock, numbers slaughtered, and meat produced, consumed and traded.

meat trade

For analysing trade opportunities, individual meat products are assumed to be identical whether locally produced or imported, and whether domestically consumed or exported. The country affected is considered to be 'small' because it is assumed to be influenced by, but not to significantly influence, the world market price for the meat type. Domestic and world prices are affected by *ad valorem* import tariffs, export subsidies and quotas and international transport costs to the world market for the meat type. Under free trade, the local meat price lies between the world export parity floor and the world import parity ceiling. The most a consumer would pay for meat is the import parity price and the least a producer would receive for meat is the export parity price. The world export parity price is the price in the world market less the international unit transport cost from the domestic market to the world market. The world import parity price is the price in the world market plus the international unit transport cost to the domestic market.

Under free trade, if there are net gains from exporting, the local price rises from the pre-trade level to the export parity price. Similarly, if there are net gains from importing, the local price falls from the pre-trade level to the import parity price. If there are zero net gains from trade then the local price lies strictly within the world parity bounds. Gains from trade between countries arise because of differences in available resources, technologies of production or in consumer tastes. As Robson (2003) explains, these differences can be exploited through trade because trade allows the choice of goods produced to be decoupled from the choice of goods consumed. Gains from trade result where overall choices in an economy are increased.

meat supply

On the supply side in the model, the meat industry is small. It is assumed to be influenced by, but not to significantly influence, many input costs other than the cost of the industry specific livestock, which is determined in the model.

Livestock numbers grow at a natural rate and decline through slaughter after fattening. Current livestock prices reflect forward looking behaviour, including future livestock prices in the model. This is because the animal stock is a natural capital asset. Investment is costly as it involves a near term loss in meat production to build up the stock. A representative livestock farmer's decision today on how many animals to take from the herd or flock for fattening and subsequent slaughter depends on current profitability and future profit opportunities. If conditions tomorrow look better than today, then fewer animals are slaughtered now, so there are more animals tomorrow to maximise the discounted sum of producer net benefits (profit) over time, and hence producer net wealth. Meat prices in the model reflect livestock prices and feed costs.

meat consumption and feed use

On the demand side, consumer meat prices are the producer meat prices plus marketing costs. Domestic consumption depends on income and prices with constant 'elasticities'.

In the model an animal's feed use, and hence weight per animal, increases if the price of meat rises relative to the cost of feed, to maximise profit. As the industry is assumed not to affect the cost of feed, this cost is taken as given. Equivalently, feed cost can be assumed to be determined on world markets and is taken as given.

disease scenario design

The dynamic simulation model was used to examine the direct economic effects of a livestock disease outbreak and of various domestic and international policy responses to disease management in the meat sector experiencing the outbreak. Separate livestock disease outbreaks are modelled for pigs, poultry or beef cattle, in Viet Nam and Thailand. A disease outbreak is assumed to reduce flock or herd size by 70 per cent in the base year. This clearly has implications for the base year and for other years, depending on natural rates of stock recovery and changes in future profit opportunities. The model is annual and all years of the projection period – here chosen to be 30 years – are solved simultaneously, starting from the base year. Base year data are needed to calibrate the model. The year chosen as the base year was 2003, for which FAO agricultural statistics were the main and most readily available source (see www.faostat.fao.org). Values for behavioural terms, including price response parameters, are drawn from the literature.

The model analysis is expressed in real terms, with prices and costs expressed in constant US dollars of the base year. General economic conditions determining world prices and general input costs are assumed to be constant in real terms over the model horizon. In the absence of any disease outbreak, it is assumed that the outlook for meat improves markedly in response to strong economic growth that increases consumption over time and from feed conversion improvements that increase production without increasing unit costs. The latter is consistent with the rapid adoption and spread of technical know-how and economies of scale in global commercial feed operations. In the simplified environment of certainty and where a disease outbreak primarily kills animals but has no further long term productivity effects, the scenario analysis asks: what is an indicative upper limit on the cost of a domestic livestock disease management option beyond which that policy option is not warranted?

The domestic policy responses for disease management that are considered here are:

» prevention

» no domestic action to eradicate disease

» early action to eradicate disease

» later action to eradicate disease

» late action to eradicate disease.

Scenario descriptions are listed in table 1.

Prevention is the domestic policy in force for the 'no disease' reference case scenario. Most other simulations involve a disease outbreak and a policy action by other countries in the form of a sanitary and phytosanitary (SPS) trade ban for a length of time that is linked to the assumed successful application of domestic control measures to eradicate the disease following an outbreak. Typically, governments of importing countries react to a disease outbreak by banning trade. Trade may be banned indefinitely if there is no domestic policy action to control a disease outbreak. If there is early, later or late domestic action that controls and eradicates disease, the trade ban is assumed to be in effect for the first year, first five years or first ten years respectively of the thirty year simulation period. A simulation of a disease outbreak without any trade ban imposed is used to obtain a benchmark for the effects of an SPS trade ban. By comparing the impact of disease with no ban to any simulation with a disease outbreak and a ban, the impact of the ban alone may be isolated.

table 1 **list of reference and disease simulations**

domestic policy action	policy action by other countries no ban	ban imposed
no disease outbreak	**reference case**	
disease outbreak	**simulation 1:**	**simulation 2:**
no domestic policy action	disease/ no ban	disease/indefinite ban
		simulation 3:
early domestic policy action		disease/1 year ban
		simulation 4:
later domestic policy action		disease/5 year ban
		simulation 5:
late domestic policy action		disease/10 year ban

The simulation results are summarised using net economic benefit, so that the economic merits of the various domestic policy responses to livestock disease management may be compared. Under conditions of certainty, policy A is preferred to policy B if the net economic benefit of A (that is the economic benefit of A less the cost of implementing A) exceeds the economic benefit of B less the cost of implementing B. That is:

(1) **if** benefit (A) – cost (A) > benefit (B) – cost (B), **then** policy A is preferred.

In this expression the benefit obtained from a policy is the damage cost avoided by the policy. Equation (1) may be rearranged to:

(1') **if** cost (A) < benefit (A) – benefit (B) + cost (B), **then** policy A is preferred.

This means policy A is preferred to B if the cost of implementing it is less than the relative benefit (that is, the damage cost avoided by pursuing A rather than B) plus the cost of implementing B. It is the damage cost avoided by a policy relative to the alternative that is measured from the simulation results of the model. This relative damage cost avoided is the benefit from A less that for B. Implementation costs are not measured using the model. However, from equation (1′), if the cost of implementing policy A is less than the relative benefit, in terms of damage cost avoided by policy A rather than B, then policy A is preferred since the implementation costs of policy B can only make any gain from policy A larger.

The right hand side of equation (1′) is in fact the upper limit on the cost of pursuing policy A over B, beyond which policy A is not warranted. For example, the upper limit on the cost of implementing late action (policy A) relative to no action (policy B) is the damage cost avoided by late action. (There is no implementation cost for no policy action as it involves natural adaptation.) The upper limit on the cost of prevention (policy C) relative to no action (policy B) is the damage cost avoided by prevention. The upper limit on the cost of early action (policy D) relative to late action (policy A) is the damage cost avoided by taking early rather than late action plus the cost of late action (policy A).

Damage costs are calculated as reductions in welfare (net economic benefit) from the 'no disease outbreak' reference case scenario. It is the net present value of annual welfare changes that is used to compare policies over an infinite time horizon (see appendix D). A net present value is the discount weighted sum of a stream of annual welfare changes, where a real social discount rate of 5 per cent is used to account for timing of the changes. The change in total welfare during any year is the sum of changes in producer and consumer welfare. (Commodity specific tax revenues are assumed to be nil in the model applications.) For each scenario, the model is first used to project the change in annual profits to producers (producer welfare) and the change in annual surplus to consumers (consumer welfare) over the 30 year projection period. This time horizon is the minimum needed to ensure that overall damage costs are stable in the sense that an even longer horizon has no impact on the results.

5

key results

The overall damage costs of a disease outbreak are shown in table 2 and are expressed relative to the no disease outbreak reference case simulation. Cases are grouped into three categories reflecting the trade orientation of the industry: importers, small export orientation and large export orientation.

table 2 **key damage costs of disease simulations** in 2003 US dollars
absolute difference from reference case in net present value

	disease outbreak with no domestic policy action		disease outbreak with domestic policy action		
	simulation 1: no ban	simulation 2: indefinite ban	simulation 3: 1 year ban	simulation 4: 5 year ban	simulation 5: 10 year ban
importers	US$m	US$m	US$m	US$m	US$m
Viet Nam poultry disease					
producers	200	200	200	200	200
consumers	0	0	0	0	0
total	200	200	200	200	200
Viet Nam beef disease					
producers	669	669	669	669	669
consumers	0	0	0	0	0
total	669	669	669	669	669
Thailand beef disease					
producers	1 383	1 383	1 383	1 383	1 383
consumers	0	0	0	0	0
total	1 383	1 383	1 383	1 383	1 383
small export orientation					
Viet Nam pig disease					
producers	677	937	677	677	696
consumers	1 308	1 050	1 308	1 308	1 288
total	1 984	1 987	1 984	1 984	1 984
Thailand pig disease					
producers	270	343	270	270	274
consumers	587	514	587	587	583
total	857	857	857	857	857
large export orientation					
Thailand poultry disease					
producers	492	5 432	492	797	1 266
consumers	148	-3 465	148	-79	-422
total	640	1 967	640	718	844

importers: Viet Nam poultry meat, Viet Nam beef and Thai beef industries

Where a country is a small importer of a homogeneous meat product it has no impact on the world price of that product. In this situation, any adverse production event that raises the cost of domestic meat production is fully reflected in the quantity supplied to the regional market, with zero compensating upward adjustment in the domestic meat price. So when a country is a small importer, local livestock producers bear the full direct cost of the sector specific disease outbreak. There is no impact on consumers who are insulated from domestic cost increases as they face world market prices (table 2). Any impact of the livestock disease on local consumer preferences is likely to be temporary and so was left out of the analysis.

Producers lose because the disease reduces their animal asset holdings and hence their short term production and growth potential. The disease reduces the initial stock of animals that are available for fattening and slaughter, raising the unit cost of production until stocks are rebuilt.

In the model, it is assumed that a country's commodity market is affected by the world price but the country cannot significantly influence the world price – that is, the country is 'small' in the commodity. If an ASEAN importing country is 'small' in this sense prior to the disease outbreak, it has no impact on the world meat price. The domestic price is already at its upper limit, given by the import parity price (the landed price of imports in the country). In this case, the domestic price of meat can go no higher, after adjustment for any local import tariff. So the increased cost of domestic meat production results in reduced domestic production and increased imports to meet the same consumer needs, with no increase in meat prices.

In this importer case, the prevention of a major livestock disease outbreak using precautionary culling and providing compensation to farmers may prove to be cost effective as compensation could be readily calculated in terms of the import parity price.

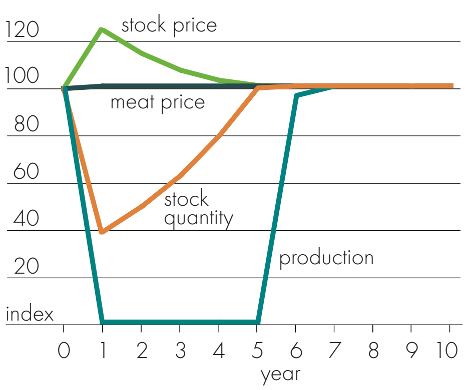
In the simulations, if the country is an importer and there are no further damage costs after stocks are rebuilt following a disease outbreak (that could have been avoided by an active policy response), there would be no benefit from a policy response. After stocks are rebuilt, an active policy response involves implementation costs but there would be no benefits in terms of damage costs avoided.

In a more general simulation setting, a disease outbreak could lead to ongoing damage costs – for example, from productivity losses in addition to initial animal stock losses. If this were the case, an active policy response that eradicated the disease would be justified if the benefits from avoiding ongoing productivity losses exceeded the costs of implementing the eradication program. Moreover, an active policy response would be appropriate if there were positive expected net benefits from doing so. This might happen where policy reduced the likelihood of another disease outbreak locally or where it has joint net benefits from stopping the disease from spreading to a neighbouring country under a joint management arrangement.

For an ASEAN importer the results also show that the direct costs of a livestock disease outbreak are smaller for poultry disease in Viet Nam than for beef disease in either Viet Nam or Thailand (see simulation 1 in table 2). The damage costs of the same percentage stock reduction are higher for beef than for poultry because cattle are slower maturing, a factor that is also reflected in a higher animal stock price for feedlot fattening and slaughter. It takes much longer for the beef cattle herd to recover from the disease stock shock, and herd rebuilding is at the direct expense of production – as shown in figure C.

For example, following a disease outbreak, beef prices in Viet Nam in year 1 are at their upper limit given by import parity pricing (figure C). The outbreak cuts the opening stock in year 1 by over 60 per cent, causing the stock price to peak temporarily. (Each series is expressed as an index relative to the reference case time series. A value of 100 indicates coincidence with the reference case. Also note that it is the closing stock that is shown in the figures.) Costs rise sufficiently for imports to outcompete domestic production, leading to maximum conservation (where there is zero production). It takes five years for closing stocks to recover because of the slow natural growth, and in year 6 it becomes economic to recommence domestic production at trend.

fig C **impact of a disease outbreak – Viet Nam beef industry**



small export orientation: Viet Nam and Thai pig meat industries

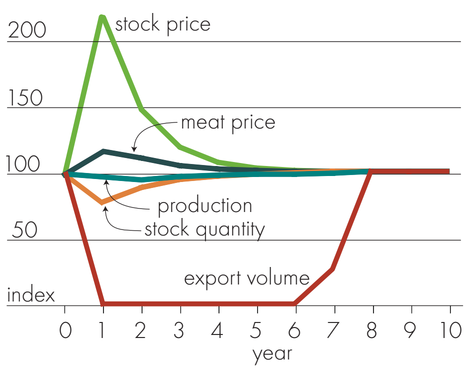
Initially, with pig meat production oriented predominantly to the domestic market, Viet Nam and Thailand both export a very small share of production under the reference case where there is no disease outbreak. So, if a trade ban were imposed by other countries on imported livestock products, any overall losses would be relatively small. For example, in the case of a disease outbreak in Viet Nam's pig industry, the estimated overall additional cost from closing the export market permanently would be only $US3 million (measured as the difference between the results for simulations 1 and 2 in table 2).

In a meat sector that is mainly oriented to the domestic market, like Viet Nam's pig meat industry, both producers and consumers lose from a livestock disease outbreak but producers lose less than consumers. Producers are able to pass on much of the higher costs of meat production associated with the disease to local consumers in the form of higher prices because local demand is relatively price insensitive. However, price can increase by no more than the world import parity price.

For an exporter, a disease outbreak raises price above the world export parity level initially until stocks recover. In the simulations, meat production costs rise temporarily to the import parity level. When there are small overall gains from exporting in the absence of disease, short term profit opportunities from temporarily higher local prices tend to delay the full rebuilding of stocks and the recommencement of exports. For example, it is not until year 7 that stocks return fully to trend when exports recommence and it is year 8 when exports return to trend under a disease outbreak in Viet Nam's pig industry (figure D).

On the other hand, the effect of a trade ban alone on an exporter is to lower local prices as product is diverted to the domestic market that would otherwise have been exported, which benefits consumers and harms producers,

fig D **impact of a disease outbreak – Viet Nam pig industry**



and total welfare overall. This is why costs to producers and to consumers are similar under the joint simulation of disease with an indefinite export ban for pig meat in Viet Nam (see simulation 2 in table 2). However, the addition of the export ban has little overall effect on total costs (compare simulation 2 and 1 in table 2).

Therefore, if an industry has a small export orientation and is oriented mainly toward the domestic market, then the major direct cost on the local meat sector from a livestock disease outbreak arises from the loss of stock to the disease itself rather than from any trade bans introduced by other countries. Local efforts should therefore concentrate on preventing the disease in the first place and if that fails then on control, where the benefits in terms of damage costs avoided exceed the implementation costs. Specifically, serious consideration should be given to preventing outbreaks of pig diseases in Viet Nam as the estimated total damage costs from disease outbreaks are large (around US$2 billion in simulation 1 of table 2). However, care is needed in designing cost effective preventative measures since, for example, compensation at the export parity price does not provide sufficient incentive for farmers to disclose animal health status when prices are temporarily higher.

large export orientation: Thai poultry meat industry

Thai chicken meat production is strongly export oriented in the disease free conditions of the reference case, reflecting strong welfare gains from the export trade. As modelled, both consumers and producers would lose from a disease outbreak. Producers would lose more than consumers in the poultry meat sector because of the industry's strong export orientation (see simulation 1 in table 2). Local consumers would lose because there would be a temporary price rise as costs of meat production peaked from the initial livestock shortage. However, this loss would be small compared with the relatively large loss from the export market, where the price is capped.

Production and price paths for Thai poultry disease without a trade ban are shown in figure E. In the first year of the outbreak, price peaks at the import parity level. Producers, where they can, take advantage of these higher prices as poultry are fast growing. In the absence of a trade ban, exporting would be unprofitable in the first year. It remains so under a one year trade ban for the large disease outbreak modelled. Costs return to reference case levels in year 2, so exports recommence and production recovers markedly. By the end of year 2, stocks are back on trend, so there is full recovery from year 3 to the disease outbreak.

As noted earlier, a trade ban can only restrict exports – so the larger the welfare gains from exports, the larger are the overall losses from an export ban. Consumers gain from the export ban, while producers lose as the ban is equivalent to an export tax. The ban has a depressing effect on local prices as product that would otherwise have been exported must be sold on the domestic market. Given the strong export orientation of Thailand's poultry industry, the welfare costs to producers of a disease outbreak itself would be lower than the costs to them of a five or more year trade ban initiated by importers in response to the disease outbreak in Thailand. The longer the ban, the larger the damage cost. The maximum damage cost from a poultry disease outbreak in Thailand would be almost US$2.0 billion under an indefinite trade ban (simulation 2 in table 2). The damage cost would be negative for consumers (that is, consumers gain) because the export ban impact (lower domestic prices) would be larger than the impact of the disease induced stock reduction (higher prices). Consumer gains amount to US$3.5 billion and producer losses US$5.4 billion.

For a meat sector with a strong export orientation, the results show that there are major gains from a policy response to control and eradicate disease because of the high damage costs of not being able to export. In other words, industries with the greatest export exposure have the most to lose from not acting to control disease as export markets would be lost in addition to the direct costs of a disease outbreak itself. Policies that reduce the intensity and duration of an export ban could be particularly important in lowering the overall cost of a livestock disease outbreak.

In the case of Thailand's poultry industry, damage costs of US$1.3 billion could be avoided by a domestic policy response of early action that contains and eradicates a disease outbreak, allowing an export ban to be lifted after one year compared with a policy of inaction that results in an indefinite ban. The US$1.3 billion is the difference in the total damage costs between simulations 2 and 3 in table 2 and mainly reflects the large gains from Thai poultry trade in the reference case.

Alternatively, if early action fails to be effective in disease control, US$1.1 billion of damage costs could still be avoided by domestic policy action that allowed the trade ban to be lifted after ten years. This is the difference in total damage costs between simulations 2 and 5. In other words, late policy action would still be warranted if the cost of implementing late control was less than US$1.1 billion.

If producers foresee that significant export markets will be permanently closed following a disease outbreak, they will react by destocking when prices are highest from stock shortages caused by the disease outbreak. In this case production would be increased from what it would otherwise have been under the scenario of a disease with no trade ban present. In the simulation results shown in figure E, stock numbers at the end of the first year of the outbreak are 60 per cent of the reference case level if the export market is permanently closed down. This is 20 percentage points lower than under a disease only shock in figure F. By year 3, conditions have settled and the meat price, stock price and meat production are permanently lower than the reference case because of the indefinite export ban.

Based on these results, there could be a disincentive in practice to report animals that test positive to the disease if the price of compensation was the export parity price, which is lower than the local price. This could increase the risk of disease spread. To avoid such a disincentive, the local price should be paid as compensation for preventative culling.

fig E **impact of a disease outbreak – Thailand poultry industry**

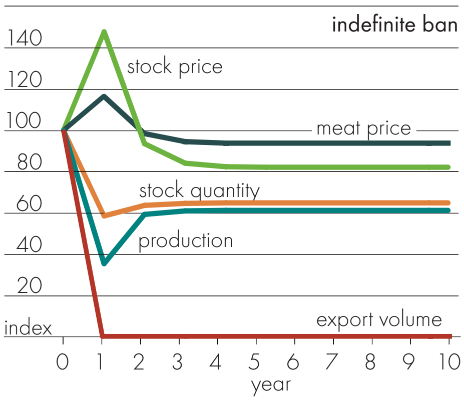
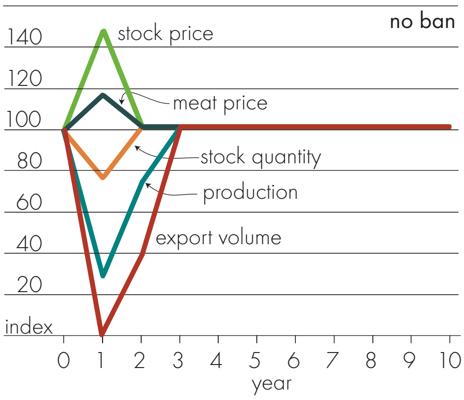


fig F **impact of a disease outbreak – Thailand poultry industry**



6

trade impacts of SPS bans on Thai chicken meat

Results in the previous chapter illustrated how a sectorwide trade restriction imposed by the rest of the world could be the single largest cost of a disease outbreak for a highly export oriented meat sector like the Thai poultry industry. This leads to the question: is there a cost effective option that may be used to minimise the use of trade bans and still protect importers from unacceptable disease risks? Provided there are net gains from trade overall, it is in the interests of both exporter and importer to find such a least cost option. The greatest incentive to find such a solution is where there are large benefits from trade in the absence of disease. Using Thai chicken as an example, the purpose in this chapter is to quantitatively illustrate how meat processing (cooking) to destroy disease may prove to be a cost effective solution to prevent trade restrictions.

The concept of compartmentalising production methods and systems into 'effectively disease free' and 'potentially at risk' categories for trade, like geographic zoning, is an important mechanism that parties to trade may use under the World Trade Organisation's Sanitary and Phytosanitary Agreement (WTO 1995), to ensure that foreign biosecurity measures are least trade distorting. SPS measures are policies imposed by importers to reduce the risk of disease spread through trade.

As discussed earlier, prospects for ASEAN meat exports depend on keeping costs competitive with other global producers. Besides the normal costs of production, including feed, capital and labour costs, exporters face transport costs as well as trade and SPS restrictions to get products to international markets. SPS measures are emerging as a key concern for exporters in maintaining access to existing markets, and in expanding access to new markets. The general purpose in this chapter is to answer the question: what are some key effects on Thai chicken meat exports of SPS trade bans?

A comparative static mathematical programming model of world chicken trade was developed in the General Algebraic Modelling System (GAMS) and used to simulate the key effects of trade bans.

static modelling approach

The static programming model is designed to analyse SPS restrictions on global trade in chicken meat, where chicken meat is separated into unprocessed and processed types to distinguish different SPS risks between principally cooked and uncooked types of chicken meat products. Appendix E contains the model's algebraic formulation. The model is applied here to Thailand's chicken trade to see how this trade with key partners would be affected by changes in livestock disease risks. The model could also be used for other meat types by inclusion of the relevant base data and parameters. The model is static, providing a snapshot of the world market at a single point in time. It shows what the market looks like before and after particular changes to SPS trade bans. The initial snapshot in time corresponds to actual conditions in year 2003, while the final situation is a snapshot in time after all adjustments to the policy changes are assumed to have occurred.

The model has a treatment of domestic and international prices that fully reflects the effects of import tariffs and tariff quotas. As the emphasis in this model is on trade volumes, domestic production and consumption are not part of the analysis. Trade volumes and unit values for the base year 2003 were taken from the database of the UN COMTRADE (2007), while the aggregated trade protection data used in the analysis came from various sources including the Economic Research Service – Penn State University PEATSim (2007) model.

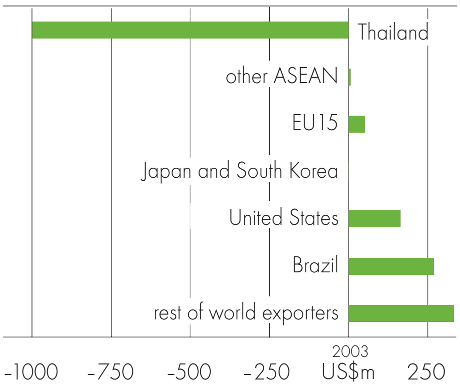
For each of the processed or unprocessed meat types in the model, product from a region shipped to other regions is treated as identical, with the same export price, while product imported by any region is distinguished by region of origin and can have different import prices.

In terms of demand in the model, import demand into a region, by region of origin and process type, is a linear function of prices from all regions of origin, and both meat process types. In particular, all products are imperfect substitutes in consumption so that if the price of one rises, substitution in consumption toward another product is less than perfect. In terms of supply in the model, total export supply from a region, and for a processed or unprocessed meat type, is a linear function of the export prices of both supply types. Processed and unprocessed products are imperfect substitutes in production so that if the price of one rises, substitution in production toward this product is less than perfect.

key results from SBS bans on Thai chicken trade

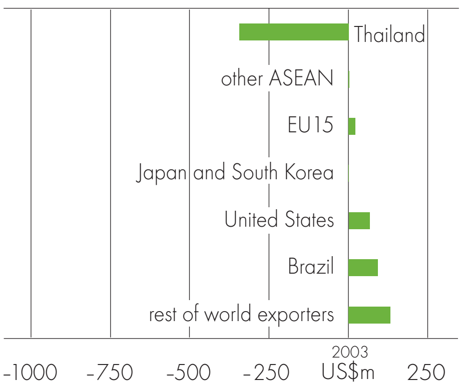
Results from this static world chicken trade model show that Thai exports worth around US$1 billion (relative to the 2003 reference case used in this analysis) would be lost under a severe SPS ban that eliminated Thai chicken meat exports to non-ASEAN countries. The gains to other exporters fall short of Thailand's losses (figure G).

fig G impact of a severe trade ban
value of exports, relative to reference case



If, on the other hand, Thailand was able to limit unacceptable SPS risks, and the associated trade ban, to just unprocessed chicken meat, the cost of a trade ban could be much lower. In this case, with trade in processed meat continuing, there is strong production switching toward processed meat, the reduction in Thailand's export revenue would be around US$345 million (relative to the 2003 reference case) (figure H). This is around a third of the cost of a ban on all chicken meat. Under this partial ban, Thailand is able to regain US$655 million of market access. This is the loss under the total ban less the loss under the partial ban.

fig H impact of a partial trade ban
value of exports, relative to reference case



However, some of the benefits of continued market access for processed Thai product could be lost if major importers were to raise their level of trade protection on processed product. This could arise wherever an actual applied tariff rate for processed product was lower than the WTO bound (maximum) rate and an importer decided to increase protection.

In a hypothetical example, the simulated benefits of retained market access were reduced when a tariff rate quota (TRQ) applied by the European Union was adjusted for a change in the volume of processed chicken trade. In particular, a hypothetical maximum tariff rate of 60 per cent (the above-quota tariff) was assumed to cut in at 20 per cent of the 2003 trade volume. Such a measure would reduce Thai export revenue by a further US$180 million, increasing the cost of the partial ban to US$525 million relative to the reference case (figure I). In this case, the gain from partial market access with the hypothetical change in the EU TRQ would be US$475 million. This is the loss under the total ban less the loss under the partial ban with the EU TRQ. Overall, the hypothetical change in the EU TRQ reduces the gain from partial market access by around 30 per cent.

fig I **partial ban and EU TRQ imposed on Thai chicken meat imports**
value of exports, relative to reference case

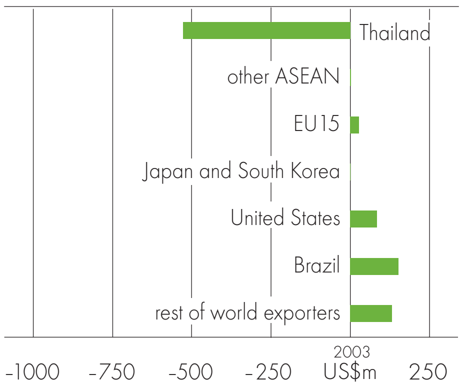
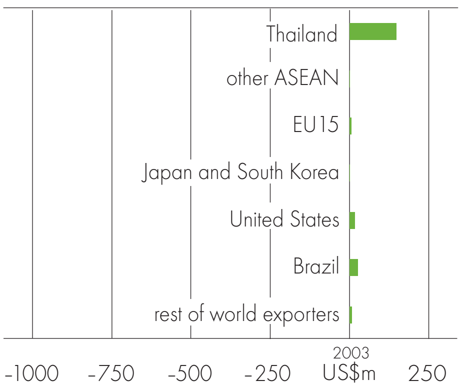


fig J **United States removes trade ban on Thai processed chicken meat imports**
value of exports, relative to reference case



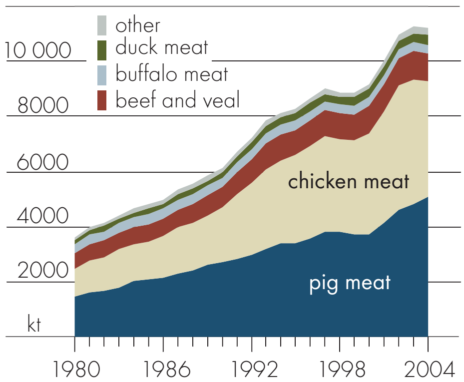
Of course, if Thailand was successful in overcoming chicken diseases, it might be possible to gain access to markets that have been closed to it. In an illustrative example, it was assumed in setting the model parameters that Thailand gained access to the US market, and that most of the increase in trade would be in processed chicken meat. In these circumstances, the value of Thai chicken meat exports would increase by almost US$150 million a year, relative to the 2003 reference case, if it gained access to the processed US chicken market, where product is more highly differentiated (see figure J).

As indicated earlier, the model framework could also be applied to analyse restrictions on market access in other meat products. It includes a realistic treatment of import tariffs and tariff quotas. Another critical feature is the framework's capacity to deal with situations where trade is initially positive and is reduced to zero in a policy simulation. This was the case in the first scenario where a disease outbreak caused a total ban on all Thai chicken meat exports outside of ASEAN. The model also has the capacity to deal with a situation where trade is initially zero, but trade develops as a result of a change in disease status for imports. This may occur, for example, through a process of compartmentalisation as in the last simulation or through zoning.

trends in ASEAN meat production

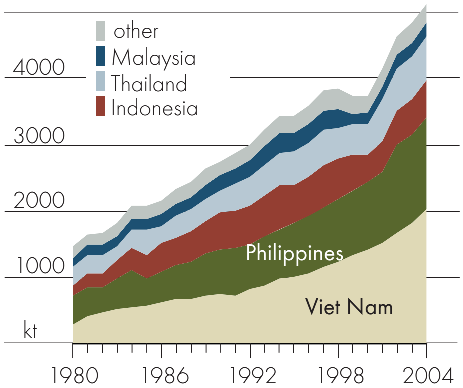
This appendix outlines major trends in ASEAN meat production over the past twenty-five years.

fig K **ASEAN meat production**



Total ASEAN meat production, excluding Singapore, more than tripled from 3.6 million tonnes in 1980 to 11.2 million tonnes in 2004 (figure K). Meat production in the region is dominated by pig meat and chicken meat. In 2004, pig meat production totalled around 5 million tonnes (or 45 per cent of ASEAN meat production), while chicken meat production was around 4 million tonnes (or 37 per cent). Bovine meat production was around 1 million tonnes (or 12 per cent).

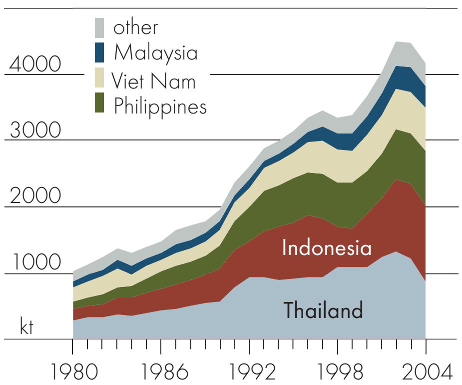
fig L **ASEAN pig meat production**



The main pig meat producers in ASEAN are Viet Nam (2 million tonnes or 40 per cent of total ASEAN pig meat production in 2004) and the Philippines (1.4 million tonnes or 27 per cent) (figure L). Pig meat production in Viet Nam and the Philippines grew at an average rate of 7 per cent a year between 1990 and 2004.

Chicken meat production in ASEAN increased significantly over the two decades to 2003, to 4.5 million tonnes, before the avian influenza outbreaks. The major chicken meat producers in the region are Thailand (30 per cent of total ASEAN chicken meat production in 2004) and Indonesia (22 per cent). Malaysia, the Philippines and Viet Nam are also significant producers (figure M). Chicken production fell sharply in 2004, particularly in Thailand and Viet Nam, which were severely affected by avian influenza outbreaks.

fig M **ASEAN chicken meat production**



Production of bovine meat in ASEAN is relatively small compared with production of pig and chicken meat. Cattle are traditionally raised as draft animals for working on rice farms and are kept as secure assets by farmers. They are sold for meat after they are retired from work. A lack of suitable land with good pasture has also constrained bovine meat production (Nidhiprabha 2007).

B appendix

trends in ASEAN meat consumption

In this appendix, major trends in ASEAN meat consumption over the past twenty-five years are outlined.

As incomes per person rise, consumption patterns in the region reflect the general trend toward lower cereal consumption and higher meat consumption per person. For example, meat consumption per person in Viet Nam and Myanmar doubled between 1990 and 2005. In the Philippines and Indonesia, per person meat consumption increased more than 30 per cent. Meat consumption per person is highest in Brunei Darussalam (66 kilograms per person in 2005) and Malaysia (50 kilograms per person), where incomes are relatively higher than for other members of ASEAN (FAO 2007). In contrast, meat consumption remains low in low income countries, such as Cambodia, Myanmar, Indonesia and Lao PDR, at less than 17 kilograms per person (table 3).

The type of meat consumed varies from country to country in the ASEAN region. Poultry is the main meat consumed in Brunei Darussalam, Indonesia, Malaysia, Myanmar and Thailand. In Cambodia, the Philippines and Viet Nam, pig meat is the main meat consumed, while in Lao PDR both bovine meat and pig meat are important.

A number of factors affect meat consumption. These include income, prices, quality of meat, consumer preferences, health concerns, and religious and ethnic backgrounds. For example, consumption of pig meat is relatively small in Indonesia and Malaysia, where the majority of the population is Muslim, while beef consumption is very low in Myanmar where the population is predominantly Buddhist. In the Philippines, pig meat is preferred (Abuel-Ang 2006). Differences in consumer preferences within the ASEAN region and between these countries and the rest of the world may be an important source of gains from international trade.

Overall, strong economic growth in many ASEAN countries for more than a decade has largely contributed to an increase in local meat consumption. ASEAN economies are expected to continue to grow by 5–8 per cent a year, at least in the short term (Asian Development Bank 2006). Given the low consumption of meat per person in some ASEAN countries, particularly the low income countries, sustained economic growth at moderate to high levels could be expected to result in a significant increase in demand for meat in the future.

Meat consumption is higher in urban than rural areas. Hall et al. (2006) concluded that a rapid increase in demand for meat in Viet Nam has been driven by rising incomes, particularly in urban areas. Fabiosa (2005) also found that households in urban areas in Indonesia had higher consumption of animal protein source products, particularly beef and poultry, than rural households.

table 3 **food consumption, 2005 – ASEAN**

	Brunei	**Cambodia**	**Indonesia**	**Lao PDR**	**Malaysia**	**Myanmar**	**Philippines**	**Thailand**	**Viet Nam**
daily calorie intake per person	calories	calories	calories	calories	calories	calories	calories	calories	calories
vegetable products	1 999	2 173	2 743	2 894	2 502	3 137	2 120	2 366	2 418
animal products	552	154	106	137	410	129	310	233	305
total	2 551	2 327	2 849	3 031	2 912	3 266	2 430	2 599	2 723
consumption per person	kg	kg	kg	kg	kg	kg	kg	kg	kg
cereals	187.4	275.4	252.4	365.5	190.3	352.1	203.2	162.3	287.6
wheat	43.5	2.8	18.0	1.6	60.2	3.9	20.8	17.5	11.2
rice	130.7	257.5	204.2	327.3	112.3	339.8	172.3	132.7	255.0
starchy roots	26.7.5	20.1	68.6	35.6	23.9	9.5	28.6	42.6	15.6
sugar and sweeteners	69.4	34.2	119.3	42.4	395.4	105.6	221.3	401.2	94.1
vegetables	104.4	30.8	32.3	119.4	39.3	51.6	62.5	41.1	83.8
fruits	77.3	22.7	51.6	38.5	53.6	34.7	103.1	82.8	60.5
meat	66.4	16.1	11.9	16.2	49.6	12.9	28.9	23.3	31.4
bovine meat	9.3	5.0	2.4	6.4	4.7	1.7	5.1	2.4	2.2
mutton and goat meat	1.5	0.0	0.6	0.1	0.9	0.2	0.4	0.0	0.1
pig meat	4.9	9.4	2.7	6.1	8.1	4.1	14.7	9.8	23.3
poultry meat	50.6	1.8	6.2	3.5	35.9	6.9	8.4	11.1	5.6
other meat	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.2
eggs	16.0	1.1	3.8	1.8	10.9	1.9	5.9	8.5	2.3
fish and seafood	35.1	23.3	21.0	16.8	57.3	22.9	30.5	30.4	22.8
milk, excl butter	66.1	1.6	7.3	4.9	45.9	17.5	16.0	22.1	6.6

Source: FAO 2007.

In addition to rising income and urbanisation, consumption of meat is influenced by other factors. For example, high prices of beef, particularly for high quality beef imports, negatively affect beef consumption. Health concerns caused by the avian influenza outbreaks have resulted in a substantial fall in poultry meat consumption. A rapid expansion of fast food businesses and modern retail sectors in high and middle income countries in ASEAN have also contributed to an increase in meat consumption.

C appendix

damage costs of disease a outbreak, by ASEAN country

Analogous to the simulation results for Viet Nam and Thailand presented in chapter 5 of the main text, simulation results for key damage costs for Indonesia, Malaysia, the Philippines, Myanmar, Brunei Darussalam, Cambodia and Lao PDR are presented in table 4. Singapore was excluded owing to a lack of data.

Note that in the reference scenario (as in the base year for net exports), Indonesia (like Thailand) exports pig and poultry meats but not beef, while Lao PDR exports pig meat and beef but not poultry meat. Malaysia, Myanmar and Cambodia (like Viet Nam) each export one of the pig, poultry or beef meat types and import the two other types in the reference scenario (as in the base year for net exports). Malaysia exports poultry meat and Myanmar and Cambodia export beef in the reference scenario (as in the base year for net exports). The Philippines and Brunei Darussalam import all three products in the reference scenario (as in the base year for net imports). There is no commercially significant pig meat industry in Brunei Darussalam so a pig disease outbreak was not modeled for that country.

table 4 **damage costs of a disease outbreak, by ASEAN country**
in 2003 US dollars absolute differences from reference case in net present value

	disease outbreak with no domestic policy action		disease outbreak with domestic policy action		
	simulation 1: no ban	**simulation 2: indefinite ban**	**simulation 3: 1 year ban**	**simulation 4: 5 year ban**	**simulation 5: 10 year ban**
	US$m	US$m	US$m	US$m	US$m
Indonesia pig disease					
production	253	416	253	253	268
consumption	422	261	422	422	407
total	*675*	*678*	*675*	*675*	*675*
Indonesia poultry disease					
production	471	508	471	471	475
consumption	326	289	326	326	322
total	*797*	*797*	*797*	*797*	*797*
Indonesia beef disease					
production	2 300	2 300	2 300	2 300	2 300
consumption	0	0	0	0	0
total	2 300	2 300	2 300	2 300	2 300

continued...

table 4 **damage costs of a disease outbreak, by ASEAN country** *continued*

in 2003 US dollars absolute differences from reference case in net present value

	disease outbreak with no domestic policy action		disease outbreak with domestic policy action		
	simulation 1: no ban	simulation 2: indefinite ban	simulation 3: 1 year ban	simulation 4: 5 year ban	simulation 5: 10 year ban
	US$m	US$m	US$m	US$m	US$m
Malaysia pig disease					
production	162	162	162	162	162
consumption	0	0	0	0	0
total	162	162	162	162	162
Malaysia poultry disease					
production	318	823	318	340	389
consumption	187	-304	187	165	117
total	504	519	504	505	506
Malaysia beef disease					
production	122	122	122	122	122
consumption	0	0	0	0	0
total	122	122	122	122	122
Philippines pig disease					
production	1 099	1 099	1 099	1 099	1 099
consumption	0	0	0	0	0
total	1 099	1 099	1 099	1 099	1 099
Philippines poultry disease					
production	329	329	329	329	329
consumption	0	0	0	0	0
total	329	329	329	329	329
Philippines beef disease					
production	1 126	1 126	1 126	1 126	1 126
consumption	0	0	0	0	0
total	1 126	1 126	1 126	1 126	1 126
Myanmar pig disease					
production	108	108	108	108	108
consumption	0	0	0	0	0
total	108	108	108	108	108
Myanmar poultry disease					
production	127	127	127	127	127
consumption	0	0	0	0	0
total	127	127	127	127	127
Myanmar beef disease					
production	485	713	485	485	485
consumption	336	121	336	336	336
total	821	834	821	821	821

continued...

table 4 **damage costs of a disease outbreak, by ASEAN country** *continued*
in 2003 US dollars absolute differences from reference case in net present value

	disease outbreak with no domestic policy action		disease outbreak with domestic policy action		
	simulation 1: no ban US$m	simulation 2: indefinite ban US$m	simulation 3: 1 year ban US$m	simulation 4: 5 year ban US$m	simulation 5: 10 year ban US$m
Brunei Darussalam poultry disease					
production	7	7	7	7	7
consumption	0	0	0	0	0
total	7	7	7	7	7
Brunei Darussalam beef disease					
production	20	20	20	20	20
consumption	0	0	0	0	0
total	20	20	20	20	20
Cambodia pig disease					
production	98	98	98	98	98
consumption	0	0	0	0	0
total	98	98	98	98	98
Cambodia poultry disease					
production	9	9	9	9	9
consumption	0	0	0	0	0
total	9	9	9	9	9
Cambodia beef disease					
production	221	227	221	221	221
consumption	252	247	252	252	252
total	474	474	474	474	474
Lao PDR pig disease					
production	13	13	13	13	13
consumption	34	33	34	34	34
total	46	46	46	46	46
Lao PDR poultry disease					
production	7	7	7	7	7
consumption	0	0	0	0	0
total	7	7	7	7	7
Lao PDR beef disease					
production	99	133	99	99	99
consumption	85	52	85	85	85
total	184	185	184	184	184

D appendix

algebraic description of dynamic meat outlook model

The equations of the dynamic meat outlook model are described below as an annotated version of the GAMS equation listing (the model being run using the GAMS software and Path Solver). Before this, a list of sets, variable names and exogenous parameters is provided. Each equation's name identifies the variable it determines. This correspondence is only necessary for equations with inequalities, to enable GAMS to infer complementary slackness conditions. For simplicity, rather than define special subsets, the convention is followed that variables for which index ranges are not meaningful are fixed to zero prior to solving. This also implies that the corresponding equation elements are automatically removed prior to solving in GAMS.

All prices are real, expressed in US dollars of the base year 2003. Quantity data are in thousand of tonnes except for stock numbers which are in thousands. Prices are per tonne or per animal. Stocks are measured at year end and flows are measured during the year.

notation

sets

t	annual time periods/1*30/
tf(t)	first time period/1/
t1(t)	last time period/30/
sim	simulation case

parameters

pfed(t)	feed mix price over time
pproc	unit cost of processing animal for meat
ascale	scale term meat yield production function
tcfed(t)	meat yield augmenting technical change index

gtcfed	growth rate meat yield augmenting technical change
alpha	share of feed in meat production cost
gnow	instantaneous net growth rate animal numbers
*stkan*0	initial (base year) number of stock in national herd or flock
carr	maximum potential number of stock in national herd or flock
c1*jpr*0	scale term animal agistment unit cost in the herd
eflsp(t)	agistment cost penalty for calibration
gamma	power term unit cost stock agistment
facterm	infinite horizon steady state adjustment factor
opeld	own price elasticity of domestic consumer demand for meat
*b*1*(t)*	scale term consumer demand curve for meat: adjusts for taste
ydom(t)	domestic income as measured by real GDP index
yeld	domestic real income elasticity of consumer demand for meat
pwexo(t)	world real price of meat over time
atc	international transport cost as fraction of world price of meat
aet(t)	*ad valorem* equivalent export tax as share of domestic price
atm(t)	*ad valorem* equivalent import tariff as share of landed price
xqta(t)	export quota on meat product over time

positive variables

qan(t)	number of animals for feedlot and then slaughter
qmtan(t)	meat yield per animal
qfedan(t)	feed input per animal
pstkan(t)	animal stock price to the feedlot
stkan(t)	number of animals in the national herd or flock
qc(t)	domestic consumption volume of meat product
pc(t)	domestic consumer price for meat product
qex(t)	quantity of meat exports
qim(t)	quantity of meat imports
pxqta(t)	*ad valorem* equivalent rental price of export quota as share of domestic price

model equations

offtake: number of animals sold for slaughter–price arbitrage condition

$$qaneq(t)..\ pstkan(t) + pfed(t) * qfedan(t) \geq [pc(t) - pproc] * qmtan(t)$$

This is a price arbitrage condition used to determine the number of animals for fattening and slaughter. It is a mixed complementarity problem (MCP) condition because the condition is an inequality.

The generic interpretation of an MCP condition is as follows. If the left hand side exceeds the right, then the shadow value associated with the condition, in this case *qan*, should be zero. This is because the product of the variable and the gap between the right and left hand sides, the complementary slackness condition, must be zero. If the variable associated with the condition, which is *qan*, is positive, then the condition holds with equality to meet the complementary slackness condition.

For the livestock farmer, the offtake condition is used to determine when and how many animals to sell for slaughter. In the model, breeding and fattening operations are integrated. Livestock are removed from the breeding herd and fattened and sold for slaughter only if it is most profitable to do so. If it is profitable to sell (*qan* > 0, so the condition holds as an equality), the number sold is such that further net gains from selling any more are just exhausted – this is where marginal cost equals marginal benefit. Alternatively if it is not profitable to sell (the condition is a strict inequality, so *qan* = 0) – that is, if the unit cost of supply exceeds the marginal benefit received from selling, then animals will be retained in the herd until economic conditions improve for sale to be profitable.

In this offtake condition, the marginal cost of production of an animal for slaughter is the price of an animal to be fattened plus the unit cost of fattening that produces the meat yield. The marginal benefit from the animal for meat is the producer price of meat times the yield. The producer price is less than the consumer price, reflecting slaughter and other costs of livestock meat marketing, processing and delivery.

meat yield

$$qmtaneq(t)..\ ascale*[qfedan(t) * tcfed(t)]^{**}\ alpha = qmtan(t)$$

This meat yield per animal production function takes intensive Cobb-Douglas form. This relationship implies that the percentage weight gain is alpha times the percentage change in the effective feed input. The latter is the percentage change in the amount of mix fed plus the percentage change in exogenous feed input augmenting technical advance that improves the weight gain.

feed input intensity

$$qfedaneq(t)..\ qfedan(t) = alpha*[pc(t) - pproc]*\ qmtan(t)/pfed(t)$$

The feed intensity rises directly in proportion to the producer price and falls directly in proportion to the unit cost of feed mix. The term alpha is the cost share in production attributable to feed input and when production is profitable the price of the animal input to the feed lot sums to the remaining share of costs given zero pure profit in overall livestock production for meat.

intertemporal livestock balance for the herd or flock

$$\begin{gathered} pstkaneq(t)..\ \{1 + gnow*[1 - (\ stkan(t-1) + stkan0\$tf(t)\ )/\ carr]\} \\ *\ \{stkan(t-1) + stkan0\$tf(t)\} - qan(t) = stkan(t) \end{gathered}$$

The first bracketed term is 1 plus the net natural growth rate of the stock of animals in the herd or flock. (The expression *y$x* means do *y* if *x* is true.) Stocks are measured at year end and stock growth is logistic. The opening level of stocks in the base year is *stkan*0 and it is this term that is reduced under a disease outbreak in the simulations.

Numbers in the herd or flock are constant if the numbers taken from the herd for fattening and slaughter equal the numbers entering the herd from net natural growth. The net growth rate is a symmetric hill shaped quadratic with zero growth at zero stock level and at the maximum carrying capacity. This reflects the notion that overcrowding and undercrowding may limit stock growth.

stock: number of animals in herd or flock — price arbitrage condition

$$\begin{gathered} stkaneq(t)..\ pstkan(t) + c1jpr0*\ eflsp(t)*\ stkan(t)**\ gamma = \\ pstkan(t+1)*[1 + gnow*\ (1-2*\ stkan(t)/carr\ )]/(1+r) \\ \{facterm*[pstkan(t)*\ gnow*\ (1-2*\ stkan(t)/carr) \\ -\ c1jpr0*\ eflsp(t)*\ stkan(t)**\ gamma\ )]\}\$t1(t) \end{gathered}$$

An animal in the herd is a form of natural capital asset and its price reflects this. The value of an animal today plus the unit cost of agistment today equals the value of an animal in the herd tomorrow inflated by natural growth effects and discounted for delay. The *$t1(t)* term condition adds in the relevant value of an animal next year in the terminal year. This is needed to avoid terminal value problems in the model such as an artificial rundown in stock at the end of the horizon if the price in the post-terminal year had no value. In particular, the value of an animal one year post terminal is the marginal profit from having an animal in the herd in the terminal year inflated by the term *facterm* that takes account of an assumption that profit grows at a constant rate from the terminal year (see the discussion of welfare measured below).

domestic consumer demand function for meat

*qceq(t).. qc(t) =[pc(t)** opeld]* b1(t)*[ydom(t)** yeld]*

This is a log linear function for domestic meat consumption. Consumption increases if the meat price falls or real income increases or taste for the meat improves.

regional meat market balance

pceq(t).. qmtan(t) qan(t) + qim(t) = qc(t) + qex(t)*

In the model, the meat product is homogeneous: so exported, local and imported products are perfect substitutes, and production equals household consumption plus net exports. The domestic price of a commodity clears the local market for the good. In this model the world price of meat is exogenous, determined outside the model, assuming the economy is too small to influence the world price to any significant extent in the long run. Under this small country assumption, if at the world export (import) parity price there is additional demand (supply) in the form of exports (imports) then this extra demand (supply) is met as the domestic price rises (falls) from its pre-trade level to export (import) parity.

meat exports–price arbitrage condition

qexeq(t).. pc(t) ≥ pwexo(t) (1 – atc)/[1 + aet(t) + pxqta(t)]*

The lowest price that a homogeneous product can be traded at is the export parity price. If exports occur, then the domestic price must equal the export price. If the domestic price is higher, then exporting is not profitable and will not occur.

If the domestic price were lower, then product would be sold overseas until the domestic price rises to the export parity price. The export parity price is the free on board (fob) price – that is, what the product is worth loaded at the port of exit to be shipped overseas, with adjustments for border trade and SPS measures. The adjustments modelled here are export taxes and equivalent quota rentals. An export tax reduces the price received by domestic producers and paid by domestic consumers. The export parity price is lower than the fob price where there are export taxes and equivalent quota rentals. An export tax amounts to a tax on domestic production and a subsidy to domestic consumption. The fob price is the price at the world market less what it costs to transport it there from the domestic market. In the model, transport costs are measured as a proportion of the world price.

meat imports–price arbitrage condition

$$qimeq(t)..\ pwexo(t)^{*}\ (1 + atc)^{*}[1 + atm(t)]) \geq pc(t)$$

The highest price at which a homogeneous product can be traded is the import parity price. If imports occur then the domestic price must equal the import price. If the domestic price is lower, then importing is not profitable and will not occur. If the domestic price were higher, product would be bought from overseas until the domestic price fell to the import parity price. The import parity price is the cost insurance and freight (cif) price – that is, what the product costs landed at the port of entry to the domestic economy, with adjustments. The only adjustment modelled here is an import tariff that increases the price received by domestic producers and paid by domestic consumers. The import parity price is higher than the cif price where there are import tariffs (or equivalent import quota rentals). An import tariff amounts to a subsidy on domestic production and a tax on domestic consumption. The cif price is the price at the world market plus what it costs to transport it from there to the domestic market.

meat export quota constraint

$$pxqtaeq(t)..\ xqta(t) \geq qex(t)$$

An export constraint is an upper limit on the volume of exports. If the constraint is binding, then there is a price or rent associated with the constraint or export tax equivalent. For ease of solution, this rent is measured here as an *ad valorem* equivalent.

welfare measurement

Results from different simulations of the model are summarised in differences in the net present value of producer welfare (profit), consumer welfare (consumer surplus) and government welfare (commodity specific tax revenue) that may be derived from the model. Indeed the equations of the model can be derived from the welfare maximising choices made by producers and consumers.

livestock farming profit

The livestock farmer's producer welfare measure, because it involves an intertemporal optimisation problem, is explained from first principles here. The livestock farmer chooses the levels of output and inputs to maximise the net present value of the stream of annual profit over time. It is costly to build up the number in the herd or flock but investment is warranted where long run profit prospects are good from higher future meat prices or lower costs of production. Specifically, the optimisation problem facing the livestock producer is to maximise the net present value of livestock annual profit indefinitely:

(1) *npvprof* = sum[*t* = 1 to *t*1, *dr(t)* * *prof(t)*] + sum[*t* = *t*1+1 to infinity, *dr(t1)* * *prof(t)*]

where:

(2) sum[*t* = *t*1+1 to infinity, *dr(t1)* * *prof(t)*] = *dr(t1)* * *profterm**
sum[*t* = 1 to infinity, *((1+g)/(1+r))*** *ord(t)*] = *facterm** *dr(t1)* * *profterm*

Also note that the term *ord(x)* is a set reference to the *x*'th element *x* of set *x*, and:

(3) *dr(t)* = 1/(1+*r*)** *ord(t)*

(4) *facterm* = (1+*gqse*)/(*r* - *gqse*)

Now from equations *qmtaneq* and *qfedaneq*, assuming the meat price, unit processing cost and feed input are constant, the growth rate in the meat yield is:

(5) *gqse* = *alpha** *gtcfed*/(1-*alpha*)

In equation (1), the net present value of annual profit is the sum of two terms. The first is the discounted sum of the stream of annual profit over the simulation period.

The second term accounts for profit beyond the terminal year. It is assumed that the farming operation is in a stationary state from the terminal year, with profit growing at rate *gqse*, where the meat price, unit processing cost and feed input and stock are constant. The discount rate *dr* is the real risk free compound interest rate used to adjust for the time value of money.

Annual profit for the model during the simulation period, *prof(t))*, is:

(6) *prof(t) = qan(t)*[(pc(t) – pproc) qmtan(t) – pfed(t)* qfedan(t)]*
– eflsp(t) {[c1jpr0/(1+gamma)]* stk(t)** (gamma+1)}*

The first two terms in this equation are annual revenue less annual feed cost. The last term is the annual total cost to agist animals in the breeding herd or flock. The marginal cost of agistment slopes up with a rising stock level. In addition, to readily calibrate the model to a balanced growth path, as this agistment cost rises, *eflsp* increases at growth rate *gqse*. The term *eflsp* acts like a fixed factor tax here on natural capital that is returned to the livestock owner and producer.

Annual profit for the model in the terminal year, assuming a stationary state once there, *profterm*, is:

(7) *profterm = gnow(t)* (1 – stk(t1)/carr)* stkan(t1)**
[(pc(t) – pproc) qmtan(t) – pfed(t) qfedan(t)]*
– eflsp(t) {[c1jpr0/(1+gamma)]* stkan(t)** (gamma+1)*

This involved using equation *pstkaneq* to replace *qan* in (6) with the stationary state number of animals to be taken from the herd such that the stock stays constant from the terminal year.

The livestock farmer's optimisation problem is to choose the number to be slaughtered and the amount of feed input to maximise (1) subject to the intertemporal livestock balance *pstkaneq* and using the definition of meat yield *qmtaneq*. This results in the first order conditions (including Kuhn-Tucker conditions where inequalities apply) for *qaneq*, *qfedaneq* and *stkaneq* given above. By construction, the value of animals sold for fattening and slaughter, *pstkan*qan*, may be inserted in equations (6) and (7) using the zero pure profit in livestock farming from equation *qaneq*, to give:

(6') *prof(t) = qan(t)* pstkan(t)*
– eflsp(t) {[c1jpr0/(1+gamma)]* stkan(t1)** (gamma+1)}*

and:

(7′) $$profterm = pstkan(t1)*\ gnow(t1)*\ (1 - stkan(t1)/carr)*\ stk(t1) - eflsp(t1)*\ \{[c1jpr0/(1+gamma)]*\ stkan(t1)**\ (gamma+1)\}$$

It is *facterm* times the derivative of *profterm* with respect to *stkan* that appears in *stkaneq* for the one period post terminal value for the stock.

reported welfare measures

The actual welfare measures used for reporting are expressed as differences from the reference case simulation. This is done because it is only the difference in consumer surplus that is meaningful to calculate since demand is inelastic. The following formulas are expressed in billions of US dollars for 2003 and a simulation index has been introduced for clarity.

The **net present value of the annual differences in consumer surplus** is:

(8) $$ednpvcsurp(sim) = \mathrm{sum}(t,\ dr(t)*\ dcsurp(t,\ sim)) + dr(t1)*\ dcsurp(t1,\ sim)*\ facterm/1000$$

The **net present value of the annual differences in profit** is:

(9) $$ednpvprof(sim) = \mathrm{sum}(t,dr(t)*\ dprof(t,\ sim)) + dr(t1)*\ dprofterm(sim)*\ facterm/1000$$

The **net present value of the annual differences in government tax revenue** is:

(10) $$ednpvgov(sim) = \mathrm{sum}(t,dr(t)*\ dgov(t,\ sim)) + dr(t1)*\ dgov(t1,sim)*\ facterm/1000$$

The **net present value of the annual differences in total welfare from the meat sector** is:

(11) $$ednpvwelf(sim) = ednpvcsurp(sim) + ednpvprof(sim) + ednpvgov(sim)$$

Annual consumer expenditure during the simulation period is:

(12) *cexp(t, sim) = pc(t, sim)* qc(t, sim)*

The difference in annual consumer surplus during the simulation period is:

(13) *dcsurp(t,sim) = – (1/(1+opeld))* (cexp(t, sim) – cexp(t, 'simref'))*

Annual government tax receipts during the simulation period are:

(14) *gov(t,sim) = pwexo(t)* (1+atc)* atm(t)* qim(t, sim) + pwexo(t)* (1–atc)* aet(t)/[1+aet(t)]* qex(t,sim)*

The *difference in annual government tax receipts* during the simulation period is:

(15) *dgov(t,sim) = gov(t,sim) – gov(t, 'sim1')*

Annual profit was defined above and the difference in annual profit during the simulation period is:

(16) *dprof(t,sim) = prof(t,sim) – prof(t, 'sim1')*

Annual profit in the terminal year assuming a stationary state was defined above and the difference in annual profit from the terminal year assuming a stationary state once there is:

(17) *dprofterm(sim) = profterm(sim) – profterm('sim1')*

E appendix

algebraic description of world chicken trade model

The equations of the world chicken trade model are described in this appendix following the GAMS conventions mentioned in appendix D. As before, notation is explained first before presenting the equations.

notation

sets

s regions of the world/Thai, *oasn, eu15, japk, usa, bra, rowe, rowm/*

k quota *tranches/inqta, ovqta/*

c commodity types/*unproc, proc/*

aliases

(r, r2, r3)

(c, c2, c3)

parameters

aqd(c, r2, r)	intercept term in import demand function for good c from *r*2 in *r*
bqd(c, r2, c3, r3, r)	slope term in import demand function for good c from *r*2 in *r* due to price of good c3 from *r*3 in *r*
aqs(c, r)	intercept term in export supply function for good c in *r*
bqs(c, c3, r)	slope term in export supply function for good c in *r* due to price of good c3 in *r*
qtalim(c, r2, r)	base year in-quota import limit on good c from r2 in *r*
taradvl(c, r2, r, k)	*ad valorem* tariff rate on good c from *r*2 in *r* for quota tranche *k*

tarspec(c, r2, r, k)	specific tariff rate on good c from *r2* in *r* for quota tranche *k*
utc(c, r2, r)	unit transport cost of good c from *r2* to *r*
dvadvl(c, r2, r)	dummy variable indicating if *ad valorem* tariff rate quota applies on good c from *r2* to *r*
dvspec(c, r2, r)	dummy variable indicating if specific tariff rate quota applies on good c from *r2* to *r*

positive variables

qd(c, r2, r)	import consumption of good c from *r2* in *r*
qs(c, r)	export production of good c from r
pd(c, r2, r)	user import price of good c from *r2* in *r*
ps(c, r)	fob export price of chicken product c from *r*
pqta(c, r2, r)	rental price *ad valorem* or specific tariff rate quota as relevant
qovqta(c, r2, r)	imports over tariff rate quota on chicken product c from *r2* to *r*

model equations

import demand function

$$pdeq(c, r2, r)..\ qd(c, r2, r) = aqd(c, r2, r) + \mathrm{sum}[(c3, r3), bqd(c, r2, c3, r3, r) * pd(c3, r3, r)]$$

Quantity imported is a linear function of own and substitutes' prices.

export supply function

$$pseq(c,r)..\ qs(c, r) = aqs(c, r) + \mathrm{sum}[c3, bqs(c, c3, r) * ps(c3, r)]$$

Quantity exported is a linear function of own and substitutes' prices.

commodity balance condition

$$qseq(c, r2)..\ qs(c, r2) = \mathrm{sum}[r, qd(c, r2, r)]$$

Exports from a country equal the sum of imports to all other countries from that country.

bilateral trade zero unit pure profit condition in international trade

$$qdeq(c, r2, r)..\ ps(c, r2)*[1 + taradvl(c, r2, r, \text{'inqta'}) + dvadvl(c, r2, r)*\ pqta(c, r2, r)] + [tarspec(c, r2, r, \text{'inqta'}) + dvspec(c, r2, r)*\ pqta(c, r2, r)] + utc(r2, r) \geq pd(c, r2, r)$$

This is a price *arbitrage* condition on trade flows. (See appendix D for a generic explanation of the MCP inequality.) In this condition, if the supply price to the end user, from the inverse supply or marginal cost curve for imports, exceeds the consumer's demand price, from the inverse demand curve or marginal benefit curve which measures the marginal willingness to pay for imports, then there is no trade because it is uneconomic. Picture the inverse supply curve lying above the inverse demand curve at all points in the positive *orthant* except for the case where the curves possibly intersect with the vertical price axis. Alternatively, if trade occurs then it must be the case that all profit opportunities from *arbitrage* are exhausted so the consumer price equals the user's unit cost of supply for the product. Picture the inverse supply curve intersecting the inverse demand curve in an interior point of the positive *orthant* where the point of intersection is by definition the 'price quantity pair' that maximises the net benefits from trade.

As defined in *qdeq*, the unit cost of supply is the free on board (fob) price plus any tariff or tariff rate quota (imposed by the importing country) plus the unit cost of international transport. The model caters for *ad valorem* and specific tariffs, where a dummy variable as necessary is used to flag which sort of tariff applies. For example, the first square bracketed term on the left hand side of the equation refers to an *ad valorem* tariff rate quota. The term *taradvl* refers to the in-quota tariff rate expressed as a fraction, where *'inqta'* is short for in-quota, and the term *pqta* is the additional tariff rate or *ad valorem* rental price that applies in the presence of a binding *ad valorem* tariff rate quota. (A uniform tariff is a subcase when the quota limit is infinite.) The second square bracketed term contains the analogous expression for a specific tariff rate quota. Also note for simplicity, international transport costs are set to zero in the simulations. They are generally small shares of total user costs of imports for existing markets. The situations that may arise under the tariff rate quota are discussed further below.

In the case of an SPS trade ban, *qd* is fixed to zero so the equation *qdeq* is automatically deleted. The model still determines the fob unit cost of supply, *ps*, and the consumer's marginal willingness to pay, *pd*, and the gap after adjusting for transport costs, *pd–ps–utc,* is the exact prohibitive tariff that makes trade uneconomic. It is important that the demand equations allow for the possibility that demand can be zero while prices remain uniquely defined since the demand system responds to cross-price as well as own-price effects. This criterion is a key reason for adopting a linear structure as demand has a choke price.

tariff rate quota rental balance

$$pqtaeq(c, r2, r)..\ qtalim(c, r2, r) + qovqta(c, r2, r) \geq qd(c, r2, r)$$

If demand is relatively weak (less than the in-quota limit), the (inverse) import demand curve intersects the in-quota limit, *qtalim,* at a point below the level of the in-quota supply price, then the rental price of quota *pqta* is zero as the quota does not bind. Alternatively, if the inverse demand curve intersects the quota limit at a point that is above the in-quota supply price then the rental price of quota is positive at a demand level which equals or exceeds the in-quota limit. If the rental price of quota is positive then the equation holds with equality.

Overquota imports zero pure profit condition

$$\begin{aligned}&qovqtaeq(c, r2, r)..\ dvadvl(c, r2, r)*\ taradvn(c, r2, r, 'ovqta') +\\&dvspec(c, r2, r)*\ tarspec(c, r2, r, 'ovqta') \geq\\&dvadvl(c, r2, r)*\ taradvn(c, r2, r, 'inqta') +\\&dvspec(c, r2, r)*\ tarspec(c, r2, r, 'inqta') + pqta(c, r2, r)\end{aligned}$$

If the inverse demand curve intersects the in-quota limit below the overquota supply price, importing overquota is zero because trade over quota is not economic. In this case the overquota tariff rate exceeds the actual tariff rate at the quota limit. The actual tariff rate is the in-quota tariff rate plus any rental price for quota. Alternatively, the inverse demand curve intersects the overquota supply price. In this case, the equation holds with equality and the rental price of quota is the gap between the in-quota and overquota tariff rates. Overall and in effect, under a tariff rate quota either the in-quota tariff rate applies, as demand is relatively weak, the overquota tariff rate applies as demand is relatively strong, or demand is at the in-quota limit such that the actual tariff rate is endogenous between the in- and overquota rates where the precise value is read from where the inverse demand curve intersects the in-quota limit.

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