The expected economic impact of selected exotic diseases on the pig industry of Australia

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Submitted for publication: 5 February 2001
Accepted for publication: 17 April 2001

Summary
The authors assess the expected economic impact of three exotic diseases on the pig industry of Australia. An integrated epidemiological/economic approach was used to assess the effects of classical swine fever, Nipah virus and porcine reproductive and respiratory syndrome. Scenarios involving either an epidemic event, in which the outbreaks were confined to selected regions and were eradicated, or an endemic situation, in which the diseases became established in Australia, were studied. Based only on loss of sales and disposal costs, epidemics resulted in regional losses in income of the order of AUS$10 million-AUS$30 million (16%-37%) depending on disease and region. If any of these diseases became established, opportunity losses in gross national pig income of 5%-11% per year would occur, with classical swine fever the most serious of the three diseases. Establishment of any of the diseases would lead to rapid structural change in the pig industry, with concomitant social and economic dislocation in regional Australia.

Keywords

Introduction
The Office International des Epizooties (OIE) provides guidelines and principles for conducting transparent, objective and defensible risk analyses for international trade (20). Import risk analysis has four components, namely: hazard identification, risk assessment, risk management and risk communication. Risk assessment is the component that estimates the risk associated with a hazard and by definition includes evaluation of the likelihood of entry and the biological and economic consequences of establishment and spread of a pathogenic agent within the territory of an importing country. The consequences of an exotic agent may be direct (e.g. animal infection, disease and production losses or public health consequences) or indirect (e.g. surveillance and control costs, compensation costs, potential trade losses or adverse consequences to the environment).

A number of recent studies have examined the hazards and likelihood of introducing exotic diseases with imports (4, 9, 12, 16). However, to date, relatively few studies have addressed the consequences of a disease introduction into a country previously free of that disease.

The present study was undertaken to assess the economic consequences expected to result from entry and elimination, or establishment, of three exotic diseases in the pig population of Australia. An integrated epidemiological/economic approach was used to assess the effects of the diseases and the associated losses.

The pig industry in Australia
Pig production in Australia is intensive and heavily reliant on purchased inputs. There are approximately 3,000 pig farms with 304,600 sows in Australia (Fig. 1), for a total population of approximately 2.8 million pigs (3). The average herd size is 100 sows, but the largest thirty-eight producers (defined as having more than 1,000 sows) account for 42% of the total number of sows.
The pig industry is a significant contributor to the economy of Australia. The annual production of pig meat in Australia in 1998-1999 was 370 kt (based on carcass weight), with a gross value at the farm gate of AUS$663 million (3). Pig meat constituted 10% of the total livestock slaughter value in the country, of AUS$6,935 million, and 2.3% of the total farm production of AUS$28,218 million. The per capita consumption of pig meat in 1998-1999 was 20 kg. Although the pig industry of Australia is relatively small by world standards, international trade is becoming increasingly important. Australia is a net exporter of pig meat with exports expanding rapidly in recent years. In 1998-1999, exports were valued at more than AUS$76 million and are expected to double in 1999-2000, due to rising demand from markets in Asia (5).

The diseases

The exotic diseases considered by this study are classical swine fever (CSF), porcine reproductive and respiratory syndrome (PRRS) and Nipah virus disease (Nipah). These diseases were chosen for several reasons. Firstly, the pig is the only, or the principal livestock species affected and all three are considered economically important. Classical swine fever is an OIE List A disease, PRRS is an OIE List B disease and Nipah is a new zoonosis as yet not classified by the OIE. Secondly, all three diseases would have significant domestic and export cost implications for the pig industry of Australia.

Classical swine fever

Classical swine fever is highly contagious and in economic terms is one of the most important diseases of pigs. The clinical disease may be acute, chronic or mild. In the acute form, CSF is associated with fever, depression, occasional trembling and convulsions, and death. Mortality rates may reach 90% (14).

Direct contact with infected animals is the most frequent means of spread. Infected pig products are an important factor, especially in introducing CSF into new regions. Exposure can also occur from contaminated vehicles, bedding, multi-dose vaccine/needles, clothing and footwear. Mechanical transfer by pets, birds, flies and some external parasites is possible.

In Australia, CSF has occurred in 1903, 1927-1928, 1942-1943 and 1960-1961 (14). The first three outbreaks were of virulent disease and resulted from either imported pig meat or the use of food refuse from ships as swill-feed for pigs. The 1960-1961 outbreak was caused by a strain of low virulence and was probably of a similar origin. On each occasion, CSF was eradicated by traditional stamping-out procedures, including slaughter, disinfection, quarantine and movement controls. As a result of structural changes to the pig industry, it is considered that an outbreak of CSF would now be difficult to eradicate and could require considerable resources (1).

Porcine reproductive and respiratory syndrome

Porcine reproductive and respiratory syndrome appeared as a new disease in the mid- to late 1980s. The disease has subsequently been identified as an important cause of reproductive failure in sows, and respiratory disease in young pigs. Different strains of the PRRS virus exist. Isolates from Europe are similar to each other but exhibit considerable differences when compared to those from North America. Infection in pig herds is characterised by abortion, premature farrowing, stillborn and mummified pigs, and respiratory disease with death and chronic poor performance of nursing and weaned pigs (18).

Introduction of pigs shedding PRRS virus is by far the most common means of disease spread to a herd. The disease can also be transmitted through semen. Experimental work indicates that the duration of PRRS shedding in semen is variable and may not be correlated with seroconversion or viraemia (7). Transmission of PRRS through pig carcasses is generally reported as unlikely, although field and experimental data are equivocal.

No specific treatment exists for PRRS. Once introduced, the costs of eradicating the disease are high. Control by vaccination is of limited value since new strains of the virus are evolving constantly. National and international attempts to control the spread of the disease have been largely unsuccessful. This is because little is known about the spread of the PRRS virus,
especially carrier status in pigs, while diagnosis can be difficult because of problems with standardisation of test methods and types of samples submitted.

**Nipah**

Nipah is a newly recognised viral disease that primarily affects pigs and humans. In the latter months of 1998, Japanese encephalitis was thought to have been responsible for an episode of human disease near Ipoh, Malaysia. A virus isolated in March 1999 and subsequently named Nipah virus was identified as the cause. The virus subsequently spread south to other states of Malaysia and to Singapore. The spread of the disease was associated with the movement of pigs from infected farms. Overall, 265 cases were reported in humans (mostly pig farm workers), leading to 105 deaths (8, 19).

The causal virus, a paramyxovirus, was isolated from both humans and pigs (19). The only member of the paramyxovirus family with which Nipah serologically cross-reacted was Hendra virus. Hendra virus was first isolated in Australia during an outbreak of severe respiratory illness that affected twenty horses and two humans in the Brisbane suburb of Hendra in September 1994 (17).

Fruit bats are believed to be the reservoir of Nipah virus (11). Pigs are believed to be infected by direct or indirect contact with bats, the virus is then transmitted directly to in-contact pigs. All fluids and discharges of infected pigs contain virus of high titre, and pigs appear to be the source of infection for humans, horses, dogs and cats, which are all thought to be dead-end hosts of the virus.

**Risks of introduction**

**Classical swine fever**

Ingestion by pigs of pig meat or pig meat products infected with the CSF virus is important in introducing the disease to new areas. This is believed to have been the source of previous incursions of CSF into Australia. Even though the feeding of swill is illegal in Australia, the introduction of pig products from endemic countries is considered the greatest risk (1). These products could be smuggled through airports or the mail, or could enter the country as garbage from ships, aircraft, yachts, etc. Fishing vessels from some countries of Asia may constitute a risk if pigs or pork products are carried. The high level of disease awareness and biosecurity practised by modern intensive pig units suggest that smaller 'backyard' pig farms are the most probable entry point of infection.

**Porcine reproductive and respiratory syndrome**

The most likely means of entry of PRRS into Australia is through sub-clinically or asymptomatically infected live pigs or via semen. A small risk exists of introducing PRRS virus into Australia in uncooked pork products if fed to domestic pigs. If PRRS were to be introduced through a contaminated batch of semen, a multi-focal outbreak could result.

**Nipah**

As Nipah virus appears to be a virus of fruit bats, the most likely cause of an outbreak in pigs is considered to be direct or indirect contact with infected fruit bats. If fruit bats from infected colonies were to fly to Australia, Nipah virus could be introduced. Direct contact with infected pigs is thought to be the most likely route of further viral transmission.

Paramyxoviruses do not persist or retain infectivity for long periods in meat or in the environment. Therefore, the virus is highly unlikely to be introduced into Australia directly or indirectly by infected fomites, or by pig meat from a Nipah-infected country. Humans, horses, dogs and cats are believed to be 'dead-end' hosts, and thus, are not considered a risk for introducing the virus into Australia.

**Approach to exotic disease outbreaks in Australia**

The approach to outbreaks of serious exotic diseases in Australia is described in the Australian Veterinary Emergency Plan (AUSVETPLAN) (see http://www.aahc.com.au/ausvetplan/index.html). This is a systematic and integrated approach to managing disease emergencies developed by the Commonwealth and State Governments in co-operation with industry. The preferred approach, where feasible, is to eradicate exotic diseases. Control will generally be based on quarantine of infected premises (IP), movement restrictions in the area and slaughter of stock on affected premises (stamping-out), followed by cleaning and disinfection.

Movement restrictions would apply at several levels. Quarantine would be imposed on all farms on which the disease is either known or suspected. The restricted area (RA) is a relatively small area declared around the IP that is subject to intense surveillance and movement controls. Movement out of the RA would, in general, be prohibited, while movement into the RA would only be by permit. Multiple RAs may exist within one control area (CA). The CA is larger in area than an RA, and restrictions are applied to reduce the chance of the disease spreading further afield. The CA may be reduced in size as confidence about the extent of the outbreak becomes clearer, but must remain consistent with international requirements. Movement of animals and specified products out of the CA, into the disease-free area, would be by permit only.

Once the outbreak was under control, consideration would be given to adopting 'zoning.' This would involve declaring a large area of Australia free from the disease. The disease-free area
would be based on geographic boundaries and would comply with OIE requirements.

These responses are described in detail in specific AUSVETPLAN disease strategy documents. An AUSVETPLAN strategy has been detailed for CSF (1) and a draft strategy exists for PRRS (2). As yet, no specific strategy has been proposed for Nipah.

Assessing the consequences of introduction

Through quarantine policies, and to a lesser extent through the management practices of industry participants, Australia has the ability to exert a degree of control over exotic diseases entering the national pig population. Implicitly, the option, or opportunity exists to maintain the current health status and the associated levels of production and economic value. Presuming that the opportunity to avoid exotic diseases exists, the cost of not exercising this opportunity is given by the difference between the current level of production and the level of production subsequent to the introduction of disease into one or more areas and either being stamped-out or becoming established. This difference, or opportunity cost, can be estimated using partial budgeting and modelling techniques.

The impacts of disease incursions can be derived from a technical assessment of biological and price effects associated with specific disease events. For this study, several outbreak scenarios have been examined with a view to comparing the effects of the three diseases under similar circumstances. These scenarios involved two approaches, as follows:

– epidemic event: assumes the initial outbreaks are confined to selected regions. Each disease is assumed to be eradicated following a successful control campaign. To demonstrate potential regional variations, discrete areas in northern and southern Australia were studied.

– endemic disease: assumes the diseases become established in Australia.

When considering any hypothetical disease outbreak, assumptions must be made about the means of introduction and spread of the disease. The epidemic outbreak scenarios used modelling to simulate the size and duration of likely outbreaks in the two regions, based on the expected behaviour of the disease under the conditions present in Australia, and on the control measures likely to be taken.

The endemic scenarios are defined descriptively, based on international experience of the diseases in endemic situations. The overseas observations have been adapted to take into account the structural and management factors that apply to the pig industry in Australia.

Study regions

The study focused on two important pig production areas, in the States of Queensland and Victoria. The regions were based on statistical divisions classified by the Australian Bureau of Statistics (ABS). These were the statistical division of Darling Downs in south-east Queensland (hereafter referred to as Darling Downs), and the statistical divisions of Loddon and Goulburn in northern Victoria (hereafter referred to as Northern Victoria). Both of these regions are important agricultural areas. The agricultural, forestry and fishery sector accounts for 15.7% and 12.2% of regional employment respectively, compared with a national average of 4.2%.

Darling Downs covers an area of approximately 90,000 km² (Fig. 2) and has a population of 200,132 people. Based on ABS data for 1997-1998 (6), the area has 144 pig farms with an average farm size of 2,100 pigs (Table I). Northern Victoria covers an area of approximately 41,800 km² (Fig. 2), has a population of 342,907 and 77 pig farms with an average farm size of 3,200 pigs. The ABS figures are based on producers who describe their principal source of income as pig farming; these figures therefore underestimate the total number of pig farmers and overestimate the average size of farms. Within these regions, pigs account for between 18% and 28% of the total value of livestock slaughtered compared to a national average of 11% (Table I). In over 50% of pig farms, the value of animals produced is in excess of AUS$200,000 per annum (Fig. 3).
Epidemic event

**Scenarios**

**Classical swine fever**
The epidemic scenario assumes that CSF is introduced through a contaminated pig meat product that is fed to animals on a single small ‘backyard’ farm in the region. Subsequently, CSF is mechanically spread to a commercial farm and then affects a number of farms in the surrounding area. In this study, an acute form of the disease has been assumed.

**Porcine reproductive and respiratory syndrome**
As Australia maintains strict quarantine controls on the introduction of live pigs and semen, contaminated meat is assumed to be the source of introduction for a single farm. As with CSF, the disease is assumed to originate in a small ‘backyard’ farm, from which point spread to other farms occurs.

**Nipah**
In this scenario, the pigs are assumed to become infected through close contact with an infected flying fox. The disease is not recognised until a worker on the farm suffers encephalitis and Nipah is included in the differential diagnosis by medical authorities.

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**Table I**
**Statistical information on the study regions**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Darling Downs</th>
<th>Northern Victoria</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td>90,230</td>
<td>41,799</td>
<td>7,692,030</td>
</tr>
<tr>
<td>Population</td>
<td>200,132</td>
<td>342,907</td>
<td>17,892,423</td>
</tr>
<tr>
<td>Employment in the agriculture sector (%)</td>
<td>15.7</td>
<td>12.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Livestock numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle</td>
<td>1,430,634</td>
<td>1,033,489</td>
<td>26,780,017</td>
</tr>
<tr>
<td>Sheep</td>
<td>1,534,565</td>
<td>4,374,957</td>
<td>120,228,131</td>
</tr>
<tr>
<td>Pigs</td>
<td>305,543</td>
<td>240,714</td>
<td>2,555,223</td>
</tr>
<tr>
<td>Pig farms *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>144</td>
<td>77</td>
<td>1,187</td>
</tr>
<tr>
<td>Average size (no. of pigs)</td>
<td>2,122</td>
<td>3,126</td>
<td>2,153</td>
</tr>
<tr>
<td>Value of livestock slaughtered annually (AUS$ thousands)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle and calves</td>
<td>309,937</td>
<td>165,080</td>
<td>3,390,089</td>
</tr>
<tr>
<td>Sheep and lambs</td>
<td>10,102</td>
<td>78,286</td>
<td>1,038,926</td>
</tr>
<tr>
<td>Pigs</td>
<td>69,266</td>
<td>102,809</td>
<td>671,091</td>
</tr>
<tr>
<td>Poultry</td>
<td>1,801</td>
<td>14,865</td>
<td>1,053,300</td>
</tr>
<tr>
<td>Total</td>
<td>391,335</td>
<td>380,956</td>
<td>6,180,061</td>
</tr>
<tr>
<td>Value of pigs slaughtered as a proportion of total (%)</td>
<td>17.7</td>
<td>28.4</td>
<td>10.8</td>
</tr>
</tbody>
</table>

* based on producers who describe the principal source of income as pig farming. The total number of pig farms in Australia in 1999 was 3,018 (3).
Source: Australian Bureau of Statistics (6)

**Fig. 3**
**Estimated value of output for pig farms, by region**
Source: Australian Bureau of Statistics (6)

**Model**
A stochastic state-transition model, developed from a Markov chain, was used to generate the outbreak scenarios and has been described previously (13).

**Model parameters**
To run the model, values must be specified for a number of parameters. The key disease parameters for the model are as follows:

- latent period (period from exposure until the infected herd is capable of infecting other herds)
- infectious period (the period over which an infected herd can spread infection to other herds)
- dissemination rate (DR) (the expected number of herds coming into contact with each infective herd per unit of time).

The DR is one of the most difficult parameters to estimate in any disease modelling exercise. In the absence of local data, the value must be estimated from outbreaks in other countries. Given the potential uncertainty associated with such estimates, a sensitivity analysis was undertaken by varying DRs over a range of 20% above and below the point estimates used for each disease scenario.

Additional parameters are required to simulate the effects of control operations.

**Control measures**
The delay until the disease is recognised, the type of control measures used, and the efficiency with which these controls are applied (including any resource constraints) will affect the course of an epidemic.

Quarantine, movement restrictions, and closures of saleyards and markets will slow the rate of disease spread and can be
represented by a reduction in DR. For stamping-out, various probabilities that IP will be identified and removed at defined intervals after becoming infected are specified. Stamping-out of animals on dangerous contact premises (DCP) will remove herds ‘incubating’ the disease. As tracing procedures are unlikely to be 100% effective, not all incubating herds will be removed, and a proportion of disease-free herds is also likely to be removed. The likely success of tracing procedures must be estimated.

Availability of resources may be an important factor in determining the size of operations that can be undertaken. Limits on the number of herds that can be removed per week can be set in the model. These are assumed to increase with time, as authorities become more organised in their response.

**Movement restrictions**

Given that the model is non-spatial, an estimate of the number of farms in RAs and CAs requires some assumptions about the number of foci of infection associated with the epidemics. These assumptions need to take into account the fact that pig farms are not uniformly located throughout the study regions. Indeed, the number of farms in RAs will depend on the locations of the IP and the degree of clustering of farms at the hypothetical locations. For this study, RAs are assumed to have a radius of 3 km around the IP. The authors have assumed that the CAs will comprise the remainder of the study regions (i.e. outside the RAs) for each scenario (as illustrated in Figure 4). Figure 4 shows four IP in two foci, thus two RAs are present, with the rest of the study region making up the CA.

![Fig. 4](image-url)  
*Fig. 4 Disease control areas*

In the current study, zoning is assumed to be successfully implemented as part of the control measures applied to the epidemic scenarios, i.e. trade in those parts of Australia outside the defined regions is assumed to continue.

Values for the model parameters were based on AUSVETPLAN disease strategies, expert opinion and a previous study (13).

No specific AUSVETPLAN strategy exists for Nipah, hence assumptions regarding the response to this disease were necessary. The values of parameters are hypothetical, but are as realistic as possible, based on current understanding of the epidemiology of Nipah. Given the risks to public health, it has been assumed that, as in Malaysia (19, 21), the preferred strategy in Australia would be to use expeditious stamping-out to eradicate outbreaks. Stamping-out would be applied to all IP and DCP. The RAs and CAs would be declared and movement restrictions on susceptible livestock species applied. Extensive surveillance would also be undertaken.

The model parameters for each of the three diseases are summarised in Table II. The outbreaks are assumed to originate with disease introduced to a single farm.

**Endemic disease**

The endemic scenarios are defined descriptively, based on international experience of the three diseases in endemic situations and expert opinion regarding what could be expected. The approach takes into account the structure of the pig industry in Australia and environmental and management factors. By definition, the regions used in the epidemic scenarios are not relevant to the endemic scenarios. However, even if any of the diseases were to become established, spread to all regions of Australia would not be inevitable. Based on the structure of the pig industry in Australia, quarantine of the east of the continent from the west should be possible, or vice versa. For the purpose of estimating the endemic impacts, it has been assumed that only the eastern side of Australia would be affected.

**Classical swine fever**

The scenario assumes that following initial introduction, delays in diagnosis lead to widespread infection. Following unsuccessful attempts at eradication, the disease is considered endemic and emphasis shifts, at least for the short-term, from eradication to control. Vaccination at the discretion of owners is permitted and voluntary industry-based accreditation schemes are established.

**Porcine reproductive and respiratory syndrome**

In this scenario, PRRS is assumed to have been introduced through a contaminated batch of semen that is used by pig producers in several states. By the time authorities become aware of the disease, it is widespread. Initial attempts to control the disease are unsuccessful and the high cost of operations, together with the economic and welfare problems caused to the industry, lead to eradication measures being abandoned.

**Nipah**

The scenario assumes that following initial introduction, serological surveys indicate widespread infection of bats in
those states of Australia with fruit bat populations. The emphasis shifts from eradication to control by restricting contact between bats and pigs. The pattern then observed is sporadic outbreaks of Nipah associated with occasional cross-over of infection from bats to pigs.

Economic assessments

Economic impacts of a disease event occur at two levels, broadly categorised as direct and secondary. Direct economic impacts will be felt by those people dependent on the affected part of the industry, such as producers and piggery employees, transport operators and meat processors. The extent of losses is likely to be greatest in the case of individual producers if the disease event entails destruction of the herd and loss of the capital value of the piggery (because the establishment suddenly becomes non-productive).

Regional businesses and individuals that provide goods and services to the agricultural sector generally will feel secondary economic impacts. Employment, business success and community vitality within regional Australia are all critically linked to the performance of primary industry. This applies particularly to intensive industries, such as pig meat production, that are large purchasers of inputs, including labour.

Epidemic event

The cost of an epidemic event would be acute for those producers directly affected, and for those within the RA and CA, but would diminish quickly with distance from the outbreak. Depending on the management of the disease, the first wave of losses would include the loss of sale pigs that die or have to be destroyed according to AUSVETPLAN directives, and closure of export markets for pig and pig products. The analysis assumes that all directly affected producers and the industry generally will be able to return to their original financial positions within a defined period of time.

Another cost incurred at this time will be that associated with eradicating the disease. This cost includes managing quarantine, movement controls, surveillance, slaughter and burial of the affected herds, and sanitising the infected piggery. The remaining loss will depend on the length of time required to re-establish the status quo. This analysis will assume that affected producers re-commence production once they are confident of receiving full market price for their sale pigs. A ‘reasonable’ production break is assumed to be one year. All the margins that would normally accrue over this period count as a collateral loss. Costs associated with re-commencing production include the cost of replacing the breeding herd and any other inventory that had to be destroyed at the time of the disease event (e.g. feed, equipment).

Epidemic events would give rise to industry-wide effects if the disease were viewed negatively by export markets and local consumers. Export markets are particularly sensitive to the disease problems of trading partners as they may have their own health status to protect. If zoning is accepted, it may be possible to re-open export markets after a period, but in the interim, all exports would be lost.

### Table II

| Disease and control parameters for classical swine fever (CSF), porcine reproductive and respiratory syndrome (PRRS) and Nipah virus disease |
|--------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Parameter                                         | Darling Downs   | Northern Victoria | Darling Downs   | Northern Victoria | Nipah virus disease     |
| Delay until control measures implemented (weeks) | 2               | 2               | 4               | 3               | 3                           |
| Initial dissemination rate (herds/week) *         | 1.35            | 1.5             | 1.2             | 1.4             | 1.0                        |
| Stamping-out: probability (%) of identifying infected herds |                     |                  |                  |                  |                             |
| Week 1 post infection                             | 95              | 95              | 70              | 70              | 75                          |
| Week 2 post infection                             | 100             | 100             | 90              | 90              | 90                          |
| Week 3 post infection                             | 100             | 100             | 100             | 100             | 100                         |
| Average number of DCP per infected herd           | 4               | 5               | 2               | 3               | 1.5                         |
| Probability of removing incubating herds with dangerous contact slaughter | 0.70            | 0.65            | 0.75            | 0.65            | 0.85                        |
| Herds able to be slaughtered per week:            |                  |                  |                  |                  |                             |
| Week 1                                           | 2               | 2               | 3               | 2               | 2                           |
| Week 2                                           | 4               | 3               | 6               | 5               | 4                           |
| Week 3+                                          | 7               | 5               | 9               | 7               | 5                           |

* CSF: dissemination rate reduces to one fifth of the initial value four weeks after control measures have been applied; PRRS: dissemination rate progressively reduces to one-quarter of the starting value three weeks after control measures have been implemented; Nipah: dissemination rate progressively reduces to one tenth of the starting value three weeks after control measures have been implemented.

DCP: dangerous contact premises.
Loss of export markets would cause extra volume to be redirected onto the local market. Considered in isolation, this would reduce domestic pork prices according to the volume involved and the elasticity of demand. In addition, news of the disease would be widely publicised and regardless of assurances from industry organisations and public health authorities, some consumers would be likely to stop buying pig meat. Discounting and diversion of more product into processing may help to maintain total throughput, but the overall impact on price would be negative. Thus, consumers who continued buying pork might be better-off. Stamping-out may not result in an immediate return of consumer confidence.

In the case of a short-lived epidemic, estimation of the additional cost of producing pig meat is of little value. The opportunity losses of greatest interest are those associated with price effects and eradicating the disease. Some of the latter costs will be incurred by producers and some by animal health authorities.

**Endemic disease**

In the case of endemic disease, the whole industry is assumed to be permanently affected and the opportunity cost can therefore be expressed as a dollar amount per year. Should zoning prove feasible, some producers in areas not affected by the disease may escape the negative impacts on productivity. The opportunity losses would generally arise from higher costs of production.

The price effects would probably not be as severe as in the epidemic situation, especially in terms of local consumer attitudes. However, a new disease could be expected to significantly increase costs of production (due to increased mortality, slower growth rates, treatment costs, etc.) and over time, this could induce structural change. Higher costs, without any beneficial price effects, are likely to make those producers currently operating at the margin non-viable. Structurally, the long term effect might be further concentration of the industry in the hands of those producers best equipped to withstand external shocks, such as sudden changes in costs and prices.

**Results**

**Epidemic event**

**Size of epidemics**

As the model is stochastic, different outcomes are possible (Fig. 5). Therefore, results are expressed as means and standard deviations derived from 5,000 simulation runs in each case. The mean demonstrates the average or ‘expected’ result and the standard deviation is an indicator of the associated uncertainty. Duration of the epidemic is measured from the time at which the disease was recognised. The size and duration of the epidemics are summarised in Table III.

The results of the sensitivity analysis are summarised in Table IV. Predictably, increasing the rate of spread increased the average duration of an outbreak and the number of affected farms. Reducing DR had the opposite effect. The size of the change varied according to the disease and region. However, over the range of values used, these changes were not large. The maximum reduction in an epidemic was one week and the maximum increase was 0.6 weeks.

**Table III**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CSF</th>
<th>PRRS</th>
<th>Nipah</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Darling Downs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration (weeks)</td>
<td>3 ± 1.0</td>
<td>4 ± 1.7</td>
<td>2 ± 1.5</td>
</tr>
<tr>
<td>Secondary infected farms</td>
<td>4 ± 2.8</td>
<td>8 ± 5.3</td>
<td>3 ± 2.6</td>
</tr>
<tr>
<td>Dangerous contact farms</td>
<td>6 ± 2.6</td>
<td>9 ± 4.4</td>
<td>3 ± 2.1</td>
</tr>
<tr>
<td>Farms stamped-out</td>
<td>11 ± 4.5</td>
<td>18 ± 9.4</td>
<td>7 ± 4.3</td>
</tr>
<tr>
<td>Farms in restricted area</td>
<td>6</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Farms in control area</td>
<td>127</td>
<td>119</td>
<td>132</td>
</tr>
<tr>
<td><strong>Northern Victoria</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration (weeks)</td>
<td>3 ± 1.3</td>
<td>4 ± 1.8</td>
<td>2 ± 1.4</td>
</tr>
<tr>
<td>Secondary infected farms</td>
<td>5 ± 3.2</td>
<td>7 ± 4.0</td>
<td>3 ± 2.8</td>
</tr>
<tr>
<td>Dangerous contact farms</td>
<td>6 ± 2.9</td>
<td>8 ± 3.6</td>
<td>3 ± 2.4</td>
</tr>
<tr>
<td>Farms stamped-out</td>
<td>12 ± 5.2</td>
<td>16 ± 7.4</td>
<td>8 ± 4.3</td>
</tr>
<tr>
<td>Farms in restricted area</td>
<td>8</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Farms in control area</td>
<td>57</td>
<td>52</td>
<td>63</td>
</tr>
</tbody>
</table>

CSF : classical swine fever  
Nipah : Nipah virus disease  
PRRS : porcine reproductive and respiratory syndrome
Costs
The costs incurred on affected farms can be considered in terms of loss of sale pigs, stamping-out costs and costs associated with replacing the herd. Each disease protocol requires herds on IP and DCP to be stamped-out. For CSF and Nipah, destruction and burial on the farm is necessary, but for PRRS, salvageable stock can be sold for slaughter. In cases of CSF and Nipah, the first cost after notification is assumed to be loss of the usual sale stock (i.e. porkers and baconers). In the case of PRRS, this stock can be sent directly to a designated abattoir. In addition to porkers and baconers, gilts and some sows could be sold (although only approximately 5% of sows would be acceptable). Although a small market for weaners exists in normal times, an outbreak of PRRS would create a glut. Accordingly, anything smaller than porkers, and unsuitable breeding stock, is assumed to be disposed of on-farm.

Table IV
Sensitivity analysis: the effect of reducing or increasing dissemination rate by 20% on average duration and size of epidemics

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Reduced dissemination rate</th>
<th>Increased dissemination rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duration (weeks)</td>
<td>Secondary farms (n)</td>
</tr>
<tr>
<td>Classical swine fever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Darling Downs</td>
<td>0.16</td>
<td>0.61</td>
</tr>
<tr>
<td>Northern Victoria</td>
<td>0.98</td>
<td>2.30</td>
</tr>
<tr>
<td>Porcine reproductive and respiratory syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Darling Downs</td>
<td>1.05</td>
<td>3.33</td>
</tr>
<tr>
<td>Northern Victoria</td>
<td>0.13</td>
<td>2.61</td>
</tr>
<tr>
<td>Nipah virus disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Darling Downs</td>
<td>0.27</td>
<td>0.30</td>
</tr>
<tr>
<td>Northern Victoria</td>
<td>0.19</td>
<td>1.33</td>
</tr>
</tbody>
</table>

The actual numbers of pigs involved in stamping-out operations can be derived by combining the modelling results with the average herd size for each region. A value can be assigned to each stock category according to their proportion of the total herd, respective weights and value relative to baconers. The affected pigs for each disease and category and their respective values for Darling Downs are shown in Table V, assuming an average baconer price of AUSS$2.10 per kg carcass weight.

Hassall and Associates provided an estimate of the cost of destocking piggeries in the event of exotic disease in Australia (15). These costs included labour, hire of equipment and facilities, slaughter, disposal, decontamination and other items such as laundry, stores and communications. Those costs associated with managing the response at the local level were also included. The costs across three states ranged from AUSS$524 per pig to over AUSS$1,000. Since the Hassall report, increases in costs have occurred, and this analysis uses the median value of approximately AUSS$600 per pig. The figures derived for PRRS reflect the fact that some pigs from each herd would be accepted for slaughter.

To capture the full cost of the diseases, the analysis assumes that all stock either classed as sale stock at the time of the outbreak, or actually sold following the outbreak (as with PRRS), are replaced. This occurs after the piggeries have been cleaned, disinfected and made safe for re-commencement of production. Although sentinel animals may be reintroduced approximately one month after decontamination, a considerable period of time would elapse before an infected piggery could resume full production. This analysis has assumed that twelve months would be required to generate marketable stock.

Table VI summarises the estimated losses to affected farms. The largest epidemics occurred with PRRS. However, CSF produced the highest losses, because salvage of marketable pigs is permitted with PRRS. The limited size of the Nipah epidemics meant that this disease caused the lowest losses. Losses were consistently higher in Northern Victoria compared to Darling Downs.

In addition to those producers whose animals are infected with the disease, others will be affected due to being located in RAs and CAs. Movement of pigs out of an RA will generally be prohibited, thus preventing sale pigs from leaving the farm. Movement from a CA may be possible with a permit, but permits would be unlikely to be issued within the first few weeks of an outbreak. In practice, the IP may have no other pig farms in proximity. However, this analysis has assumed that in a typical pig producing area, other farms will be located in the vicinity, and as such, RAs and CAs will become operative. The relevant numbers assumed for the scenarios are shown in Table III.

The losses due to inability to market pigs will depend on the period of time the movement restrictions remain in place. If a producer normally sells porkers or lightweight baconers, a
restriction period lasting two to three weeks would not impose a significant cost. However, if a producer normally sells heavy baconers (as is the case for most large piggeries) or the movement restrictions last longer than approximately six weeks, the costs could be high. The duration of outbreaks of CSF and PRRS in Table III would significantly reduce the value of heavy baconers if movement restrictions were to stay in place for these periods of time. The costs for each disease, assuming that just one crop of baconers is lost from the RA farms in the course of an epidemic, is shown in Table VII. Due to the short durations expected for Nipah epidemics, these have not been assigned any RA cost. Failure to rapidly control the event, or any extension of sales restrictions to the larger CA, would greatly increase these figures.

It can also be expected that an outbreak of exotic disease could lead to a temporary cessation of exports of pigs and pig meat, and adverse publicity, leading to loss of consumer confidence and negative price effects. If zoning can be effectively implemented, given the limited size of the epidemics described here, re-opening of export markets may be possible for the non-affected part of the country after five to six weeks, although the actual time period would depend on reactions of trading partners. These price effects will be of little consequence for IP and DCP (as these producers will be excluded from production for the whole period of depressed prices). However, any weakening in prices will affect all other producers in the industry and this could over-shadow the eradication costs shown in Table VI. The gross output figures for 1998-1999 suggest an average farm-gate price for pigs of AUS$1.80 per kg carcass weight (i.e. AUS$663 million for 370,000 tonnes) (3). A reduction in this price of only 5% would translate into a reduction in gross earnings of more than AUS$30 million. In the early stages of an epidemic, the price effects could be large. Based on overseas experience, the relative impacts over twelve months for each disease are assumed to be a reduction in value of 5% for CSF, 3% for PRRS and 1% for Nipah.

Table VIII summarises the direct nation-wide costs of disease epidemics in terms of stamped-out farms, farms subjected to movement restrictions in RAs/CAs and whole industry price effects. These ranged from AUS$17 million to AUS$63 million, depending on disease and region.

### Endemic disease

**Impacts**

The impacts associated with the three diseases becoming established in Australia are briefly described below and summarised in Table IX.

Based on estimates in AUSVETPLAN (1) it is reasonable to suggest that CSF could spread in one year to piggeries holding up to 15% of the total pig population in Australia. Mortality
The presence of PRRS in a breeding herd could be expected to affect the marketability of breeding stock. Abattoirs should not be unwilling to slaughter and process pigs from infected piggeries. However, local pressures may disrupt some trade practices. Exports of pork products should not be seriously affected, because this disease is present in most pork-producing countries. However, export trade of breeding stock to countries free of PRRS would be lost.

Pigs infected with Nipah virus suffer a vague syndrome of fever and respiratory disease with occasional nervous involvement. The morbidity is high and mortality usually low (8). Pigs of all ages are infected. It is assumed that when infection is initially introduced into a totally susceptible herd, explosive outbreaks of depressed, fevered, coughing pigs would occur with approximately 90% morbidity and 10% mortality. The disease would then 'settle down', resulting in a chronic respiratory syndrome causing 2.5% mortality, 10% loss in feed conversion efficiency and 20% reduction in viable piglets.

In-contact humans suffer low morbidity disease with a high case fatality rate. Dogs, cats and horses have a low prevalence, sub-clinical disease.

### Costs

In the case of endemic disease, the whole industry is assumed to be permanently affected and the opportunity loss can be expressed as a cost per year. Depending on the disease, some reduction in demand and price could occur. Should zoning prove feasible, some producers in areas not affected by the disease may escape the negative impacts on productivity. This has been assumed in the calculation of costs. Generally, the opportunity losses result from higher costs of production.

Based on the technical data provided in Table IX, losses can be derived as detailed in Table X. The calculations assume average annual production of 122 tonnes per herd (carcass weight) and an average price of AUSS1,800 per tonne.

Of the three diseases considered, CSF is clearly the most serious. Although more herds are affected by PRRS, the costs...
... per herd are much higher for CSF. Based on the estimates of reduced productivity, this disease would reduce the current value of pig meat production in Australia by 10%. Inclusion of price effects would increase this figure. For Nipah, considerable extra costs to those described can be expected (associated with medical expenses for human clinical cases, and occupational health and safety testing and prevention programmes).

**Indirect costs**

Regional economies benefit by providing goods and services to agricultural industries. This situation can be demonstrated for the pig industry by tracing the inputs that are purchased off the farm. In 1998-1999, the total average cost per pig sold was AUS$134 (3). Half of this cost is spent on feed and one-third of the balance on labour (including an owner/operator allowance). Of the remaining AUS$40 per pig sold, approximately 70% is spent on purchases of goods and services from outside the immediate farm economy. This expenditure, combined with the expenditure of disposable income by owner/operators and workers, has a multiplier effect on the local economy. In general terms, for every one employee working in the pig industry, another two people will be employed in providing goods and services to the pig industry directly or to employees in the pig industry.

The pig industry benefits regional economies through job creation at two levels. Farm level jobs are created in direct proportion to activity levels within the industry. Based on 1.34 hours per pig sold and sales in 1998-1999 of 5,176,300 pigs (3), the total labour employed in the pig industry in Australia is over 6.94 million hours per year, and approximately 3,470 people were employed in the industry in 1998-1999.

The cost of this labour can also be derived from first principles. The average cost of piggy labour is AUS$0.25/kg of live weight sold or AUS$23.29 per pig sold (3). This equates to AUS$427 per sow and 20% of total production costs. Based on 306,000 sows and labour costs of AUS$420 per sow, the total labour costs in 1998-1999 were AUS$128 million. These figures can be used as a basis for establishing the impacts due to any decrease in the regional pig population.

**Discussion**

The focus of this study has been to estimate the costs to the pig industry of introductions of exotic pig diseases. Specific epidemic events were found to reduce gross income by 16%-37% within the target region (Table XI), based only on lost production and disposal costs. The highest impact was caused by CSF and the least by Nipah, with PRRS falling in-between. Expressed on a national basis, with price effects included, the regional epidemics would reduce gross national pig industry income by between 3% and 10% (Table XII). Although the national impacts appear comparatively minor, these would result from infections on very few farms. Moreover, at the national level, the costs of stamping-out are insignificant compared to the impact on price due to loss of export markets, exacerbated by negative perceptions among local consumers. From a national perspective, some of the producer losses can be assumed to be negated, since they become benefits for those consumers who buy pork at lower prices.

Given that PRRS is more likely to become endemic than CSF, the long-term costs of an introduction of PRRS into Australia would be greater than a short-term, controlled outbreak of CSF.

---

**Table X**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Classical swine fever</th>
<th>Porcine reproductive and respiratory syndrome</th>
<th>Nipah virus disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of herds affected</td>
<td>390</td>
<td>1,030</td>
<td>15</td>
</tr>
<tr>
<td>Fall in output (tonnes)</td>
<td>38,064</td>
<td>18,849</td>
<td>366</td>
</tr>
<tr>
<td>Value of lost production annually (AUS$ thousands)</td>
<td>68,000</td>
<td>34,000</td>
<td>658.8</td>
</tr>
</tbody>
</table>

---

**Table XI**

**Expected gross income (AUS$) of the regional pig industry following disease epidemics**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Darling Downs</th>
<th>Northern Victoria</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>63 million</td>
<td>80 million</td>
</tr>
<tr>
<td>Classical swine fever</td>
<td>45 million (28%)</td>
<td>50 million (37%)</td>
</tr>
<tr>
<td>Porcine reproductive and respiratory syndrome</td>
<td>50 million (21%)</td>
<td>55 million (31%)</td>
</tr>
<tr>
<td>Nipah virus disease</td>
<td>53 million (16%)</td>
<td>64 million (20%)</td>
</tr>
</tbody>
</table>

* based on the average of the two regions studied
Should any of the diseases become established (endemic), losses would range up to 11% per year, based on productivity considerations alone (Table XII). Establishment of exotic disease in the local pig industry is likely to reduce demand, leading to a fall in prices relative to the prevailing supply-demand situation. The negative impact on price would be a result of the loss of export markets and loss of local market share to alternative meats such as beef, poultry and fish.

In practice, the extent of secondary impacts will depend on the effectiveness of disease control. Thus, a disease outbreak that is rapidly stamped-out may generate negative impacts only in the immediate region. It is conceivable that producers outside the affected area could benefit through higher prices or better access to production inputs. However, if a disease becomes established, all producing regions would be likely to suffer, due to loss of demand for goods and services normally used by the pig industry. A smaller pig industry may confer some benefits on other meat producers or pork importers, but these would be small relative to the losses connected to the pig industry. In general terms, establishment of an exotic disease in the pig industry would lead to a net loss in secondary wealth generation in regional Australia. A further consequence of an exotic disease becoming established in Australia could be an erosion of the good reputation of the country in terms of freedom from most serious livestock diseases. Such an event could cast doubts on the efficiency of import control mechanisms, leading to increased costs for the livestock export sector associated with more stringent certification and testing requirements.

The scenarios used in this study are based on expert opinion and assumptions about the likely behaviour of the diseases and effectiveness of control programmes. As CSF has been recognised for some time, a reasonable body of information is available from overseas on which to estimate disease parameters. Similarly, a clear description of the official approach to managing an incursion in the country is available (1). For PRRS, a disease that has only been recognised since the late 1980s, less information exists, although the disease has been studied in some detail and a draft response strategy is available (2). However, Nipah is a newly identified virus and epidemiological information on which to estimate key disease parameters is scarce. In modelling epidemics, the DR used can significantly influence the results. A sensitivity analysis demonstrated that while the choice of DR will affect the size of the epidemics, given the other assumptions used in this study (particularly the relatively short delays until the diseases are recognised and the effectiveness of control operations) the effects are not large.

Although the study attempted to make the scenarios as realistic as possible, in some senses, the cost estimates can be considered conservative. For example, analysis is confined to the more important commercial sector of the pig industry (i.e. based on statistical data on farmers who describe pig production as the major source of income). In reality, this underestimates the total number of farms at risk. The study also does not consider possible infection of feral pigs and impacts on recreational hunting and the game pig meat industry. The study assumes that those pig farmers affected by movement restrictions applied to RAs lose only one crop of baconers. Failure to control the epidemic rapidly or any extension of movement restrictions over larger areas would greatly inflate these figures. The application of zoning is also assumed to be rapidly accepted by trading partners, thereby limiting losses of exports to relatively small areas. For the regional endemic scenarios, the cost estimates are based on production losses and disposal costs alone. Inclusion of price effects would elevate the figures.

Through estimating the losses that might reasonably be expected to follow from disease entry and elimination or establishment, the nature and magnitude of the risk faced by the industry and the nation generally can be demonstrated. Thus, a low probability of disease entry and establishment and minimal consequences following establishment would imply low quarantine risk. In contrast, a high probability of entry and establishment and a significant on-going impact (in the form of opportunity costs) would suggest a serious risk. Armed with evidence of significant (negative) economic consequences in the event of disease entry and establishment, quarantine authorities are in a better position to manage the risk through the imposition of appropriate measures. These could include restrictions on importation of specific products, or application of measures to reduce the risk.

Acknowledgements

This study was supported by the Australian Pig Research and Development Corporation (Project 1626). The authors would also like to thank Drs J. Allen, R. Cutler and M. Nunn for helpful comments and advice. Mr G. Aranda of the Australian Pork Corporation kindly provided the map showing the distribution of pig farms in Australia.
Incidence économique escomptée de certaines maladies exotiques sur la filière porcine en Australie


Résumé
Les auteurs évaluent l’incidence économique escomptée de trois maladies exotiques sur la filière porcine australienne. Les effets de la peste porcine classique, de l’infection due au virus Nipah et du syndrome dysgénésique et respiratoire du porc ont été évalués en utilisant une méthode épidémiologique et économique intégrée. Les scénarios envisagés portaient sur les deux cas de figure suivants : d’une part, apparition d’un épisode épidémique limité à certaines régions suivie de l’éradication de tous les foyers ; d’autre part, apparition puis persistance de l’une de ces maladies à l’état enzootique en Australie. Pour ce qui concerne le premier scénario, sur la seule base du manque à gagner et des coûts d’élimination, les épidémies se solderaient par des pertes de revenus de l’ordre de 10 à 30 millions de dollars australiens (16 %-37 %) selon la maladie et la région considérées. En cas d’enzootie, les pertes pour le revenu national brut de la filière porcine pourraient s’élèver à 5 %-11 % par an, la peste porcine classique induisant les pertes les plus considérables. La présence de l’une de ces maladies à l’état enzootique conduirait à un changement structurel rapide de la filière porcine et, parallèlement, à un bouleversement social et économique dans les communautés rurales d’Australie.

Mots-clés

Cálculo de las repercusiones económicas de ciertas enfermedades exóticas para el sector porcino australiano


Resumen
Aplicando un método que integra consideraciones epidemiológicas y económicas, los autores calcularon las eventuales consecuencias económicas para el sector porcino australiano de tres enfermedades exóticas: la peste porcina clásica, la infección por el virus Nipah y el síndrome disgenésico y respiratorio porcino. Se contemplaron hipótesis diversas, con situaciones de tipo tanto epidémico (brote limitado a ciertas regiones hasta su erradicación) como endémico (las enfermedades llegaren a establecerse en territorio australiano). Contabilizando únicamente las ventas perdidas y el coste de descarte de los animales, la eventualidad de una epidemia supondría pérdidas a escala regional de entre 10 y 30 millones de dólares australianos (16%-37%), según la enfermedad y la región de que se tratara. Si alguna de las enfermedades llegara a ser endémica, los ingresos nacionales brutos ligados al sector porcino sufrirían pérdidas (en concepto de ingresos no realizados) de entre un 5% y un 11% anuales. En tal hipótesis, la más dañina de las tres enfermedades seria la peste porcina clásica. El endemismo de cualquiera de ellas provocaría rápidas transformaciones estructurales del sector porcino, lo que a su vez alteraría el equilibrio socioeconómico de las comunidades rurales australianas.
Palabras clave

References


