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AUSTRALIAN Pork

A Desktop Cost Benefit Analysis of Pork Production with Entire Male Vs Immunocastration

Report
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University of Melbourne
Alex Sinnett, Frank Dunshea, Darryl D'Souza, Bill Malcolm and Garry Griffith
Grattan Street
Parkville Victoria 3010

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Executive Summary

Australian Pork Limited is committed to reducing product failure rates from all causes, including boar taint. Consumers of pork have long been aware of the risk of their pork purchase not meeting expectations due to unpleasant taste or smell or other unsatisfactory quality characteristics such as lack of tenderness. Some consumers, because of a poor eating experience, will buy pork less frequently or may stop buying pork. This desktop analysis has focused on the costs and benefits of reducing boar taint in pork by increased use of immunocastration (IC) by producers. Currently IC is used in about 60 per cent of Australian pork producing herds. A proportion of producers do not this technology, probably because of the costs of this technology are perceived to outweigh the benefits. For this reason, comprehensive benefit cost analysis was needed.

This research has considered the industry-wide benefits and costs for producers and consumers of IC of pigs produced for the fresh pork market. The costs of IC include the costs of the vaccine, extra labour costs, and costs in processing from abscesses causing product downgrades and stoppages of the slaughter line for cleaning. A major benefit of IC for the pig industry is a reduction in consumers having poor eating experiences of fresh pork. Over time, reducing the occurrence, and risk of occurrence, of having an unsatisfactory experience preparing and eating pork has the potential benefits of avoiding losing customers and even increasing demand above what it would be with the continuation of poor experiences and the risk of poor experiences with boar-tainted pork.

Unknowable in this analysis is how much loss of demand would be achieved or how much demand might increase with less prevalence of boar-tainted pork which would result from increased use of immunocastration. This study has evaluated the net benefit under different scenarios of adoption, cost of the technology, and changes in demand.

Over the next 10 years, with national consumption of pork increasing at the trend of the past decade, benefits from avoided annual losses of demand or from increases in demand by 0.5 per cent of total annual national consumption of pork, would cover the cost of the whole industry adopting immunocastration. This is the conclusion if IC was adopted fully immediately and the cost of doing the IC was the lower of the range of possible cost estimates, at $0.10/kg carcass weight. If producers adopted immunocastration more slowly over 5 years and the cost to them was $0.10/kg carcass weight, then a loss of annual demand of 1.5 per cent of total pork annual consumption would need to be prevented to cover the costs of reducing product failure from boar taint in the industry.

Adding a further analytical dimension to the standard benefit cost analysis, an equilibrium displacement model (EDM) of the Australian pig industry was used to test the results of the benefit cost analysis. The results from the EDM also showed that only small changes in demand are required to offset the industry-wide costs of an expansion in the use of immunocastration. The other result from the EDM is once the effects of added costs and benefits of widespread use of immunocastration have worked their way through the value chain, most of the costs and the benefits end up with consumers. Pig producers will receive 12 per cent of total benefits, value chain participants will receive 9 per cent of total benefits and consumers 79 per cent, with costs also shared in the same proportions. Importantly, net economic surplus to the industry is highly likely to be increased, i.e., everyone gains.

The overall conclusion is that an increased use of immunocastration in Australia's pig production system that reduces the prevalence and the risk of boar taint and poor preparation and eating

experiences for buyers of fresh pork has a very high likelihood of delivering a net benefit to industry participants. Total benefits will exceed costs and consumers and producers would be made better off.

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1. Introduction

Odour is an important sensory attribute that determines whether consumers will be satisfied with a meat product. Boar taint is an offensive odour or taste noticeable to many consumers when they prepare, cook and eat pork from uncastrated male pigs that have reached puberty. Boar taint is one of the most important factors responsible for what surveys of consumers of pork call 'Bad Eating Experience' and 'Pork Fail Rates'. When consumers purchase food, the quantity they buy, and how often, depends on their preferences, the price of the product, the price of alternative foodstuffs they regard as substitute products they could also buy, as well as the risk the purchased product may not meet their expectations of providing a satisfactory consumption experience. This is the context in which the experience of purchasing offensive boar-tainted pork, or just the risk of doing so, has to be analysed.

Immunocastration (IC) is one of the ways to deal with off-odour and off-flavour issues in pork. Many studies show IC is effective at eliminating boar taint. In addition to the costs of vaccine and the labour required to vaccinate the young male pigs, IC affects some production parameters, which may have costs and benefits. For example, a meta-analysis has shown that adopting IC using the recommended regime (slaughter at greater than 4 weeks after second immunization) will increase finisher feed intake (+429 g/d), finisher daily feed gain (+119 g/d), HSCW (+2.09 kg) and P2 (+1.5 mm) (Dunshea et al., 2013). In addition, IC reduces lysine and other nutrient requirements (Moore et al., 2016), increases survival rate (Dunshea, unpublished), improves eating quality (Channon et al., 2018), increases muscle pH (Dunshea, 2019) and has possible impacts on carcass trimming as a result of vaccination abscess (negative) or a reduction in injury and carcass damage from aggression (positive) (Dunshea et al., 2001). All of these factors can have an impact on the costs and returns from pork production.

These effects of IC on production and other parameters are well known, and IC is used in about 60 per cent of Australian pork producing herds. Still, there exists reluctance by a proportion of producers to adopt the technology. This reluctance would be because of the cost of purchasing and applying the vaccine and the potential for an increase in P2 backfat that commonly occurs due to using IC, which is a major determinant of price received.

Another major reason for producer reluctance to adopt IC is that unless the pork is identified as coming from entire males, IC males or females, price premiums are not received at the retail level, nor is such price differentiation received at the farm-level unless the producer is in a position to negotiate with their buyer and pass-on some portion of the added cost of using IC. These and other factors are barriers to the adoption of IC for around 40 percent of the male pigs produced for pork[1].

To date, there has not been a comprehensive benefit-cost analysis (BCA) of pork production using IC that accounts for all the parameters mentioned above affecting both the supply of and demand for fresh pork.

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[1] There are alternative approaches to using IC to mitigate some of the perceived negative effects of IC. For example, slaughter of pigs 2 weeks after administration of the second dose of vaccine (Lealiifano et al., 2011) or feeding albus lupins to curb feed intake (Moore et al., 2021) can eliminate boar taint compounds without increasing P2. These strategies warrant closer examination too, though they are beyond the brief of this BCA.

Without a comprehensive BCA the accurate story of IC and how IC affects the risk of 'Product Failure' and effects on pork supply and demand, producers will not be fully informed about the potential costs, benefits, and net benefits to the industry from using IC. The impact of IC on consumers through eating quality and re-purchase intention and risk of a bad eating experience (individually and across the whole sector) are not considered in production decisions by all producers because the industry-wide effects are not known.

The industry-wide benefits and costs for producers and consumers of IC of pigs produced for the fresh pork market is investigated in this study. The economic performance of the pork industry "With" and "Without" use of IC is the comparison. Standard benefit-cost methods are applied, using aggregate pig industry data about supply and demand for pork in the various markets, production costs, output, and price data from a representative pig production system. The BCA method involves identifying and quantifying all sources of extra costs and extra benefits resulting from adopting and implementing IC technology in Australia's pig production systems and through value chains to the consumers.

In the BCA, the additional costs to industry post-farmgate of using IC are related to vaccine and labour and carcass downgrades due to abscesses and stoppage time on the processing chain and measures needed to reduce negative effects on P2 backfat from using IC. The benefits come from the gains in the quantity and value of pork that is not boar-tainted in markets and which replaces pork that is currently boar-tainted. This is pork sales that are not lost as a result of boar taint affecting consumers purchasing of pork in the future, or it could be any market growth attributable to the potential to supply increased pork that is free of boar-taint that occurs and would not have occurred without removing the risk of an unsatisfactory, boar-tainted, pork eating experience. Additional benefits at production level come from positive effects on feed conversion efficiency, giving savings in feed costs per kilogram of liveweight turnoff, survival benefits, and processing efficiencies. There may also be increased flexibility across a wider range of carcass weights.

The adoption profile by producers of IC over the life of the technology determines the aggregate benefits and costs, which are discounted to present values to give net present values and B:C ratios, using standard discount rates. The time horizon of the BCA is 10 years: a time assumed to allow for adoption of the IC technology to varying degrees, including full adoption across the industry, and time for consumer experiences and perceptions to improve as more pork that is free of boar taint can be purchased and the risk of poor eating experiences attributable to boar taint is reduced. Also, in a decade or more, alternative technology to reduce boar taint may become available and make the current IC technology redundant. Scenarios for adoption of IC and domestic consumption of pork that needs to be 'increased by not being lost' over the project life will be analysed.

The standard BCA method gives a measure of net social welfare from the innovation in production but does not indicate how these net benefits (or costs) are shared. The current version of the Equilibrium Displacement Model of the Australian pig industry (Zhang et al., 2018) is applied to determine how the net benefits of the innovation are shared between producers and consumers.

1.1. Pork Consumption and Quality Attributes

The amount of fresh pork Australian consumers purchase depends on the mix of attributes the product supplies and the willingness of consumers to pay for this mix of attributes. At the start of the 2020s, Australians consume around 27-28 kg of pig meat per annum. In 2020 fresh pork was 11.2 kg per capita (ABARES, 2021).

The pig meat industry in Australia has strategic goals about the quality of pig meat and the quantity that is consumed. One goal is to increase the consumption of Australian pork. The industry's Strategic theme to "Drive Consumer Demand" program aims to increase the per capita consumption of Australian pork. To this end the industry conducts surveys and assembles empirical information about consumer responses to the quality of the pork they buy, cook and eat.

Research by Australian Pork Limited (APL) into eating quality and bad eating experiences includes surveys of pork consumers about the prevalence of displeasing eating experiences since 2015 (Thrive Insights). This research has identified reasons for poor eating experiences, from attributes of the product (suppliers) to the cuts of pork to its preparation (consumer), and by demographics, and changes over the past seven years. The data shows consistently over 5 recent annual surveys that around 10 per cent of consumers of pork have a bad eating experience. Among the various reasons for their bad experience with pork, common was an off-putting smell: boar taint.

Consumer awareness of boar taint has been consistent at around 20 per cent in most years, increasing to 28 per cent in 2020. Of the people aware of boar taint, 4 out of 5 reported that the smell affected their perception of and preference for pork (Thrive Insights, 2020). Most people do not say they will stop consuming pork despite unsatisfactory experiences with it, for various reasons – but some do. Ten per cent of people say they will buy pork less frequently for a time, some for the future (Thrive Insights, 2020)

The important point to note is that surveys of consumers of pork do not capture the views of people who do not consume pork, for whatever reason, some of whom may be considered as being potential consumers if they were confident of a good eating experience with less risk of an unpleasant eating experience. Some of the population may be considered as being potential pork eaters. Less pork in the market that might give a bad eating experience will increase the likelihood that less current customers will experience a bad eating experience and reduce or cease consuming pork, and more positive experiences eating pork could increase community confidence about having a good eating experience consuming pork which has the potential to increase the total number of pork customers. Consumers of pork are affected by bad and good experiences of preparing and eating pork, so too are non-consumers who have an association with pork consumers and may be swayed one way or another by the experiences of the consumers of pork.

The pig meat industry uses some key performance indicators about eating quality based on measures about the number of regular consumers, such as the percentage of households consuming more than a given number of times per year. For instance, the Australian Pork Limited Annual Report 2017-18 (APL, 2018) under-eating quality pathways performance had a category 'product fail rate percentage in best sales channel (bad taste)'. The target for 2017-18 was 2.15 percent product fail rate. The realized rate of 'product fail' was 5.91 percent. This meant that 5.91 percent of sales in this selected channel came in with a response 'bad taste'.

In the 2018-19 Annual Report (APL, 2019) the Eating Quality Pathways Performance had a KPI with two criteria:

- Product Fail Rate Percentage in Best Sales Channel. The target was 5.11 per cent and the result was 5.65 percent
- Bad Taste/Smell/Dry/Chewy/Tough. The target was 8.63 per cent and the result was 9.87 percent.

A large amount of research has been conducted to identify the specific attributes of fresh pork that adversely affects consumer acceptance of the product. Specifically, the eating quality of pork has been investigated by focussing separately and jointly on a group of the characteristics that play a role in determining the eating quality of fresh pork, to varying degrees and with varying degrees of interaction effects. These characteristics are:

- Gender
- Aging
- Initial Ph
- Handling
- Chilling
- Aging
- Cut type and cooking method
- End point temperature
- Moisture infusion
- Hanging method
- Ultimate ph
- Electrical stimulation

Sensory research has been used to identify the significance of these factors – critical control points for eating quality - single and in combination and to develop Pork Quality Scores (PQS). Statistical analyses show gender is a statistically significant factor in consumers liking or disliking or pork.

Eating quality scores are used to identify the extent to which consumers prefer or dislike pork from entire male pigs, IC pigs and females.

In an 'overall liking' rating for a standardized treatment sample loin roast (70 °C, non-moisture infused, non-electrically stimulated, entire male carcase aged for one day with ultimate pH less than 5.5), the entire male scored an overall liking rating of 52.4 out of a possible 100. The industry has set a target of consumers giving an overall liking rating for pork of 65 in the future. This research demonstrated the well-known consumer distaste for pork from male entire animals and preference for pork from female and castrated animals. Female pork scored 2.1 points higher, physical castrate scored 3.5 points higher and the IC male scored 2.4 points more than the entire male for overall liking. This represents a 4.6 percent increase in PQS attributable to removing the boar taint only – not all the other important factors that affect quality such as pH and cooking. A large database containing over 250 published and non-published datasets on effects of production, processing and cooking parameters on pork eating and technological quality indicated an overall liking of pork from entire males of PQS 48.37; for IC pork the overall PQS was 57.60. This represents a 19 percent improvement in eating quality score when all the factors affecting eating quality, including boar taint, are accounted for. The pork from the IC pigs also had higher intramuscular fat percentage, at 2.21 percent, compared with the entire male pork at 1.82 percent. At present, intramuscular fat is not included in the PQS system due to a lack of data on high and low intramuscular fat levels measured in commercial breeds of pork in Australia.

Consumer preferences for pork are affected by the whole mix of attributes, from production to processing to preparation by the consumer, with the greater impacts on eventual quality and consumer acceptance in processing and consumer preparation. Research indicates that the sex of the animal from which the pork is derived is a medium impact/risk factor relative to factors further along the value chain through to consumer preparation.

At the production level, the statistically significant factor is gender. Entire male pigs have a lower pork quality for a range of reasons, one of which is the offensive odour and flavour called 'boar taint', with 'chewy', 'tough' being other adverse attributes reported in the Eating Quality Pathways Performance surveys. The 'maleness' of the pigs producers supply to markets is something producers can have complete control over by using castration.

2. Method

This study is about the benefits and costs of immunocastration of the Australian pig herd. How would the Australian pork industry look without IC and with IC across the whole herd? At present around 60 per cent of the male pigs that are produced are immunocastrated. The questions at hand:

- Over the next decade, what would be the costs of immunocastrating the balance of the uncastrated Australian male pigs produced each year?
- What are the likely benefits of immuno-castrating the Australian male pigs produced each year, over the next decade?

To answer these questions, it is necessary to

- Identify sources of benefits and costs of using immunocastration
- Quantify the sources of benefits and costs of using immunocastration
- Run the BCA model with generated inputs for plausible scenarios
- Weigh up the probability of these scenarios being achieved in reality

The major costs of immunocastration are the vaccine, extra labour and costs in processing from abscesses causing product downgrades and stoppages of the slaughter line for cleaning. Other possible effects would include measures required to reduce negative effects on P2 backfat and dressing percentage.

The benefits of IC of all male pigs produced nationally include reduced aggression, thus reducing fighting, injury, mortalities, carcase condemnation and improving animal welfare is a reduced proportion of the pork that consumed nationally 'failing' – being classified by dissatisfied consumers as 'product fail'. Another way to see this would be if IC was part of a package of improvements, such as less range in pH, longer aging and so on, the benefits could be gauged in terms of improved Pork Quality Score from the present level around the mid-50s towards the industry targets of 60 by 2022 and 65 by 2024 (APL 2020-2025 Strategic Plan (V. Gole, pers. comm,)

Using the threshold approach where the focus is on the required loss of sales avoided from reducing a single major element of poor eating experience is a less speculative approach. Undoubtedly, improved eating quality would have potential twin effects: less losses and even gains in market. For BCA, if the source and size of benefits that exceed costs can be plausibly estimated, then other benefits that may also occur, but which are not counted in the BCA are a bonus. Benefits to the whole industry about which there is considerable confidence of achieving and exceeding costs are necessary to justify the investment, with the promise of less certain or harder to value additional benefits simply adding weight to the conclusion.

One way to interpret the benefit of IC of the whole male pig population is avoiding the ongoing loss of sales of pork that would be lost due to dissatisfaction of consumers with pork because they disliked the distasteful boar smell and flavour of pork. At present, annually, 8 percent of pork meals surveyed (3,741 consumers) comes in with a response 'bad smell and taste' and around 19 percent is rated Bad Taste/Smell/Dry/Chewy/Tough. (Thrive Insights, 2020). It appears that boar taint remains a major contributor to the 'product fail ratings' despite the availability of technology in Australia that has the potential to eliminate the major causes of boar taint, androsterone and skatole. Removing boar taint increases the predictive PQS by nearly 5 percent.

Data from APL surveys since 2014 shows the 'poor eating experience' percentage has increased consistently since 2015 to 2020 – and at a faster rate than for sheep meat, beef or chicken. This evidence alone is sufficient justification for investigating how much it would cost to remove one of the major causes of poor eating experience, the unwanted boar taint, and how a marginal reduction of the supply of boar tainted pork would have potentially significant benefits by slowing the rate of increase in poor eating experience. The justification for defining the benefits of IC in reducing the proportion of pork sales that customers rate as a failed purchase is the premise that customers experiencing an adverse consumption experience will not be continuing customers, at the least for a time. A customer not lost is a sale gained.

Avoiding lost customers by reducing the negative experiences of the adverse responses of customers to boar taint and its associated other product characteristics of toughness etc is only part of the story. Potential losses of pork sales in the future will also be reduced by increasing positive customer experiences, which is the aim of several other elements of the 2020-2025 APL Strategic Plan.

Another way to consider the benefits of broader adoption of IC in pork production is from the perspective of potential increases in demand for pork. The surveyed results of consumers having bad experiences with pork consumption do not include those people who are not pork consumers, either because they know someone who has had such an experience, or they have had an experience of unappealing aspects of pork such as odour without ever being a pork consumer.

A further perspective is to consider potential increases in demand for pork as a result of people not having bad experiences with pork consumption, including in preparation, and people not being dissuaded from being consumers of pork by people they regard as credible convincing them about their own adverse experiences of preparing and eating pork. People associated with people who have experienced offensive odours of boar-tainted pork while preparing a meal may well be potentially lost customers. Increases in demand that might occur are problematic as it is simply not possible to know. Using data from the annual Thrive Surveys, McAlister (2020) considered there was a 2.5 percent potential increase in demand from reducing negative eating experiences: minimizing dry tough pork and bad taste and smell. Estimates of 1 to 1.5 percent increases in demand for pork from small increases in eating quality too have been made by experienced industry participants (V Gole 2021, personal communication, 6 July).

Ultimately the decision to purchase pork comes with a risk associated with the likelihood that the purchase may turn out to be a poor buy. The probability of this happening can be expressed as potentially a 20 percent chance if 20 percent of pork is not castrated. More precisely, if 10 percent of consumers report they experience a poor eating experience – and this has been happening each year over the past five years and is increasing (Thrive Insights) – then the probability of the purchase of pork turning out to be a poor decision is at a minimum around 10 percent. One chance in 10 would be odds of 9/1 against. These odds have to be weighed up by the consumer considering buying pork or an alternative source of protein and the odds of getting a bad eating experience.

A consumer with a choice of types of meat to buy, considers price, preferences, cooking method, type of cut and risk of the cut not meeting expectations. Risk of product failure is one part of the decision to purchase meat of some type. Suppose the risk of a purchase of a cut of pork turning out to be a poor buy is higher than the risk associated with purchasing an alternative meal of chicken, lamb, beef, or some other protein considered to be an alternative such as fish of grains. In that case, the risk factor is a critical consideration along with the other factors that come into the decision.

2.1 The BCA criteria: benefits from loss of demand for pork avoided or increase in demand for pork exceeds costs

The tests of the success of adoption of wider use of IC in producing pork are:

- Avoided loss of pork consumers (whom previously identified boar taint occurring during cooking or eating); and
- Increased consumption of pork because there is no boar taint and more favourable perception and less unfavourable impressions of pork as a meat meal held throughout the general population by both consumers and non-consumers.

If the value of avoided lost sales exceeds the cost of avoiding these sales losses using IC, in present value terms, then the benefit cost ratio is positive, i.e., there is a net benefit. Expressed another way, if an increase in demand was attributable to less boar taint in pork and the value of the increase in demand outweighed the increase in cost of the industry to supply pork free of boar taint, then the cost of adopting IC throughout the industry would represent a sound investment.

As the value of sales that would be lost due to poor eating experience cannot be known accurately, a threshold or breakeven approach is used in this analysis. Thus, the question is turned around to:

> What proportion of the potential losses of market each year as a result of a poor pork consumption experience would need to be avoided for the dollar value of benefits (the dollar value of avoided losses/retained sales) to exceed the costs of using IC to achieve these benefits/prevent these losses?

For example, if the costs of immuno-castrating the remaining 20 percent of male pigs that are not castrated is exceeded by the benefit from preventing the loss of one percent of the current 10 percent of 'failed product rating' then IC has a net benefit to the industry. The implicit assumption is that of the 10 percent of consumers who rated their pork purchase as being a 'failed product', at least 1 percent of these consumers would have given up on pork as a product they wish to consume for some time at least into the future.

The conclusion about the net benefit of IC rests on the likelihood that without IC of the remaining non-castrated males at least some of the dissatisfied consumers will cease to buy pork and would have continued to buy pork if not for the boar taint effect – and, in the absence of boar taint, would be continuing customers of pork in future. Survey results from work by Thrive Insights indicated that despite a bad eating experience with pork, only 10 percent of customers said they would buy less frequently in the future. Of these, half said they would eventually return to their usual frequency. The other half said they would purchase pork less often in the future. Thus, a bad eating experience results in losing customers for both a short and long time. Not counted are potential customers who have been turned off forever or never 'turned onto' pork, possibly by vicarious experience.

2.2 The Benefit Cost Analysis Data

2.2.1 Price and consumption data

The apparent annual consumption of fresh pork in Australia is the starting point of the analysis. The steadily increasing albeit relatively slight trend in apparent consumption of fresh pork from 2010 to 2019 is assumed to continue for the next decade. This growth has been the result of economy and community-wide changes and is net of the annual losses of consumers of pork resulting from an adverse eating experience – the near 10 percent 'product failure' as a result of bad smell and/or taste that shows up consistently in surveys. Consumers who give up purchasing pork each year because of poor eating experience of pork associated with boar taint, whether for a short or a long time, are included in the projected increases in pork consumption. If annual pork consumption increases at 1 percent per year, this is the combined effects of changes in population, relative prices and preferences each year, and absorbs any losses that may also be occurring as a result of customer dissatisfaction for a range of reasons, including boar taint.

Apparent annual fresh pork consumption 2010-2019 is shown below. Consumption ranged from 300,000 tonnes to 225,000 tonnes with an average of 256,000 tonnes, but with a consistent upward trend from 2010 to 2019. In the analysis the average annual trend in consumption over the past 10 years has been applied to the next 10 years.

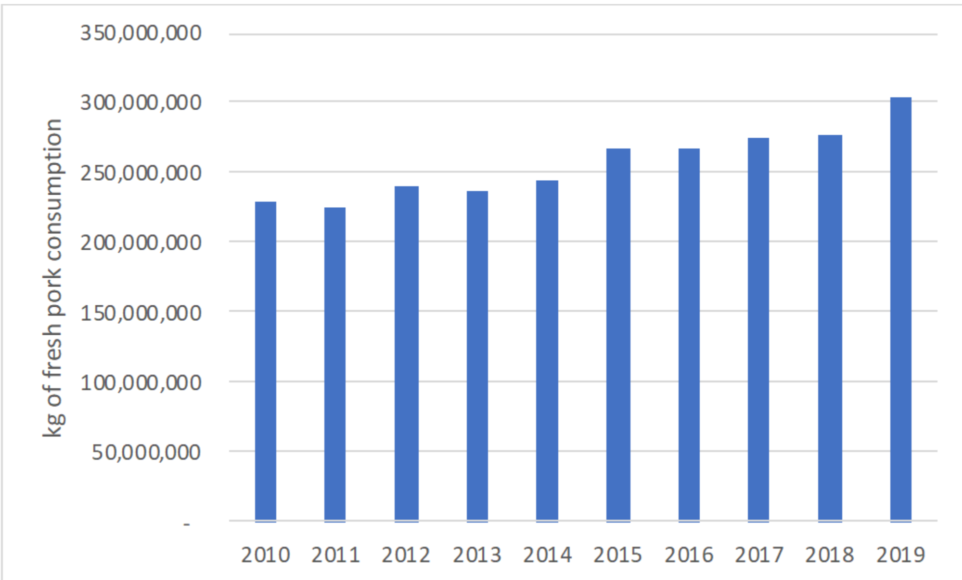

Figure 1. Apparent annual fresh pork consumption (kgs), Australia, 2010-2019 (ABARES, 2021)

Annual total pork production and farm and consumer prices vary year on year and within year because of increasing and decreasing grain prices, domestic production levels and net availability of pork to retailers, wholesalers and manufacturers after exports and imported pork is accounted for, and world pig meat production and prices. While the BCA could be done on the basis of likely average consumer prices over the period of the analysis – and this would give a reasonable approximation of the average net benefits – it can be more informative about the size of net benefits to account for the variations in the value of pork that will inevitably occur over the period of the benefit cost analysis.

The consumer price of pork is used to value the losses of pork sales that might be avoided by removing boar taint. Deriving a retail price of fresh pork consumed in Australia is more complex and with less information available than the farm price because of the many forms and cuts of fresh pork and the range of values for different forms and cuts of fresh pork sold through supermarkets, butchers, fresh produce markets and food service. The retail carcass equivalent value of fresh pork was estimated as $5/kg cold weight (the value across the major fresh pork cuts after allowing for the proportion of a carcass they represent, and the different additional value added to different cuts (see Table 1).

As part of the cost benefit analysis, the typical extra costs of using IC in pig production systems are the cost of the vaccine, additional casual labour and additional backfat (see Table 2). Although there is potential for additional benefits for a producer (Dunshea et al., 2013) there are also additional costs[2]. In summary, the extra cost of IC for a pork producer was set at $0.10/kg and $0.12/kg. Further work, beyond this desktop analysis, could look in greater detail at the costs and benefits of changing from producing entire males to IC for an individual producer.

Table 1. Farm level changes in costs for a pork producer moving from entire males to IC

Costs of IC	**Net Change in costs for a producer ($/pig)**
Vaccine	$4.50
Additional casual labour	$1.00
Additional backfat	$2.00
Total ($/pig) for a large producer	$7.50
Total ($/kg HSCW – assuming 75kg HSCW) for a large producer	$0.10
Vaccine (cost could be higher for smaller producers)	$6.00
Additional casual labour	$1.00
Additional backfat	$2.00
Total ($/pig) for a small producer	$9.50
Total ($/kg HSCW – assuming 75kg HSCW) for a small producer	$0.12

In addition to the costs for the producer from IC, there are expected to be costs associated with processing IC pork. The processor costs are associated with deep tissue abscess from the vaccine. The cost for the processor was estimated to be $1,075,000[3].

2.2.2 Adoption of Immunocastration in Pork Production

Forty percent of male pigs produced in Australia in 2021 are not castrated. The BCA is done with an assumed rate of adoption of IC, and that adopted IC results in nil boar taint. The adoption question is problematic in that 60 percent of the male pigs are already immunocastrated, predominantly done by the largest firms. This technology has been around for decades. Producers who do not castrate their pigs will no doubt have good reasons in the context of their operation why they do not castrate pigs. The adoption of IC technology is assumed to be on the mature part of the sigmoidal adoption curve and hence it will require more extension and market force incentives to bring the remaining late adopters and laggards to using IC.

[2] From industry experience, the difference between entire male and improvac diets are minimal and the benefits from IC are weight gain but costs are dressing percentage and backfat. Further, the increase in carcass weight is not enough to outweigh the costs of an increase in backfat.

[3] The cost associated with deep tissue abscess are: downgrading of shoulder primal; boning room stoppage, cleaning of equipment, reduced throughput and increased labour. The estimated cost extra processor was estimated to be $1,075,000 if IC was fully adopted.

Adoption of more IC across the industry could be anticipated to be slow, unless new incentives including information are brought to bear on the issue. Quantifying the potential future losses of markets with the current level of non-use of IC and the benefit of not losing market by using IC ought to be information that would have some positive effect on the incentive to adopt IC. Further, suppose the benefits of removing potential losses from boar taint affects effects are large compared to the costs of implementing IC across the entire industry. In that case, there are excess benefits available that could be used to encourage the adoption of IC that is required.

In the BCA a range of rates of adoption over the next 10 years to 2030 are investigated to identify the impacts of fast versus slow and small versus large rates of overall adoption of IC in the industry. The greatest net benefit comes from a large proportion of the non-castrating population of producers adopting IC rapidly. In this scenario, while costs are large and occur early in the 10-year planning horizon used in the analysis, so too are the benefits.

3. Results

3.1 Results of the Benefit Cost Analysis of Increased Use of Immunocastration in Producing Pork

It is likely to be a good investment for the pork industry to increase the use of immunocastration. These results are from looking at costs and benefits over the next 10 years to examine whether it is worth increasing the adoption of IC. As happens, the costs and benefits would continue in perpetuity.

A range of benefit cost ratios have been calculated for different scenarios made up of two different costs of implementing IC at producer level ($/kg IC cost) and the percentage of annual total pork demand that has to be either retained or increased. At a 6 percent p.a. real opportunity cost rate, increasing the rate of immunocastration from 60 per cent of the whole production herd (both sexes) to 100 per cent immediately (from year 1) would be a good investment depending on the level of demand retained or grown and the costs of making this change at the farm level. This is evident in both the benefit cost ratio (BCR) and net present value figures (NPV) (Tables 2 and 3).

Table 2. Benefit Cost Ratio (at 6% p.a. real discount rate) if 100% adoption of IC from year 1

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
percent of demand retained or gained	**0.4%**	0.8	0.7
	0.5%	1.1	0.9
	1.0%	2.1	1.8
	1.5%	3.2	2.7

Table 3. Net Present Value ($) (at 6% p.a. real discount rate, 10 years) if 100% adoption of IC from year 1

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
percent of demand retained or gained	**0.4%**	(7,545,881)	(16,010,031)
	0.5%	3,034,305	(5,429,844)
	1%	55,935,239	47,471,089
	1.5%	108,836,172	100,372,023

If the adoption of IC takes time (eg. 5 years), or if it is never fully adopted, it could still be a good investment, but this depends on the size of demand gained or avoided (Tables 4 -13).

Table 4. Benefit Cost Ratio (at 6% p.a. real discount rate) if it takes 5 years to get to 100% adoption (assuming adoption and benefits and costs are incurred at a cumulative 20% each year– see the appendix scenario 2)

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	0.9	0.8
	0.5%	1.1	1.1
	1%	2.1	2.1
	1.5%	3.2	3.2

Table 5. Net Present Value $ (at 6% p.a. real discount rate) if it takes 5 years to get to 100% adoption (assuming adoption and benefits and costs are incurred at a cumulative 20% each year– see the appendix scenario 2)

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	(5,730,492)	(5,922,634)
	0.5%	2,511,284	2,319,142
	1%	43,720,164	43,528,022
	1.5%	84,929,044	84,736,902

Table 6. Benefit Cost Ratio (at 6% p.a. real discount rate) if it takes 5 years to get to 100% adoption (assuming adoption and benefits and costs are incurred at different rates each year– see appendix scenario 3)

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	0.8	0.8
	0.5%	0.95	0.94
	1%	1.89	1.88
	1.5%	2.8	2.8

Table 7. Net Present Value $ (at 6% p.a. real discount rate) if it takes 5 years to get to 100% adoption (assuming adoption and benefits and costs are incurred at different rates each year – see appendix scenario 3)

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	(9,421,078)	(9,613,220)
	0.5%	(2,101,948)	(2,294,090)
	1%	34,493,700	34,301,557
	1.5%	71,089,348	70,897,205

Table 8. Net Present Value (at 6% p.a. real discount rate) if it takes 5 years to have only a proportion of those who have not adopted IC now adopting IC (assuming adoption and benefits and costs are incurred at same rates each year – see the appendix scenario 4)*

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	(3,265,456)	(3,361,527)
	0.5%	1,452,128	1,356,056
	1%	25,040,045	24,943,974
	1.5%	48,627,962	48,531,891

** assumed that 60% of the remaining 40% of producers who are not currently using IC, now adopting IC*

Table 9. Benefit cost ratio (at 6% p.a. real discount rate) if it takes 5 years to have only a proportion of those who have not adopted IC to now adopt IC (assuming adoption and benefits and costs are incurred at different rates each year – see the appendix scenario 5)*

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	0.4	0.4
	0.5%	0.5	0.5
	1%	0.96	0.96
	1.5%	1.4	1.4

** assumed that 60% of the remaining 40% of producers who are not currently using IC, now adopting IC*

Table 10. Net Present Value (at 6% p.a. real discount rate) if it takes 5 years have only a proportion of those who have not adopted IC to now adopt IC (assuming adoption and benefits and costs are incurred at different rates each year – see the appendix see appendix scenario 5)*

		cost of IC for a producer of pork S/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	(13,636,031)	(13,732,103)
	0.5%	(11,511,092)	(11,607,163)
	1%	(886,394)	(982,465)
	1.5%	9,738,304	9,642,233

** assumed that 60% of the remaining 40% of producers who are not currently using IC, now adopting IC*

Table 11. NPV (at 6% p.a. real discount rate) if it takes 10 years to have only a proportion of those who have not adopted IC to now adopt IC (assuming benefits and costs adoption and benefits and costs are incurred at same rates each year – see the appendix scenario 6)*

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	(2,278,229)	(2,335,872)
	0.5%	1,056,344	998,701
	1%	17,729,208	17,671,565
	1.5%	34,402,072	34,344,429

** assumed that 60% of the remaining 40% of producers who are not currently using IC, now adopting IC*

Table 12. Benefit cost ratio (at 6% p.a. real discount rate) if it takes 10 years to have only a proportion of those who have not adopted IC to now adopt IC (assuming adoption and benefits and costs are incurred at different rates each year – see the appendix scenario 7)*

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	0.3	0.3
	0.5%	0.3	0.3
	1%	0.69	0.68
	1.5%	1.0	1.0

** assumed that 60% of the remaining 40% of producers who are not currently using IC, now adopting IC*

Table 13. Net Present Value (at 6% p.a. real discount rate) if it takes 10 years to get have only a proportion of those who have not adopted IC to now adopt IC (assuming adoption and benefits and costs are incurred at different rates each year – see the appendix scenario 7)*

		cost of IC for a producer of pork $/kg pork produced	
		$0.10	**$0.12**
per cent of demand retained or gained	**0.4%**	(11,322,429)	(11,380,072)
	0.5%	(10,248,906)	(10,306,549)
	1%	(4,881,293)	(4,938,935)
	1.5%	486,321	428,679

** assumed that 60% of the remaining 40% of producers who are not currently using IC, now adopting IC*

An existing equilibrium displacement model (EDM) of the Australian pork industry (Zhang *et al*., 2018) was also used to add a further analytical dimension to the standard benefit cost analysis. The details are provided in an appendix. These sorts of models are calibrated with best estimates of the underlying supply and demand elasticities, and a set of price and quantity data that reflects a typical year, either a particular year like 2019, or an average of several years to even out for example climate-related variations. The model used here is calibrated on an average of 2012-2016 data. Given the short time frame for this analysis, it was not considered necessary to update the underlying data to more recent years. However, given the similar values for gross value of production, the measures of benefits should be reliable.

Using the EDM model, given the model assumptions and data, the results show that at full adoption, even the lowest demand change in association with the highest cost of IC results in a positive net benefit. Scenario 5 shows that with a much higher change in demand, the benefits to the whole Australian pork industry are substantial.

4. Discussion

The quicker IC is fully adopted, the better the investment in IC for the Australian pork industry. The best case is the cost to producers of IC is $0.10/kg pork produced. This requires only 0.5 percent of pork consumption to be retained due to lower incidence of bad smell or taste due to the elimination of boar taint in 100% of the national herd.

If adoption is slow, and low, reaching only 60 percent of the potential adopting population- the producers of the remaining 20 percent of pork produced not using IC – and the benefits and costs do not accrue linearly, then demand needs to increase (or the loss of demand avoided) to 1.5 percent to make an investment in IC worthwhile.

To form a view about the likelihood of the investment in IC delivering a BCR greater than one and thus earning the opportunity cost return on investment that is required, it is necessary to consider the required increase in demand or avoidance of demand lost in the context of the proportion of total pork consumed each year that is deemed a ‘failed product’ and the extent to which this failure is attributable to boar taint.

Ten percent of pork each year falls into the category ‘failed product’ for the reason of bad smell or bad taste, which are likely, but not limited to boar taint. Boar taint contributes significantly to bad eating experiences and low eating quality score. Removing boar taint alone increases eating quality score by nearly 5 percent.

The conclusion of the BCA is that if between 0.5 and 1.5 percent more of the pork sold each year over 10 years did not end up as a failed product and gave a good eating experience, the investment pays off from an industry perspective.

This means that if between 5 percent and 15 percent of the total annual failed product due to bad smell/taste is transformed into an acceptable eating product due to not having boar taint by using IC, the investment is a good one.

Using the EDM model, given the model assumptions and data, the results show that at full adoption, even the lowest demand change in association with the highest cost of IC results in a positive net benefit. Scenario 5 shows that with a much higher change in demand, the benefits to the whole Australian pork industry are substantial.

There are acknowledged differences between the data used for the BCA and the EDM (in fact the EDM represents a pig industry in 2012-2016 that is about 20 percent larger than the industry in 2020), and retail prices are treated a little differently, but the bottom line is that *only small changes in demand are required to offset the industry-wide costs of an expansion in the use of IC.*

The other result available from the EDM is the distribution of the benefits across the various value chain participants. These shares are shown in Table 15, and they are consistent across all scenarios.

Pig producers receive 12 percent of total benefits, value chain participants 9 percent and consumers 79 percent. These shares are consistent with other types of simulated industry changes reported in Zhang et al. (2018). However, the converse is that consumers eventually pay almost 80 percent of the costs incurred at the farm level.

Table 14. Percentage shares of total surplus changes (%) to pig producers, value chain participants and domestic pig meat consumers from all scenarios, medium term

Change in economic surplus to	**All Scenarios**
	%
Pig Producers	12
Abattoirs and boning rooms	1
Retailers/exporters/importers	8
Domestic pork Consumers	78
Domestic Bacon Ham Smallgoods (BHS) Consumers	1
Total Surplus	100

5. Conclusion

The results of this benefit cost analysis show that an increased use of immunocastration in Australia's pig production systems that reduces the risk to buyers of pork of Product Failure/Boar Taint, and which achieves a small avoidance of otherwise lost consumption of pork from Product Failure/Boar Taint, or achieves small increase in demand for pork, would justify the cost of increased use of IC in the Australia pig industry. Well-informed judgement holds that there is high probability of achieving the reduced loss of sales and/or the increased demand for pork that is required to justify the cost of using IC to reduce or remove the incidence of boar taint from pork.

The results of the benefit cost analysis are supported by a parallel industry-wide analysis in which supply and demand are modelled using the Equilibrium Displacement Method. Given the model assumptions and data, the results of this analysis using industry figures of costs and benefits of immunocastration being used throughout the pig industry delivered positive net benefits, even with the smallest likely increase in demand (or loss of demand avoided) in association with the highest likely cost of IC of $9 per treated male pig.

In sum: only a small positive effect on demand is needed to justify the cost of widespread use of IC throughout the pig industry.

Further, in the medium term, consumers would bear most of the additional costs incurred in the industry of immunocastration – economic analyses show that around 80 percent of the added cost is paid by consumers once the supply and demand effects have worked their way through the industry. Producers bear just over 10% of the added cost and value chain participants around the same share of the additional cost. The benefits too are shared in the same proportions.

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7. Appendix

7.1 Raw Data and assumptions behind the analysis

Table 15. Data used to estimate the trend in domestic fresh pork consumption

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Apparent consumption (tonnes) (ABARES 2020)	571,745	563,032	602,020	593,293	610,312	667,964	665,656	685,933	692,669	757,151
Processed consumption (tonnes) (assumed 60% of consumption)	343,047	337,819	361,212	355,976	366,187	400,778	399,394	411,560	415,601	454,291
Fresh pork consumption (tonnes) (assumed 40% of consumption)	228,698	225,213	240,808	237,317	244,125	267,186	266,262	274,373	277,068	302,860
Imports (tonnes) (ABARES 2020)	283,064	270,197	296,437	279,947	292,146	335,256	321,405	326,933	322,473	403,094
	59,983	67,622	64,775	76,029	74,041	65,522	77,989	84,627	93,128	51,197
Fresh pork consumption (tonnes)	228,698	225,213	240,808	237,317	244,125	267,186	266,262	274,373	277,068	302,860
Export fresh (ABARES 2020)	50,055	51,431	46,157	46,554	44,027	41,410	41,803	48,973	54,018	43,678
Domestic fresh pork consumption (tonnes)	178,643	173,782	194,651	190,763	200,098	225,776	224,459	225,400	223,050	259,182

Notes: To calculate the quantity of fresh pork consumption followed approach of Zhang *et al* (2018) then used excel function TREND along with the domestic fresh pork consumption data for the past 10 years to project forward the expected domestic fresh pork consumption.
Raw data sourced from: https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/data#2020

Table 16. Estimated domestic fresh pork consumption for 2020 to 2029

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Estimated domestic fresh pork consumption (tonnes)	254,588	262,772	270,955	279,138	287,322	295,505	303,688	311,871	320,055	328,238

Table 17. Estimated kg that will incur the cost of IC

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Total Kg of fresh pork	254,588,453	262,771,736	270,955,018	279,138,301	287,321,583	295,504,865	303,688,148	311,871,430	320,054,713	328,237,995
Of that 60% is from IC herd	152,753,072	157,663,041	162,573,011	167,482,980	172,392,950	177,302,919	182,212,889	187,122,858	192,032,828	196,942,797
Of that 40% is from herd without IC	101,835,381	105,108,694	108,382,007	111,655,320	114,928,633	118,201,946	121,475,259	124,748,572	128,021,885	131,295,198
Of that 40%, half the number of kg will incur the cost of IC -Males	50,917,691	52,554,347	54,191,004	55,827,660	57,464,317	59,100,973	60,737,630	62,374,286	64,010,943	65,647,599

7.2 Adoption scenarios

Scenario 1: 100% adoption in year 1, all benefits and costs incurred from year 1

Scenario 2: Assumed it would take 5 years to get to 100% adoption

	1	2	3	4	5	6	7	8	9	10
adoption: % of full adoption 100%	20%	40%	60%	80%	100%	100%	100%	100%	100%	100%
proportion of benefit	20%	40%	60%	80%	100%	100%	100%	100%	100%	100%

Scenario 3: Assumed it would take 5 years to get to 100% adoption and assumed benefits and costs accrue at different times

	1	2	3	4	5	6	7	8	9	10
adoption: % of full adoption 100%	20%	40%	60%	80%	100%	100%	100%	100%	100%	100%
proportion of benefit	0%	20%	40%	60%	100%	100%	100%	100%	100%	100%

Scenario 4: Assumed it would take 5 years to get a proportion of those who have not adopted IC now adopting this technology (that is 60% of the 40% of producers who have not adopted IC now adopt IC)

	1	2	3	4	5	6	7	8	9	10
adoption: % of full adoption 100%	10%	20%	30%	40%	60%	60%	60%	60%	60%	60%
proportion of benefit	10%	20%	30%	40%	60%	60%	60%	60%	60%	60%

Scenario 5: Assumed it would take 5 years to get a proportion of those who have not adopted IC now adopting this technology (that is 60% of the 40% of producers who have not adopted IC now adopt IC) and assumed benefits and costs accrue at different times

	1	2	3	4	5	6	7	8	9	10
adoption: % of full adoption 100%	10%	20%	30%	40%	60%	60%	60%	60%	60%	60%
proportion of benefit	0%	0%	10%	20%	30%	30%	30%	30%	30%	30%

Scenario 6: Assumed it would take 10 years to get a proportion of those who have not adopted IC now adopting this technology (that is 60% of the 40% of producers who have not adopted IC now adopt IC)

	1	2	3	4	5	6	7	8	9	10
adoption: % of full adoption 100%	6%	12%	18%	24%	30%	36%	42%	48%	54%	60%
proportion of benefit	6%	12%	18%	24%	30%	36%	42%	48%	54%	60%

Scenario 7: Assumed it would take 10 years to get a proportion of those who have not adopted IC now adopting this technology (that is 60% of the 40% of producers who have not adopted IC now adopt IC) and assumed benefits and costs accrue at different times

	1	2	3	4	5	6	7	8	9	10
adoption: % of full adoption 100%	6%	12%	18%	24%	30%	36%	42%	48%	54%	60%
proportion of benefit	0%	0%	10%	20%	30%	30%	30%	30%	30%	30%

7.3 Using an Equilibrium Displacement Model of the Pig Meat Industry

An existing equilibrium displacement model (EDM) of the Australian pig meat industry (Zhang et al., 2018) was also used to add a further analytical dimension to the standard benefit cost analysis. Equilibrium displacement models of agricultural industries set out the various main markets in the industry, with estimated demand and supply schedules for farm, processing, retail and export sectors of the industry. That is, they model the whole value chain. These models represent the operation of the industry at a point in time and can be used to investigate the effects of a change in the conditions of supply or demand in any of the main markets included in the model, and how these effects flow through all the connected markets in the industry. The effects of an increase in costs at farm level because of additional costs of immunocastration in a significant segment of the production sector, plus the minor costs incurred in the processing sector, can be traced using an EDM through to the subsequent effects on costs to processors and consumers, and associated effects on quantities supplied and purchased at the different levels in the value chain. Changes in consumer demand can be included as well. For example, earlier versions of this model have been used to examine the returns to industry from productivity improvements in pig meat production and from successful advertising campaigns (Mounter et al., 2005), and from hypothetical new products with higher willingness to pay by consumers (Slattery et al., 2010).

Importantly, since an added cost or benefit in a value chain is not all borne or received where it is initially incurred, the EDM shows where the additional costs and benefits of IC at production and processing levels and at the consumer end up in the value chain. This is called the 'incidence' of the costs or benefits. Some costs are borne by producers, some by consumers and some by processors. Some of the benefits go to consumers, some to producers and some to processors. In all such value chain analyses, the great majority of added costs and added benefits within a value chain end up being paid and received by consumers and producers with little going to the agents in between them. These shares depend on the relative responsiveness of the supply and demand for the product in question at the different market levels – called price elasticities of supply and demand. In models of food and agricultural industries, depending on the characteristics of supply and demand and the degree of processing required, producers and consumers share the added costs and benefits in proportions that can range from 30 percent to consumers and 70 percent to producers, through to 10 percent to producers and 90 percent to consumers.

These sorts of models are calibrated with best estimates of the underlying supply and demand elasticities, and a set of price and quantity data that reflects a typical year, either a particular year like 2019, or an average of several years to even out for example climate-related variations. The model used here is calibrated on an average of 2012-2016 data. Given the short time frame for this analysis, it was not considered necessary to update the underlying data to more recent years. It should be noted that while prices are lower now than 7-8 years ago, output is up, and therefore gross value of production at the farm level is very similar as in 2012-2016: $1.447 billion then (Zhang et al., 2018) vs $1.425 billion now (latest production and average price data from APL). The total $ values of measures of benefits will be very similar. Economists use 'changes in economic surplus' as the measure of benefits. This is not a revenue or expenditure measure – it is an aggregate measure of the changes in profits to producers given by price received minus cost of production, and the changes in perceived benefits to consumers given by willingness to pay minus actual price paid.

The other point about EDMs is that they are static models – they represent a new equilibrium in a market in the future, based on a shock to the model in the base situation, without any indication of the time path of how the new equilibrium was reached. In the type of analysis reported here, the EDM can offer some broad order-of-magnitude validation of the overall net benefits and the distribution of that net benefit across all of the value chain participants.

The three inputs of interest in this application are the proportional change in the whole herd cost of production of pigs due to the use of IC, the proportional change in the cost of processing due to the positive and negative impacts on carcase quality, and the hypothesised proportional change in the demand for pork brought about by the use of IC. The raw data required for these assumptions has been presented above.

The change in the net cost of IC implementation, taking into consideration downgraded carcasses due to fatness, was estimated to lie between $0.07/kg and $0.12/kg, depending on the cost of the vaccine and whether the potential benefits from increased carcase weight and reduced mortality were included. Given the underlying equilibrium assumptions of the model and reducing the actual inputs by 80 percent to reflect the portion of the herd that already uses IC and the share of males, the two extreme farm production cost increases become 0.35 and 0.59 percent.

The increase in the cost of processing was estimated by one operator to be $215,000 per year for approximately 20 percent of the national kill (1.1 million progeny pigs). This results in an increase in the cost of processing of $0.0042/kg, or less than half a cent. This is represented in the model as an increase in costs of just 0.0000016 percent for the appropriate target group of pigs.

Scenarios 1 and 2 reported in Table 14 show the costs to the Australian pig meat industry of these cost increases, without any offsetting demand change. The whole Australian pig meat industry would be worse off if there was no positive demand effect by between $4.2 million and $7.1 million by fully adopting IC on the remaining proportion of entire males, if there was no offsetting demand change. Avoided losses of demand or increased demand of $4.2 million - $7.1 million to offset the added cost would, at $5/kg retail, amount to extra pork sales of 840 tonnes to 1,420 tonnes. This is less than half a percent of total pork production.

Table 18. Annual economic surplus changes ($ million) from selected scenarios, medium term (based on 2012-2016 data)

Change in economic surplus to	**Scenario 1 Lower bound producer costs plus processor costs**		**Scenario 2 Upper bound producer costs plus processor costs**		**Scenario 3 Lower bound producer costs plus processor costs plus lower bound demand shift**		**Scenario 4 Upper bound producer costs plus processor costs plus lower bound demand shift**		**Scenario 5 Upper bound producer costs plus processor costs plus upper bound demand shift**	
	$m	%	$m	%	$m	%	$m	%	$m	%
Total Surplus	-4.18	100	-7.05	100	5.36	100	2.49	100	29.22	100

Scenarios 3 and 4 show whether these cost increases can be offset by changes in demand as described above, that is by an increase in the quantity demanded of just 0.4 percent of retail sales. These demand changes are already calibrated to the quantity of pork in the category of failed product, but one change necessary is to redo these quantity changes as equivalent price changes to fit with the underlying assumption that both supply and demand shifts need to be shown in the price axis. Given the assumed own-price demand elasticity for fresh pork of -1.2, these two quantity changes translate into price changes of 0.33 and 1.25 percent, respectively.