The relationship between health and productivity: implications for health policy

PhD Thesis

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Certificate of original authorship

I, ***Kathleen Manipis*** declare that this thesis, is submitted in fulfilment of the requirements for the award of ***Doctor of Philosophy*** in the ***Business School*** at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Impact of the COVID-19 pandemic

The COVID-19 pandemic had an enormous impact on my PhD. Although there were some benefits to working from home such as reducing my daily commuting time there were also some challenges. Not being able to work in the office made it difficult to connect with colleagues and discuss ideas and topics. Although video conferencing mediums (zoom and Microsoft teams) provided a means to participate in meetings and in conferences, there were also less opportunities engage with others in academia, where otherwise, you may have met face-to-face and fostered a collaboration in research. There is a learning curve in how to best communicate and connect with others through these video conferencing mediums. While communication was initially difficult, I was lucky my supervisors were available (via email, phone, text and zoom) to discuss PhD work.

One positive aspect that has come from the COVID-19 pandemic was the opportunity to study the impact of health issues on productivity as the COVID-19. The second DCE study was changed to incorporate COVID-19 restrictions, so that this PhD, reflected a more contemporary health issue affecting productivity.

Abstract

Productivity loss resulting from illness affects individuals, firms and society. Foodborne illnesses (FBIs) and infectious diseases affect health and welfare, but the impacts are unclear. Better information is required to assist decision-makers in setting priorities and developing control measures.

This thesis uses two case studies of communicable disease: FBI and COVID-19, to explore trade-offs for individuals and policy-makers that affect health, welfare and productivity. Both cause acute illness with potential risk of long-term morbidity or death, and varying impacts on productivity. Preventive measures impose costs on individuals and/or firms, and these need to be considered.

The research uses three empirical methods (survey, discrete choice experiments and economic evaluation) across four case studies to investigate the estimation of lost productivity, measurement of trade-offs and assessment of competing priorities.

Study one used a DCE to estimate the willingness-to-pay (WTP) to avoid FBI. A key feature of the Australian labour market, the availability of sick leave entitlements was considered, and was found to influence the estimated WTP to avoid a range of acute and chronic FBIs.

Study two involved a survey of employers to estimate the time and costs of replacing a worker in Australia from a firm's perspective to inform the friction cost approach (FCA) for estimating lost productivity. This was the first such study in Australia, and found that the time taken to replace a worker in Australia was consistent with international estimates.

Study three combines the outputs from the first two studies, to explore the application of results from a DCE and a friction cost survey to inform an economic evaluation. Productivity losses due to FBI were valued using three methods (human capital approach (HCA), FCA and WTP), and a combination of the FCA + WTP to adjust the perspective of the analysis. The methods led to different estimates of the burden of disease, consequently influencing allocation decisions.

In the final study, a DCE is used to assess general population preferences for COVID-19 policies. Trade-offs between the health risks (for self and for others), as well as productivity impacts were key concerns raised with the COVID-19 pandemic. The results showed an alignment between what the public is willing and was compelled to endure.

The thesis explores the potential of different economic approaches to better inform decisions about investment to improve health and support participation in productive activities.

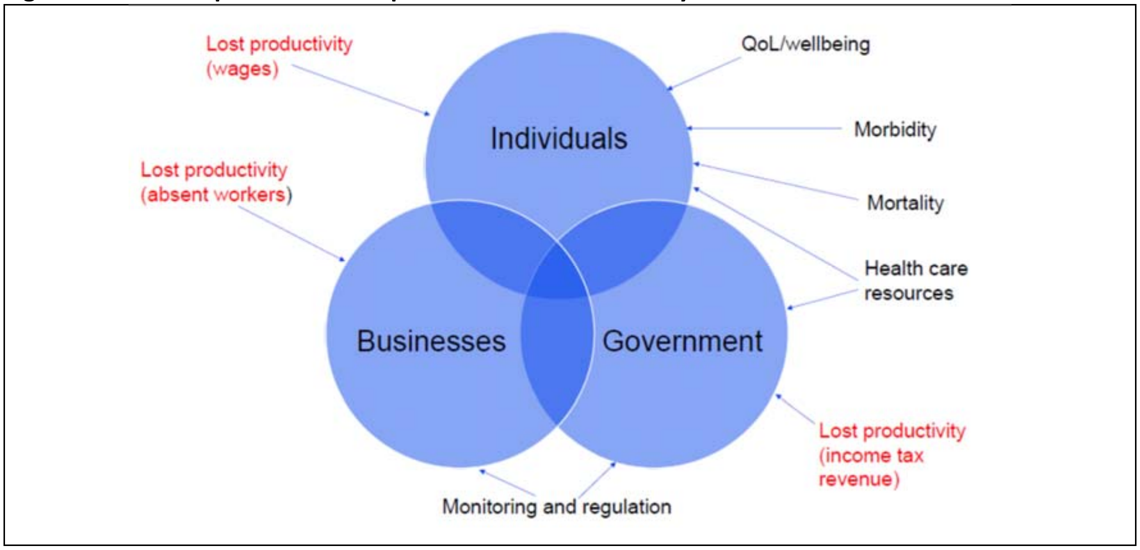
Chapter 1: Introduction

1.1 Overview of the impact of health problems on the economy

Health conditions, illness and injury cause disruption to people's lives, with negative impacts for individuals, businesses and societies [1]. When an individual takes time off work to recover from an illness or to care for a person who is ill, there are not only impacts on the individual's wellbeing but also the potential for a loss of productivity for the economy [2, 3]. Individuals who suffer illness experience morbidity and negative impacts on quality of life, which can temporarily or permanently reduce their health status. Because of the functional limitations caused by their illness, individuals may find it difficult to be in the workforce or to participate in their usual daily activities. These impacts may be temporary and able to be resolved with treatment, or they may be long-term, leading to individuals being unable to work at all. In either case, health care conditions can lead to reduced workforce participation where time is taken off work due to illness (known as absenteeism), reduced productivity while at work (known as presenteeism), loss of income, increased caring responsibilities or unemployment [4].

As an individual's health status is an intrinsic part of their human capital that enables them to work or participate in other productive activities, it is an important factor when we make investment decisions in health and healthcare. An illustration of the impacts of health problems for individuals, businesses and governments on the economy is provided in Figure 1.

Figure 1 Impacts of health problems on the economy



In this thesis, using a range of cases studies, I explore different aspects of the relationship between health and productivity, and the implications of this relationship for economic evaluation and health policy.

For firms, the impact of health problems is felt through the effects on labour force capacity, as people who are sick, or caring for someone who is sick, will be less productive at work, or unable to work, temporarily or permanently [5]. Benefits such as employee sick leave, carers leave and personal leave represent costs of the illness which are borne by the firm and which reduce the burden on the employee [6]. Sick leave policies in Australia are a form of social insurance benefit, which provides income protection for the worker for an absence from work (sick leave policies are discussed further under Section 1.3) [7].

Before examining this relationship between health and productivity, and the implications for health policy, this chapter will introduce key concepts relevant to the research conducted for this thesis. Fundamental concepts related to productivity, health and healthcare, and government intervention are described and their importance discussed. Economic evaluation, which is a key method used to guide adoption of interventions in health, is also introduced. Concepts relating to discrete choice experiments (DCEs) are provided in Chapter 2 of the thesis. The research questions, methods and aims and objectives presented in this thesis are then described.

1.2 Productivity

Productivity is a key factor in economic growth, and is interrelated to the wellbeing of a society and its people [8]. The ability of a society to improve or maintain its standard of living over time essentially depends on its ability to sustainably raise or maintain output per resident[1]. In saying this, the work of each person, paid or unpaid, contributes to the economy in one way or another. Increases in the availability of labour (the time, effort and skills of a worker) have the potential to result in increases in production [9].

Productivity is a measure of production efficiency – that is, how the combination of the labour, capital and other inputs (e.g. land and natural resources) are used to produce goods and services [10, 11]. Firms maximise profits by selecting the optimal combination of capital and labour to produce the quantity of output at which marginal revenue is equal to marginal cost, where the marginal revenue is the revenue received from the last unit of output produced, and the marginal

[1]This thesis focuses on labour productivity, which is one component contributing to economic growth. There are other factors that increase production such as increasing capital or improvements in technology; however, this thesis mainly focuses on the impact of illness, which directly affects labour productivity.

cost is the cost of the combination of inputs required to produce the last unit of output [10, 11]. The profit maximising level of production is determined by using the marginal decision rule, where the marginal benefits (MB) are equal to the marginal costs (MC), i.e., MB=MC [10, 11]. This is because the marginal benefit for a firm is the marginal revenue, which is the price that it receives for selling the last (marginal) unit of output [10, 11].

For example, a firm has decided upon the optimal number of people to employ. The firm hires more workers until it reaches the point at which each worker contributes less additional output (i.e., it stops hiring if MC > MB, that is, if the wage rate is greater than the marginal value of the product) [10-12]. On the other hand, the higher the wage rate the more hours of labour individuals will be willing to provide [10-12]. Individuals will supply labour up until the point at which their marginal rate of substitution of leisure time for goods is equal to their wage rate. In neoclassical economic theory, individuals choose to maximise utility by allocating their scarce resource of time between goods and services, which are purchased with income, and leisure [10-12]. Allocating time to work allows more goods and services to be consumed but comes at the opportunity cost of leisure time.

There is a fundamental link between health, health care and productivity; however, this link is not always direct. Theoretically, issues stemming from health and healthcare are likely to affect labour capacity and incur changes in productivity. If a worker is unfit to work, there can be a reduction in the outputs and revenue of the firm, which may in turn impact on the wages of a worker. Therefore, a measure of productivity loss from illness is the lost wage of the worker, which, according to economic theory, reflects the value of the marginal product. For an individual who is unable to work due to illness, this also reflects the cost to the individual [10, 11].

In the workplace, the loss of productivity due to illness is a concern for both employers (firms) and employees (workers) [13]. One never knows when a person will fall ill and, as such, costs of absences due to illness are unpredictable. Employers must cope with managing labour shortfalls when employees are absent or have reduced capacity due to illness, and find a balance in maintaining levels of production, which is a continuous task for business operations. For example, they may consider delaying production, rely on other workers to make up reductions in production, or replace workers; however, all these strategies come at a cost to both employees and employers. Employees not only suffer the consequences of the illness but must also deal with lost wages and loss of leisure and family time.

1.3 Government intervention

In most high-income countries, governments are heavily involved in regulating health and health care industries [14]. These countries tend to have some form of universal health insurance, with largely publicly funded health care, although most systems also include out-of-pocket costs to individuals [15-18]. Determining which health and health care services to provide, and the appropriate level at which to provide them, requires evaluation and prioritisation of competing options [19]. To help facilitate this process, decision-makers need a sound methodology and accurate instruments to help conceptualise the trade-offs between competing objectives [19]. Taking an economic approach, the marginal costs and benefits associated with investment, or reallocation of resources, are considered. Such approaches include using economic evaluations or other forms of policy evaluations [19].

Governments intervene because of market failures such as negative externalities, incomplete information or information asymmetry or because aspects of health might be considered a public goods; these market failures can lead to inefficiencies in the allocation of resources or inequitable outcomes [20]. While intervention may improve on market efficiency, equally, there are concerns of government failure, such as where implementation of inappropriate policies exacerbates or causes market failures, or stifling private innovation. In health economics, the real issues revolve around the extent of government involvement and the methods used. Often, there are challenges in agreeing on objectives or on the best policy instrument to inform decisions, and choosing the appropriate values to populate these instruments creates the potential for government failure [20].

One example of a government regulation imposed on businesses in Australia that is designed to protect a worker's health, wellbeing and employment is provision of paid sick and carer's leave. Under the National Employment Standards [21], outlined by the Fair Work Ombudsman [21], sick and carer's leave, also known as personal leave or personal/carer's leave [6], is one of the 11 minimum requirements that employers must provide to employees. Employers must provide full time employees a yearly entitlement of 10 days paid sick leave that accrues yearly, and is prorated for part-time employees [7]; however, not all employees are covered, as employers are not obligated to pay casual workers sick and carer's leave [7]. National Employment Standards help to reduce market inequities that may arise due to unexpected illness and to increase social welfare. For example, the availability of paid sick and carer's leave reduces the burden on parents who need to take a day off work to care for a sick child. Without paid sick and carer's leave, the employee would need to trade off a reduction in their wages with prioritising their health or caring responsibilities. Employees who prioritise going to work over seeking or following medical advice, or resting, may risk delaying their own recovery or that of a child/dependant in their care [22], or spreading a communicable disease to other workers [22, 23]. There are impacts directly on the individual and externalities that impact other workers and the employer. Generally, treatment advice for individuals with infectious or contagious diseases recommends that individuals stay home and avoid contact with other people except when seeking medical care [24]. Negative externalities affect the business and the public generally, if the employee decides to work while ill and the illness is contagious [22, 23].

Sick leave policies are funded in one of three ways – through: 1) employers; 2) government social insurance and; 3) a combination of employer-mandated and government social insurance [21, 23]. Sick leave benefits catering for illnesses of a short duration are predominantly funded by employers [25]. Chronic illnesses, serious illnesses and disabilities may lead to longer absences from work, and can potentially result in employees exiting the workforce. In Australia, legislation regulating employment and workplace relations is mandated in the Fair Work Act 2009 (Cth) [26], which provides for terms and conditions of employment, and outlines the rights and responsibilities of employees, employers and employee organisations. Policies dictating minimum sick leave entitlements are set by the National Employments Standards where financing of paid sick leave is paid by the employer [6].

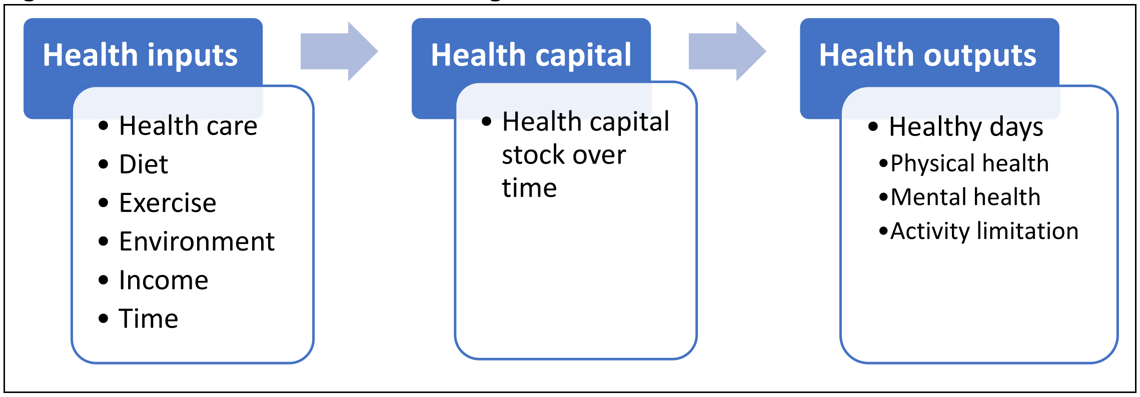
In theory, the government could improve approaches to better meet the objective of maximising the health and/or welfare of society. In practice, governments influence the allocation of resources through establishing rules and regulations [27-29]. Strategies used to implement policy aims can include using taxation, monitoring and regulation, or implementing programs such as subsidies or payments for healthcare resource use [30]. Health policy decision-makers are tasked with balancing goals against each other, and then deciding on the mix of policies to invest in and implement. As choices come with consequences, decision-makers need to choose an optimum level of intervention and consider the trade-offs in the decision-making process. In assessing policies, decision-makers need to consider the costs, benefits, outcomes and impacts of implementing an intervention. Each policy that is introduced impacts the distribution of resources and the welfare of the public in different ways. The interests of individuals, firms and the community may not be aligned or have conflicting viewpoints, and the balance of policies implemented should be acceptable to society if it is to be successful. The metrics used in measurement should be accurate and meaningful to help guide investment decisions. Most developed nations have frameworks for public health policies for sharing the risks and costs of health care and distributing these across the population to ensure universal access to health care.

1.4 Health capital: health and healthcare

Human capital theory, as developed by Becker (1964) [31], Ben-Porath (1967) [32] and Mincer (1974) [33], posits that individuals invest in themselves through education, training, and health to raise their productivity capacity [34]. Grossman (1972) [35] further developed this theoretical framework of human capital, specifically in relation to health and healthcare. Grossman [35] highlighted an important aspect between health and productivity, where he explained that an individual's stock of health capital determines the time they can spend increasing their earnings..

The concept of health capital is illustrated in Figure 2. Individuals demand health for both consumption benefits and production benefits (i.e., increased earning capacity). Individuals desire better health to enable them to enjoy life more. To improve or maintain their health, individuals must also invest in their time (e.g., personal behaviours such as exercise) and demand health care inputs (i.e., health care interventions). By increasing or maintaining their stock of health capital, they can accumulate healthy days; thus there is value in investing in health. Health stock can also decline over time through illness and injury, or with age.

Figure 2 The Grossman model for investing in health



Source: Based on Figure 7-1 Folland et al. [20]

Health care interventions are a unique commodity because they are treated as both a 'consumption good' s and as an 'investment good' by the individual [35]. Firstly, health is consumed as it increases the capacity of an individual to participate in activities, such as leisure or work. Secondly, investing in health builds a person's health capacity, which facilitates participation in labour, through employment or in the household, and in leisure activities. As investing in health care can enhance population health, there are some important aspects pertaining to the investment and consumption of health care for individual, firms, and the government [35].

Health care may be considered a necessity as it is required for improvement or protection of public health [36, 37]. However, this does not mean all health care is necessary, as priorities need to be considered to determine the importance of health needs. But there is also a public good aspect of health and health care that is needed for producing health capital. Many individuals could gain benefits from health care being available; however, the private incentives to invest in or to produce some these health care interventions are low to negligible, especially when the costs are a significant barrier to access. Consequently, without government intervention, there is a risk of underinvestment in health and health care interventions that are of a public good nature [37, 38].

Uncertainty in health care consumption is a well-known issue [39]. Most people will need to access health care sometime in their lifetime, but when, how and how much health care they will consume is not known with certainty. Other uncertainties pertaining to health care consumption relate to: the complexity of the information about the interventions; the probability of future benefits and risks; and the level of ambiguity in the reliability, credibility and adequacy of the information about the benefits and risks of the intervention [39]. For these reasons, consumers (i.e., the patient) rely on the advice of healthcare providers (and perhaps government healthcare decision-makers) to determine what care is needed. Asymmetry of information is a known issue in health care as providers have more information than patients [39]. A principal–agency relationship is created whereby the principal (the individual requiring health care) is dependent on the agent (the health care provider). The suppliers of health care also typically have greater knowledge about the impact of the health care interventions on the patient's health (known as asymmetry of information) [39]. Individuals may also have preferences about the treatments and care they receive, and they expect the health care provider to act as a perfect agent and take these preferences into consideration [39].

Health care interventions fall into one of three broad categories [39, 40]:

1) **Curative**[2] interventions are those that either restore a patient's health status to full health or somewhat improve the health of the patient. Curative interventions are also used to reduce the degree of deterioration caused by illness (e.g., surgical removal of cataracts).
2) **Care** interventions are those that provide dignity (respect, sympathy, empathy) for people who are ill. Interventions falling under the category of care are more concerned with maintaining some aspect of health rather than improving health per se (e.g., palliative care).
3) **Preventative** interventions are those that aim to reduce the probability of illness or death (e.g., infection control measures for communicable diseases, such as food regulation or vaccinations). Preventative interventions are a special case in that these interventions aim to minimise the

[2] In this thesis, the term 'curative' does not explicitly mean that the patient no longer has the condition or is completely free from illness; it also encompasses cases where the patient has a permanent or chronic condition and medical treatments help alleviate or manage the disease.

risks of being ill (e.g., lockdown restrictions used to reduce the spread of COVID-19). As the use of these interventions traditionally lies outside the scope of what health care is usually considered to entail, interventions may be required from significant stakeholders at the government or business levels, or they may require regulation or legal enforcement, with associated costs of monitoring.

1.5 Economic evaluation

One of the key tenets in health economics is that resources are scarce, choices need to be made about how to allocate resources with the aims of maximising health, wellbeing and welfare [19]. Economic evaluation provides an organised framework to systematically compare interventions so that all relevant alternatives are clearly identified, analysed and evaluated [19]. Economic evaluation can assist the decision-making process of allocating health care resources by allowing for a comparison of different states of the world when one course of action is taken over another.

Tenets of normative economics inform the determination of the most ‘efficient’ allocation with the available resources and budget constraints. Efficiency is a fundamental concept, and in the context of public health outcomes there are two relevant definitions. The first is technical efficiency, which is achieved when health outcomes are maximised for the lowest cost. Application of these principles are primarily applied in an economic evaluation, where some aspect relating to a goal of welfare is maximised. The second form is allocative efficiency, which is achieved when the state is improved, for a given set of resources, such that there is a higher level of utility.

Two theoretical approaches have emerged from the principles of normative economics: welfarism and extra-welfarism. Welfarist and extra-welfarist approaches differ in goals, perspective and the types of analyses that are conducted.

Welfare economics is concerned with maximising social welfare, broadly defined as some function (most often an aggregation across individuals) of individual utility. Within some budget constraint, welfarists seek to maximise social welfare [19]. Welfarists assume that individuals are the best judge of their own welfare and consider all impacts on individual wellbeing. Social welfare is then estimated by aggregating the welfare of the individuals. Using the welfarist approach, the aim of economic evaluation is to compare health and healthcare interventions against all other interventions in other sectors such as education, transportation, police or defence, that also contribute to overall welfare [19]. Cost-benefit analysis (CBA) is the economic evaluation tool used to evaluate interventions using a welfarist approach. The willingness to pay (WTP) and productivity costs are typical outcomes considered in a welfarist’s evaluation. Proponents of CBA argue it is the most comprehensive and theoretically sound form of economic evaluation as it is theoretically grounded within welfare economic theory [41].

Extra-welfarists have a more specific objective. Typically, they aim to maximise health for the available healthcare budget [19]. The extra-welfarist approach is the dominant approach used by decision-makers in the field of health technology assessment – for example, it is used by the Pharmaceutical Benefits Advisory Committee (PBAC) [42] and Medical Services Advisory Committee (MSAC) [43] in Australia, the National Institute for Health and Care Excellence (NICE) in England and Wales [44], and the Canadian Agency for Drugs and Technologies in Health (CADTH) [45]. Extra-welfarists typically assume individuals with the same disease or health state are homogeneous and, thus, that distributional effects of an intervention are not influenced by an individual's socioeconomic status; for this reason, changes in productivity are not explicitly considered in extra-welfarist evaluation. Economic evaluation tools used to evaluate interventions using an extra-welfarist approach are cost-effectiveness analysis (CEA) and cost-utility analysis (CUA).

These differences between the welfarist and extra-welfarist approaches can influence the decision-making process and consequently affect resource allocation [46]. Although the welfarist approach considers the societal impacts of a policy more broadly, distributional concerns arise where economic evaluations favour interventions that support more affluent individuals [47]. For example, the WTP measures used are often influenced by factors such as age, education, income and ability to pay. This limits the applicability of this approach, as it effectively discriminates against individuals who have lower incomes or are not working [47, 48]. While the extra-welfarist approach is considered to be unaffected by an individual's ability to pay, it has also been argued that the extra-welfarist approach is not entirely free of distributional concerns [47].

The viewpoints assumed in an economic evaluation are important, as the appeal of an intervention being considered may depend on the perspective [19]. Commonly, economic evaluations take either a health care payer perspective, which includes costs pertaining to the public health care system, private health care, or a societal perspective, which may include costs for patients and their families, employers, or other government sectors. Economic evaluations taking a societal perspective, should ideally include all relevant costs and benefits, despite where costs and benefits may fall [49-51]. Evaluations taking a health care perspective limit the costs included to those paid within the health care budget; any costs outside this budget are not considered relevant. For example, productivity costs do not fall under the remit of the public health care system budget, so they would not be included. In contrast, evaluations from a societal perspective aim to include all costs and effects, regardless of where these fall, and these would include productivity costs [19]. If the objective of the economic evaluation is expanded to that of maximising welfare, costs outside the health care budget can be as important as costs covered by the health care budget. A summary of the different perspectives and where the costs fall is provided in Table 1.

Table 1 Perspective in an economic evaluation

Perspective	**Other government**	**Public health care system**	**Patients and families**	**Employers**
Costs for medical treatments				
Intervention costs		✓		
Hospital, primary care, physicians, nurses, ambulance, diagnostic, screening, pharmaceuticals, other medical services costs		✓		
Out-of-pocket costs e.g., co-payment for treatments			✓	
Productivity costs				
Patient time: seeking diagnostics and treatment, receiving treatment, travelling			✓	
Paid work: absenteeism and presenteeism			✓	✓
Unpaid work e.g., volunteering, managing household			✓	
Leisure time			✓	
School: absenteeism and presenteeism			✓	
Social services and other non-medical costs	✓			

1.5.1 Types of economic evaluation

Three types of economic evaluation – CBA, CEA and CUA – are regarded as 'full' evaluations because they provide an examination of both costs and consequences of the alternatives being compared [19]. Decisions are often made on the outcomes produced from these analyses. The main difference between these evaluations is the way in which benefits are expressed.

- Cost-benefit analysis: Costs and outcomes are both valued and expressed in monetary terms. The relevant costs and outcomes of the interventions/policies are valued from the perspective of those affected e.g., individuals' willingness to pay (WTP). Costs and outcomes can be either expressed as a ratio showing benefits relative to the costs in a benefits-cost ratio (BCR)[3] [19]. A BCR exceeding '1' indicates a positive net present value (NPV) and

[3] Drummond et al. [15] recommend CBA results not be expressed as a ratio, as the size of the ratio is dependent on what is included in the numerator (e.g., savings can be included as a cost or a benefit).

supports investment of the intervention. Alternatively, the analysis outcomes can be expressed as the net present value (NPV) of the differences in benefits and costs between the interventions.

NPV[4] WTP + S - C

where:
WTP is willingness to pay (monetary units)
S is savings for all public sectors and individuals (monetary units)
C is costs for all public sectors and individuals (monetary units)

- Cost-effectiveness analysis: Effectiveness is measured in non-monetary natural units (e.g., life years gained (LYG) or cases avoided). Alternatives are evaluated in terms of their relative incremental costs per unit of outcome as an incremental cost-effectiveness ratio (ICER) (e.g., cost ($) per LYG, cost ($) per case avoided). The ICER is calculated as:

$$\frac{(C_{intervention} - C_{comparator})}{(E_{intervention} - E_{comparator})}$$

where
C is cost (monetary units)
E is the effectiveness (non-monetary units)

- Cost-utility analysis: Effectiveness is expressed in terms of a measure that captures both morbidity and mortality impacts, typically quality adjusted life years (QALYs). A QALY is a measure of health status and is derived by multiplying a quality of life (QoL) value by the quantity of life years. The QALY weight is anchored by '0', representing the health state 'dead', and '1', representing the 'full health' or 'best imaginable' health state. All other health states will fall somewhere in between the anchored health states.[5] Alternatives are evaluated in in terms of their relative costs per unit of outcome as an ICER e.g., cost ($) per QALY gained. The ICER is calculated as:

$$\frac{(C_{intervention} - C_{comparator})}{(QALY_{intervention} - QALY_{comparator})}$$

Where

C is cost (monetary units)
QALY is the effectiveness (non-monetary units)

Differences in the treatment of savings make it more difficult to compare BCRs across different studies. The reliability of CBA results is heavily dependent on the assumptions made.

[4] NPV denoted in Drummond et al (Table 2.2 p21) as [(W') - (C1+C2+C3+C4)] or [(W+V+S1+S2+S3+S4) - (C1+C2+C3+C4)].

[5] The quality adjusted life year (QALY) weight for a health state can be valued below zero, which represents a health state that is 'worse than dead'.

Economic evaluations within health care are dominated by CEA and CUA, as healthcare payers are often reluctant to use CBA as a basis for decisions [52], largely due to the perception that explicitly placing a monetary value on a persons' life is unethical, and it is thought that health gain should be valued equally regardless of the beneficiary or an individual's ability to pay. Placing a monetary value on health outcomes may also lead to distributional issues. In Australia, both the PBAC[6] and the MSAC[7], prefer making recommendations based on the results of CUAs and CEAs. Although the PBAC do not explicitly state a WTP threshold in the guidelines [42], the monetary value on health outcomes is still considered, albeit more implicitly [53]. In relation to claims of improvements in productivity, the PBAC Guidelines [42] specify that these types of benefits should be presented in an analysis separate from the base case. The main reason that PBAC prefers CUAs or CEAs over CBAs as a primary analysis is that not all costs and benefits presented are relevant to PBAC decision-making [42].

Other government offices, such as the Office of Impact Analysis,[8] prefer to base regulatory decisions on the results of CBAs [54, 55]. Cost-benefit analysis has been used in many different areas of economic and social policy in the public sector for decision-making. The outcome is monetary, which allows for comparison of policies and programmes across regulatory sectors, thus overcoming one of the key limitations of both CEAs and CUAs.

1.5.2 Productivity in economic evaluation

Whether productivity losses should be included in economic evaluations is controversial [49, 51, 56]. Those arguing against inclusion of productivity costs view the addition of productivity costs as a strategy to improve the cost-effectiveness of interventions by increasing the estimate of incremental benefits or reducing the estimate of incremental costs. For example, if a substantial improvement in work productivity (either as a cost or benefit) for a new intervention when compared with usual care is claimed, the CEA would favour funding of the new intervention. Concerns have also been raised about the implications for equity if decisions about allocating public funds are based on substantial

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[6] The Pharmaceutical Benefits Advisory Committee (PBAC) is an independent expert body appointed by the Australian Government. Members include doctors, health professionals, health economists and consumer representatives. The PBAC is responsible for recommending new medicines for listing on the Pharmaceutical Benefits Scheme (PBS). The PBS is a program of the Australian Government that provides subsided prescription drugs to residents in Australia.

[7] The Medical Services Advisory Committee (MSAC) is an independent non-statutory committee established by the Australian Government. The MSAC are responsible for providing advice to Government on whether a new medical service should be publicly funded, including services on the Medical Benefits Schedule (MBS) or other programmes (e.g., blood products or screening programmes).

[8] The Office of Impact Analysis (OIA) (formally known as the Office of Best Practice Regulation (OBPR)), which sits within the Department of the Prime Minister and Cabinet, performs a central role in assisting departments and agencies with the new requirements, as well as in monitoring compliance over time.

societal gains that relate to improved productivity [57, 58]. For example, if interventions are prioritised based on claims of improved productivity, interventions aimed at improving the wellbeing of elderly people or those who have retired from the workforce are less likely to be funded. Other concerns are potential double counting of health impacts if productivity losses are included as an added cost, as changes in health status could be reflected in the numerator (e.g., as savings in patient and family time for an individual), denominator (e.g., if the individual considered their ability to work and earn income during valuation of the health state preference scores) or both in a cost-effectiveness ratio [56].

However, proponents arguing for inclusion of productivity costs consider that complete exclusion is also problematic and more difficult to defend [51, 59, 60]. There are many interventions where the impacts on productivity are substantial and likely to be relevant to social welfare. The proponents of this approach posit that results are not necessarily influential and recommend that the analyst consider whether inclusion of productivity losses is relevant. Following this, they consider that the pertinent question is, 'how, then, should these costs be included?' [51]. The main issue raised by proponents of productivity losses in economic evaluations is that productivity effects are largely ignored because of the lack of consensus on methodology [51]. Quantification of productivity losses will need to be considered in the economic modelling as it is claimed to be a significant consequence of illness.

Methodological guidelines for health technology assessment do vary across countries with respect to the types of productivity losses that should be included. Italy [61], Germany [62], and Norway [63] only consider absenteeism from paid work is only of interest, whereas, the Netherlands [64] encourage inclusion of presenteeism, and France [65] encourage inclusion of unpaid work loss. The NICE guidelines (UK) [66] explicitly state that productivity costs are not included in the reference (i.e., base) case. The Australian guidelines [42] stipulate (p65) a broader social perspective beyond the patient and health care system can be presented in a supplementary analysis in addition to the base case, where productivity costs are not included.

When health problems occur there are trade-offs between paid work, unpaid work and leisure, and the total time spent on the three activities will decrease due to time coping or recovering from illness; however, the reductions may not be proportional [60]. Unpaid labour commonly includes activities pertaining to household production, caregiving, and volunteer work, which are productive activities where another person outside the household or family unit i.e., third person, could theoretically be employed to do the labour, but are not for various reasons [49]. For example, a nanny could be hired to take care of the children. Time spent in pursuing leisure activities cannot be delegated to another person, which is used as the criteria to differentiate unpaid work from leisure activities [49]. However, differentiating unpaid work from leisure activities is difficult in practice as elements of utility can overlap [49], e.g., a person may derive satisfaction for helping family and friends. Although consideration on how to include unpaid work and leisure activities in an economic evaluation framework has been provided [49], however, these productive losses are seldom included [50], and consensus on what instrument should be used to measure loss of paid and unpaid work is lacking [67].

Productivity loss can be separated into components affecting the individual, those affecting other consumers, those affecting the employer and those affecting the government. Components can overlap when valued from the different perspectives [60, 68]. Components contributing to productivity losses will be explored in this thesis by examination of the different methods used to model productivity losses.

1.5.3 Methods of valuing productivity in an economic evaluation

The two main methods used to estimate the value of lost productivity are: 1) the human capital approach; and 2) the friction cost method [69]. However, these two methods can yield divergent estimates due to the differences in the key assumptions [70]. This is challenging for decision-makers and analysts.

The human capital approach assumes that individuals and firms seek to maximise utility and profits. Firms will employ workers at the point where the marginal contribution of the worker is equivalent to the gross wage. For this reason, absence from work is valued according to the gross wage. The human capital approach assumes accrual of losses over a person's lifetime, where the productivity of an individual is measured by the discounted stream of future earnings [60]. Human capital is the result of investment of education and training of individuals to increase productivity and can be a contributor to permanent economic growth. Advocates of the human capital method claim that this is the only approach founded in economic theory [41].

However, the human capital approach has been criticised for grossly overstating productivity losses as it is implicitly assumed that the labour market clears (i.e., in equilibrium), which ignores the possibility of involuntary unemployment, a common feature of labour markets. Secondly, the human capital approach assumes those who die prematurely due to illness would have worked until the end of their working life [69]. The problem with this assumption is that applying productivity costs over this time horizon overestimates losses and may not be representative of the actual losses.

The problems with the human capital approach led to the development of the friction cost approach. The friction cost approach assumes that productivity losses are only incurred during the time taken to replace an employee, known as the friction period [59, 71]. The friction period represents production loss due to reduced labour and is a standard time period defined as the time from when a vacancy occurs to when an individual fully replaces the person who is absent due to illness in the position [72]. This time period includes procedural aspects such as time for advertising and training the individual to fulfil their employment obligations.

There are criticisms of the friction cost approach. The method assumes that a replacement employee is obtained from the pool of unemployed persons; however, they may already be employed elsewhere (and hence would also need replacing in their previous role) [41]. Despite this, the friction cost approach is the method used most frequently in the Netherlands [73] to inform funding decisions for health programmes. Other authors have commented that the friction cost approach has notable advantages and may generate more realistic cost estimates; however, use outside of the Netherlands is hampered by a lack of local data to inform economic modelling [72]. Local macroeconomic conditions such as participation in paid labour and national unemployment rates influences how long it takes to replace a worker (i.e., the friction period) and the cost of replacing a worker [74].

Another approach described in the literature is the US Panel Approach, recommended by the US Panel on Cost-Effectiveness in Health and Medicine [75]. The goal of the US Panel Approach is to standardise the methods of conducting an economic evaluation given the disparity across the discipline [75]. The US Panel Approach values productivity costs in terms of quality of life effects and assumes that income changes due to health. This method implicitly assumes that there is a stable relationship between productivity, income and quality of life. The Panel considered that explicitly including productivity costs would lead to double counting because valuation is included in the health effects [56, 75]. However, many empirical studies have shown that income and productivity are not adequately captured in the US Panel Approach's quality of life measures and recommend against using this measure [76].

Another method that could be used to capture changes in income and health effects is the willingness to pay (WTP) approach. This method has been widely used outside the health sector [77, 78]. The WTP is the maximum amount of money an individual is willing to pay for a commodity; because of this, it is an indicator of utility or satisfaction. In the context of health, the WTP approach aims to ascertain the value that people attach to health care outcomes [79]. The WTP approach has been used in valuations related to foodborne illnesses [80-82]. The technique requires asking respondents how much they would be prepared to pay to obtain benefits or to avoid consequences of illness [79]. Rather than measuring productivity losses in terms of lost wages and separately from health care costs and disutility associated with side effects and treatment, a WTP approach has the potential to incorporate all the impacts on individuals in a single measure. Given that lost productivity will be reflected in forgone wages to an individual, such an approach potentially captures the burden to individuals.

1.6 Rationale for this PhD

Productivity loss due to illness impacts on individuals, firms and society. Issues affecting health are not only a public health concern; these issues can extend beyond the public health domain and affect general welfare. The extent to which issues pertaining to health impact on welfare and productivity (of individuals and on others, firms and society) is unclear. If the aim of government intervention is to maximise the health or welfare of society, better information is required to assist the prioritisation and development of control measures designed to reduce the effects from illness. These measurements should be accurate and meaningful to help inform policy and investment decisions, and, importantly, the perspective that these evaluations take will also have impacts on how allocation decisions are made. Issues relating to double counting of the impacts (productivity and utility) is also an area that remains unclear.

This thesis explores different methods of measuring the trade-offs affecting health, welfare and productivity. There are two main methods used in health economics that take into consideration the measurement of trade-offs and assessment of competing priorities: DCEs and economic evaluation.

In an economic evaluation, measurement of productivity losses due to illness can be investigated in a variety of ways, but there is no consensus of the most appropriate methodology to use [41, 69, 75, 83]. There are clear limitations in the methods currently available to estimate productivity losses and to determine the health outcomes and cost-effectiveness of public health interventions in Australia. Some of these limitations include the lack of data inputs available, such as the friction period, which is an input that underpins the FCA. This thesis aims to generate data to inform the valuation of productivity loss using FCA in the Australian context.

This thesis looks at scenarios where respondents explicitly and simultaneously consider the impacts of illness and effects on productivity, from an individual perspective and a national perspective. As trade-offs may be influenced by the perspective taken, this thesis investigates the effect of different perspectives by examining the trade-offs between health and productivity.

The potential for DCEs to be used to inform an economic evaluation has been noted [52, 84]. A DCE valuing the WTP to avoid foodborne illness in conjunction with the effect on productivity has been conducted as part of the research from this PhD. This thesis will explore the potential of using results from a DCE to inform an economic evaluation.

Methods used in health technology assessment for PBAC and MSAC decisions, differ from other health authorities (such as Food Standards Australia and New Zealand (FSANZ)). Interventions considered under the remit of PBAC and MSAC are typically more expensive and focus on a more targeted population. Methods used in the health technology assessment setting is not the norm for the evaluation of public health interventions. Work in this thesis considers the application of health technology assessment methods to other settings as a proof of concept.

FSANZ are the statutory authority that develop food standards for Australia and New Zealand. Food standards are then monitored by authorities in the states and territories, and the Department of Agriculture, Water and the Environment. As FSANZ have previously used a cost benefit analyses [85] to inform costs relating to foodborne illness in Australia, I use methods utilised by PBAC and MSAC i.e., cost utility analysis.

The research presented in this thesis focuses on two case studies of morbidity: foodborne illness and COVID-19. Issues extending from these illnesses are not easily resolved by providing treatments to those with the illness and typically require preventative interventions to manage the disease spread. Interventions that are used are those that compel individuals and/or firms to shoulder some of the costs in order to prevent illness. For both these illnesses, the possible health impacts range from a mild illness to more severe outcomes, such as hospitalisation or death. Loss of productivity is claimed to be the largest factor increasing the costs of foodborne illnesses [85] and was one of the major reasons driving opposition to lockdown and social distancing restrictions implemented to manage COVID-19 [86]. The extent of actual productivity and economic loss in both these case studies is unclear.

1.6.1 Case study 1: Foodborne illness

Nearly every person in Australia would have experienced gastroenteritis due to a foodborne source [87]. Foodborne illnesses typically result in short-term conditions, such as gastrointestinal illness (diarrhoea, cramps, vomiting etc.). In some cases, serious long-term sequelae may occur, such as irritable bowel syndrome (IBS) or Guillain-Barré syndrome (GBS), haemolytic uraemic syndrome (HUS), and occasionally death [87]. Foodborne illnesses are common around the world, occurring in both developed and developing countries [88].

Costs arising due to foodborne illness and its prevention can be substantial. Associated costs include health care resource use, lost productivity of individuals and businesses, and lifestyle and mortality costs for individuals [85]. Many foodborne illnesses are preventable. Governments often intervene by making significant investments to ensure people are not infected with pathogens from a food source. Therefore, from the Governments perspective it is important to develop a framework that accurately estimates the costs associated with foodborne illness in order to determine the value of the intervention.

In Australia, food safety standards are regulated by Food Standards Australia and New Zealand (FSANZ) [89]. The goals of FSANZ is to ensure that food regulation protects the public but is also efficient. Food safety standards have been established to reduce the burden of foodborne illnesses. FSANZ makes regulatory decisions pertaining to food safety that are a significant investment of public funds and compel the use of private funds. FSANZ may be able to improve the controls used to manage risks associated with the pathogens that cause the most burden to society by employing an economic approach in making these decisions. Accurately estimating the impacts of foodborne illness is important for the development and prioritising of food safety policy.

1.6.2 Case study 2: Infectious disease

An infectious outbreak of the novel coronavirus (SAR-CoV-2, hereafter referred to as COVID-19) was declared to be a pandemic by the World Health Organization (WHO) on 11 March 2020. To reduce mortality from COVID-19, governments imposed stringent disease containment measures such as limitations on travel, physical distancing restriction and closures of schools and workplaces. While these measures have been effective in reducing the spread of COVID-19, they have significantly impacted the economy and have led to reduced economic activity, business closures and unemployment. The COVID-19 pandemic provides a unique and highly topical case study of how to consider the evaluation of policy in relation to infectious disease. The impacts on productivity were a particularly pertinent factor for the policy debate in relation to COVID-19 over recent years.

1.7 Aim and objectives

The overarching aim of this thesis is to evaluate the different methods used to value productivity losses, and to explore new methods for estimating and evaluating the opportunity costs of policy-related interventions preventing illnesses for Australia. In this thesis I explore different aspects (e.g., effect on valuation using different perspectives) of the relationship between health and productivity, and the implications of this relationship for economic evaluation and health policy, using a range of case studies and methods in the empirical chapters. With that in mind, the objectives of this PhD are as follows.

Case study 1 – Foodborne illness

1. To estimate the willingness to pay to avoid a foodborne illness using DCE methods.
2. To estimate the friction costs associated with production loss from a firm's perspective specific to the Australian setting.
3. To assess the feasibility of using the estimated willingness to pay to avoid a foodborne illness in an economic evaluation framework.
4. To develop an economic model that assesses costs and consequences of foodborne illness resulting in an acute illness and chronic sequelae for a specific foodborne pathogen. The implications of different productivity loss valuation methods (human capital approach, friction cost method, willingness to pay) are compared and appraised.

Case Study 2 – Infectious disease

5. To examine the interrelationship between policies used to manage and regulate public health risks that result in lost productivity and changes in freedom.

The work from this PhD is intended to inform the policy framework and to provide insight into opportunity costs arising from decisions being made in prevention of illnesses such as foodborne illness or infectious disease in Australia.

1.8 Outline of PhD

This thesis is presented over six chapters. An overview of DCEs is provided in Chapter 2, which includes a summary comparing the advantages and shortcomings of using revealed preference data compared with stated preference data, and the theory underpinning DCE techniques. This chapter also provides an outline of how to develop a survey incorporating a DCEs, including the steps taken: the refinement of the research question, synthesis of the attributes, designed of the experiment, data analysis and presentation of results. Chapter 2 also provides the rationale for the use of DCE techniques in this thesis.

The purpose of the next four chapters of this thesis (Chapters 3, 4, 5 and 6) is to contribute to the literature by generating new data and extending methods to measure and value changes in health and productivity, and examines the different perspectives taken.

Chapter 3 presents a study using a DCE to value the WTP to avoid foodborne illness in conjunction with the effect on productivity from the perspective of an employee (research objective 1). In this study, the ability to work with and without sick leave entitlements is considered as this is a key feature of the Australian labour market landscape.

Chapter 4 presents a study estimating the time and costs of replacing a worker in Australia from a firm's perspective (research objective 2). These estimates are needed to inform the FCA, which is one method used to value productivity loss in economic evaluation.

Chapter 5 combines the work from the studies conducted in Chapters 3 and 4 and explores the potential of using results from a DCE to inform an economic evaluation (research objective 3). Using foodborne illness as a pedagogical case study, the economic evaluation approaches used to measure productivity losses (HCA, FCA and WTP) are systematically compared and the implications of the different perspectives (individual, firm and society) in Australia (research objective 4) explored. This chapter combines the research presented in Chapters 3 and 4 to further develop the economic evaluation methodology of valuing productivity loss.

Chapter 6 builds on other chapters in that DCE techniques are used to assess preferences for policies used to manage COVID-19 from a national perspective (research objective 5). The DCE in Chapter 3 considered productivity losses from the perspective of an individual person, whereas in Chapter 6, productivity losses considered extend beyond an individual person's perspective. Trade-offs between the health risks (for self and for others) and productivity impacts (e.g., labour shortage, increasing unemployment and welfare payments) were key concerns raised at the start of the COVID-19 pandemic. The catastrophic impact of an illness on productivity would have been considered inconceivable prior to the COVID-19 pandemic. Impacts of the pandemic are broad and more severe due to the impact on people who are well or healthy. Consideration of the COVID-19 restrictions, reflects a contemporary health issue affecting productivity.

Chapter 7 presents a review and discussion of the work conducted in this PhD and examines areas for future research.

Chapter 2: Introduction to Discrete Choice Experiments

A core component of this thesis is the use of discrete choice experiments (DCEs) to examine the interrelationship between health and productivity in the context of foodborne illness and infectious disease. To provide the theoretical framework for these case studies, in this chapter I will discuss the background, key concepts, design construction and modelling methods used when developing a DCE.

Discrete choice experiments are a method of eliciting stated preferences from respondents through a structured survey that presents respondents with a series of choice tasks [90-92]. In a DCE a hypothetical, but realistic, situation is described in which a choice must be made. Respondents are shown a series of sets of possible choices, or choice tasks, where each alternative is described in terms of the levels of a number of different attributes. The multiple levels of each attribute are varied systematically across choice tasks, and the respondents are asked to choose the option they prefer from each choice task they are shown. Thus, a DCE is an attribute-based survey method used to quantitatively measure benefits or utility and to evaluate trade-offs made in decision-making [90-92].

An example of a DCE choice set is provided in Figure 3 [93]. In this DCE, the choice task represents two takeaway pizza options. Each option is characterised by six attributes, such as pizza type, size, price and delivery times, that represent realistic attributes to consider when choosing where to order a takeaway pizza. These attributes are presented at a specific level in each choice option. The respondent is then asked to choose the option (the takeaway pizza outlet, in this example) they prefer from each pair presented to them.

Figure 3 Example of a choice set in a DCE

	Outlet A	**Outlet B**
Pizza type	Traditional	Gourmet
Type of crust	Thick	Thin
Ingredients	All fresh	Some tinned
Size	Small only	Small only
Price	$17	$13
Delivery time	30 minutes	30 minutes

Suppose that you have already narrowed down your choice of take-out pizza outlet to the two alternatives above. Which of these two would you choose?

(tick one only)

Outlet A ◯ Outlet B ◯

Source: Street and Burgess Table 1.4 p6 [56].

The pizza DCE example illustrates that products/services can be defined by a number of different attributes and that, by creating a choice set, we are explicitly asking respondents to make trade-offs across the levels of the attributes. In this choice task, for instance, if a respondent really wanted a traditional pizza they would have to pay $4 more.

There are quite a number of good systematic reviews available of published DCEs [94-97]. Three systematic reviews specifically examine DCEs conducted in health economics over the period from 1990 to 2017 [94, 95, 97], whilst one other review [96] provided a review of DCEs used in numerous fields (e.g., transport, environmental, and health economics) over the last 50 years. In the systematic reviews specific for health economics, DCEs identified covered a wide range of policy questions, as well providing an overview around the change in trends of methodology over time. DCEs have been used in a various areas of applications examining issues relevant to: valuing patient and consumer experiences, valuing health outcomes, investigating trade-offs for health outcomes and/or patient/consumer experiences, estimating utility weights, job choices, priority setting, preferences for screening and treatment options [94-97].

Understanding preferences is useful for policy and planning. Policies that incorporate features that are considered to be most important to consumers/users are more likely to receive public acceptance and, consequently, to result in greater compliance [94-97]. Many DCEs aim to inform health policy development, as they can be used to elicit opinions to obtain an overview of public perceptions [94, 95, 97]. For example, DCE methods have been used to elicit preferences for features of the Australian health system, where attributes representing level of health, equity, responsiveness and healthcare financing were considered [98]. Another DCE examined public preferences where prioritisation health care concerns were based on personal characteristics that are not explicitly related to a patients' health (i.e., occupational status, health status, quality of life, unhealthy lifestyle, age and family status) [99]. Concerns about using DCEs in the wider policy space centre around concerns of the validity and robustness of the method [100, 101]. Using appropriately designed DCEs, the aims of this thesis include the examination of the importance of policies relating to health and productivity.

Specifically, DCE techniques are used in this thesis to investigate two health problems:

- In the first study, I develop and implement a DCE with the aim of estimating the willingness to pay (WTP) to avoid a range of acute and chronic foodborne illnesses (FBIs). A further aim of this study is to estimate whether ability to work, availability of paid sick leave and quality of life (QoL) affect the WTP to avoid different FBIs. In scenarios where people experience a foodborne illness, respondents are asked to trade off duration of illness and treatment costs against income, where they were asked to consider the trade-offs in ability to work, and sick leave entitlements.

- In the second study, the aim was to understand the preferences of Australians regarding strategies to control the risks of a pandemic. Specifically, the study sought to measure the trade-offs between mass unemployment, restrictions in freedom, and mortality and health risks at a national level and how preferences across individuals and groups might differ.

2.1 Overview

2.1.1 Data: revealed vs stated

In economic theory, it is assumed that consumers seek to maximise their utility from the choices they make and that the utility associated with goods or services can therefore be inferred from these choices. That is, preferences can be ascertained from observed choices, allowing utility functions to be estimated. The two main types of data used to analyse preferences are revealed and stated preference data.

Traditionally, economists use observed market consumption behaviour (i.e., revealed preference data) to estimate demand or to determine an individual's preferences for particular goods or services, as the choice made is assumed to maximise utility subject to their budget constraint [84]. These data are typically obtained from transactions that are made in actual market situations, and the choices that consumers make are recorded [91, 92, 102, 103]. For example, sales information can be obtained using supermarket scanner data, and information can thereby be collected on the choices that consumers make and their preferences for products or the features of a particular product can be inferred. However, even in standard markets, it is not always possible to infer preferences from revealed preference data [102, 103]. For example, a pharmacy might only stock three types of over-the-counter (OTC) pain medication (e.g., ibuprofen, paracetamol and diclofenac), but there are other OTC pain medications that are not stocked, such as aspirin or naproxen. Ascertaining the preferences for OTC pain medications using sales data may be difficult for a few reasons. Firstly, it may be unclear which of the features of the product led to final purchase [102, 103]. Perhaps the consumer considered the side effects profiles or felt that one type had more benefits than the other types. If there is limited variation between the product features, such as differences in price, that may influence the choice made, then the impact of product features on preferences will be difficult to estimate [102, 103]. Other information may be unknown when analysing the sales data [102, 103]; for example, the set of options available to the consumer from the pharmacy, and whether or not the pharmacist made a recommendation at the point of sale, may not be known to the analyst. Sales data will also exclude preferences for consumers who choose not to purchase one of the three types of OTC pain medications the pharmacy stocked. The use of revealed preference data is more difficult in many areas of applied social science research, such as health economics, when it is not always possible to directly observe preferences or choices made in actual markets or there is not enough information such that observed choices can be used to estimate preferences [97]. Some general limitations include [102]:

1) The product/intervention/program of interest does not exist yet. Therefore, there are no revealed preference data available to determine preferences.
2) There may be correlation between the underlying features of the intervention, making it difficult to ascertain which features are preferred by consumers.
3) Revealed preference data exists but there is little to no variation in the explanatory variables making it difficult to develop reliable models of behaviour.

As discussed in Chapter 1, consumers may not always know when, how or how much health care they will need, and often rely on the advice of healthcare providers. Due to these distinctive features of health and healthcare commodities (e.g., uncertainty and risk), estimating preferences or choices made by consumers using revealed preference data can be difficult [91]. Limitations in using revealed preference data to estimate preferences that are specific for health economics arise due to:

1) Asymmetry of information: where there is a disparity in knowledge between the consumer and the provider. Due to this, health and healthcare choices made by consumers may not be independent of recommendations made by the provider.
2) The existence of insurance (public and private), where the purpose of insurance is to guard against the costs of uncertainty and illness. Insurance changes the demand for healthcare for consumers, as it means that they are shielded from some of the costs of health and healthcare commodities.
3) Revealed preference data are limited by the extent of the data that was collected and choices recorded may be subject to omitted variable bias. We may observe the outcome of the choice, but other information around the circumstances that led to that choice may be lacking sufficient detail; for example, other changes may have been introduced at the same time that may have confounded or influenced the choices made, but this data is not recorded. This is more relevant for choices pertaining to health and healthcare where there is more risk and uncertainty associated with the final decision than there is for other choices such which breakfast cereal to buy.

To overcome these limitations, stated preference methods provide an alternative approach to elicit and estimate the preferences of consumers. In stated preference experiments, it is common to describe a situation in which a choice needs to be made, together with a set of possible options, and respondents are then asked to state their preferred alternative [102]. Other advantages of using stated preference methods are that there is flexibility in observing hypothetical choices behaviour by being able to control the relationships between attributes, enabling for comparisons between existing, generic or proposed alternatives, and collecting multiple observations from each respondent [102, 103]. Typically, respondents are shown a number of different sets of possible options and their choices can be used to model the relative attractiveness of features of each the options. Although, there are some criticisms of stated preference methods that should be noted. The main criticism often cited as a concern is that stated preference methods are subject to hypothetical bias reducing the face validity of results, as the choice observed may not be what is chosen in reality [95, 104]. Results can be used to derive welfare measures and conduct of policy analyses, raising concerns of potential misuse [104]. For example, respondents may have a vested interest in that good or service being provided and as such overstate their WTP which is above what can actually be paid [104].

A DCE is a type of stated preference method.

2.1.2 What is a DCE

A DCE is a stated preference method that elicits preferences from consumers by exploring the trade-offs they make when choosing between a set of products/services [97]. In a DCE, respondents are exposed to one or more hypothetical scenarios (referred to as the choice context or scenario) and, for each scenario, are presented with a series of choice sets (also called choice tasks) representing products or services. They are then asked to choose the option they prefer. Each choice task is nested under a scenario, and each option represents a product or service described by attributes with varying levels. The attributes are chosen to represent the features of the product or service that may impact on the decisions that a person makes. Choice responses are then modelled to estimate the impact on the utility of each of the attributes and the different levels of the attributes.

DCE methods have been used in many fields, such as transport economics, environmental economics, marketing and health economics [97, 105, 106]. DCEs were introduced into health economics in the early 1990s and have been used to investigate a wide range of topics, including estimating demand for new products or programs, assessing changes in policy, understanding patient experiences, valuating health outcomes, making job choices, setting priorities and determining preferences for treatment and screening [97].

2.1.3 Advantages of DCEs methods

For health services researchers, DCEs have some notable advantages:

1) A properly designed DCE is an efficient way to establish respondent preferences, especially when revealed data are unavailable. The assignment of choosing an option is easily understood from a respondent point of view and, given that respondents are asked to repeat the tasks, the choice tasks should be easy to comprehend.
2) As data to be collected is determined prospectively, preferences can be explored in more detail than would be possible using revealed preference data, which is subject to endogeneity issues and can make it difficult to disentangle the impact of different attributes on choices made. Firstly, the relative importance of each attribute can be estimated individually. This is particularly useful when exploring the importance of the levels of the attributes, as well as the relative strength of their importance (holding all else equal), and whether these attribute levels are desirable or not, relative to the base level of the attribute. Secondly, DCEs can be used to estimate the trade-offs between the different attributes. This is particularly relevant when cost is included as an attribute, as it is possible to calculate the WTP for each of the attribute levels. WTP has the additional benefit of providing a common base in which to compare strength of preferences.
3) DCEs have also been used to estimate WTP values in numerous health-related studies [97]. Between 2013 to 2017, 80 studies had reported outcomes in terms of WTP using DCE techniques [97]. It is also possible that WTP values derived from DCEs could be used to inform economic evaluations [84]. Guidance for using DCE in an economic evaluation has been outlined by Lancsar and Louviere (2008) [84].

2.1.4 Limitations of DCE methods

There are also some limitations with a DCE approach that should be acknowledged. Results from DCEs are occasionally viewed with some scepticism as the method is inherently hypothetical in nature and, consequently, has been criticised for lacking external validity [107]. As an example, bias in results may arise if choice tasks do not adequately reflect real-life decision-making, such as when an important attribute that could potentially influence a respondent's choice is not included (known as missing attribute bias). Alternatively, a DCE that is too cognitively demanding – for example, due to the inclusion of too many attributes or too many options in each choice task – may lead to respondents becoming fatigued and/or developing techniques that simplify the choice process, such as focusing on a limited number of attributes, or choosing the first option that is 'good enough'. These are some of the issues that can bias the results of a DCE, as preference data is incomplete

[107]. During the analysis stage, misspecification of the model can also lead to an inaccurate assessment of the impact of the attribute levels.

As DCEs can be used to derive WTP values, it is also important to note that the range of WTP estimates are determined in part by the range of costs included in the study, and so may not reflect the maximum that a consumer is willing to pay. True estimates of the WTP are conditional on taking up treatment.

To minimise the impact of some of these pitfalls, DCEs require careful development and should be piloted to test for understanding and comprehension.

2.2 Theoretical framework

DCEs are based on Lancaster's economic theory of consumer choice and McFadden's random utility theory (RUT) framework [108]. In Lancaster's theory of consumer choice [109], it is assumed that utility is derived from the underlying attributes of the goods, and that preferences for these attributes (and therefore utility) across options are revealed through consumption choices [109]. The theory of consumer choice posits that an individual will choose the option that maximises their utility when faced with several choices, and changes in the features (of a good) can effect a switch from one option to another option.

The concept of RUT was proposed by Thurstone in 1927 [110], introduced into economics by Marschak in 1959 [111] and further developed by McFadden in 1974 [108], who argued utility comprises a systematic component and a random component [92]. The theory behind RUT states that an individual has the ability to perfectly discriminate between options presented to them, so they can construct the utilities of each of their available options. The key assumption that underpins random utility models (RUMs) is that individuals make a discrete choice, because they can only choose one option (i.e., one bundle of goods), and that choice is the option that provides the greatest utility for that individual. However, a researcher may not be able to observe all factors that affect preferences; hence, utility is unobservable and assumed to be random [103]. The random components may arise because of unobserved or unobservable attributes, unobserved variations in taste, and measurement and specification errors.

Random utility theory provides the framework to analyse the choices made by individuals in DCEs [108]. The RUM of behaviour [108] can be used to explain how an individual, i, who is faced with a choice among j alternatives, obtains a level of utility, U_{ij} from each alternative. The alternative that provides the greatest utility is chosen by the individual so that $U_{ik} > U_{ij}$ for all $j \neq k$.

Individual choice behaviour is probabilistic. The probability of an individual choosing *j* is given in Equation 1 [112]:

Equation 1

$$
\begin{aligned}
P\,(Y_j = 1) &= P(U_{ij} > U_{ik}) \qquad \forall\, j \neq k; \\
&= P(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}) \\
&= P(V_{ij} - V_{ik} > \varepsilon_{ik} - \varepsilon_{ij})
\end{aligned}
$$

where $Y_j = 1$ is an indicator that the individual has chosen alternative *j* if that alternative has maximised their utility (and is zero otherwise). The term $V_{ij} - V_{ik} > \varepsilon_{ik} - \varepsilon_{ij}$ cannot be determined exactly, as the difference between the error terms, $\varepsilon_{ij} - \varepsilon_{ik}$, is unobserved. The alternative chosen is assumed to have highest utility and these utilities will not change; hence, in discrete choice models only differences in utilities matter [103].

The specification for the individual's utility (U_{ij}) for a particular alternative is given in Equation 2 [112]:

Equation 2

$$
U_{ij} = X_{ij}\beta + \varepsilon_{ij} \qquad \text{where } i = 1,\dots,n;\ j = 1,\dots,J;
$$

where, the deterministic component, $X_{ij}\beta$, consists of X_{ij}, which is a (0,1) vector indicating which levels of each attribute appear in option *j* (assuming dummy coding[9]) motivating the choices, and β, which is the vector of coefficients to be estimated. Utility is not observed as the component ε_{ij} is unobservable. The models that are then estimated depend on assumptions that are made about the distribution of the error term and the nature of the choice being modelled [92]. This is discussed further under data analysis below.

2.3 Development of a DCE

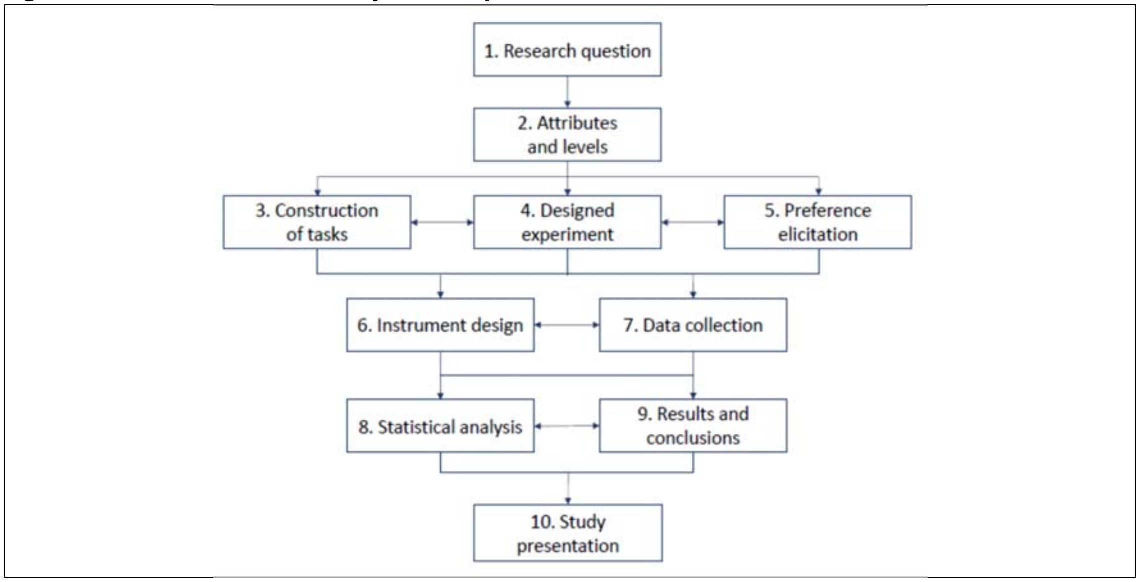
In contrast to revealed preference methods, where data is observational in nature, stated preference methods require prospective collection of experimental data. Study designs need to be considered *a priori* and factors affecting or biasing the study results should ideally be identified and minimised. For this reason, a thorough deliberation about what data should be collected in the survey instrument, including the choice tasks of the DCE design, and how data is to be analysed should be conducted to ensure research objectives can be met before any study data is collected.

[9] For dummy coding, there is an omitted level (i.e., base level) for each attribute that allows for a comparison of the other attribute levels with the base level.

The survey instrument developed should also provide a clear explanation of the choice context to respondents.

Qualitative and quantitative methods are used to develop a survey featuring a DCE. Steps in developing a survey instrument incorporating a DCE have been recommended by the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) taskforce, which has provided a checklist to facilitate good research practices [113]. Additional guidelines for the qualitative development of DCEs are outlined by Hollin et al. [114]. A summary of the stages of developing a survey instrument incorporating a DCE is provided in Figure 4.

Figure 4 Checklist for conjoint analysis in health care



Source: Bridges et al. [113], Figure 1, p.405.

DCEs are generally designed to test hypotheses relating to the strength and relative importance of preferences and trade-offs between attributes defining the research question specified [115]. Qualitative methods – such as literature reviews, consultation with experts, and focus groups and interviews – are used to identify and select attributes and attribute levels. The aim at this stage is to ascertain the potential attributes, and corresponding levels, that are considered important and relevant for decision-making. The attribute levels are selected such that differences in the alternative are apparent but not so extreme that they predetermine the choices made [113].

The observed data is modelled as a function of the attributes and levels; as such, the functional form of attributes (e.g., continuous, categorical) determines the number of parameters (i.e., coefficients, β) to be estimated in the model. If the functional form is assumed to be continuous, then the number of levels used must be large enough to accommodate the estimation of the assumed polynomial, and linearity specifications need to be assumed. Using a categorical representation for an attribute increases the number of parameters to be estimated in the model. The functional form of the attributes and levels is mapped onto choice tasks that are presented to respondents and are taken into account when designing the experiment [116].

Once the attributes and levels have been selected, a quantitative check should be conducted – for example, by conducting a simulation study or by launching a pilot study – to ascertain whether respondents have understood the survey and DCE tasks, review whether the range in the attribute levels selected sufficiently capture trading without predetermining choices, identify whether any of the attributes included are ignored by respondents (i.e., attribute non-attendance) and ensure that parameters can be estimated [116]. During this stage, issues identified may still be rectified prior to proceeding with the full study.

2.4 Designed experiment

A systematic and planned design process is used to collect data from a DCE. This process requires manipulation of the attributes and their levels such that they are predefined without measurement error, and where there is enough variation to establish the preferences among the choice alternatives within each choice set [102]. The purpose of the designed experiment is to manipulate attributes and their levels to permit rigorous testing of certain hypotheses of interest [102]. The literature on the construction of designed experiments is extensive; see Street and Viney [117] for an overview. There are many methods available to construct designed experiments, as well as software packages that can facilitate creation of designed experiments – for example, Survey Engine [118] and Ngene software [119].

2.4.1 Efficient designs

There are various ways to construct designs for DCEs. Consideration of the design of the DCE is important as which models can be estimated is dependent on the underlying structure of the choice sets, and it is important that parameter estimates are precise and unbiased [93]. The aim of an efficient design is to minimise some property of the variance–covariance matrix prior to conducting the survey [117]. The optimality criterion most commonly used is D-optimality, whereby the determinant of the variance–covariance matrix is minimised, which corresponds to minimising the generalised variance of the parameter estimates [93, 117]. While other functions of the covariance matrix have been used (such as the trace, the minimisation of which corresponds to minimising the average variance of the parameter estimates), the fact that the determinant of the inverse of a matrix is the inverse of the determinant of the matrix means that it is easy to move between thinking about the information matrix and the covariance matrix, and so it has proved to be the most popular way to assess design optimality [120].

In the two studies in which DCEs are presented in this thesis (Chapters 3 and 6), the designed experiment were forced choice and used to fit main effects models. I used two methods of design construction, one in each chapter. For Chapter 3, where a DCE is used to estimate the WTP to avoid a foodborne illness, a D-efficient design constructed using Ngene software [119] was used. This D-efficient design was constructed with a goal of estimating the main effects of a multinomial logit (MNL) model. Construction of D-efficient designs using Ngene software is a method frequently used to design experiments in health economics; 21% of DCEs described in publications in health economics between 2013 and 2017 used Ngene for DCE design [97].

For Chapter 6, I used a design constructed using an L^MA approach [93]. As initially introduced by Louviere, Hensher and Swait [102], the L^MA strategy requires an orthogonal main effects plan (OEMP) in which each of the M*A attributes has L levels. The rows of the OMEP correspond to the choice sets of the DCE, and in each row the first A attributes are used to define the first option, the next A the next option and so on. This can be generalised to allow for different numbers of levels for each of the attributes. While the optimality properties of L^MA designs are application dependent, in this case the benefit of being able to have a small design in which various amounts of overlap were present outweighed any gains in efficiency that might have been achieved using another approach. In this study, a DCE is used to explore the trade-offs between economic and health outcomes during a pandemic. For this study, it was likely that respondents would focus on the number of deaths and always choose the option with the lower number of deaths. To prevent choices being driven by this attribute, overlap (i.e., the presence of the same level in both options) had to be present in some of the choice tasks. When overlap is present across the options, respondents are forced to trade off on the other attributes presented. However, as the attribute for the number of deaths may not have been the only driver of choices, choice sets needed to be constructed such that there was overlap for other attributes in the options presented as well. Using an L^MA design allows for more complex designs that have this feature.

2.4.2 Main effects and interaction

Designs for DCEs commonly only consider main effects, which assumes that each attribute has a direct, independent effect on the choice made. It is anticipated that these direct effects will explain most of the variation in preferences [94]. However, main effects may not be the only effects influencing choices made, and interactions between attributes may also be of interest [116]. Interaction effects were not allowed for in the estimation from the designed experiments discussed in this thesis, as the inclusion of interactions requires a much larger design and thus a much larger sample than was possible for these studies.

2.4.3 Priors

During the construction phase of the designed experiment, prior knowledge or information (i.e., priors), such as data from other studies, a pilot study, or logic can be used to inform the likely magnitude of the coefficients. The variance–covariance matrix is a function of the true values of the parameter vector, β, which is to be estimated, and some argue that assumptions need to be made about the parameters so that the best design for a DCE can be chosen [119]. Other authors [121, 122] argue that a robust design that makes no assumptions about the prior values is preferable. Priors can be included into a design by either assuming a fixed point prior value for parameter β, for example, $\beta = 0$ or $\beta = \beta_p$, or by incorporating the uncertainty of the prior information by assuming a prior distribution for β, such as $N(\beta_p,\Sigma_p)$ [119].

Inclusion of informative priors could result in a more statistically efficient design; conversely, the application of incorrect priors may reduce the expected efficiency of a designed experiment relative to another design with uninformative priors [121, 122]. A small negative prior for the cost attribute ($\beta_{cost} = -0.001$) was used to inform the DCE in Chapter 3 (WTP to avoid a foodborne illness) [119]; no priors were used inform the DCE in Chapter 6 (Exploring the trade-off between economic and health outcomes during a pandemic) [121, 122].

2.5 Survey instrument software

Collecting data via an online survey is a common approach to collecting DCE responses and has been effective for other DCE studies conducted for health economic research [123-125]. Such a collection can enable data to be collected from population panels in a timely and efficient manner. The full survey including the DCE was programmed using Survey Engine [118], an online software platform specifically designed to collect DCE data. Using Survey Engine software, surveys can be created with graphics, complex branching and randomisation of respondents to the blocks of the DCE. For both DCEs in this thesis, for the main launch Survey Engine collected data from the online panels and reported on the progress of enrolment.

Survey Engine provides different level of services for researchers wishing to conduct survey research (URL https://surveyengine.com/services/). Surveys can be conducted by either uploading the survey oneself or with full support from Survey Engine. For the first DCE study (Chapter 3, WTP to avoid different FBIs), the full survey and designed experiment were provided to Survey Engine for coding online. Once the full survey was uploaded by Survey Engine, I tested the survey functionality, reviewed all survey questions and provided feedback on changes to be made prior to launch. This study was jointly funded by Food Standards Australia New Zealand (FSANZ) and the Department of Health.

For the second DCE study (Chapter 6, COVID-19 restrictions), I programmed all survey questions and choice sets from the designed experiment using the Survey Engine software. This was to take advantage of a free student licence and provided an opportunity to learn how to code the survey, conduct pilots and test the survey independently.

2.6 Data analysis

There are several software packages that can be used to analyse choice experiment data. For this thesis, data were analysed using Stata software versions 15.1 and 16.1 [126, 127].

The MNL analysis method is often employed as the starting model for analysis of choice models [90, 128]. The conditional logit model (CLM) is a form of MNL analysis and was conducted as the initial analysis in both studies. Extensions of MNL analyses were also conducted, specifically the random parameters mixed logit model (MXL) [103] and the latent class model (LCA) [129].

As discussed, under the theoretical framework, the RUM of behaviour [108] can be used to explain how an individual, *i*, who is faced with a choice among *j* alternatives in scenario, *s*, obtains a level of utility, U_{ijs}, from each alternative. Given the scenario *s*, the alternative that provides the greatest utility is chosen by the individual; that is, if *j* is chosen then $U_{iks} > U_{ijs}$ for all $j \neq k$. The specification for utility (U_{ijs}) is given in Equation 2 above and has been extended in Equation 3 to include the scenarios, *s*.

Equation 3 $$U_{ijs} = X_{ijs}\beta + \varepsilon_{ijs}$$

where $i = 1,\ldots,n$; $j = 1,\ldots,J$; $s = 1,\ldots,S$

The deterministic component, $X_{ijs}\beta$, consists of X_{ijs}, which is a (0,1) vector indicating which levels of each attribute appear in option *j* (assuming dummy coding), and β, which is the vector of coefficients to be estimated. The component ε_{ijs} is unobserved; consequently, utility is not observed. However, this disturbance term ε_{ijs} is treated as random for all *j* alternatives and assumed to be independent and identically distributed (IID) type-I extreme value, which results in a MNL specification. The MNL specification imposes a restriction that assumes that choices are independent of the other options in the choice set such that *j* and *k* only depend on the characteristics of *j* and *k* (i.e., independence of irrelevant alternatives (IIA) assumption). Modelling under this assumption restricts substitution between these alternatives and implies a proportional substitution pattern, which does not take into account preference heterogeneity.

The MXL extends the MNL model by allowing for random coefficients, which allows for modelling of preference heterogeneity. Specification of a random variable in the model estimates an additional parameter, which is the standard deviation of the effect among the individuals. A flexible variance–covariance structure for the unobservable errors in MXL can be specified, which relaxes the restriction of independence of irrelevant alternatives (IIA) necessary for MNL modelling. By relaxing the IIA constraint, flexible substitution between alternatives is permitted. The panel nature of the data, in the form of repeated observations per respondent, is also taken into account. The specification for the MXL is given in Equation 4 [112]:

Equation 4 $$U_{ijs} = X_{ijs}\beta + (\eta_i X_{ijs} + \varepsilon_{ijs})$$

where $i = 1,\ldots,n$; $j = 1,\ldots,J$; $s = 1,\ldots,S$, η_i is a random term with a zero mean and distribution which can be specified, $\eta_i \sim N(0,\Sigma)$ and ε_{ijs} is random with an IID extreme value distribution. Assuming random variables to be specific to an individual induces correlation across choice situations.

The latent class (LC) model can be used as an alternative way of exploring preference heterogeneity. The LC model assumes there are *Q* latent classes with distinct preferences and predicts the probability of an individual belonging to a specific class [130]. Preferences do not vary within each class; however, preferences vary across the latent classes. Each LC has its own fixed β, which is the vector of coefficients to be estimated. The optimal number of latent classes is determined by comparing the goodness of fit statistics of LC models, which differ by the number of classes. This procedure requires several models to be run with differing class numbers (e.g., from 2 to 7 classes). The goodness of fit statistics used to assess the optimal number of classes are the Bayesian Information Criterion (BIC); Akaike's information criterion (AIC); and Consistent Akaike's information criterion (CAIC). The LCA model selected with the best fit is based on the review of goodness of fit statistics by Dziak et al. [131], where the theoretical and practical advantages and disadvantages of selecting model fit based on various criteria for goodness of fit are discussed. In this review, model selection should consider sample size, relative importance of sensitivity compared with specificity, and ease of the interpretation of results.

Latent classes can be investigated by adding class membership parameters as covariates for predicting class membership; for example, this may include age, sex, employment status and income [132]. Alternatively, characteristics of respondents likely to have preferences aligned with each latent class can be investigated using MNL regression models. In these analyses, respondents are assigned to a latent class based on the highest posterior probability based on their choice responses. Class assignment was used as a dependent variable and respondents characteristics were used as the independent variables in an MNL model.

The trade-offs between attributes are estimated using the marginal rate of substitution (MRS), which is the willingness of a consumer to replace one good for another good. These part-worth utilities are estimated using coefficients from the MNL to calculate the MRS. For example, the marginal WTP for each part-worth utility can be derived using the coefficient for cost as the numeraire.

The ISPOR guidance checklist recommends presenting statistical findings, including which attributes or levels were or were not significant in the context of the research question, and uncertainty associated with the estimates [113]. For this thesis, both DCEs were conducted using the ISPOR guidance checklists [113, 115, 116].

Chapter 3: Willingness to pay to avoid a foodborne illness

3.1 Overview

As outlined in the introductory chapter, foodborne illnesses (FBIs) are very common. In 2010, there were an estimated four million cases of foodborne gastroenteritis and 35,000 cases of chronic related sequelae in Australia [133]. Thus, while most FBIs are mild and self-resolving, there are some long-lasting serious sequelae that require long-term intensive treatments.

Food safety policy-makers need quantitative and accurate estimates of the economic and public health burden of FBI, so they can evaluate the risks, benefits and effectiveness of food safety regulations [134]. Understanding these impacts using accurate estimates can aid in determining how resources can best prioritise and allocate funds in preventing FBI, especially when resources are limited [134].

Despite the short duration of most FBIs, lost productivity is one of the largest costs associated with FBI, where productivity losses are borne by businesses and individuals where time off work is needed to recover from illness or to care for others [85, 135]. However, the methods typically used to estimate lost productivity have been criticised for overestimating the actual burden of illness, particularly when using the human capital approach (HCA) to estimate productivity costs [136, 137]. Although the friction cost approach (FCA) could be used (since the FCA is considered to be more conservative, as costs are limited to the duration of the friction period), both of these methods capture only the costs of lost wages; neither typically includes costs associated with disutility caused by the illness [136]. Another approach to estimating lost productivity is to estimate an individual's willingness to pay (WTP) to avoid a foodborne illness. The WTP is a measure of benefit from the perspective of an individual, which is grounded in welfare economic theory [52]. In the context of health, WTP is the maximum amount of money an individual is willing to pay to avoid an illness and is therefore a good indicator of utility or satisfaction [10]. One benefit of focusing on WTP is that, rather than estimating productivity losses in terms of lost wages, a WTP approach has the potential to incorporate all impacts, such as lost wages, health care costs and disutility in a single monetary measure.

WTP can be estimated directly using revealed preference techniques (as described in Chapter 2). For example, estimates can be derived from responses to the price based on market observations from actual market transactions. Stated preferences techniques can also be used to estimate WTP even when market data are unavailable. Stated preference techniques include direct survey methods, where respondents are asked how much they are willing to pay for a product, and indirect techniques based on rating or ranking exercises using conjoint analysis and discrete choice analysis.

A few studies have estimated the WTP to avoid a foodborne illness where the severity and duration illness were considered [81, 82]. While these studies have accounted for the pain and disutility associated with foodborne illnesses, they have not explicitly taken into account lost wages from the employee's perspective. In this chapter, I address these shortcomings by estimating the WTP to avoid and reduce the duration of a foodborne illness while accounting for lost earnings and reduced quality of life. As a novel addition to this experiment, I also investigate whether having employee paid sick leave impacts an individual's WTP estimate.

In this study I develop and implement a DCE to estimate the WTP to avoid a range of acute and chronic FBIs. As part of the experiment, respondents are asked to trade off the negative consequences of acquiring a FBI against the respondent's ability to work, availability of paid sick leave and quality of life (QoL). To my knowledge this is the first DCE to examine preferences to avoid the negative aspects of both acute FBIs and the chronic sequelae of FBI.

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Author contribution: The research question and methodology and the design of the study were developed by KM, SG, PH, BM and RV. I performed the data analysis and interpretation of results and drafted the manuscript. All co-authors contributed to the interpretation of the results, reviewed the manuscript and approved the final version for submission to a journal.

Post publication notes:

The work from this Chapter was under peer review at the time I submitted the thesis for examination and was accepted prior to receiving the examiner reports. At the time of acceptance, the peer reviewers considered the paper was interesting, important and impactful, and that the interpretations of this paper were appropriate. Post publication another reasonable interpretation of the results was suggested by one of the examiners and this is presented below.

Respondents were asked to imagine having the illness. The duration of illness was not specified in the vignette, which forced respondents to make a choice. The base levels for the attribute, duration of illness was set to one day for an acute illness and one year for a chronic illness. Accordingly, the marginal WTP for duration of illness could also be interpreted as a reduction to one day for an acute illness or one year for a chronic illness. The marginal WTP estimated in this DCE, does not consider the difference between absence of disease compared with one day or one year of disease, consequently, the marginal WTP may be underestimated. This is an area that could benefit from future research to estimate the difference between the absence of illness compared to one day (acute illness), or one year (chronic illness) to obtain a more accurate estimate of the WTP.

3.2 Publication/manuscript

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ORIGINAL PAPER

Estimating the willingness-to-pay to avoid the consequences of foodborne illnesses: a discrete choice experiment

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Abstract

Lost productivity is one of the largest costs associated with foodborne illness (FBI); however, the methods used to estimate lost productivity are often criticised for overestimating the actual burden of illness. A discrete choice experiment (DCE) was undertaken to elicit preferences to avoid six possible FBIs and estimate whether ability to work, availability of paid sick leave and health-related quality of life affect willingness-to-pay (WTP) to avoid FBI. Respondents ($N = 1918$) each completed 20 DCE tasks covering two different FBIs [gastrointestinal illness, flu-like illness, irritable bowel syndrome (IBS), Guillain–Barre syndrome (GBS), reactive arthritis (ReA), or haemolytic uraemic syndrome (HUS)]. Attributes included: ability to work, availability of sick leave, treatment costs and illness duration. Choices were modelled using mixed logit regression and WTP was estimated. The WTP to avoid a severe illness was higher than a mild illness. For chronic conditions, the marginal WTP to avoid a chronic illness for one year, ranged from $531 for mild ReA ($1412 for severe ReA) to $1025 for mild HUS ($2195 for severe HUS). There was a substantial increase in the marginal WTP to avoid all the chronic conditions when the ability to work was reduced and paid sick leave was not available, ranging from $6289 for mild IBS to $11,352 for severe ReA. Including factors that reflect productivity and compensation to workers influenced the WTP to avoid a range of FBIs for both acute and chronic conditions. These results have implications for estimating the burden and cost of FBI.

Keywords Discrete choice experiment · Productivity · Foodborne illness · Willingness-to-pay · Compensation · Sick leave

JEL Classification I12

Introduction

Foodborne illnesses (FBIs) are very common, with an estimated two billion cases per year worldwide [1]. Foodborne illness can result in gastrointestinal (GI) and non-gastrointestinal illnesses, and can have serious long-term chronic sequelae [2, 3]. While mild cases are typically of short duration, self-resolving or managed with over-the-counter medications [1, 4], sequelae of serious cases of FBI may require intensive treatment over a long period of time [1, 2, 4].

Most FBIs occur unexpectedly, and the focus of intervention is on prevention through food safety and on management of side-effects. Accurately estimating the burden and cost of FBI is important for the development and prioritising of effective food safety policy and treatments. In Australia and the UK, the annual cost of FBIs has been estimated at AUD$1.2 billion (USD $860 million) and £1.9 billion (USD $2.4 billion) respectively [5, 6]. These estimates included costs, such as health care use and lost productivity. Productivity losses are one of the main drivers of cost, where double counting or omission of health impacts remains a key issue [5, 7–9]. Productivity is the output per unit of input of capital or labour and measures the contribution of individual workers to a firm [10]. If a worker is unfit to work there is a loss of productivity (reduced output), and under the assumptions of a competitive market, this can be measured by the wage of the worker which reflects the value of the marginal product [12, 31–33]. There may also be a loss of wages to the individual who is unable to work due to illness, but this may not capture the full cost to the individual because it does not capture the disutility of being ill.

The willingness-to-pay (WTP) to avoid a FBI is another measure that could be used within a cost–benefit analysis framework and help inform decision making. The

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individual's WTP should in theory capture the value to them of the lost productivity (in the form of foregone wages), as well as the disutility of illness and any out of pocket costs of treatment. However, established labour market structures and compensation mechanisms such as paid sick leave entitlements in Australia, may affect WTP estimates [11]. Having paid sick leave entitlements means time can be taken off work without financial loss to the individual, but these costs are generally borne by the employer [8, 12]. Therefore it is important to consider the effect of paid sick leave in any WTP estimates.

One method available to assess population level preferences and measure WTP is through a discrete choice experiment (DCE) [13]. DCEs are a stated choice method where alternative scenarios are described in terms of various features (attributes) and respondents are asked to choose their preferred option from those presented. These choices can then modelled to estimate preferences for each level of each attribute presented in the experiment. DCEs have become widely used in health economics [14, 15]. By including a cost attribute the WTP for a good or service can be estimated. In previous research, DCE methods have been used to assess respondent preferences for risk of contracting campylobacter via food or water [16], and to assess the negative impacts of irritable bowel syndrome (IBS) (though without the specific context of FBIs) [17].

In this study we develop and implement a DCE with the aim of estimating WTP to avoid a range of acute and chronic FBIs, to inform cost estimates of different FBIs. The WTP to avoid an illness provides a measure of the opportunity cost associated with the illness because it captures both the impacts on QoL and the opportunity cost of time. A further aim of this study is to estimate whether ability to work, availability of paid sick leave and quality of life (QoL) affect the WTP to avoid different FBIs. To our knowledge this is the first DCE to examine preferences to avoid the negative aspects of both acute FBIs and the chronic sequelae.

A variety of pathogens cause FBI, including *Campylobacter* spp., Shiga toxin-producing *E. coli*, *Salmonella enterica*, *Salmonella enterica* ser. Typhi, *Shigella* spp., *Yersinia entercolitica*, norovirus, *Listeria monocytogenes*, and *Toxoplasma gondii* [18]. Common symptoms are nausea, vomiting, and diarrhoea. Symptoms may differ among the pathogens and some FBI may become severe and life-threatening. In this experiment, six common conditions were chosen, two acute illnesses: GI illness and flu-like illness; and four chronic illnesses: IBS, Guillain–Barre syndrome (GBS), reactive arthritis (ReA), and haemolytic uraemic syndrome (HUS). These chronic illnesses were considered to be the prominent sequelae of foodborne infection [2, 3] with long-term health impacts, and have been considered in several burden of FBI studies [4, 5, 9, 19, 20].

Methods

We designed a DCE that described typical FBIs and their consequences as attributes. The theoretical framework for DCE techniques is based on Lancaster's economic theory of consumer choice and McFadden's random utility theory framework [21, 22]. The survey instrument was developed using the steps recommended by the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) taskforce [23].

Survey development

The DCE tasks were developed, assessed and revised in stages using qualitative and quantitative methods. Existing literature and clinical input were used to develop the vignettes, attribute descriptions and levels. Several studies have investigated the burden of FBIs in developed countries, including a number of studies that have considered QoL (or utility) effects [4, 5, 9, 19, 20]. The utility studies [24–27] used to inform burden of illness studies were reviewed to understand the characteristics that underlie health impacts of FBIs, and assist in developing vignettes and attribute descriptions.

The vignettes, attribute descriptions and levels were assessed and refined based on detailed feedback from a focus group, comprising researchers with experience in implementation of DCEs, and review by a medical expert to ensure descriptions were comprehensive and accurate. Before implementation of the DCE, the funder (Food Standards Australia and New Zealand), also arranged for an external peer review. The DCE survey was pilot tested in a general population sample of Australians ($N = 200$), focussing on the functionality of the survey system, the randomisation procedure, and clarity of the instructions (assessed using feedback questions). The survey contained three sections: (1) demographic information to ensure representativeness in terms of age group, gender, and location by state and territory; (2) the DCE task which comprised a total of 20 choice sets per respondent, with respondents randomised to two different illnesses; and (3) supplementary demographic questions about employment, health, and debriefing questions. Within the choice task section respondents were presented with 10 DCE tasks for the first illness and 10 DCE tasks for the second illness. For each illness, two health states of differing severity were presented (five mild and five severe). A summary of the survey flow is provided in the Appendix (Fig. 4).

DCE task development

Respondents were presented with a series of choice tasks describing a specific FBI profile and were asked to select the most preferred of two treatment options. An example of a DCE task is presented in Fig. 1. Each choice task incorporated three components: (1) a vignette describing the illness, (2) a health state profile describing the QoL and illness severity, and (3) a choice set describing two treatments and work profiles, defined by duration of illness, cost of treatment, and paid sick leave availability/ability to work (Table 1). Respondents were asked to imagine having the illness and health state as described in the vignettes, compare the attributes in the choice set, and then select the most preferred treatment to help the respondent return to normal health.

Vignette

The vignette consisted of background information on one of the six FBIs (Appendix Table 4) and a specific health state profile incorporating QoL and illness severity dimensions (mild or severe) (Appendix Fig. 5).

As part of the background information, a brief description of the symptoms was provided for the two acute illnesses on the basis that these are common with well understood

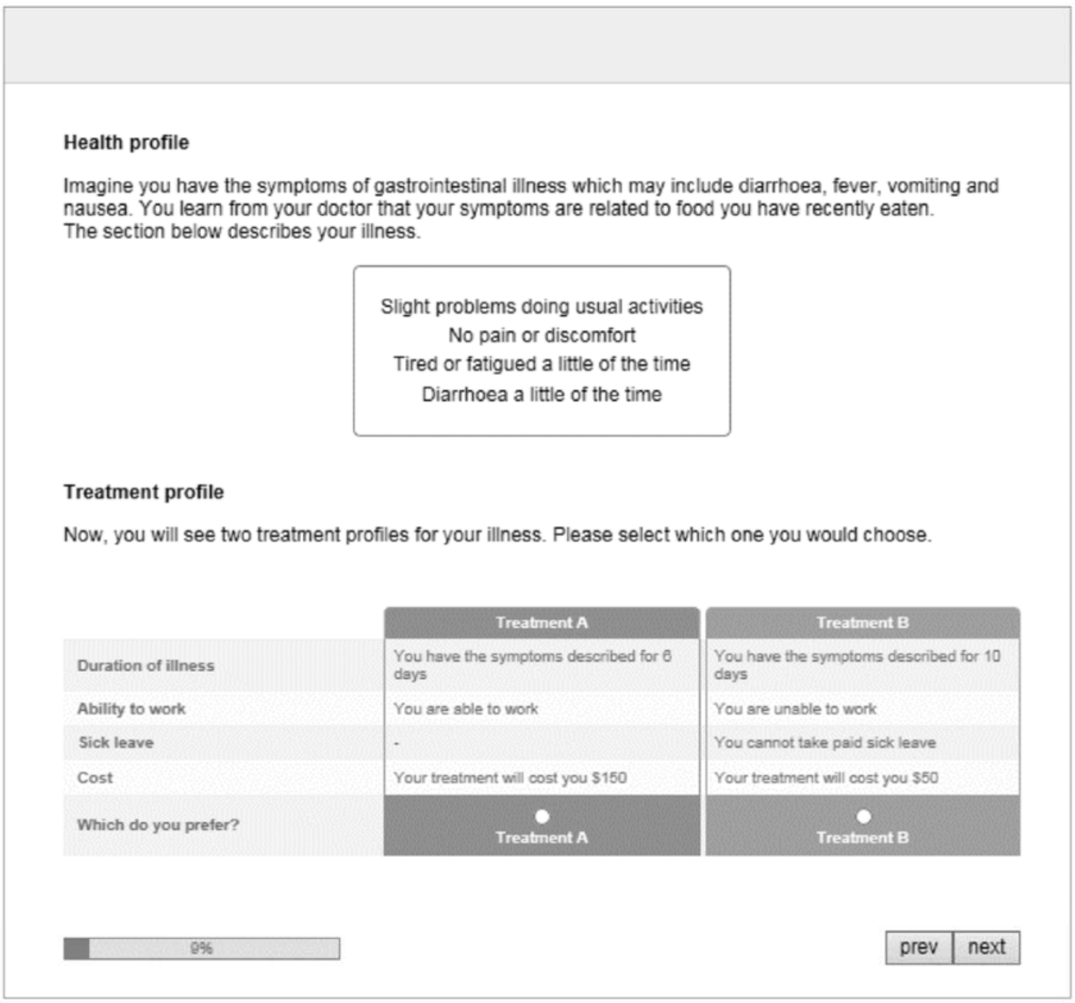

Fig. 1 Example discrete choice experiment

Table 1 Attributes and levels

Attribute	Description	Levels	A priori expectations
Acute illness			
Duration of illness	The duration of symptoms for an illness	You have the symptoms described for 1 day	A negative preference for a longer duration was expected
	Treatment A was always restricted to be of shorter duration than Treatment B	You have the symptoms described for 3 days	
		You have the symptoms described for 6 days	
		You have the symptoms described for 8 days	
		You have the symptoms described for 10 days	
Costs	The out of pocket costs due to the illness	Your treatment will cost you $0	A negative preference for a higher cost was expected
	Treatment A was always restricted to be more expensive than Treatment B	Your treatment will cost you $50	
		Your treatment will cost you $100	
		Your treatment will cost you $150	
		Your treatment will cost you $200	
		Your treatment will cost you $250	
Sick leave[a]	Time off work an employee can use for a health issue without losing pay	You are able to work	No a priori information imputed
	No restrictions were applied for this parameter	You are unable to work and can take paid sick leave	A positive preference for being able to work, followed by being able to take paid sick leave is expected
		You are unable to work and cannot take paid sick leave	
Chronic illness			
Duration of illness	The duration of symptoms for an illness	You have the symptoms described for 1 year	A negative preference for a longer duration was expected
	Treatment A was always restricted to be of shorter duration than Treatment B	You have the symptoms described for 3 years	
		You have the symptoms described for 6 years	
		You have the symptoms described for 8 years	
		You have the symptoms described for 10 years	
Costs	The out of pocket costs due to the illness	Your treatment will cost you $0	A negative preference for a higher cost was expected
	Treatment A was always restricted to be more expensive than Treatment B	Your treatment will cost you $2000	
		Your treatment will cost you $5000	
		Your treatment will cost you $10,000	
		Your treatment will cost you $15,000	

Table 1 (continued)

Attribute	Description	Levels	A priori expectations
Sick leave[a]	Time off work an employee can use for a health issue without losing pay	You are able to work	The first and last levels are ordered correctly, however it is unclear how the other levels should be ordered. There are trade-offs between the levels
	No restrictions were applied for this parameter	You are unable to work some of the time and can take paid sick leave	
		You are unable to work some of the time and cannot take paid sick leave	
		You are unable to work most of the time and can take paid sick leave	
		You are unable to work most of the time and cannot take paid sick leave	

[a]In the DCE, the sick leave attribute was split into two descriptors, 'ability to work' and 'sick leave'

symptoms for the general population. More detailed descriptions were used for the chronic illnesses because these are less familiar to the general population. Descriptions of the illnesses were reviewed by the medical expert and focus groups.

Health state profile

Descriptors of QoL and illness severity were used to differentiate the two health state profiles of the mild and severe cases of each illness. Each health state profile incorporated QoL and illness severity dimensions. The descriptions of the health state profiles for each illness are provided in the Appendix. The descriptions used in the survey to convey the health states to participants was based on validated questionnaires (EQ-5D [28, 29], SF-36 and SF-6D [30, 31], IBS-QoL [32]), which use phrases and statements that have previously been tested with the general population. Severity levels for each condition were reviewed by a medical expert to ensure the language used to describe the health state was consistent with the signs and symptoms of each condition and comprehensible for a layperson.

Attributes

To estimate WTP a monetary attribute needs to be included in the choice experiment. In this experiment this was achieved by including an attribute which described the costs of treatments which could reduce the duration of the episode of illness.

The levels for durations of illness were informed by the literature [2–4] and input from a medical expert. The duration of illness ranged from 1 to 10 days for an acute illness, and from 1 to 10 years for a chronic illness. The levels for the cost attribute were separately defined based on the duration and severity of the illness being valued and were intended to be realistic to respondents. A five-level attribute described the cost of treatment of the acute conditions (range $0 to $250), and a four-level attribute described the cost of treatment of the chronic conditions (range $0 to $15,000). Costs were presented to respondents as the amount that they would pay for treatment.

The ability to work and sick leave attributes were assigned three levels for the acute conditions and five levels for the chronic condition. This was to account for the different characteristics over a longer time horizon. The description of time spent being unable to work was based on the social functioning domain of the SF-36 and SF-6D [30, 31]. Combinations of the ability to work were coupled with availability of paid and unpaid sick leave to explore how respondents consider illness and loss of income simultaneously. The ability to work and sick leave attribute were presented as two separate descriptions in the choice sets to help respondents compare between the components.

Designed experiment

Two designs containing 30 choice sets were selected [33], one for the acute conditions and one for the chronic conditions. D-optimal methods was used to select choice sets using the design software NGene [34] to allow for estimation of the main effects (duration of illness, cost of treatment, and ability to work/sick leave) of a multinomial logit (MNL) model. Duration of illness and cost of treatment were fitted as continuous variables, and ability to work/sick leave was coded as a categorical variable in the design. The choice sets were constructed to force respondents to trade-off between duration of illness and cost, such that the profile for Treatment A in the choice set was always more expensive and had a shorter duration than Treatment B. This ensured that choice sets were not dominated. No restrictions were placed on the sick leave/ability to work attributes. The same design was used across the mild and severe health state profiles to explore how respondents trade based on the severity of the health state.

The sample size was calculated based on the rule-of-thumb to determine the minimum sample size by Johnson and Orme (1996); $N > 500^*c/(t^*a)$, where, c = the largest number of levels of any one attribute; t = no. of tasks; a = no. of alternatives per task. For this DCE, the minimum sample size for one mild or severe illness was $N > [500^*6/(5^*2)] = 300$. Each illness was to be completed by approximately 600 respondents (total $n = 1800$), to provide 6000 observations per illness. This is consistent with the number of observations suggested for valid estimates of DCE parameters [35].

Data collection

Two thousand respondents were recruited (200 for the pilot and 1800 for the main data collection) from an online panel (Toluna Australia). Invitations to participate were sent via email, and respondents were recruited consecutively, then randomised to two different conditions. A small monetary incentive was provided to respondents completing the survey in more than the preset minimum completion time of three minutes. Quotas for age, sex and location by state and territory, were established to ensure comparability to the Australian population.

Data analysis

Data were analysed using Stata software version 15.1. Descriptive statistics were used to analyse the characteristics of the overall sample. Two approaches were used to account for heterogeneity; mixed logit (MXL) and latent class (LC) modelling.

Mixed logit modelling relaxes the constraint that the coefficients are the same for all individuals and allows for flexible substitution between alternatives [36]. Two models for each illness (mild and severe) were estimated using the 'mixlogit' command in Stata, which takes into account repeated observations per respondent [36]. Duration of illness and ability to work/sick leave were specified as random variables in the models. Cost and duration of illness variables were coded as continuous variables, and the ability to work/sick leave was coded as dummy variables. Standard errors were clustered by respondent. Each model was simulated with 500 Halton draws. The reference level for each attribute was used to compare the estimated coefficients (1 day or 1 year; $0; and 'You are able to work').

Latent class modelling is used to classify responses into a distinct number of classes [37], where preferences are similar within a class but differ across the classes. Latent class models for each illness were estimated using the 'lclogit' command in Stata [37]. The number of classes to include was informed by the model with the lowest BIC [38] across models ranging from two to eight classes. Characteristics that are likely to affect preferences and WTP are employment status and income. Given these characteristics affecting WTP, the variables used inform class membership were age (less than 45 years; 45 years and older), gender (male; female), income (less than $52,000 per annum; $52,000 per annum or more), employment status (employed; not employed) and sick leave (no sick leave; paid sick leave).

The marginal WTP for each part-worth utility was derived using coefficients from each mixed logit model using the cost of treatment attribute to calculate a marginal rate of substitution (MRS), that is, the change in the cost attribute that would compensate for a change in another attribute [39]. The WTP to avoid a health state for each illness is relative to the respondents' perception of 'no foodborne illness' or 'full health'. The differences in the value between the severe and mild health states provides information about certain characteristics of the state descriptions used for the illnesses and provides an indication of the perceived severity order of the conditions relative to the health states described. To estimate the WTP to avoid an illness, the marginal WTP for the duration and ability to work/

Table 2 Demographics: comparison of respondents and the Australian population

	Completers ($N=1918$) *n* (%)	Australian population[a]
Age, years		
18–24	194 (10)	13.2%[b]
25–34	338 (18)	14.8%
35–44	351 (18)	13.4%
45–54	363 (19)	13.1%
55–64	311 (16)	11.5%
65 and over	361 (19)	15.2%
Gender, male, *n* (%)	876 (46)	49.7%
Residential state in Australia		
Australian Capital Territory	30 (2)	1.6%
New South Wales	589 (31)	32.0%
Northern Territory	16 (1)	1.0%
Queensland	401 (21)	20.1%
South Australia	162 (8)	7.1%
Tasmania	48 (3)	2.2%
Victoria	491 (26)	25.2%
Western Australia	181 (9)	10.8%
Country of birth, Australia	1465 (76)	71.5%
Highest level of education completed		
Primary or secondary	597 (32)	43.0%
Trade certificate/diploma	600 (31)	20.8%
Bachelor's degree	528 (28)	17.0%
Higher degree	193 (10)	5.5%

[a]Source: Australian Bureau of Statistics [41, 42]

[b]Includes age groups 15–19 year old and 20–24 year old

Table 3 Income and employment status

	Completers ($N=1918$) *n* (%)
Employed	1041 (54)
Self-employed	172 (9)
Working for an employer	869 (45)
Entitled or eligible to receive sick leave	672 (77)
Gross income, per year	
\$52,000 or more	633 (33)
\$20,800—\$51,999	614 (32)
\$1—\$20,799	356 (19)
Other, nil income, negative income, prefer not to say	315 (16)

sick leave level are added for each health state. For example, the WTP to avoid one day of a severe case of GI illness when sick leave is not paid would be \$176 (i.e., \$32+\$144).

Results

Population

The survey was completed by 2022 respondents (response rate 45.8%). Analyses were conducted on respondents who completed the full survey ($N=1918$). The majority (76%) of the sample agreed or strongly agreed that they considered the whole description whilst completing the tasks.

The demographic characteristics of the sample are summarised in Table 2 and Table 3. Respondent demographics characteristics were similar across all conditions. Compared to the national average, respondents were slightly less likely to be born overseas and had a higher level of educational attainment. Over half of the respondents were employed (54%), and of those 62% reported working full time in the past week; 77% reported having paid sick leave entitlements. Respondents in our sample on average had lower incomes (AUD \$600 to \$799 per week) than the Australian median (AUD \$1012 per week) [40]. Approximately two fifths of the sample had prior experience of an acute FBI.

Preference weights

Mixed logit models

The results for each MXL model are presented for each illness in Fig. 2 and in the Appendix (Table 5, 6). For all illnesses, respondents preferred lower costs for treatment and shorter durations of illness. The coefficients for treatment costs and duration of illness were significant for all illnesses ($p<0.01$). The availability of paid sick leave affected preferences. Respondents would prefer unable to work with a case of severe acute GI if paid sick leave were available ($p=0.009$), compared with being able to work. The standard deviations for all random coefficients in the acute illness models (except for flu-like illness, unable to work with paid sick leave), indicated that there is heterogeneity in the preferences across the sample.

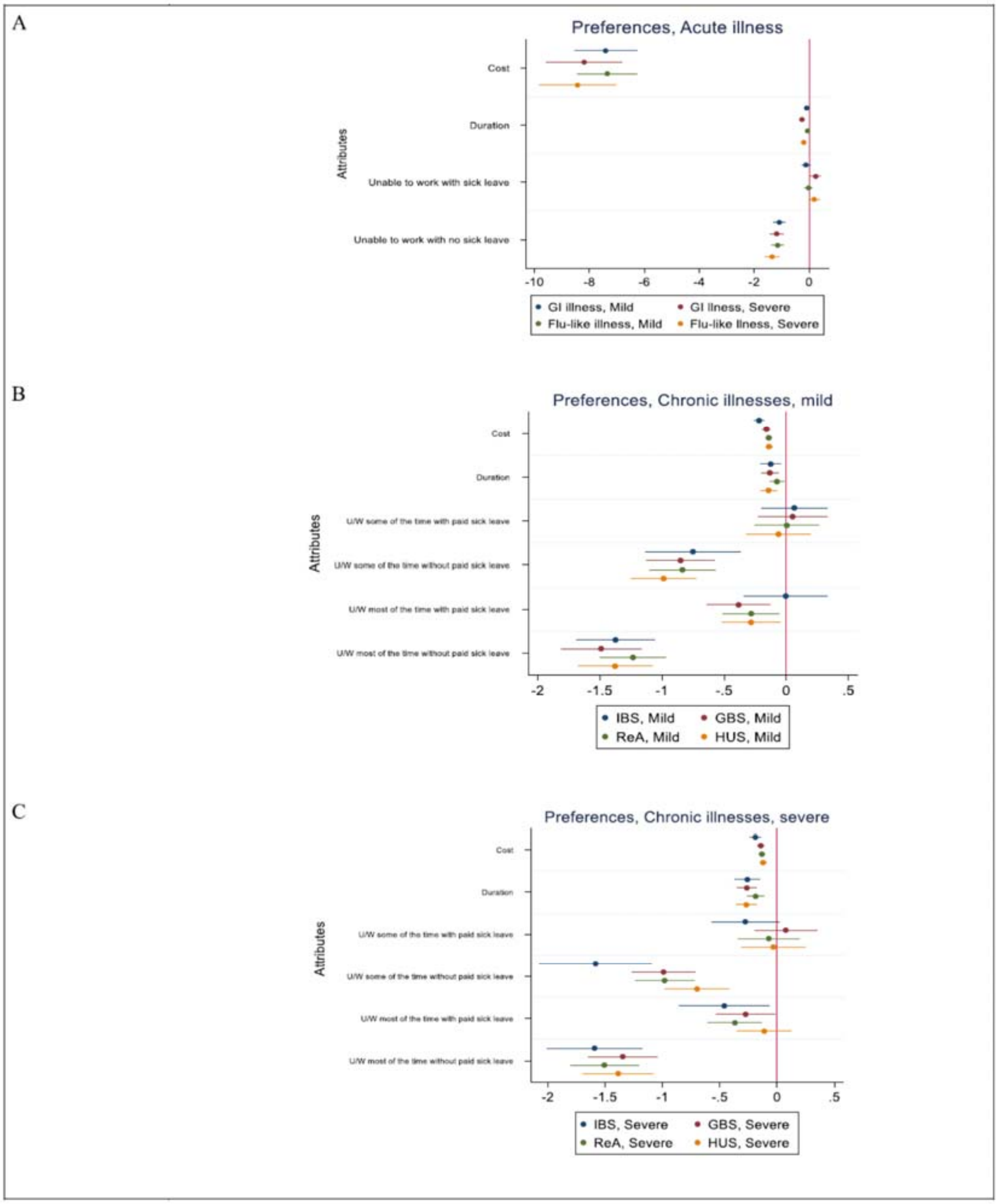

Fig. 2 Preference estimations (95% CI). *CI* confidence interval, *GBS* Guillain Barre syndrome, *GI* gastrointestinal, *HUS* haemolytic uraemic syndrome, *IBS* irritable bowel syndrome, *PSL* paid sick leave, *ReA* reactive arthritis *U/W* unable to work

For the chronic illnesses, the coefficients for being unable to work some of the time when paid sick leave was available were not significant. There was significant heterogeneity in preferences when paid sick leave were available and faced with being unable to work some of the time for mild GBS and severe HUS and being unable to work most of the time for severe IBS, severe GBS and mild HUS.

The results indicate that respondents had the strongest preference to avoid being ill and unable to work when sick leave was not available. In all models, coefficients for being ill without paid sick leave were statistically significant ($p < 0.01$). Except for severe GBS, severe ReA, and mild HUS, the standard deviations were statistically significant for the coefficients where sick leave was not paid, indicating a variation in the preference estimates with respect to being unable to work when sick leave pay is not available.

The overall results for the ability to work and sick leave attribute in the chronic illness health states were ordered as expected. Being able to work was preferred to being unable to work, and being unable to work some of the time was preferred to being unable to work most of the time. This pattern was consistent across all models.

Latent class models

The results for each LC model are presented for each illness in the Appendix (Tables 7, 8, 9). Based on the BIC estimates the best fit was the model with three classes for all illnesses, other than for mild and severe flu-like illness (the best fit was four classes), and mild GBS (two classes). As the improvements in BIC estimates for these models were minimal (less than 1%) compared with the three class models, the models with three classes are presented for all illnesses for consistency. Across the 12 illnesses no clear pattern was discernible, although, there were differences in preferences for duration of illness and costs observed.

The LC model for the mild flu-like illness was able to clearly distinguish between differences in the underlying taste pattern (mean posterior probability, 0.820). Class 1 (share, 47.9%) were more likely to be male ($p < 0.05$) and older ($p < 0.05$) compared with class 3 (share, 17.8%). Class 1 prefers being well to not being ill for any duration ($p < 0.001$), not paying for treatment costs ($p < 0.001$), and prefers not being unable to work without paid sick leave ($p < 0.001$). Class 2 (share, 34.2%) were more likely to be older ($p < 0.05$) and not employed ($p < 0.05$) compared with class 3. Class 2 strongly prefers not paying for treatment costs ($p < 0.001$); surprisingly, class 2 prefers being ill to being well ($p < 0.001$). Preferences estimates for the ability to work and the availability of sick leave attribute were not statistically significant for class 2.

In the LC model for ReA, Class 1 (share, 35.3%) were more likely to be older ($p < 0.05$) than class 3 (share, 51.3%). Class 1 preferred being ill to being well for any duration ($p < 0.05$) and preferred not paying for treatment costs ($p < 0.01$). Class 1 preferred being unable to work some of the time with paid sick leave, however strongly preferred not being unable to work most of the time without paid sick leave. Class 2 (share, 13.4%) were more likely to be younger in age compare with class 3, and strongly preferred not being ill for any duration ($p < 0.001$). In the reference, class 3, preferences were ordered such that respondents preferred not being ill for any duration ($p < 0.001$), not paying for treatment costs ($p < 0.001$), and they preferred being able to work compared with not being able to work some or most of the time, with or without sick leave.

Willingness-to-pay to avoid an illness

The marginal WTP values for each attribute are presented in Fig. 3, and Appendix Tables 7, 10, 11. Results are reported in Australian dollars in 2017. The marginal WTP to avoid a mild acute GI illness for one day was $12 and $32 for a severe acute GI illness. The results for flu-like illness were similar. The marginal WTP to avoid a mild chronic illness for one year ranged from $531 for ReA to $1025 for HUS, and for a severe chronic illness ranged from $1367 for IBS to $2195 for HUS.

The increase in the WTP is generally larger when transitioning from the mild to the severe health states compared to the transition from not being ill to a mild illness health state. Respondents were willing to pay more to avoid a severe case over a mild case for one year; 114% more for HUS, 122% more for GBS, 138% more for IBS, and 166% more for ReA.

If unable to work most of the time without paid sick leave, the marginal WTP ranged from $6289 for IBS to $9872 for HUS to avoid a mild chronic illness; and to avoid a severe chronic illness the marginal WTP ranged from $8,394 for IBS to $11,352 for ReA.

The marginal WTP to avoid a chronic condition were not statistically significant when respondents were faced with being able to work some of the time and if sick leave was paid for the mild and severe health states. There is a large variation in the results of marginal WTP for ability to work/paid leave across all the illness models reflecting differences in the perceived severity of the conditions.

Discussion

The study included a range of FBIs, which has allowed for an assessment of preferences for avoiding the health and loss of work disutility associated with different illnesses over short and long-terms using WTP. When using WTP to estimate

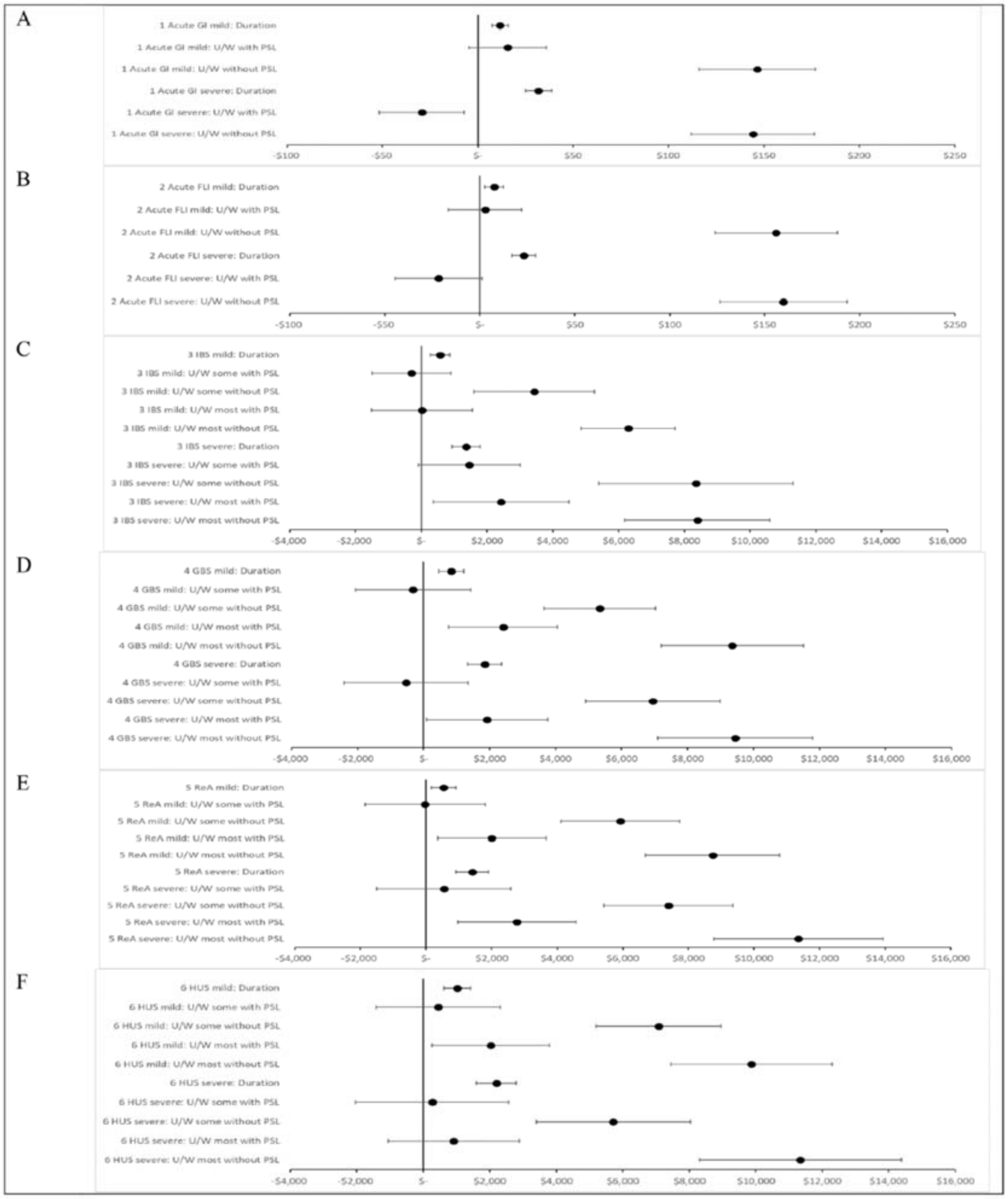

Fig. 3 mWTP (95% CI) ($AUD 2017). *CI* confidence interval, *FLI* flu-like illness, *GBS* Guillain Barre syndrome, *GI* gastrointestinal, *HUS* haemolytic uraemic syndrome, *IBS* irritable bowel syndrome, *mWTP* marginal willingness-to-pay, *PSL* paid sick leave, *ReA* reactive arthritis, *U/W* unable to work

the costs of these illnesses, the WTP will incorporate both the disutility of the illness to the individual and the impact of productivity losses (as measured by foregone wages). This means that WTP has a potential advantage compared with using market wages alone as it incorporates disutility to the individual as well as productivity losses. The inclusion of an attribute that varied ability to work, with and without paid sick leave, allowed us to consider how these factors affect individuals' assessment of WTP. By considering paid and unpaid sick leave we are able to capture the extent to which this is a factor that would drive differences between productivity losses as measured by wages and productivity losses as measured by WTP. These estimated values could be used in economic evaluations that are based on a cost–benefit analysis framework.

The increases in the WTP for mild and severe health states were ordered as expected, with smaller incremental costs being associated with the transition from not being ill for any time to a mild illness health state, compared with transitions from the mild to the severe health states. The largest influence on the WTP to avoid a specified illness was observed when respondents were asked to consider their ability to work and the availability of paid leave. For all conditions, when sick leave was not available, participants expressed a stronger preference to avoid being ill and were willing to pay more to be able to work.

The MXL analyses revealed heterogeneity in preferences pertaining to cost, duration and ability to work without paid sick leave. Latent class modelling revealed distinct differences in the preferences observed across the classes with respect to duration of illness and costs of treatment. The preferences for the duration of illness were varied. For each LC models, preferences to not be ill for any duration of time were observed in two of the three classes; however, five of the models included a class where preferences for being ill for a duration of time were observed (class 2 mild and severe flu-like illness; class 1 mild ReA; class 3 mild HUS; class 1 of severe GBS). Preferences observed for most classes across the illnesses were for not paying for costs of treatment.

In the study by Hammitt and Haninger [41, 43] the WTP to reduce risk for a short-term morbidity was approximately $10,000 per statistical case avoided for adults and was twice as large for children. Our estimates for the marginal WTP to avoid a mild acute GI illness and flu-like illness were much smaller in magnitude. This may be explained by the fact that Hammitt and Haninger [43] used attributes based on risk reduction and mortality risk, whereas the attributes in this study focussed on the effect on work force participation and income, cost of treatment and duration of illness.

Respondents had divergent views on the consequences of the acute illnesses. Although we cannot compare the results of each illness directly, based on the MXL results, there is a preference to avoid the impacts of a mild GI illness in comparison to mild flu-like symptoms. The format of the DCE task presented two health states describing the acute illnesses that only differed on one descriptor (diarrhoea and fever), and this may indicate that there is a stronger preference to avoid an increase in frequency of experiencing diarrhoea in comparison to experiencing fever (as described in this study).

There are limitations of this work, as well as criticisms of DCE methods that should be acknowledged. Firstly, although DCEs have been shown to reasonably predict preferences, DCEs are fundamentally hypothetical and have been criticised for lacking external validity [14, 44, 45]. Our study was designed so that Treatment A was always more expensive and seen first, which was done to reduce cognitive burden for respondents. There is some evidence of left–right bias in previous DCEs [46]. In this study, the majority of respondents demonstrated trading behaviour between the two treatment profiles, but there was a small proportion of respondents who always chose the lowest cost (11%) or the shortest duration (4%). Furthermore, there was no opt-out option included. This decision was made during the design of the study, as we opted for forced choice to maximise the information gained from the choice sets. An opt-out could have been added for the acute illnesses, but for consistency across the illnesses we retained the forced choice framework. It is possible that the forced choice leads to higher WTP values. Other limitations in this study pertain to the WTP. Income disparities are a known issue, as the WTP measure is influenced by factors such as age, education, income, and ability to pay [47, 48]. Although we applied quotas by age, sex and location, we did not apply quotas based on income. True estimates of the WTP is conditional on taking up treatment. It is also important to note that the range of WTP estimates are determined in part by the range of costs included in the study, and so it may not reflect the maximum that a consumer is willing to pay for respondents whose WTP is outside of the costs for the average range in a market [49].

The findings need to be considered in the context of the health system, which may have affected preferences in relation to health care costs. If the illness was severe, it may be perceived that healthcare costs could be covered by other means, such as Medicare (Australia public subsidised health care) or via private health insurance. This may differ in other health systems; therefore there is a strong case for repeating this DCE internationally in different health settings. Further qualitative work investigating the reasons behind the different choices made across the conditions, different health profiles, and in the context of different healthcare systems may be beneficial. For example, some of the free text comments entered by respondents indicate that they were also considering other costs that may not be associated with treatment, or only focussed on the productivity costs, or the direct costs, due to out of pocket costs being high for them individually.

Lastly, it is important to note that our descriptions of illnesses were informed by the literature and a medical expert rather than the lived experience of patients. For rare conditions (eg GBS, ReA and HUS), this information would be a valuable addition, for example, by basing the descriptions on qualitative research such as interviews with patients to ensure relevant aspects are captured and the language is appropriate from a patient point of view.

There are notable advantages in using DCE techniques, such as enabling an efficient way of establishing preferences in the absence of revealed preference data and allowing for the relative importance of each attribute to be estimated individually [50]. Another strength of the study was the use of a large representative (in terms of age, gender and region) sample. Feedback from respondents regarding the ease of completion of the survey were comparable to other DCES valuing health states [46]. There is potential for WTP of various populations to be explored, and further work is required to explore the interpretation of these results to inform decision making.

The results suggest that the estimated WTP to avoid FBI is related to the amount of income lost when ill. Entitlements such as paid sick leave reduces the WTP estimates, suggesting that respondents are considering paid sick leave entitlements when they respond. When assessing the welfare changes associated with FBI, care should be taken to avoid double counting. The WTP with compensation reflects the impact of ill health, while the WTP without compensation reflects to some extent the individual income loss. The later would result in double counting if the productivity losses faced by firms were also included, therefore it may be more appropriate to estimate productivity losses separately.

Conclusion and policy implications

Reliable estimates of the economic costs of specific foodborne infections are needed for policy makers to develop, prioritise and implement control measures with a net benefit to society. Most FBI can be prevented which reduces health care use and treatment costs. Preventative strategies are usually employed in food safety policy to reduce the incidence of FBI.

Lost productivity is one of the largest costs associated with the burden of FBI, but is often criticised for overestimating the actual burden of illness. Using WTP offers an alternative method for estimating costs, but it is important that this considers the effects of employment conditions, which influences values differently for short-term and long-term illnesses.

The findings from this DCE study illustrate that respondents value the consequences of the FBI based on important factors of severity of the illness and do consider the effect on productivity to be important in the long term. There are differences in preferences that translate into substantial differences in WTP to avoid an illness. These results have implications for estimating the burden and cost of FBI and suggest that as income loss is tempered by availability of paid sick leave.

Appendix

See Figs. 4, 5, 6 and Tables 4, 5, 6, 7, 8, 9, 10, 11

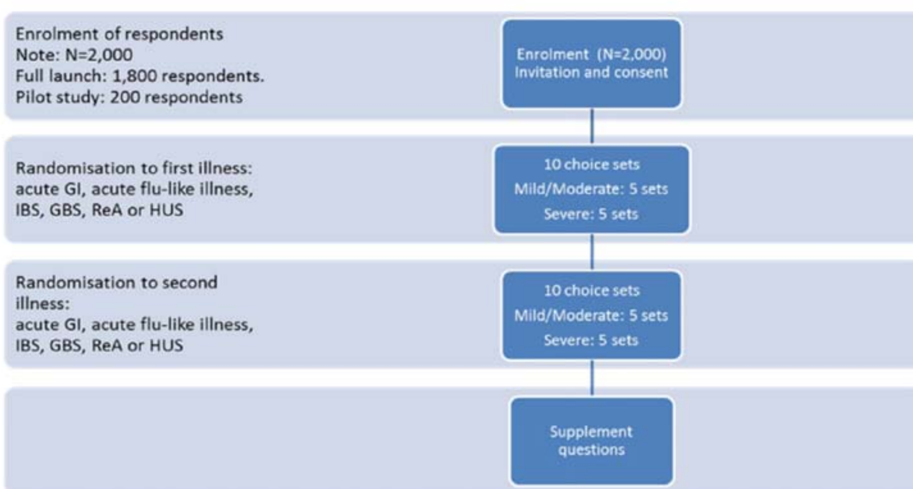

Fig. 4 Survey layout

Gastrointestinal illness

		Mild	to	Severe
No foodborne illness	→	Slight problems doing usual activities No pain or discomfort Tired or fatigued a little of the time Diarrhoea a little of the time	→	Severe problems doing usual activities Moderate pain or discomfort Tired or fatigued most of the time Diarrhoea most of the time

Flu-like illness

No foodborne illness	→	Slight problems doing usual activities No pain or discomfort Tired or fatigued a little of the time Fever a little of the time	→	Severe problems doing usual activities Moderate pain or discomfort Tired or fatigued most of the time Fever most of the time

Irritable bowel syndrome

Full health	→	Slight problems doing usual activities No pain or discomfort Tired or fatigued a little of the time Nervous, anxious or sad about your illness some of the time Somewhat restricted in the kinds of food you eat You have some warning of symptoms occurring You have 2 episodes a month	→	Severe problems doing usual activities Moderate pain or discomfort Tired or fatigued most of the time Nervous, anxious or sad about your illness most of the time Very much restricted in the kinds of food you eat You have no warning of symptoms occurring You have 6 or more episodes a month

Guillian-Barre syndrome, reactive arthritis, and haemolytic uremic syndrome;

Full health	→	Slight problems doing usual activities No pain or discomfort Tired or fatigued a little of the time Nervous, anxious or sad about your illness some of the time Slight problems in walking about Slight problems washing and dressing yourself	→	Severe problems doing usual activities Moderate pain or discomfort Tired or fatigued most of the time Nervous, anxious or sad about your illness most of the time Severe problems in walking about Moderate problems washing and dressing yourself

Fig. 5 Health state descriptions

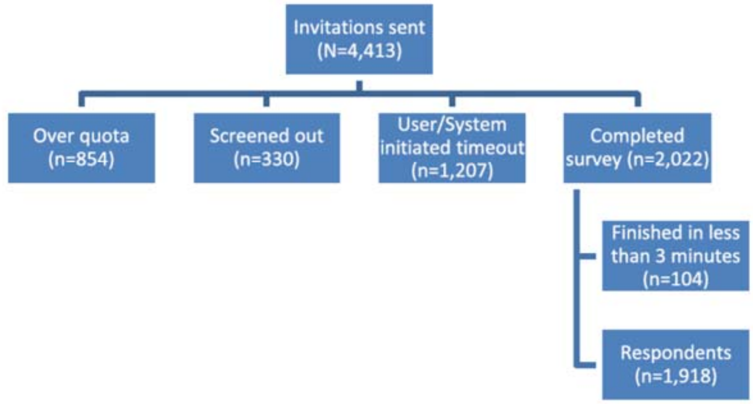

Fig. 6 Disposition of respondents

Table 4 Description of the illness

Condition	General description
Gastrointestinal illness	Imagine you have the symptoms of gastrointestinal illness which may include diarrhoea, fever, vomiting and nausea. You learn from your doctor that your symptoms are related to food you have recently eaten
Flu-like symptoms	Imagine you have symptoms which may include fever, muscle or body aches, headaches and are feeling tired. You learn from your doctor that your symptoms are related to food you have recently eaten
Irritable bowel syndrome	Irritable bowel syndrome (IBS) is a condition that results in pain and altered bowel habits, such as diarrhoea or constipation. People with IBS generally have abdominal cramping, lower belly pain, discomfort and bloating. The pain associated with IBS may be relieved by going to the toilet. The condition can last a long time and can affect life on a daily basis. For most people, the symptoms are intermittent. Symptoms associated with an episode of IBS generally last for two or so days
	What is an episode? An episode is diarrhoea or constipation that may last for a few days at a time
	For some people, the onset of an episode can be related to the types of food they eat, and there may be some warning of an episode, however, others may receive no warning of an episode. This may affect how or when they go out with friends or family, what they eat, or how they plan their day. This can result in social isolation
	When people with IBS go out, they often need to consider availability of toilet facilities. There are periods of time where sufferers have more frequent episodes than other times
	Irritable bowel syndrome doesn't cause lasting damage and doesn't contribute to the development of serious bowel conditions, such as cancer or colitis. There is no known cure for IBS and treatments are generally for management of individual symptoms
Guillian-Barre syndrome	Guillain-Barré syndrome is a rare and serious condition of the nervous system. It occurs when the body's immune system attacks part of the nervous system
	The symptoms of Guillain-Barré syndrome usually develop two to four weeks after a minor infection, such as a cold, sore throat or gastroenteritis (an infection of the stomach and bowel). Symptoms often start in your feet and hands before spreading to your arms and then your legs
	Initially, you may have: pain, tingling and numbness, progressive muscle weakness, co-ordination problems and unsteadiness (you may be unable to walk unaided)
	This can result in hospitalization or an emergency department visit
Reactive arthritis	Reactive arthritis is an illness which describes a group of symptoms including arthritis (swelling and pain of the joints), conjunctivitis (irritation and inflammation of the eye), and urethritis (urinary tract inflammation). In many patients, one or two of these symptoms may be present. Swelling and pain in the joints most commonly occurs in the knees and ankles, which may cause pain when walking or exercising
	The symptoms of reactive arthritis usually develop one to four weeks after a minor infection, such as gastroenteritis (an infection of the stomach and bowel)
	There is no known cure for reactive arthritis and treatments are generally for management of individual symptoms used to reduce inflammation and simple pain relief
Haemolytic uremic syndrome	Haemolytic uraemic syndrome (HUS) is a rare condition caused by a bacterial infection that releases toxins into the body. The illness stops the kidney's filtering system from working
	The symptoms of HUS usually start as abdominal pains and diarrhoea lasting about a week. Fatigue and weakness then develop about two to eight days after the initial infection
	Appropriate treatment can lead to recovery, however, permanent kidney damage is possible, and in some cases HUS is fatal. Treatments may admission to hospital and in more severe cases admission to the intensive care unit. If chronic kidney disease develops, close observation in the hospital is required, and long-term treatments including dialysis, a kidney transplant and blood transfusions may be required

Table 5 Preference, acute illnesses (mixed logit models)

	Gastrointestinal illness ($N=670$)				Flu-like illness ($N=662$)			
	Mild		Severe		Mild		Severe	
	β	SD	β	SD	β	SD	β	SD
Cost of treatment[a] (base: $0)	−7.413***		−8.193***		−7.351***		−8.436***	
Duration of illness (base: 1 day)	−0.087***	0.324***	−0.261***	0.599***	−0.056**	0.371***	−0.196***	0.579***
Ability to work and availability of paid sick leave (base: able to work)								
Unable to work WITH paid sick leave	−0.115	−0.531**	0.240**	−0.861***	−0.02	0.105	0.183	−1.001***
Unable to work WITHOUT paid sick leave	−1.086***	1.131***	−1.182***	1.470***	−1.147***	1.181***	−1.348***	1.412***
Obs	6700		6700		6620		6620	
Loglikelihood	−1938		−1824		−1863		−1789	
AIC	3889		3661		3741		3591	
BIC	3937		3709		3788		3639	

SD standard deviation

[a]Cost was scaled by $x/1000$

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 6 Preferences, chronic illnesses (mixed logit models)

	Irritable bowel syndrome ($N=539$)				Guillain Barre syndrome ($N=603$)				Reactive arthritis ($N=607$)				Haemolytic uraemic syndrome ($N=597$)			
	Mild		Severe		Mild		Severe		Mild		Severe		Mild		Severe	
	β	SD	β	SD	β	SD	β	SD	β	SD	β	SD	β	SD	β	SD
Cost of treatment[a] (base: $0)	−0.218***		−0.190***		0.159***		−0.143***		0.141***		−0.133***		−0.140***		−0.122***	
Duration of illness (base: 1 year)	−0.126**	0.594***	−0.259***	0.856***	−0.133***	0.653***	−0.264***	0.805***	−0.075**	0.546***	−0.187***	0.729***	−0.143***	0.579***	−0.268***	0.762***
Ability to work and availability of paid sick leave (base: able to work)																
Unable to work some of the time with paid sick leave	0.065	0.118	−0.277	0.431	0.051	0.730*	0.075	0.087	0.004	−0.468	−0.072	−0.319	−0.063	0.216	−0.032	−0.880**
Unable to work most of the time with paid sick leave	−0.004	0.037	−0.461*	−0.843**	−0.384**	−0.573	−0.274*	−0.734**	−0.282*	−0.304	−0.368**	0.087	−0.284*	−0.619*	−0.112	−0.281
Unable to work some of the time without paid sick leave	−0.751***	−1.149***	−1.583***	1.201***	−0.851***	−0.710**	−0.990***	−0.564	−0.836***	−0.772**	−0.981***	0.022	−0.987***	−0.454	−0.698***	−0.840**
Unable to work most of the time without paid sick leave	−1.374***	1.211***	−1.592***	1.599***	−1.490***	1.211***	−1.346***	−0.806*	−1.233***	−0.727*	−1.507***	−0.555	−1.378***	−0.981***	−1.386***	−0.684*
Obs	5390		5390		6030		6030		6070		6070		5970		5970	
Loglikelihood	−1386		−1381		−1609		−1562		−1647		−1570		−1619		−1577	
AIC	2794		2784		3240		3145		3316		3162		3260		3176	
BIC	2866		2856		3314		3219		3390		3236		3334		3250	

SD standard deviation

[a]Cost was scaled by $x/1000$

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 7 Preferences, acute illnesses (latent class model)

	Gastrointestinal illness ($N = 670$)						Flu-like illness ($N = 662$)					
	Mild			Severe			Mild			Severe		
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Attributes												
Duration of illness (base: 1 day)	−0.131***	0.045	−0.334***	−0.449***	0.063	−0.103*	−0.222***	0.179***	−0.089	−0.03	0.153***	−0.319***
Cost of treatment (base: $0)	0.282	−15.312***	−9.510***	−2.382**	−15.868***	−7.321***	−9.545***	−12.443***	6.139	−10.349***	−12.808***	−3.632***
Ability to work and paid sick leave (base: able to work)												
Unable to work with paid sick leave	0.122	0.07	−0.629*	0.369**	0.439*	0.032	−0.049	0.127	0.04	−0.502	0.317	0.175
Unable to work with no paid sick leave	0.044	−0.714***	−2.435***	−0.099	0.179	−2.159***	−1.408***	−0.506	−0.261	−5.404	−0.214	−0.675***
Class membership parameters												
Gender	−0.598	0.031	0	−0.327	−0.141	0	0.930*	0.455	0	0.066	−0.035	0
Age	−2.131***	−0.966**	0	−0.192	−0.285	0	0.856*	0.778*	0	0.034	0.127	0
Income	0.291	−0.038	0	0.28	0.582	0	0.543	0.186	0	−0.215	−0.298	0
Employment status	0.054	−0.393	0	0.065	−0.586	0	−0.317	−0.958*	0	0.261	−0.544	0
Sick leave	−0.83	−0.391	0	−0.065	−0.007	0	−0.049	−0.086	0	0.201	0.473	0
Constant	1.419*	1.232*	0	0.352	0.232	0	0.181	0.589	0	−1.423**	−0.383	0
Class share	0.274	0.410	0.316	0.387	0.288	0.325	0.479	0.342	0.178	0.162	0.309	0.529
Unconditional probability	0.470	0.604	0.625	0.543	0.529	0.612	0.606	0.607	0.437	0.645	0.546	0.551
Conditional probability	0.565	0.771	0.748	0.746	0.788	0.754	0.687	0.827	0.647	0.902	0.823	0.662
Model statistics												
Mean posterior probability	0.797			0.834			0.820			0.867		
Loglikelihood	−1909			−1813			−1839			−1799		
CAIC	3998			3806			3859			3778		
BIC	3974			3782			3835			3754		
Observations	6700			6700			6620			6620		

Class membership parameters: gender: male = 0, female = 1; age: < 45 y = 0, ≥ 45 y = 1; income: < $52 k pa = 0, ≥ $52 k pa = 1; employment status: unemployed = 0, employed = 1; sick leave: no sick leave = 0, paid sick leave = 1

Cost was scaled by $x/1000$

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 8 Preferences, chronic mild illnesses (latent class models)

	Irritable bowel syndrome ($N=539$)			Guillain Barre syndrome ($N=603$)			Reactive arthritis ($N=607$)			Haemolytic uraemic syndrome ($N=597$)		
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Attributes												
Duration of illness (base: 1 year)	−1.148**	−0.170***	0.147	0.168	−0.160**	−0.281***	0.176*	−0.873***	−0.158***	−0.342***	−0.254***	0.193***
Cost of treatment (base: $0)	−0.049	−0.142***	−0.474***	−0.473***	−0.419***	−0.049***	−0.502**	−0.042	−0.111***	−0.03	−0.263***	−0.203***
Ability to work and paid sick leave (base: able to work)												
Unable to work some of the time with paid sick leave	−1.577	0.125	0.497	−0.712	0.547	−0.189	2.086**	0.942	−0.375**	−0.214	−0.586	0.431
Unable to work most of the time with paid sick leave	−1.463	−0.22	0.946	0.674	−1.263*	−0.446***	0.922	−0.149	−0.428**	−0.439*	−0.199	−0.184
Unable to work some of the time without paid sick leave	−2.798	−0.817***	−0.351	−0.398	−3.654**	−0.587***	−0.431	0.271	−1.085***	−0.463*	−2.454***	−0.204
Unable to work most of the time without paid sick leave	−2.945	−1.124***	−1.211*	−0.26	−4.312***	−0.885***	−1.202**	−0.399	−1.167***	−0.669***	−2.692***	−0.254
Class membership parameters												
Gender	−0.422	−0.073	0	−0.029	0.814*	0	−0.061	−0.496	0	0.397	0.545	0
Age	−1.424***	−0.744**	0	0.564*	0.961**	0	0.579*	−1.076**	0	−0.882***	0.236	0
Income	0.771*	0.267	0	−0.369	0.027	0	−0.014	0.918*	0	−0.083	0.565	0
Employment status	0.209	0.068	0	0.187	0.011	0	−0.509	−0.896	0	0.419	0.364	0
Sick leave	0.185	0.095	0	−0.304	−0.207	0	−0.074	−0.22	0	−0.266	−0.577	0
Constant	−0.665	0.732*	0	−0.665*	−1.852***	0	−0.391	−0.412	0	0.222	−0.674	0
Class share	0.116	0.529	0.355	0.300	0.208	0.492	0.353	0.134	0.513	0.361	0.311	0.328
Unconditional probability	0.433	0.599	0.659	0.598	0.649	0.511	0.638	0.456	0.563	0.500	0.626	0.581
Conditional probability	0.872	0.639	0.920	0.933	0.838	0.628	0.906	0.885	0.596	0.690	0.773	0.842
Model statistics												
Mean posterior probability	0.888			0.879			0.880			0.843		
Loglikelihood	−1355			−1562			−1595			−1585		
CAIC	2929			3347			3412			3393		
BIC	2899			3317			3382			3363		
Observations	5390			6030			6070			5970		

Class membership parameters: gender: male = 0, female = 1; age: < 45 y = 0, ≥ 45 y = 1; income: < $52 k pa = 0, ≥ $52 k pa = 1; employment status: unemployed = 0, employed = 1; sick leave: no sick leave = 0, paid sick leave = 1

Cost was scaled by $x/1000$

*$p<0.05$; **$p<0.01$; ***$p<0.001$

Table 9 Preferences, chronic severe illnesses (latent class models)

	Irritable bowel syndrome ($N=539$)			Guillain Barre syndrome ($N=603$)			Reactive arthritis ($N=607$)			Haemolytic uraemic syndrome ($N=597$)		
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Attributes												
Duration of illness (base: 1 year)	−0.511*	0.268	−0.150***	1.762**	−0.771***	−0.196***	0.208	−0.658***	−0.192***	−0.155***	−1.150**	−0.004
Cost of treatment (base: $0)	0.056	−1.484***	−0.114***	0.12	−0.027	−0.165***	−0.479*	0.011	−0.142***	−0.093***	−0.044	−0.686***
Ability to work and paid sick leave (base: able to work)												
Unable to work some of the time with paid sick leave	0.222	−4.441*	−0.173	−2.603*	0.388	−0.290*	−0.185	0.558	−0.513***	−0.255	−0.329	−0.184
Unable to work most of the time with paid sick leave	0.103	−9.523**	−0.422*	−0.702	−0.39	−0.457**	1.055	−0.512	−0.561***	−0.177	−0.497	1.115
Unable to work some of the time without paid sick leave	−0.383	−4.140**	−1.355***	0.233	−0.639	−1.204***	0.403	−0.371	−1.294***	−0.735***	−0.446	−0.874
Unable to work most of the time without paid sick leave	−0.603	−6.214**	−1.327***	−1.243	−0.891**	−1.379***	−0.518	−0.847*	−1.683***	−1.260***	−1.988*	−0.812
Class membership												
Gender	−0.314	0.013	0	0.031	−0.022	0	−0.446	−0.359	0	0.029	0.569*	0
Age	−0.639*	0.644*	0	−0.193	−0.353	0	0.701**	−0.524*	0	−0.897***	−0.817**	0
Income	0.041	−0.233	0	−0.238	0.205	0	−0.389	0.381	0	0.014	0.17	0
Employment status	0.16	0.098	0	−0.47	−0.275	0	−0.408	−0.451	0	0.161	0.504	0
Sick leave	−0.449	−0.534	0	0.358	0.175	0	0.134	0.126	0	−0.147	0.009	0
Constant	−0.106	−0.653*	0	−0.386	−0.229	0	−0.377	−0.054	0	1.035***	−0.158	0
Class share	0.249	0.294	0.457	0.308	0.234	0.458	0.286	0.258	0.456	0.462	0.272	0.266
Unconditional probability	0.492	0.595	0.587	0.525	0.500	0.573	0.577	0.503	0.581	0.556	0.541	0.537
Conditional probability	0.845	0.951	0.647	0.894	0.928	0.640	0.934	0.875	0.644	0.590	0.917	0.920
Model statistics												
Mean posterior probability	0.886			0.894			0.890			0.892		
Loglikelihood	−1333			−1539			−1519			−1530		
CAIC	2885			3300			3261			3281		
BIC	2855			3270			3231			3251		
Observations	5390			6030			6070			5970		

Class membership parameters: gender: male = 0, female = 1; age: < 45 y = 0, ≥ 45 y = 1; income: < $52 k pa = 0, ≥ $52 k pa = 1; employment status: unemployed = 0, employed = 1; sick leave: no sick leave = 0, paid sick leave = 1

Cost was scaled by $x/1000$

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 10 Acute illnesses: mWTP (95% CI) ($AUD 2017)

	Gastrointestinal illness ($N=670$)		Flu−like illness ($N=662$)	
	Mild	Severe	Mild	Severe
Duration of illness (base: 1 day)	$12 ($7, $16)	$32 ($25, $39)	$8 ($3, $13)	$23 ($17, $30)
Ability to work and paid sick leave (base: able to work)				
Unable to work with paid sick leave	$16 (−$5, $36)	−$29 (−$52, −$7)	$3 (−$17, $22)	−$22 (−$45, $1)
Unable to work without paid sick leave	$146 ($116, $177)	$144 ($112, $177)	$156 ($124, $188)	$160 ($126, $193)

Table 11 Chronic illnesses: mWTP (95% CI) ($AUD 2017)

	Irritable bowel syndrome ($N=539$)		Guillain Barre syndrome ($N=603$)		Reactive arthritis ($N=607$)		Haemolytic uraemic syndrome ($N=597$)	
	Mild	Severe	Mild	Severe	Mild	Severe	Mild	Severe
Duration of illness (base: 1 year)	$575 ($272, $877)	$1367 ($938, $1795)	$835 ($453, $1217)	$1852 ($1337, $2367)	$531 ($156, $907)	$1412 ($915, $1909)	$1025 ($630, $1419)	$2195 ($1596, $2794)
Ability to work and paid sick leave (base: able to work)								
Unable to work some of the time with paid sick leave	−$296 (−$1501, $909)	$1461 (−$91, $3013)	−$319 (−$2061, $1423)	−$529 (−$2409, $1351)	−$28 (−$1858, $1801)	$544 (−$1506, $2594)	$449 (−$1418, $2316)	$266 (−$2036, $2567)
Unable to work most of the time with paid sick leave	$18 (−$1518, $1554)	$2429 ($367, $4491)	$2409 ($764, $4054)	$1925 ($90, $3759)	$2001 ($347, $3654)	$2773 ($968, $4578)	$2032 ($262, $3801)	$915 (−$1048, $2878)
Unable to work some of the time without paid sick leave	$3437 ($1599, $5276)	$8347 ($5394, $11,301)	$5342 ($3660, $7024)	$6945 ($4913, $8977)	$5925 ($4121, $7729)	$7393 ($5416, $9371)	$7072 ($5192, $8953)	$5712 ($3392, $8032)
Unable to work most of the time without paid sick leave	$6289 ($4862, $7716)	$8394 ($6189, $10,599)	$9355 ($7202, $11,508)	$9442 ($7097, $11,787)	$8743 ($6697, $10,789)	$11,352 ($8770, $13,934)	$9872 ($7450, $12,294)	$11,338 ($8301, $14,375)

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Author contributions KM, SG, PH, BM and RV developed the research question and methodology and the design of the study. KM performed the data analysis. All authors contributed to the interpretation of the results, the writing of the manuscript and approved the final version for publication.

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Data availability statement The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest Kathleen Manipis, Brendan Mulhern, Phil Haywood, Rosalie Viney, and Stephen Goodall have no conflicts to disclose.

Ethical approval Ethical approval for this study was obtained from the University of Technology Sydney (UTS), Human Research Ethics Committee (HREC) under the Centre for Health Economics Research and Evaluation (CHERE) Programme Ethics Approval (UTS HREC Reference number: 2015000135).

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Chapter 4: Friction period: How long does it take to replace a worker?

4.1 Overview

Productivity costs are usually an estimate of the economic value of forgone production associated with the loss of paid employment. The methods commonly used to value productivity costs were discussed in the introductory chapter – namely, the human capital approach (HCA) and the friction cost approach (FCA). Using the HCA, productivity losses can be easily estimated by multiplying the length of time absent from work due to illness by the market wage rate, adjusting for labour participation and unemployment rates. However, critics argue that HCA measures the potential lost productivity, rather than the actual loss incurred by society, and therefore tends to overestimate lost productivity [51, 69].

The friction cost approach was developed to address criticism of the HCA. The FCA assumes that productivity costs are limited to the time it takes to replace a worker (known as the friction period) and include the short-term costs incurred by employers in replacing a lost worker [69]. FCA assumes that there is an internal labour reserve that takes up some of the slack when an employee is absent, and, in the event that a worker needs to be replaced, the FCA assumes that there is a pool of unemployed workers available to take over the role after a period of training. Due to this friction period constraint, productivity losses are limited to the period a person is absent or the period until the worker is replaced. This friction period also includes procedural aspects of replacing a worker, such as time for advertising and training the individual to return production of the firm to an optimal level. This friction period is a key input used in an economic evaluation that uses the FCA to value productivity costs.

Central to using the FCA is the estimation of a robust friction period that can be used consistently within a jurisdiction. Inputs used to inform modelling have underlying assumptions and the validity of these assumptions is crucial for deriving estimates suitable for a specific location and setting. There have been some studies that have estimated country-specific values for the duration of the friction period [72-74]; however, the relevance of these international estimates is limited as the friction period may be influenced by local labour market conditions such as participation in paid labour, national unemployment rates and immigration rules. These are some of the factors that influence how long it takes to replace a worker.

Currently, there are no estimates of the friction period, and the costs incurred by employers when replacing a worker, available for Australia that can be used to inform economic modelling using the FCA. In this study I estimate the time (i.e., the duration of the friction period) and costs (i.e., friction period costs) of replacing an employee for the Australian context specifically. One of the strengths of this study is that Australian businesses were surveyed directly to ascertain time and costs of replacing employees. As transaction costs of replacing employees can be extensive, and direct and out-of-pocket costs incurred during a friction period are rarely collected, this study provides detailed estimates of friction period costs appropriate to Australia.

A handful of studies have estimated the duration of the friction period in various countries, including the Netherlands, Belgium, Germany, France, the UK, Norway and Sweden [72, 74, 138]. Different methods were used to estimate the friction period, where two of the studies used data from offices collating national statistical data [74, 138] and one study used national and firm level data from used national and firm level data from four different organisations [72].

The friction period was defined differently across the studies, where van Ours and Ridder [138] defined the friction period as the time when the employers commence looking for a new employee, which ceased when the new employee is found. This differs from this study in that time beyond when the new employee is found was included. i.e., time for training. It is unclear whether the definition used by van Ours and Ridder [138] included time where the contract was accepted by the new employee and the first day of employment. Kigozi et al [72] defined the friction period as a standard period (the time vacancy is raised to when the individual starts work) plus an additional four weeks. The additional four weeks is assumed to cover time taken for recruitment, successful uptake and training following day one of the replacement. This definition is most similar to this survey where the time taken to train the new employee was explicitly asked.

The results derived from this study are used to inform the economic evaluation in presented in Chapter 5 of the thesis.

Publication details

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Post publication notes:

Suggested improvements that have been made post-publication. These additional notes do not impact on the results from this study, which are used in the economic model presented in Chapter 5. For example, the appendix labels sections in the survey as A, B and C, whereas the main manuscript labels the sections of the survey as 1, 2 and 3. However, readers would be able to connect these sections i.e., A maps to 1, B maps to 2, and C maps to 3.

Questions in the survey were generally framed, which meant that estimates provided from respondents of the time and costs to recruit a person (in section 2/B) could possibly relate to reasons other than replacing a worker that is sick. For example, respondents may have considered recruitment was for backfill, general attrition, retirement, or career progression. In some of these circumstances, such as for retirement or career progression, the planning horizons for recruiting may be longer and less urgent for those planning of recruiting for the worker that needs to be replaced.

4.2 Publication/manuscript

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ORIGINAL PAPER

Employer survey to estimate the productivity friction period

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Abstract

Objectives The friction cost approach (FCA) is one way to estimate lost productivity, which considers the time taken to replace an employee, known as the friction period. The friction period may be influenced by local labour market conditions, limiting the relevance of international FCA estimates. The objective was to estimate the time and costs of replacing an employee in Australia.

Methods Staff responsible for recruitment in businesses across Australia were surveyed about the last management and non-management employee hired, workforce composition, friction period time and costs, and team dynamic effects. Primary analyses were conducted on respondents that recruited in the past 12 months. The friction period was decomposed into three periods: recruitment decision, recruitment period, and training period. Descriptive statistics of the friction period time and costs, and team dynamic effects were calculated.

Results The sample consisted of Australian businesses ($N=274$), primarily micro-organisations (2–4 employees, 44%) in urban locations (75%). The time (12.3 weeks; SD 15.1) and costs ($6230; SD $17,502) to replace a manager were higher than those to replace non-managers (10.0 weeks, SD 13.01; $2666, sd $7849). The training period represented the longest time component in replacing an employee (38–40% of the total friction period). There was an increasing impact on other employees' productivity, particularly for absent managers as time off work increased.

Conclusions The friction period in Australia was similar to international estimates. Interestingly, the friction period mainly consisted of time outside the recruitment period; the decision to recruit and the training period.

Keywords Friction cost approach · Friction period · Productivity loss · Economic evaluation

JEL Classification I1

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Appendix: Friction period survey

How long does it take to replace a worker?

This is a survey about recruitment and work in Australian organisations.

Your responses will be used to help us understand what characteristics of your organisation, employees and team environment affect how long it takes to replace a worker, and the impact this has on your business or organisation.

This survey is being conducted by the Centre for Health Economics Research and Evaluation at the University of Technology Sydney. Your participation in this study is completely voluntary. Your responses to the survey are strictly confidential and at no time will the answers you give be linked to your identity.

This survey contains three sections:

Section A - questions about you and your organisation.

Section B - questions about your organisation's experience with recruiting people/employees.

Section C - questions about the team environment in your organisation.

The survey will take approximately 15-20 minutes to complete.

Section A: About you and your organisation

What is your position / role in your organisation?

- I work in Human Resources ☐
- I work in Management ☐
- I work in another area (please specify) ☐

How long have you worked at your organisation?

- Less than 1 year ☐
- 1 to 5 years ☐
- 6 to 10 years ☐
- More than 10 years ☐

What state are you based in?

- NSW ☐
- VIC ☐
- QLD ☐
- SA ☐
- WA ☐
- TAS ☐
- NT ☐
- ACT ☐
- Other, ______________________________ ☐

How many people are employed in your organisation?

- 0 – 1 employee ☐
- 2 - 4 employees ☐

5 – 19 employees ☐

20 – 49 employees ☐

50 – 99 employees ☐

100 – 499 employees ☐

500 or more employees ☐

Which of the following would best describe the industry your organisation operates in?

Agriculture, forestry & fishing ☐

Mining ☐

Manufacturing ☐

Electricity, gas, water & waste services ☐

Construction ☐

Wholesale trade ☐

Retail trade ☐

Accommodation and food services ☐

Transport, postal & warehousing ☐

Information media & telecommunications ☐

Financial & insurance services ☐

Rental, hiring and real estate services ☐

Public administration & safety ☐

Education and training ☐

Health care and social assistance ☐

Arts and recreation services ☐

Other (please specify) ☐

What type of workers do you employ in your organisation? *Please select all that apply*

Manager	☐
Professional	☐
Technician and trade workers	☐
Community and personal service provider	☐
Clerical and administrative worker	☐
Sales worker	☐
Machinery operator and driver	☐
Labourer	☐
Other (please specify)	☐

What proportion of vacancies in your organisation are not filled through formal recruitment processes? *Formal recruitment includes advertising in newspapers, listing on seek.com, using LinkedIn or using a recruitment agent or head-hunter*

	0	10	20	30	40	50	60	70	80	90	100
% not filled through formal recruitment processes											

Levels in your organisation

We are interested in how the recruitment process might differ for positions at different levels of the organisation. For this survey, we are defining two different levels:

Level	**Description**	**Examples**
Manager	• Has strategic responsibilities in conduct or operations of the business, and/or; • Is in charge of a number of employees. • Is not usually entitled to overtime.	Alice is a senior accountant. Alice is responsible for business development and for attracting new clients. She manages a team of 5 junior accountants. Other examples: team leader, business owner, chief financial officer.
Non-manager	• Doesn't have strategic responsibilities and/or; • Reports to someone else. • Might be entitled to overtime.	Tim is a primary school teacher. He doesn't have strategic responsibilities. He reports to the school principal and teaches the curriculum as mandated by the school. Other examples: secretary, customer service representative, junior accountant.

Approximately, what proportion of positions in your organisation are at a manager and non-manager level? *Please enter whole numbers – your total must equal 100%*

Manager	%
Non-manager	%
Total	*[automate such that values are added for respondent]*

Section B: Recruitment experiences

Please think about the most recent position your organisation recruited for in the last 12 months when answering these questions.

Manager

Have you recruited at the manager level in your organisation in the last 12 months?

Yes ☐

No ☐

Where was the last position you filled at a manager level?

Metropolitan ☐

Regional ☐

Rural ☐

Was the last position you filled at a manager level casual, contract or permanent?

Casual position (i.e. ad hoc basis or as needed) ☐

Contract position (i.e. for a defined period of time, e.g. one year) ☐

Permanent position ☐

Other ____ ☐

Was the last position you filled at manager level full-time or part-time?

Full-time ☐

Part-time ☐

Was the last position you filled at manager level open to overseas applicants?

Yes ☐

No ☐

Non-manager

Have you recruited at the non-manager level in your organisation in the last 12 months?

Yes ☐

No ☐

Where was the last position you filled at a non-manager level?

Metropolitan ☐

Regional ☐

Rural ☐

Was the last position you filled at a non-manager level casual, contract or permanent?

Casual position (i.e. ad hoc basis or as needed) ☐

Contract position (i.e. for a defined period of time, e.g. one year) ☐

Permanent position ☐

Other ____ ☐

Was the last position you filled at non-manager level full-time or part-time?

Full time ☐

Part time ☐

Was the last position you filled at non-manager level open to overseas applicants?

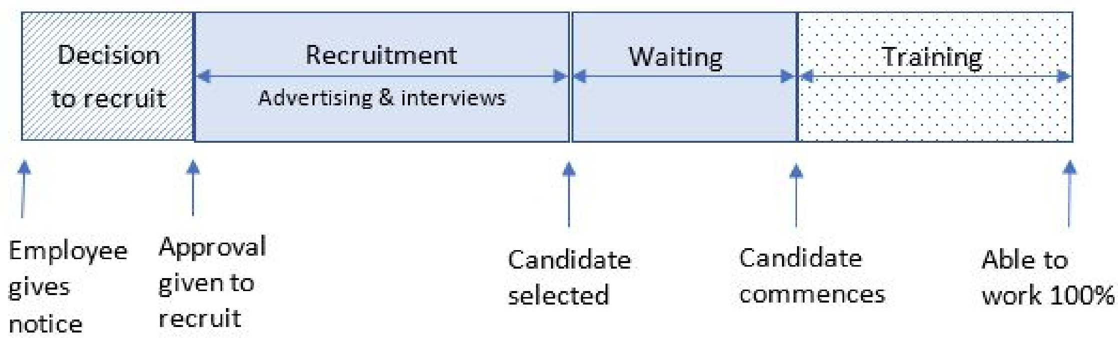
Yes ☐

No ☐

Time to recruit

This timeline represents the (general) process of recruiting a new employee. It starts from the time you decide a new employee is needed from the time the new employee is considered to be 100% able to perform duties required for the job.

For each question, please consider the last position you recruited for at that level in your organisation. If you don't know the exact answer, please give us your best estimate.



Approximately how long (in weeks) did each part of the recruitment process take for the most recent position that your organisation recruited?

	Manager	**Non-Manager**
Recruitment decision – Weeks from when the previous incumbent gives notice to resign or when the decision is made to create a new position, to when the approval to recruit is given.	[weeks]	[weeks]
Recruitment process – Weeks from when recruitment commences up until the new recruit starts their first day.	[weeks]	[weeks]
Training – Weeks from first day of work until the new employee is competent in their role.	[weeks]	[weeks]

Approximately how much (in dollars) did each part of the recruitment process cost for the most recent position that your organisation recruited?

	Manager	**Non-Manager**
Employee departure – Costs of an exit interview, administration of employee removal etc.	[$]	[$]
Recruitment process – Cost of advertising, recruitment firm fees, travel costs for panel members or applicants. Please do NOT include cost of time for internal employees.	[$]	[$]
Training – Cost of training courses or materials required to get a new worker to be competent in their new role.	[$]	[$]

Are there other costs not included in recruitment and training, that are incurred when your organisation hires a new employee?

Yes ☐

No ☐

Please describe the other costs (outside recruitment and training) that your organisation incurs when recruiting for a position, and provide the estimated value, at each level.

Open text field.

Section C: Team environment

Elasticity

We are interested in how the absence of one employee from an organisation can effect their own work and the work of others. Please think about the most recent position your organisation recruited for when answering these questions.

What proportion of an individual's work contributes directly to the goods and/or services that the organisation produces?

Example: Tim – teacher (non-manager): The service the school provides is education for children, so the time Tim spends preparing, teaching and marking is the time his work contributes directly to the *schools services. Tim spends about 5% of his time attending meeting and professional development activities, so about 95% of his work contributes directly to the service that the school provides.*

Example: Alice – accountant (manager level): The service the accounting firm provides is tax advice to clients, so time Alice spends advising clients contributes directly to the accounting firms services. As a senior accountant Alice only spends about 50% of her time directly seeing clients. The rest of the time she is overseeing junior accountants and business development. This means 50% of her work contributes directly to the service the accounting firm provides.

Example: Sean – secretary (non-manager): The service the accounting firm provides is tax advice to clients, and Sean provides administrative support to Alice. Because Sean doesn't provide tax advice, 0% of Sean's work contributes directly to the service the accounting firm provides.

	0 10 20 30 40 50 60 70 80 90 100
Manager	
Non-manager	

Catching up on work

How much work can be made up for by a sick employee on their return to work?

For example, if Alice the accountant is away for one day, she can postpone her client meeting and work longer hours the next day to catch up on her paperwork. But, if Alice is away for a month her clients will be seen by someone else, but she can still catch up on her paperwork when she gets back. This mean if Alice is away for a day she can catch up on all her work, but if Alice is away for a month she can catch up on about half of her work.

For each time period, how much of a <u>managers</u> work can be made up on their return from leave:

	None	A little	About half	Most	All
1 day					
1 week					
1 month					
6 months					
1 year					

For each time period, how much of a non-managers work can be made up on their return from leave:

	None	A little	About half	Most	All
1 day					
1 week					
1 month					
6 months					
1 year					

Help from someone else

When someone is on sick leave, how much work can another employee do to cover the person's absence?

For example, if Tim the teacher is away, the other teachers in the school can't take his class because they have their own students. So none of Tim's work can be done by someone else in the school while he is away. In this example we are assuming the substitute teacher is not an employee of the school.

For example, if Alice the accountant is off sick for a month, her colleague can see some of her scheduled clients. So a little of Alice's job can be done by someone else if she is away for a month.

For each time period, how much of a managers work can someone else employed by the business do if they're on leave:

	None	A little	About half	Most	All
1 day					
1 week					
1 month					
6 months					
1 year					

For each time period, how much of a non-managers work can someone else employed by the business do if they're on leave:

	None	A little	About half	Most	All
1 day					
1 week					
1 month					
6 months					
1 year					

Impact on others

If someone is on sick leave, how much of other people's work is affected while that employee is away?

For example, when Tim the teacher or Wendy the writer are away for a day it does not impact on anyone else's work, so none of other people's job is affected if they are away for a day.

For example, if Alice the accountant is away, Sean her secretary can't get her signature on invoices. This means a little of Sean's work is affected while Alice is away.

For each time period, how much of other people's work is affected when a manager is on leave:

	None	A little	About half	Most	All
1 day					
1 week					
1 month					
6 months					
1 year					

For each time period, how much of other people's work is affected when a non-manager is on leave:

	None	A little	About half	Most	All
1 day					
1 week					
1 month					
6 months					
1 year					

Replacing workers

Would you consider replacing (temporarily) an employee if they were not able to work?

For example, when Tim the teacher is away for a day, a substitute teacher must be brought in. So you would replace Tim (temporarily) if he was away for a day.

For example, when Sean the secretary is away for up to a week you wouldn't consider replacing him. But, if Sean the secretary is away for a month or more you would hire a temp to cover his work.

For each time period, would you consider replacing a manager if they were not able to work?

	Yes	No
1 day		
1 week		
1 month		
6 months		
1 year		

For each time period, would you consider replacing a non-manager if they were not able to work?

	Yes	No
1 day		
1 week		
1 month		
6 months		
1 year		

Briefly describe the positions you were thinking about whilst completing this survey. If you have any other comments about recruitment experiences or this survey, you can also write them here.

Open text field.

Demographics

What is your sex?

- Male ☐
- Female ☐

How old are you?

- Under 18 ☐
- 18 – 24 ☐
- 25 – 34 ☐
- 35 – 44 ☐
- 45 – 54 ☐
- 55 – 64 ☐
- 65 – 74 ☐
- 75 – 84 ☐
- 85 or older ☐

Chapter 5: Comparing methods of modelling productivity losses using foodborne illness as a case study

5.1 Overview

Resources are finite and methods are therefore required to inform efficient allocation of these limited resources. Economic evaluations provide an explicit framework to compare the costs and benefits, and to guide decisions on how to allocate limited resources [19]. Modelled economic evaluations are typically used to inform decisions, and consequently can support that interventions or policies be given a higher priority, compared with an alternative course of action [19]. It is important to understand what is being measured and valued in these models [19]. The aim of this study was to illustrate these issues by developing a generic model of foodborne illness caused by infection with campylobacter, and using this model to examine how different methods of valuing productivity losses influence the results. This provides a test of robustness of modelling approaches.

The first section focuses on the choice of foodborne illness as a case study, as almost all foodborne illnesses are preventable. In purchasing food, informational asymmetries arise for consumers when assessing the risk of foodborne illness (FBI). Everyone should have access to food that is safe for consumption, however, improper handling can cause food to be unsafe. Improper handling can occur anywhere within the supply chain [134]. This makes the detection of foodborne pathogens difficult particularly for consumers. Governments intervene by developing and enforcing policies to regulate food safety to protect health, which reduces the risks of FBI [134]. Interventions may include implementing strict hygiene measures, decontamination, and other regulations such as the displaying of use-by dates. Governments and businesses expend considerable resources to reduce the impacts of foodborne illnesses [134]. Productivity loss is claimed to be one of the largest costs resulting from foodborne illnesses in developed nations, and therefore avoiding these losses is a major benefit of intervention [85, 139, 140].

Productivity losses are generally valued using two main methods, the human capital approach (HCA) and the friction cost approach (FCA) [60]. The HCA assumes that individuals have the potential to produce outputs (i.e., productivity) during their working life. Productivity loss is valued as the net present value of that person's future wages. One of the major criticisms of the HCA is that it overestimates productivity losses because the absence due to illness is valued by the total gross income [69]. This led to the development of the FCA, which confines productivity losses to the time taken to replace an employee, known as the friction period [59]. The friction period for Australia was estimated in Chapter 4 of this thesis, which is a key input needed to estimate productivity losses using the FCA. The WTP to avoid an illness is another option for measuring costs and benefits that could be used to value productivity losses in an economic evaluation; however, to date, the use of WTP has been limited in economic evaluation studies [141]. As discussed in Chapter 3, the WTP to pay to avoid an FBI were estimated for alternative scenarios where employees do or do not have access to paid sick leave.

In this chapter, I compare the impact of three different methods of measuring productivity losses using a FBI cost-effectiveness model as a case study, specifically to investigate whether the methods chosen for estimating productivity losses lead to different decisions regarding resource allocation. The methods include:

1. Human capital approach (HCA) based on the median wage rate in Australia;
2. Friction period approach (FCA) based on the estimates calculated in Chapter 4 of this thesis; and
3. Willingness to pay (WTP) to avoid the consequences of a foodborne illness based on the findings of Chapter 3.

The overall aim is to identify the valuation methods which influence the economic model. To my knowledge this is the first direct comparison of these methods for estimating productivity losses in Australia.

For the purposes of this study, a simplified model of foodborne illness was developed using a Markov framework [142]. A Markov model is a method of discrete-time stochastic modelling which is suitable when costs and effects are distributed over a longer period of time. In this case, a 10-year time horizon was chosen because it captures the working life of an individual [142]. In a Markov model the timing of events is important and it is possible for events to occur more than once (e.g., an acute foodborne illness). It is also possible to model long-term sequelae resulting from the initial infection. A Markov model is made up of several mutually exclusive Markov states. Events of interest are modelled as transitions from one Markov state to another. The model assumes that a person is always in one of these Markov states at any one time. The model is run over a series of cycles, defined by the cycle length (e.g., 1 day, 1 month) and people move between Markov states if their health status changes (e.g., if they recover or develop long-term symptoms). People remain in the same Markov state if their health status is unchanged. Rewards (costs and health effects) are assigned to each Markov state after each cycle. Rewards are applied based on the percentage of the cohort that reaches that node in that cycle. The total costs and effects are calculated as a cohort expected value analysis.

Health benefits are captured in the model in terms of the quality adjusted life years (QALYs) gained. The QALY is a measure commonly used in economic evaluations to quantify health effects [42]. The QALY captures both quantity and quality of life, where the health states are assigned a utility value ranging from one (i.e., 1.0 indicating full health) to zero (i.e., 0 indicating death). The time an individual spends in each health state is multiplied by the utility value to calculate the QALYs gained.

Publication details

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5.2 Publication/manuscript

Abstract

Background: Modelled economic evaluations enable simulation and forecasting, which can then inform decisions about adoption of policies and interventions. Although, cost-effectiveness analysis (CEA) excluding productivity losses is the main technique used for health technology assessment in Australia, there are two main methods are used to value productivity, the human capital approach (HCA) and the friction cost approach (FCA). The WTP to avoid an illness is another option, but is seldom used. Different perspectives are taken in modelling productivity losses using these methods i.e., health system, employees, and employers. Productivity loss is claimed to be one of the largest costs resulting from foodborne illnesses (FBI) in developed nations, and avoiding these losses is a major benefit of intervention.

Aim: To compare and examine the impact of valuation methods used to measure productivity loss in an economic evaluation.

Method: Using FBI due to campylobacter as a case study, a simple and tractable Markov model was developed with four health states representing morbidity and productivity impacts of FBI due to campylobacter: 'healthy', 'acute gastroenteritis', 'irritable bowel syndrome (IBS) and being unable to work some of the time', and 'IBS and being unable to work'. Productivity loss due to FBI were valued using three different methods (HCA, FCA and WTP), as well as a combination of the FCA and WTP methods to adjust for differences in the perspective of analysis. Five methods were compared: Model 1 (CUA), Model 2 (HCA), Model 3 (FCA). Model 4 (FCA+WTP to avoid illness with paid sick leave (PSL)), and Model 5 (WTP to avoid illness without PSL).

Results: The highest incremental cost-effectiveness ratio (ICER) was observed in Model 1 ($57,323/quality adjusted life year gained (QALYG)). Inclusion of productivity costs in Models 2 to 5 significantly increased the total costs in both the arms of the models, but significantly reduced on the ICERs (Model 2, $20,431/QALYG; Model 3, $28,546/QALYG, Model 4, $27,344/QALYG, Model 5, $31,508/QALYG).

Conclusion: Different methods of modelling productivity loss can influence the ICER and the decision to adopt a new policy or intervention. The key differences between the approaches were the perspective taken in the analysis, which influences how the short-term and long-term productivity losses are treated.

Introduction

Methods used to value productivity losses in an economic evaluation remain subject to debate [143-145]. Recommendations about which methods should be used vary by country [42, 145, 146]. Modelled economic evaluations are useful as they enable simulation and forecasting, which can then inform decisions about adoption of policies and interventions [19]. However, because modelling outcomes can be influenced by assumptions made, there is a potential for opportunity costs to arise if modelled outcomes favour adopting options forecasted to be cost-effective, but are not in reality. This is a barrier in ensuring efficient resource use and allocation across the economy [147].

The inclusion of productivity losses in economic models is itself subject to debate; however, there are situations in which it is important to consider the productivity impacts of policies and interventions. Policies aimed at reducing foodborne illness (FBI) is one area in which this is the case. Interventions typically aim to prevent FBI occurring. The costs of adopting the intervention to prevent FBI impacts on suppliers and the food production chain (e.g., through additional hygiene measures, packaging, or monitoring). The consequences of infection with a foodborne illness impacts on the consumer, where a very common impact of FBI is the need to take time off work. For acute FBI, this may be the key impact. A societal perspective in assessing the extra costs of preventative strategies requires consideration of all costs – whether they are health care costs, loss of wellbeing or productivity costs from time off work – in order to assess whether the policy is efficient. Similarly, in some situations, such as vaccination for rotavirus for children, one of the major benefits (for what is, for most infants, a self-limiting condition) is the avoidance of time off work for parents. Therefore, the consideration and appropriate valuation of productivity losses and gains may be critical in many economic evaluations to inform policy.

Broadly speaking, productivity losses (or productivity costs) have been defined as the value of losses that result from a productive person not being able to perform their usual duties that contribute to overall wealth [148]. These costs are associated with impaired or lost ability to work or participate in leisure activities due to morbidity or death [52]. Time for productive activities can be allocated between paid labour, unpaid labour, or for leisure activities; however, the time lost due to coping with illness or in being recovery is not reduced proportionally between paid labour, unpaid labour and leisure time [49]. Although there are important implications for excluding productivity losses concerning unpaid labour and leisure, these are not commonly included in economic evaluation [49, 50]. Differentiating unpaid work from leisure activities is also difficult in practice as elements of utility can overlap [49]. For this reason, this study will only focus on paid leave as a first step in comparing the different methods.

The two methods most frequently used in economic evaluations to value productivity losses are the human capital approach (HCA) and the friction cost approach (FCA). The HCA reflects lost productivity from the societal perspective and assumes that the value of an individual's human capital is reflected in their labour market earnings, and therefore the loss of productivity is reflected by the loss of earnings during any time when a person is unable to work. The FCA is a refinement of the HCA, which attempts to adjust for worker replacement in a friction period (i.e., the time it takes to replace an individual worker) and thereby measures lost productivity from an employer's perspective. The FCA limits productivity losses to the friction period [52]. One other method that could be used to value lost productivity is to estimate the willingness to pay (WTP). This is rarely included in health economic evaluations but has been used widely in other sectors such as transportation and environmental sectors [149]. The WTP is the maximum amount of money an individual is willing to pay for a commodity (a good or service); as such, it is a measure of the utility of the commodity to the individual and could be used to value productivity loss from the perspective of an individual.

These three methods will each have different implications for the measurement of the value of costs and benefits in economic evaluations of health interventions, and it is important to understand these differences. This paper aims to demonstrate the differences in valuing productivity losses due to illness using these three methods (HCA, FCA and the WTP to avoid illness) using FBI as a case study.

Methods used to estimate productivity loss

The three different methods are outlined below.

Human capital approach (HCA)

Productivity losses have been traditionally valued using the HCA [150]. Under the HCA, it is assumed that individuals and firms seek to maximise utility and profits respectively. Workers seek to maximise utility by allocating their time between work (for which they receive labour market earnings) and leisure. The firm will employ workers at the point where the marginal contribution (the marginal value of product) of the worker is equivalent to the gross wage, and at this point the firm maximises profits. Productive output and compensation to the worker (i.e., gross wage) are equal in a competitive labour market in which there is equilibrium. Under these assumptions (i.e., markets are competitive and there is no excess demand or supply), absence from work can be valued according to the gross wage. Valuation of productivity losses due to morbidity and mortality using the HCA is assumed to be the net present value of that person's future contribution to production if the person had been able to work rather than being absent from work due to ill health [52, 150].

The HCA has been criticised for overestimating the value of productivity losses [59]. The criticism concerning overestimation of productivity losses argues that the HCA is the upper estimate of lost production resulting from disease [59]. One of the main reasons for overestimation is that costs of morbidity and mortality can accrue over a long time horizon, which can extend to when a person reaches retirement age; as such, this is an estimate of potential rather than actual costs. Other reasons for overestimation are the presence of excess supply of labour (unemployment or underemployment) – for example, if there are other workers who can undertake the work, or work can be postponed, which lessens productivity loss in the short-term. It is these major criticisms that led to the development of the FCA.

Friction cost approach (FCA)

The FCA was developed by Koopmanschap et al. [59, 71]. This method assumes that involuntary unemployment limits the production losses to the period of time needed to replace the worker, known as the friction period. Productivity loss is limited to the time before the sick person is replaced because lost productivity does not extend beyond the friction period. In measuring lost productivity, short-term absences (i.e., absences less than the duration of a friction period) are not replaced, and thus this lost work time is counted as lost productivity, whereas long-term absentees are replaced – i.e., absences longer than the duration of a friction period are censored at the time the worker can be replaced. The FCA assumes that initial production is restored after the period the worker is replaced (i.e., the friction period). In contrast to the HCA, the FCA typically results in the lowest productivity costs.

Willingness to pay (WTP)

Willingness to pay (WTP) is a method used to measure benefits or avoided costs. The WTP is the maximum amount of money an individual is willing to pay for a commodity (a good or service); as such, it is a measure of the utility of the commodity to the individual. Because the WTP is a monetary metric and can be modified to reflect preferences pertaining to features unique to health and productivity, the WTP could be used as a measure of value in an economic evaluation. Measures of WTP have been used across various industry sectors as a way to ascertain public support for various policies [52]. For example, WTP has been used in the development and assessment of environmental goods and services, such as for protection of national parks where degradation of the environment is a key issue. The WTP for a visitor to go diving in the Great Barrier Reef in Queensland

Australia is estimated to be $185 per trip [151]. These WTP values can inform policy-makers about the value people place on goods and services and inform pricing of these goods and services and establishing a non-market value [152, 153]. The WTP can also be used as input in cost-benefit analyses. The WTP measure is considered useful because the measure can be used to rank and compare the desirability of goods and services across sectors.

Values for WTP are obtained by estimating the compensating variation measure of welfare by observing the amount of money people are prepared to pay for improvements or accept reductions in levels of attributes of goods and/or services [152, 153]. Compensating variation is defined as the additional amount of money a consumer would need to attain their initial level of utility after changes in price, product quality or availability of new products [154].

Rather than estimating productivity losses in terms of lost wages, health care costs and disutility (associated with side effects and treatment), a WTP approach has the potential to incorporate all the impacts on individuals in a single monetary measure. There are numerous approaches used to measure WTP (e.g., auctions, field experiments, customer surveys, conjoint analysis, discrete choice experiments (DCEs)) [155]. This study uses WTP values elicited from a DCE to value productivity losses [refer Chapter 3 of thesis]. In the DCE, the WTP to avoid illness captures both the value to the individual of the lost productivity and the value to them of any other disutility associated with illness. This WTP value also captures productivity loss where the ability to work is reduced in situations when sick leave is available to the worker, and when it is not. The availability of paid sick leave is a feature of the Australian labour market, with benefits as mandated by legislation for short-term absences in Australia for some workers [6, 26]. Where paid sick leave is available, a worker does not lose wages for short-term absences but may lose wages for long-term absences.

Methods

Structure of the model

A model was developed to compare the different methods used to measure productivity and health losses in an intervention that reduces the risk of campylobacteriosis. The model estimated the cost-effectiveness of the intervention versus status quo for each productivity method. The Markov model was constructed using TreeAge® Pro 2021 software (TreeAge Software Inc., Williamstown, MA, USA). Outcomes included:

1) Direct costs: costs of illness;
2) Quality adjusted life years (QALYs);
3) Productivity costs (e.g., wages lost):

a. Human capital approach.
b. Friction cost approach.
c. Friction cost approach plus WTP to avoid illness with paid sick leave;
d. Willingness to pay to avoid illness without paid sick leave;

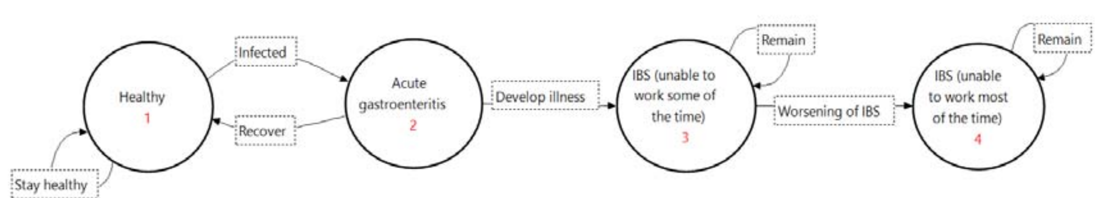
Figure 5 provides an overview of the Markov model. Four health states were chosen to represent the morbidity and productivity impacts (i.e., time off work) associated with campylobacter infection. Productivity impacts include time off work defined as: absenteeism, which is the duration of time when a person is unable to undertake paid work; and presenteeism, defined as duration of time working while sick, resulting in reduced productivity. The Markov states differed by ability to work and employment status. The model was structured based on the data that was available, specifically in considering the WTP values, to allow for a comparison of methods to value the impact of productivity losses. A targeted literature search was conducted to aid in development of this model, which is the usual method used in model development. However, many models identified [85, 156-160] were not suitable as they did not specifically fit the data that was available during the development.

The model was structured based on the data that was available, specifically in considering the WTP values, to allow for a comparison of methods to value the impact of productivity losses.

The impacts of FBI are for the most part transient and self-limiting. However, in some individuals FBI can also result in long-term sequelae, such as post-infectious irritable bowel syndrome (IBS), Guillain-Barré syndrome (GBS) or reactive arthritis (ReA) [133, 161, 162]. To date, most FBI studies that have included productivity losses have focused on measuring burden over a one-year time horizon and so may not adequately capture the long-terms effects of these sequelae [85, 137]. For this case study, a simplified model of FBI was developed to examine differences in the impacts over the short and long term. The long-term sequelae considered in the model was acute GI post-infection IBS [162]. IBS is an episodic illness in which symptoms are intermittent and debilitating, followed by periods of remission. IBS was chosen because it is more common in people of working age [163], and people with IBS are likely to have substantial impairment of their ability to attend work, and therefore experience lost productivity in their working life [164]. As a consequence, post-infection IBS may impose a greater societal burden, which affects people with the illness, their employers and society due to increased medical costs and reduced work productivity.

The cohort begins the model in the 'healthy' state. It was assumed that healthy people are well enough to work, i.e., require no time off work for absenteeism or presenteeism. As the model transitions, a proportion become infected with campylobacter and transition to the 'acute gastroenteritis (GI)' state. For these individuals it was assumed that they are absent from work for one day, based on data from the National Gastroenteritis Survey II (NGSII) [165].[10] All individuals could have an 'acute GI' case in the first year but cannot progress to a post-infection IBS diagnosis in the first year, as diagnosis can take considerable time (i.e., the probability of being diagnosed with IBS for the first 12 cycles is zero). Post-infectious IBS is considered to be a poorly understood condition, as the mechanisms underlying the development of PI-IBS are unclear [166]. After the first year, a proportion of the population will recover (i.e., go back to the 'healthy' state) and a proportion will develop IBS. Two IBS health states were chosen to capture both the episodic and chronic long-term effects of IBS, defined as 'unable to work some of the time (episodic)' or 'unable to work most of the time (chronic long-term IBS)'. Both absenteeism and presenteeism are included in the 'IBS, unable to work some of the time' health state. The model assumes that individuals who enter the 'IBS, unable to work some of the time' health state experience an IBS flare-up (i.e., they are unable to transition back to 'healthy' or to 'acute GI'). It was assumed that time off work for flare-ups equated to 4.1 days per month (see Appendix Table 13) [167]. It is also possible that the IBS becomes chronic, whereby they are 'unable to work most of the time'. At this point, it is assumed that people are living with a disability and leave the workforce.

Figure 5 Markov model



Productivity assumptions	Healthy	Acute FBI [165]	IBS (unable to work some of the time) [167]	IBS (unable to work most of the time) [168]
Absenteeism	Nil	1 day per case	2.9 days per month	Cannot work
Presenteeism	Nil	Nil	1.2 days per month	Cannot work
Total time	Nil	1 day per case	4.1 days per month	Cease employment

[10] The NGSII asked respondents about time lost from work and daily activities due to infectious gastroenteritis. Daily activities were described as working, attending school, or recreational activities. It was estimated that acute GI affected daily activities for a median of one day (Chen 2016). Only absenteeism is included in the acute GI illness health state; presenteeism is not included as acute GI illness is a transient event where work is unaffected.

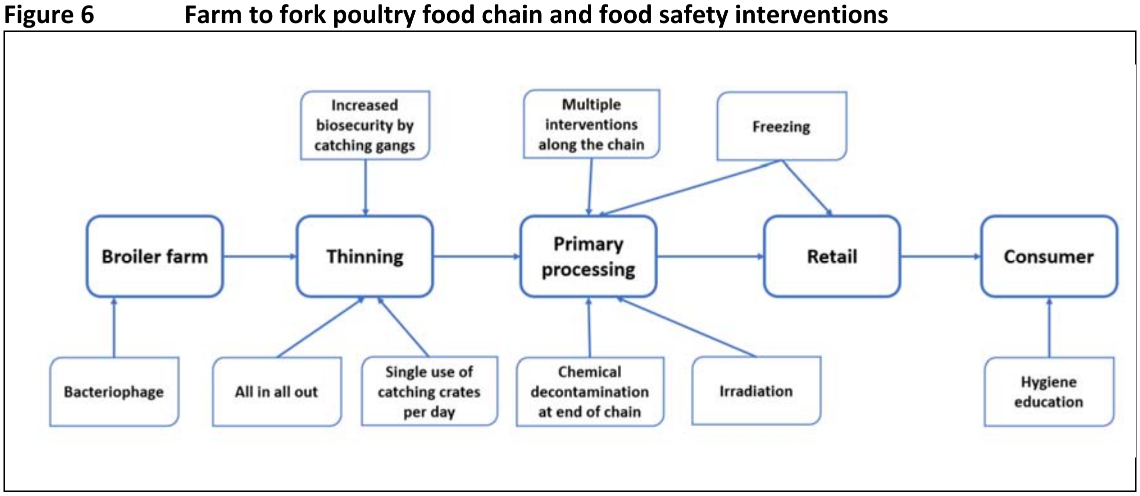
Death due to foodborne illness is very rare. In 2010, it was estimated that in Australia there were three deaths (90% credible interval: 2–4) following an acute campylobacter infection, and six deaths due to GBS following campylobacteriosis [133]. No deaths have occurred due to IBS following campylobacteriosis. Irritable bowel syndrome is not a cause of death or associated with increased mortality [169]. Therefore, the model assumes all individuals are alive after 10 years, and for simplicity all-cause mortality was also excluded from the model.

The cohort progresses through the model in one-month cycles over 10 years. The time horizon of 10 years was chosen to represent the clinical pathway in which foodborne infections can lead to chronic conditions. A discount rate of 5% per year was applied to the costs and benefits as proposed by Australian guidelines [42]. Costs from Chapter 3 and Chapter 4 were collected in 2017; for this reason, all costs were reported in Australian dollars ($) for the year 2017. Costs obtained in previous years were inflated using the Health CPI [170].

Costs and effectiveness of intervention

Consumption of contaminated poultry meat is the main cause of campylobacteriosis [171]. The supply chain for poultry meat is provided in Figure 6. Interventions used to reduce the risk of campylobacter contamination can be implemented at any point within the poultry supply chain process, from the farmer to the consumer.

Figure 6 Farm to fork poultry food chain and food safety interventions



Source: Figure 1 Lake et al. [159]

Campylobacteriosis is a notifiable illness[11] in Australia [172]. There are many interventions that are aimed at food suppliers at various stages in the food supply chain as campylobacter is a difficult

[11] Notifiable illnesses are those where doctors, laboratories, and other health professionals must report or notify to health departments. These data are collected to provide a basis for the development of public health policy for management and prevention of disease.

pathogen to control. As such, the intervention used in this model is hypothetical. The hypothetical intervention, hygiene education, is aimed at businesses handling food to reduce cross-contamination and reduce the risk of contracting campylobacter (e.g., guidance for hand washing for those handling food [173]). Effectiveness of the hygiene education is assumed to reduce cases by 30% in the model. This assumption underpinning effectiveness is tested as a sensitivity analysis.

The cost of the intervention is assumed to be borne by the food regulatory authority, which aims to prevent illnesses and deaths from contaminated food. The food regulatory system relies on government intervention to manage policy, develop standards, monitor food safety and enforce legislation. Regulation of foodborne illness in Australia is a joint effort between federal government agencies (Food Standards Australia New Zealand, the Department of Agriculture, Fisheries and Forestry, and Department of Home Affairs), state and territory governments, laboratories and local government [133]. The intervention is assumed to cost the food regulatory system $1 per person per year to spend on a hygiene education program for workers handling food.

Population and setting

The model cohort was defined to be representative of the working population in Australia (16–65 years). As of 2021, there were approximately 13 million people employed in Australia, with a median age of 39 years. It is assumed that the economy has a fixed productive capacity. Transition probabilities for acute GI and initial IBS were informed by an Australian government report[12] [133], and for worsening IBS, probabilities were informed by the literature [168] (Table 2).

Table 2 Transition probabilities

	Input	Acute GI	Chronic IBS		Calculation/Source
			Initial	Worsening	
Annual					
Incidence proportion		8,400/ 1,000,000	915/ 1,000,000	192/ 1597	Kirk 2014 [133]; Silk 2001 [168].
Probability	p_{annual}	0.00840000	0.00091500	0.12022542	incidence proportion
Rate	r_{annual}	0.00843548	0.00091542	0.12808957	$r = -\ln(1-p)$
Monthly	t_{month}				t = 1/12 = 0.08
Probability	p_{month}	0.00070271	0.00007628	0.01061736	$p = 1 - e^{-rt}$

Costs and resource use

[12] In Australia, diagnoses of certain infections are reportable. Notifiable data collected are from state and territory surveillance, the National Notifiable Disease Surveillance System (NNDSS), OzFoodNet outbreak register, the National Gastroenteritis Surveys I & II (NGSI & NGSII), hospitalisation data, and the Australian Bureau of Statistics mortality data.

Treatment costs

A health system perspective was used to calculate the direct treatment costs of an acute foodborne illness and IBS, which was informed by the literature [167, 174]. A summary of the direct treatment costs is provided in Table 3. It was assumed that there were no costs for individuals in the 'healthy' state.

For the 'acute GI' state, the costs included: general practice consultations, diagnostic tests, prescribed medications, specialist consultations, emergency department visits and hospitalisations[13] [174]. It was assumed that acute GI cost the health care system $21 per case.

For the IBS health states,[14] the costs of treatment included hospitalisation, consultations, prescription and non-prescription medications, diagnostic tests and complementary therapy [167]. The annual cost of moderate IBS was $1894 (~$158 per month) and for severe IBS $3821 (~$318 per month).

Table 3 Cost inputs in the model ($ 2017)

Input parameter	Value	Source/calculation
Healthy	0	Assumes no costs are incurred.
Acute gastrointestinal (GI) illness		
Cost per case	$20.75	Resource use included: GP consultations, diagnostic tests, prescribed medications, emergency department visits and hospitalisations. OTC medications are not included in resource use cost. Barker et al. [174] report the cost per case as $20.27 and cost per capita as $14.87.
Irritable bowel syndrome (IBS)		
Cost per case, moderate per month	$157.83	Costs to the healthcare system included: hospitalisation, consultations, prescription and non-prescription medications, diagnostic tests and complementary therapy. [167]
Cost per case, severe per month	$318.42	

Utility

The utility values used in the model were obtained from the literature [175, 176]–[177-182]. It was assumed that individuals who are healthy have a utility value of 0.89, based on the Australian

[13] Resource use costs were obtained from an Australian study (Barker et al. [122]). In this study the direct costs to the health care system due to acute GI were estimated using multiple data sources (National Gastroenteritis Survey II (NGSII); The Bettering the Evaluation And Care of Health (BEACH) program; Medicare Benefits Schedule (MBS); National Hospital Cost Data Collection 2014-2015).

[14] Resource costs were obtained from an observational 12-month multicentre study, in patients with moderate to severe IBS (N=525) (Tack et al. [114]). The study was conducted in six European countries (France, Germany, Italy, Spain, Sweden, the UK). Costs related to IBS management varied greatly between countries. The study also stratified costs by severity of IBS

population norm. A decrement of 0.078 is applied for acute FBI for the cycle. For individuals who progress from acute GI illness to develop IBS (episodic and chronic long term), their utility falls to 0.719 (Table 4). See the appendix for additional information on the studies identified to inform utility values.

Table 4 Utility

Input parameter	Value	MAUI	Sources (see appendix for more information)
Full health	0.890	Utility, EQ-5D	McCaffrey 2016 [176]; Clemens 2014 [175]
Acute GI illness	-0.078	Disutility (standard gamble)	Average of five studies reporting disutility for diarrhoea and/or nausea [183-187]. This is applied as a disutility to the 'full health' utility value.
IBS	0.719	Utility, EQ-5D	Average of six studies reporting EQ-5D values for IBS [177-182]. This utility value is applied to the IBS health states.

Incorporating productivity in the model

In total, five models were estimated and summarised in Table 5. For this reason, a simple and tractable model was developed. Different aspects being captured in the five models are described below:

- Model 1 contains costs of treatment and utilities that are commonly presented in cost-effectiveness analysis from a health care payer perspective. Productivity losses were excluded.
- Model 2 is based on model 1 with the inclusion of productivity losses measured using the *HCA.*
- Model 3 is based on model 1 with the inclusion of productivity losses measured using the *FCA.*
- Model 4 is an extension of Model 3, whereby the WTP to avoid illness, when the employee is unable to work but has employer paid sick leave, is included. The availability of paid sick leave acts as compensation for lost wages for the employee, hence the WTP to avoid illness in this scenario adds costs for disutility associated with the illness. Model 4 captures costs of treatment and productivity losses from both an employer and employee perspective.
- Model 5 includes costs of treatment and productivity losses. However, productivity losses are not valued in terms of lost wages (as they are in Models 2, 3 and 4). In this scenario, the WTP to avoid an illness whereby paid sick leave is not available is used to replace the wage rate. Disutility associated with illness is also captured in the WTP measure. Productivity losses are valued from an employee perspective only.

Table 5 Comparison of methods

	Model 1	Model 2	Model 3	Model 4	Model 5
	Base case traditional CUA	**HCA**	**FCA**	**FCA + WTP w/sick leave**	**WTP w/out sick leave**
Perspectives					
Health care system	✓	✓	✓	✓	✓
Employee	✗	✓	✗[b]	✓	✓
Employer	✗	✗[a]	✓	✓	✗
Costs					
Direct treatment	✓	✓	✓	✓	✓
Productivity loss	✗	✓ At wage rate Absenteeism & presenteeism	✓ Adjusted wage (absence multiplier[c]; friction period) Absenteeism & presenteeism	✓ Adjusted wage (absence multiplier[b]; friction period) & Absenteeism & presenteeism & DCE: WTP **with** sick leave	✓ DCE: WTP **without** sick leave
QoL	✓ QALY	✓ QALY	✓ QALY	✓ QALY & DCE: disutility of being sick	✓ QALY & DCE: disutility of being sick

Note: [a] Lost productivity is valued using the wage, which is paid by the employer. However, this is marked as 'x' as human capital is supplied by the employee.
[b] The FCA takes the perspective of the employer, as lost wages for an employee may persist beyond the friction period.
[c] Absence multiplier is applied in a sensitivity analysis.

Cost-utility analysis (Model 1)

Productivity losses due to time off work are not explicitly included in this model. The disutility associated with being ill is valued in Model 1 using QALYs.

Human capital approach (Model 2)

The HCA assumes an 'employee' perspective to calculate productivity losses. Productivity loss due to illness is estimated by multiplying the daily wage, by the number of working days lost, due to illness (value for the lost production of employees):

$$Productivity\ loss = incapacity\ for\ work\ (time)\ x\ wage\ costs\ (\$/time)$$

All time off work due to illness is considered. The average gross weekly total earnings for an adult working full-time in Australia in 2017 was $1,628 [188]. The daily wage was estimated by dividing the weekly wage over seven days ($233 per day) and the monthly wage was estimated to be $7,055 (i.e., $1,628*(52/12)). This assumes that time during the week and over a weekend are of equal value.

The duration of absenteeism and/or presenteeism is informed by the time off work discussed above for each health state (see Figure 5).

Friction cost approach (Model 3 and Model 4)

The FCA assumes an employer perspective to calculate productivity losses used to inform estimates for Model 3 and Model 4. Losses are estimated by the incapacity to work plus the costs for the employer to 'cover' for the short-term absence of the employee when they are unwell (known as team dynamic effects), plus the cost to replace the employee, once they are no longer able to work in the long-term [71, 189-192]. This approach also assumes that absence from work reduces effective labour time less than proportionally, due to compensatory mechanisms, and for this reason an estimate is required for the elasticity of annual labour time versus labour productivity [71, 190]. A summary of the inputs used for the friction cost approach that are additional to those used in the human capital approach is provided in Table 6. Additional inputs include the friction period (the time taken to replace the employee; and employer costs to replace employee), the elasticity of annual labour time versus labour productivity, and team dynamics effects.

Table 6 Friction cost approach inputs

Input parameter	Value	Source/calculation
Friction period, duration (weeks)	10.62	Weighted friction period by proportion of managers and non-managers in Australia [193]. Assumption: 25% managers; 75% non-managers • Managers: 12.26 weeks • Non-Managers: 10.07 weeks Weighted duration: 10.62 weeks Values used from Chapter 4.
Friction period, costs ($)	$3,557	Weighted cost by proportion of managers and non-managers in Australia [193] (Chapter 4 of thesis). Assumption: 25% managers; 75% non-managers • Managers: $6,230 • Non-Managers: $2,666 Weighted average cost: $3,557
Elasticity for annual labour time vs labour productivity (ε)	0.8	Dutch costing manual [190].
Absence, multiplier effects (sensitivity analysis only)	1.43	Pauly [189]; Krol [191]; Jobs selected based on those from five employment sectors;

The main differences between the HCA and the FCA is the treatment of time lost due to illness and the perspective. Productivity losses in the HCA are applied for the entire 10 years of the model, whereas losses in the FCA are limited to the duration of the friction period, represented as the time taken to replace a worker (i.e., duration of the friction period); hence, the FCA values production losses from the employer's perspective [193]. In addition, in the friction period workers can be replaced by people that are not employed and seeking work (i.e., people who are involuntarily unemployed). As discussed in Chapter 4 of this thesis, the firm also bears additional costs associated with replacing a worker, which include recruitment decisions and training costs [71, 193].

Lost productivity from a firm's perspective can also be affected by occupational characteristics such as compensation mechanisms and work-team dynamics; these characteristics are likely to be interrelated [191]. Productivity losses may be overestimated if there are compensation mechanisms where a worker can catch up on their work or work can be completed by the firms' internal labour reserve. On the other hand, productivity losses may be underestimated if the worker who becomes sick is a key member of the production team or the work cannot be easily postponed [191]. There are a few international studies showing that occupations involving team production, those with reduced availability of perfect substitute workers and those with outputs which are time-sensitive have high team dynamic multipliers [189, 194]. However, other studies have shown that work can be compensated within working hours either by the worker themselves or with help from colleagues within the team [191].

Krol et al. [191] explore the use of compensation mechanisms (defined by elasticity of annual labour time (ε), individual compensation (c)) and team dynamic absence multipliers (m). The authors propose a base case scenario, which assumes an elasticity of annual labour time versus labour productivity (ε), with a mean value of 0.8 (where the range is bound by 0 to 1). The elasticity is applied to account for a slightly less than proportionate drop in production compared with work hours, as workers or their colleagues compensate for the absence in normal work hours. For example, an elasticity value of 0.8 means that production will fall by 8% if working hours are reduced by 10%. Additional scenarios by Krol et al. [191] are presented to consider the incremental impact of individual compensation mechanisms and absence multipliers. Absence multipliers (m) are job-specific adjustments based on the ease of substitution, the extent to which productive output is team-dependent and the time sensitivity of a team's output.

For this study we present a base case analysis which assumes an elasticity of annual labour time (ε) of 0.8, based on Dutch data [190]. Values ranging from 0.6 to 0.9 are commonly applied in the literature [71]. However, as there are no Australian data to inform this parameter a sensitivity analysis is applied using the values of 0.6 and 1.0. Additional adjustments for the team dynamic absence multiplier effects (m) were applied, where it was assumed that the cost of the absence exceeds the cost of the absent worker's wage [189, 194] as a sensitivity analysis. We matched the Australian workforce demographics to relevant industries from the study by Pauly [189] (presented in the appendix Table 4), where the average multiplier effect (m) of 1.43 was used to inform the model. Individual compensation mechanisms (*c*) were not considered in the model due to the potential for double correction [76, 191].

For each health state, productivity loss is valued as:

- ***Productivity loss due to acute GI illness***: Productivity loss due to an acute GI illness is estimated by multiplying the daily wage by the number of working days lost due to illness (i.e., absence). As productivity losses are valued from the point of view of the firm, an elasticity adjustment is applied (i.e., elasticity for annual labour time vs labour productivity (ε)) such that the value is a slightly less than proportionate drop in production compared with working hours. Only absenteeism is valued in this health state.
- ***Productivity loss due to IBS*** is estimated by assuming the following:
    - IBS, unable to work some of the time: both absenteeism and presenteeism are valued in this health state. Similar to the acute GI illness health state, productivity loss due to absenteeism is valued by multiplying the daily wage by the number of working days lost due to illness, with an elasticity adjustment applied.
    - IBS, unable to work most of the time: it is assumed these workers are unable to work and, consequently, in this health state people are replaced. The productivity loss and firm costs that occur during the friction period are treated as transition cost in the model, where 'worsening of IBS' events occur.

Willingness to pay to avoid illness (Model 4 and Model 5)

Values for the WTP to avoid illness are used in Model 4 and Model 5. Two different WTP measures are used:

- WTP to avoid illness when sick leave is paid (Model 4): assumes an 'employee' perspective to estimate costs associated with the disutility of being ill. As sick leave is paid, the employee is compensated for productivity lost and the estimated value is a proxy for the disutility of being sick. For that reason, productivity losses as estimated in Model 3 using the FCA is added to the WTP values where sick leave is paid to produce results for Model 4. Theoretically, Model 4 includes a valuation of productivity loss and disutility of illness covering the employer and employee perspectives.
- WTP to avoid illness when sick leave is not paid (Model 5): assumes an employee perspective, which includes the disutility of being ill, but also, as sick leave is not paid, the valuation is a proxy for lost wages for the employee.

The estimates of WTP to avoid a case of acute GI illness and post-infectious IBS were derived in the foodborne illness DCE (see Chapter 3 thesis). In the DCE, participants were asked to value two health states (mild and severe) of a foodborne illness where the quality of life and symptoms were described. A marginal WTP to avoid an illness is then obtained by using the marginal rate of substitution (MRS), which is a ratio of the coefficients of two attributes. This method is used frequently to derive WTP values where cost has been used as an attribute in the DCE. The DCE included the attributes: cost of treatment, duration of illness and the ability to work with and without sick leave. Descriptions for an acute GI illness and IBS, and the health states are presented in Table 11 and Table 12 in the appendix [and Chapter 3 of the thesis].

A summary of the WTP to avoid an acute case of GI illness and chronic case of IBS derived from the foodborne illness DCE is provided in Table 7 and Table 8. To align the health states in the model and those valued in the DCE the following assumptions were made:

- For each illness, 50% of the cases are mild and 50% are assumed to be severe in each health state.
- The mWTP for DCE attributes ‘the duration of illness’ and ‘the ability to work’ were used to estimate the WTP to avoid an illness for the health states with sick leave and without sick leave.
- The duration of illness for an acute GI illness is assumed to be one day, consistent with the duration of illness used in the HCA and FCA. The duration of illness of IBS was valued for one year in the DCE; the estimated WTPs were divided by 12 to obtain the monthly WTP.
- Where the marginal WTP was not statistically significant, it was assumed the value was nil.

Table 7 Marginal willingness to pay (WTP) for an acute GI illness

	Mild	Severe	Average (mild and severe)
Duration of illness (1 day)	$12 ($7, $16)	$32 ($25, $39)	$22
Ability to work and paid sick leave (best level: able to work)			
Unable to work with paid sick leave	$0[a] $16 (-$5, $36)	-$29 (-$52, -$7)	-$14
Unable to work with no paid sick leave	$146 ($116, $177)	$144 ($112, $177)	$145
WTP for health state 2: acute GI illness (assumes duration of illness (DOI) = 1 day)			
Unable to work with paid sick leave			$8
Unable to work with no paid sick leave			$167

Data presented are presented as – WTP, point estimate (95% CI), ($ 2017)

Abbreviations: GI, gastrointestinal illness; WTP, willingness to pay.

[a] Text in red were the values derived from the DCE. As these were not significant the cost assumed was $0.

Table 8 Marginal willingness to pay (WTP) for chronic IBS

	DCE results: mWTP		50% mild / 50% severe	
	Mild	Severe	Annual	Monthly
Duration of illness (1 year)	$575 ($272, $877)	$1367 ($938, $1795)	$971	$81
Ability to work and paid sick leave				
Unable to work some of the time with:				
Paid sick leave	$0[a] -$296 (-$1501, $909)	$0[a] $1461 (-$91, $3013)	$0	$0
No paid sick leave	$3437 ($1599, $5276)	$8347 ($5394, $11301)	$5892	$491
Unable to work most of the time with:				
Paid sick leave	$0[a] $18 (-$1518, $1554)	$2429 ($367, $4491)	$1215	$101
No paid sick leave	$6289 ($4862, $7716)	$8394 ($6189, $10599)	$7342	$612
WTP for health state:				
Health state 3: IBS unable to work some of the time with:				
Paid sick leave			$971	$81
No paid sick leave			$6,863	$572
Health state 4: IBS unable to work most of the time with:				
Paid sick leave			$2,186	$182
No paid sick leave			$8,313	$693

Data presented are presented as – WTP, point estimate (95% CI), ($ 2017);

Abbreviations: IBS, irritable bowel syndrome; WTP, willingness to pay.

[a] Text in red were the values derived from the DCE. As these were not significant the cost assumed was $0.

Results

Base case

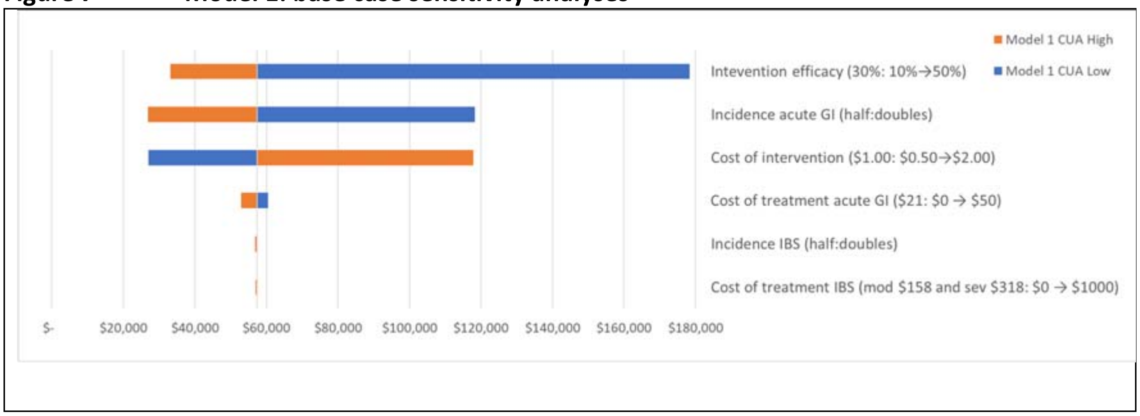
The results for the base case (Model 1) of reducing campylobacter infection by 30% in a population of workers over a 10-year time horizon is presented in Table 9. The incidence of acute GI per person over 10 years was small (current, 0.067; intervention, 0.047; difference, −0.020), and consequently, the incidence of post-infectious IBS was very small, with very few individuals developing IBS (current, 4.5×10^{-6}; intervention, 3.1×10^{-6}; difference, 1.3×10^{-6}). The number of acute GI and post-infectious IBS events, treatment costs and QALYs gained remained consistent across Models 1 to 5. Treatment costs in both arms were small due to the low incidence of acute GI and post-infectious IBS. A small incremental QALY gain of 1.3×10^{-4} was observed. The incremental costs of reducing the number of people with campylobacter infection were $7.49, resulting in an incremental cost-effectiveness ratio (ICER) of $57,323/QALY gain in the base case (Model 1).

Table 9 Results: Model 1 base case

	Current	Intervention	Increment	ICER ($/QALY)
QALYs	7.042331	7.042462	0.000131	$57,323
Costs	$1.42	$8.91	$7.49	

Univariate sensitivity analyses for the assumptions informing efficacy, and the costs of intervention and treatment are presented Figure 7 (and in appendix Table 9). Model 1 was most sensitive to the assumptions pertaining to costs and efficacy of the intervention, and assumptions underpinning acute GI, including the disutility of an acute GI illness and the incidence. This was consistent across all five models. The key driver of costs across all models were the assumptions underpinning acute GI, although the model was less sensitive to the assumed treatment costs for acute GI due to the low cost of treatment. Model 1 was less sensitive to assumptions underpinning post-infectious IBS due to the low incidence rates, including the utility values for IBS and incidence, which was also consistent across all the models.

Figure 7 Model 1: base case sensitivity analyses



Comparison of base case with models including productivity

A comparison of the results for all approaches is presented in Figure 8 and Table 10. As in Model 1, the treatment costs are small due to the low incidence of acute GI and post-infectious IBS, which was consistent across the models. The highest ICER was observed in Model 1 ($57,323/QALY gained), where cost-effectiveness is examined from a health care payer perspective.

The inclusion of productivity costs in Models 2 to 5 significantly increased the total costs in both the arms of the models and substantially impacted on the ICERs. The inclusion of productivity favours the intervention because fewer people are off work. Productivity costs valued using the HCA (Model 2) were 92% ($16.02) of total costs in the arm representing the current situation, which decreased in the intervention arm to 56% ($11.21) of total costs, which reduced the ICER to $20,431/QALY gain, which was the lowest ICER across the five models.

Productivity costs valued using the FCA (Model 3), where costs are confined to the duration of the friction period accounted for 90% ($12.50) and 51% ($8.74) of total costs in the current and the intervention arm, respectively, resulting in an ICER of $28,546/QALY gained. Productivity costs valued using the FCA including the WTP to avoid illness with paid sick leave (Model 4: FCA + WTP w/PSL) were similar to the results presented for Model 3 ($27,344/QALY gained). The addition of the WTP to avoid illness with paid sick leave was between 4% ($0.52) and 2% ($0.36) in the current and intervention arms. Productivity costs valued only using the WTP to avoid illness without paid sick leave (Model 5) were 89% ($11.21) and 47% ($7.84) of total costs in the current and intervention arm, resulting in an ICER of $31,508/QALY gained.

Figure 8 ICERs

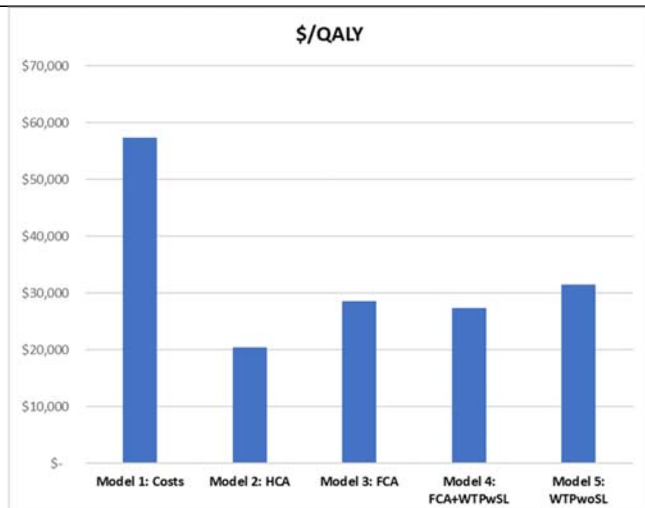


Table 10 Results: All models

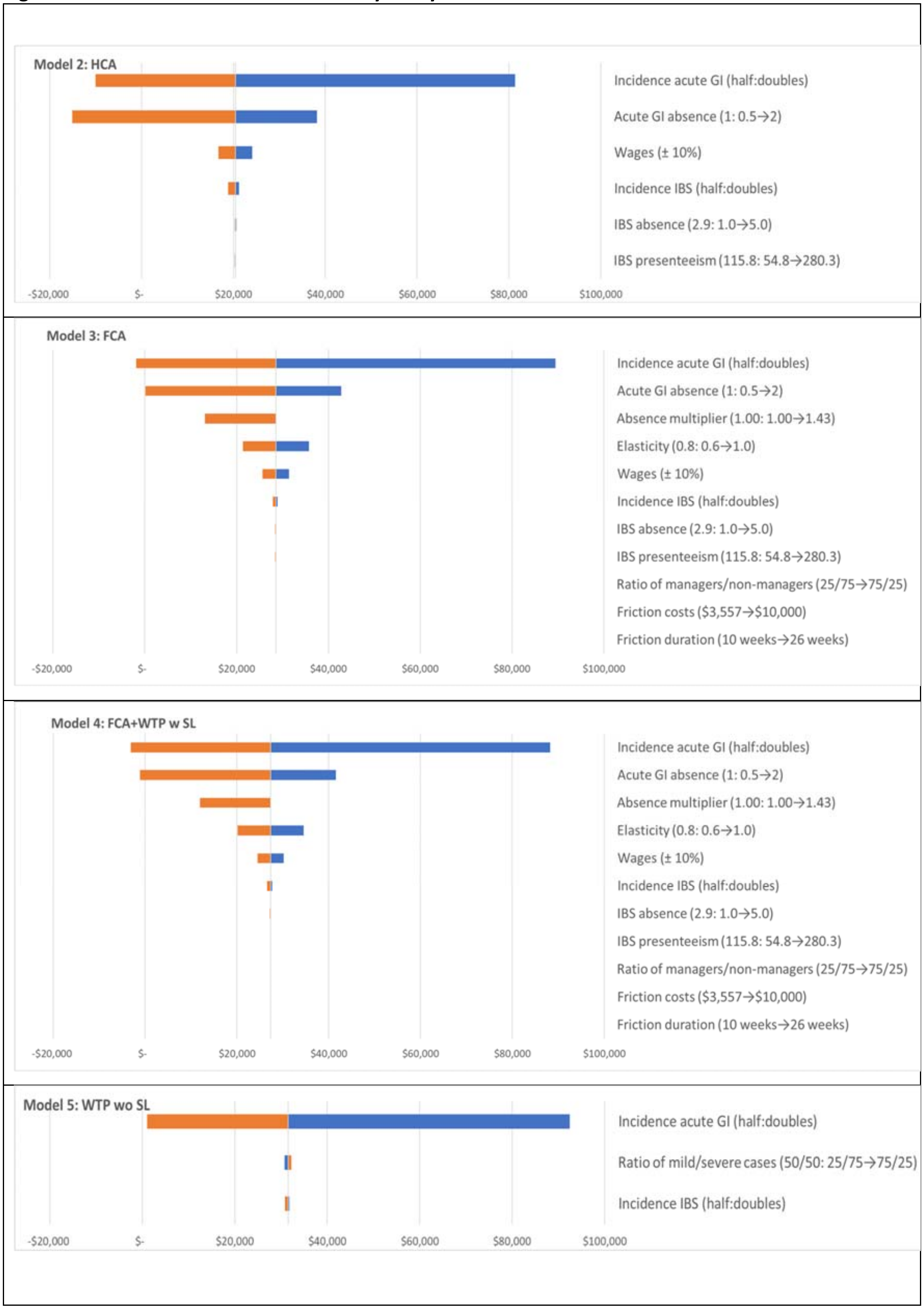
	Costs			QALYs			ICER
	Current	Intervention	Increment	Current	Intervention	Increment	$/QALY
Model 1: base case	$1.42	$8.91	$7.49	7.042331	7.042462	0.000131	$57,323
Model 2: HCA	$17.44	$20.11	$2.67	7.042331	7.042462	0.000131	$20,431
Model 3: FCA	$13.92	$17.65	$3.73	7.042331	7.042462	0.000131	$28,546
Model 4: FCA+ WTP without SL	$14.44	$18.01	$3.57	7.042331	7.042462	0.000131	$27,344
Model 5: WTP with SL	$12.63	$16.75	$4.11	7.042331	7.042462	0.000131	$31,508

Univariate sensitivity analyses were conducted to test the assumptions used to value productivity loss for the HCA, FCA and WTP measures and are presented in Figure 9 (and Table 16 in the appendix). The models including lost wages from the employee or employer perspective (Model 2, Model 3 and Model 4) were sensitive to the number of days absent for an acute GI episode, where increasing the number of days demonstrating the intervention as cost-saving.

An examination of team dynamics was conducted as a sensitivity analysis for the models using the FCA (Model 3 and Model 4). By assuming a team dynamic effect where the absence of a key worker results in a knock-on effect, productivity losses are increased substantially which was a key driver of the FCA if used in the analysis. Use of this input assumes that work cannot be recovered by the ill worker (e.g., during working hours at a later date or by another worker at the business). Also in these models (Model 3 and Model 4), increasing the absence multiplier substantially decreased the ICER below the ICER of the HCA (Model 2). Decreasing the elasticity for annual labour time versus labour productivity also decreased the ICER for Models 3 and 4.

Because the incidence of IBS was low, Models 3 and 4 were less sensitive to the friction period duration and costs for replacing a worker. Although differences in the WTP to avoid mild and severe IBS were observed in the DCE (in Chapter 3 of the thesis), Model 5 was less sensitive to the ratio of mild and severe cases assumed due to the low number of IBS events.

Figure 9 Models 2 to 5: Sensitivity analyses



Note: orange represents high value; blue represents low value.

Discussion

This study essentially focussed on the comparing methods used to value productivity losses, which was feasible using a stylised model. Productivity losses due to FBI provided the case study's setting, where short-term and long-term illnesses have different impacts on an individual's productivity. The stylised model was based on a hypothetical public health intervention that would be evaluated by a food safety authority.

Productivity loss due to FBI were valued using three different methods (HCA, FCA and WTP), as well as a combination of the FCA and WTP methods to adjust for differences in the perspective of analysis. A cost-utility analysis excluding productivity losses was also conducted alongside these valuations, as this is the main technique used for modelling within the health sector in Australia [42]. Overall, we found that considering productivity costs in modelling such illness, generates quite different ICERs and, as a result, approaches used may influence the decision as to whether to adopt a new policy or intervention. The key differences between the approaches were the perspective taken in the analysis, as this influenced how the short-term and long-term productivity losses are treated.

Model 1 did not explicitly include productivity costs, whereas Models 2 to 5 all include productivity costs from the perspective of an employee; only Models 3 and 4, also included costs from the perspective of an employer. In isolation, the HCA (Model 2) and FCA (Model 3) estimates value of illness in terms of lost productivity, however, they do not capture the value of health to the individual. The models including the WTP to avoid illness with paid sick leave (Models 4) or without paid sick leave (Model 5) do capture the value of health to the individual where preferences were elicited using DCE methods (Chapter 3 of the thesis).

The highest ICER ($57k/QALY gained) was observed in the cost-utility analysis (CUA) approach (Model 1), which takes the perspective of the health care system and did not explicitly include productivity. Assuming an ICER of $50,000/QALY gained is the cost-effectiveness (CE) threshold (i.e., the maximum cost per health outcome) that a health system is willing to pay [53] the proposed FBI intervention that reduces incidence of campylobacter by 30% may not be suitable for funding from the health care system perspective[15]. In a traditional CUA the outcome measure is the QALY, which

[15] The $50,000/QALY threshold is used as a WTP threshold for a health care payer only for the purpose of this study. The Australian system does not specify a WTP threshold and has a more holistic approach in evaluating health technologies under PBAC and MSAC, where the decision is likely to take other information into account.

captures the change in healthy years available to a person due to the intervention. Some researchers consider that the QALY is assumed to capture both the intrinsic value to the person of their health and their productivity (because it is assumed implicitly that usual activities are captured in the QALY measure) [56]. Other researchers have contested the premise that the productivity costs (or income losses) are implicit in the QALY [195-197]. They report no significant differences in the health state valuation scores between respondents that instinctively considered impacts of illness on income compared with respondents that did not think about income. These studies concluded that the impact of double counting productivity costs in the numerator of the ICER was likely to be minor; however, they note that being asked to explicitly consider income effects did influence utility scores [195-197]. The impact of double counting of productivity costs is likely to be minor as respondents were explicitly asked to consider ability to work and benefits of sick leave pay. Productivity costs were included in the numerators of the ICERs (for Models 2 to 5).

Inclusion of productivity costs (in Models 2 to 5) increased the total costs in the model arms such that costs increased (by a factor of 9 to 12 times) across Models 2 to 5, illustrating there are substantial productivity costs are associated with FBI compared with the costs of treatment alone. The significant increase in total costs is consistent with published cost of illness studies including productivity costs [70]. Including productivity costs reduces the ICER from $57k/QALY to $20k/QALY when using HCA (Model 2), $29k/QALY using FCA (Model 3), $27k/QALY using FCA plus WTP with paid sick leave (Model 4), and $32k/QALY using WTP without sick leave available (Model 5). By including productivity costs (Models 2 to 5), investing in an intervention that reduces campylobacter incidence by 30% is worthwhile based on the $50k/QALY threshold. This is consistent with the majority of other studies where inclusion of productivity costs were favourable for 76% (110/144) of cost-effectiveness/utility analyses found in a systematic review [198].

All models were driven by the incidence of the acute GI events, which allowed for focusing on the valuation of productivity losses of a short-term illness using the various methods in this case study. This model assumed that patients could not be diagnosed with post-infectious IBS until after the first year, consequently, it is possible that there are health and employment effects may affect people with post-infectious IBS within the first year after the initial GI infection. Consequently, costs and disutility due to post-infectious IBS may be underestimated in the model. On the other hand, productivity losses may have been overestimated for patients with post-infectious IBS since the model structure did not allow for patients with IBS to return to full health. However, as the incidence of IBS was very small, assumptions underpinning chronic IBS did not translate into a large difference in the CEA results when comparing the HCA and FCA methods, or the valuation of long-term productivity loss. Illnesses resulting in loss of working ability, early retirement or death have demonstrated higher productivity loss with HCA compared with the FCA [70].

As expected, productivity costs using the FCA (Model 3) were lower than the HCA (Model 2). In this study, the assumed absence multiplier used in the FCA was 1, meaning that teamwork dependencies are not impacted by the absence of the ill worker. This may be a reasonable assumption as work can be compensated within working hours either by the worker themselves or with help from colleagues within the team [191]; however, in other cases, this may lead to larger losses for some businesses or industries that rely on a team of employees for production, distribution and supply [189, 194]. As demonstrated in the sensitivity analyses, the ICER for Model 3 decreased further to $13k/QALY gained when a multiplier of 1.43 for team dynamic absences is applied. The COVID-19 pandemic has caused significant disruption in the distribution and supply chain for goods and services due to workers becoming ill or isolating due to being identified as close contacts of known infectious cases. In cases for diseases causing mass absenteeism, it may be reasonable to apply adjustments for compensation mechanisms and multiplier effects. Application of these compensation mechanism and multiplier effect parameters implies that the cost of short-term absence has a higher value when using the FCA compared with the HCA.

Using WTP offers an alternative method for estimating costs by incorporating an individuals' preferences and attitudes into social decision-making and relating this to population health outcomes [52, 152]. In using WTP to measure productivity loss, it is important that this considers the effects of employment conditions, which can influence values differently for short-term and long-term illnesses. In Model 4, where the WTP to avoid illness with sick leave pay is available, there is a marginal increase in the costs of illness for individual workers. In Model 4 the WTP to avoid illness with paid sick leave is considered to capture the value of health to the person; for this reason, these costs are coupled with the FCA valuation to include productivity costs. Paid sick leave entitlements are established compensation mechanisms used in Australia [6]. Having these paid sick leave entitlements means time off work can be taken without financial loss to the individual, as these costs are generally borne by the employer; however, not all employees have paid sick leave entitlements [6, 21, 26]. Characteristics of workers in Australia with sick leave entitlements are reported by the Australian Bureau of Statistics [199]. The proportion of workers with no access to paid leave entitlements was 37% in 2019 (24.4% of employees are casual workers;12.6% are self-employed). The proportion of workers with no leave entitlements varies across the sectors, for example, 63% of people working in the hospitality and accommodation sectors have no leave entitlements compared to 7.6% of those working in financial and insurance services [199].

There are some issues pertaining to use of the WTP to pay to avoid FBI estimate in Models 4 and 5 that should be acknowledged. Firstly, there is a double-counting of disutility of illness in Models 4 and 5. The ICER contains elements of disutility in numerator, in the WTP to avoid illness value, and in the denominator, in the QALY. The extent to which double-counting of disutility associated with illness affecting the ICER is unclear. This is a limitation in using the values derived from Chapter 3 [200] in this cost-effectiveness analysis. Secondly, Model 4 included the employer perspective through the FCA, and employee perspective using WTP values estimated using a general population. There may be a mismatch between the employer and employee expectations. Advancement of this research could consider conducting a DCE assessing the WTP to avoid illness using a business panel or from employers.

The valuation of productivity cost using the WTP without paid sick leave (Model 5) was intended to capture lost wages and productivity loss, and the value of being sick from the perspective of an individual person. This WTP cost in Model 5 is approximately 21 times higher than in Model 4, which demonstrates the importance of considering individual preferences to avoid illness in the context of an individuals' lost income. The differences in the ICERs demonstrate that income loss is tempered by availability of paid sick leave.

<u>Limitations of this study and concerns raised with including productivity in economic evaluations:</u>

In Australia, public health interventions are not typically evaluated using cost-utility analysis or cost-effectiveness analysis. Health technology assessment methods (e.g., CUA and CEA) are used as the basis for decision-making by the PBAC and MSAC, where interventions are generally targeted to a select population, may be expensive, and recommend productivity costs are presented in a sensitivity analysis and not the base case [42]. Although inclusion of productivity costs is not common in health technology assessments in Australia, inclusion of productivity losses is recommended in guidelines of other countries [61-63, 65, 146]. Other authorities, use cost-benefit analysis for decision-making purposes [152, 153] where wider economic impacts are considered. Changes in productivity costs becomes one of the key considerations in decision making [152]. Food Standards Australia and New Zealand (FSANZ) are the statutory authority that develop food standards for Australia and New Zealand. FSANZ have previously used a cost benefit analysis [201] to inform the cost of foodborne illness in Australia.

Despite the methodological merits of the WTP approach, there have been substantial criticisms of this approach in the literature [52]. Firstly, using the WTP is limited in valuing lost productivity when prices are controlled, which makes it difficult to ascertain what people are actually willing to pay, and there may be a lack of association with real economic decisions [52]. Secondly, small errors in the stated WTP may proliferate into large errors in the population WTP. Generation of inflated and unreliable valuations could lead to hampering efforts at rational decision-making.

One of the major criticisms of including productivity costs in economic evaluations is that the analyses favour those that are working and those on higher wages. An individual's WTP is constrained by the individual's ability to pay, also raising equity concerns due to a skewed distribution of income. Consideration should be given to the distributional effects of funds being allocated to treatments based on productivity losses. Productivity losses are not generally included in economic evaluations due to equity implications, where inclusion of productivity losses favours those who are working and on higher wages. As observed in sensitivity analyses, cost-effectiveness of the intervention became more favourable as the wage increased. Although this analysis excluded people who are not of working age, a future study could include people of different age groups and working status to ascertain the impact of distributional effect of including productivity losses.

This chapter focused on examining productivity losses which mainly affect a working age population, and focusing on a working age population will underestimate the utility losses associated with a foodborne illness [202]. For example, a carer's time and disutility are not considered as it is assumed in the model that people only miss out on paid work due to their own illness, not others' illness. Incidence of campylobacteriosis is higher in children under the age of 5 years and in young adults [202]. Although focusing on a working age population may underestimate the utility losses associated with a foodborne illness, this study focuses on examining productivity losses, which mainly affect a working age population.

The model was constructed using data inputs combined from several sources and is subject to multiple assumptions. There are systematic differences across studies, such as country of conduct, epidemiology of the disease within the study and the country (e.g., determinants of disease, IBS subtype, illness severity and case classification, health care systems) and resource utilisation, as well as labour context, including access to sick leave entitlements, which may affect estimations of resource use costs and lost working time.

Conclusion

Accurately estimating the burden and cost of FBI is important for the development and prioritising of effective food safety policy and treatments. Lost productivity is one of the largest costs associated with the burden of FBI. Reliable estimates of the economic costs are needed for policy-makers to develop, prioritise and implement control measures with a net benefit to society. Preventative strategies are usually employed in food safety policy to reduce the incidence of FBI, which consequently reduces health care use and treatment costs. Although economic evaluation is used within the Australian health sector, it is not generally used to assess interventions or policies used to prevent FBI.

Economic evaluation models help decision-makers in choose policies or interventions systematically so that funding for resources can be committed [19]. When the ICER (cost per QALY gained) is less than the cost-effectiveness threshold, funding the intervention is assumed to increase population health. As such, it is important to understand what is being measured and valued when each method is applied in economic evaluation models. The inclusion of productivity could potentially change whether an intervention is considered cost-effective.

This case focused on FBI due to campylobacter infection causing acute GI, possibly leading to post-infectious IBS. For this case study, the method chosen to estimate productivity costs did not impact the ICER results as much as expected; however, this may be due to the case study used. The ICERs were similar for models using the FCA (representing the business perspective, Models 3 and 4) and the model using the WTP without sick leave (employee perspective, Model 5). It is possible that the difference could have been smaller or larger in a different case study. Further research is needed to ascertain the magnitude of how the results vary based on the perspectives taken, and whether the results are consistent or divergent for other illnesses.

Although the ICERs were similar, our study shows that the methods used and underlying assumptions for estimating productivity losses can influence decisions regarding resource allocation. Perspectives for the health care system, individuals, and businesses yield different ICERs, and the perspective chosen for the analysis determines whose preferences are of greatest importance. This study demonstrates the value of presenting a comparison of the HCA, FCA and WTP approaches when evaluating new policies and interventions.

Appendix

A description of the two illnesses (one with short-term effects and one with long-term effects) resulting from campylobacter infection are provided in Table 11 and Table 12. These descriptions were provided to respondents in the foodborne illness DCE. The acute gastrointestinal illness has been combined into one health state as the costs for a mild and severe are similar [174] and Australian data from the NGSII [165] were available to populate the model.

Table 11 Acute illness – Gastrointestinal (GI) illness

Condition	**General description**	
Gastrointestinal	Symptoms of gastrointestinal illness which may include diarrhoea, fever, vomiting and nausea. Symptoms are related to food you have recently eaten.	
Health state	**Mild**	**Severe**
Usual activities	Slight problems doing usual activities	Severe problems doing usual activities
Pain/discomfort	No pain or discomfort	Moderate pain or discomfort
Tiredness/fatigue	Tired or fatigued a little of the time	Tired or fatigued most of the time
Symptoms	Diarrhoea a little of the time	Diarrhoea most of the time

Table 12 Chronic illness – Irritable bowel syndrome (IBS)

Condition	**General description**
Irritable bowel syndrome (IBS)	A condition that results in pain and altered bowel habits, such as diarrhoea or constipation. People with IBS generally have abdominal cramping, lower belly pain, discomfort and bloating. The pain associated with IBS may be relieved by going to the toilet. The condition can last a long time and can affect life on a daily basis. For most people, the symptoms are intermittent. Symptoms associated with an episode of IBS generally last for two or so days. An episode is diarrhoea or constipation that may last for a few days at a time. For some people, the onset of an episode can be related to the types of food they eat, and there may be some warning of an episode, however, others may receive no warning of an episode. This may affect how or when they go out with friends or family, what they eat or how they plan their day. This can result in social isolation. When people with IBS go out, they often need to consider availability of toilet facilities. There are periods of time where sufferers have more frequent episodes than other times. Irritable bowel syndrome doesn't cause lasting damage and doesn't contribute to the development of serious bowel conditions, such as cancer or colitis. There is no known cure for IBS and treatments are generally for management of individual symptoms

Health state	Mild	Severe
Usual activities	Slight problems doing usual activities	Severe problems doing usual activities
Pain/discomfort	No pain or discomfort	Moderate pain or discomfort
Tiredness/ fatigue	Tired or fatigued a little of the time	Tired or fatigued most of the time
Mental health	Nervous, anxious or sad about your illness some of the time	Nervous, anxious or sad about your illness most of the time
Food restrictions	Somewhat restricted in the kinds of food you eat	Very much restricted in the kinds of food you eat
Predictability	You have some warning of symptoms occurring	You have no warning of symptoms occurring
Episodic frequency	You have 2 episodes a month	You have 6 or more episodes a month

Population and setting

Transition probabilities for acute GI and IBS were obtained from an Australian study, where the annual incidence of foodborne illnesses were estimated circa 2010 [133, 203]. Data sources used to inform incidence estimates of foodborne illness in Australia were: notifiable surveillance data through the National Notifiable Diseases Surveillance System (NNDSS), surveillance data at the state territory levels, the OzFoodNet outbreak register, data from the National Gastroenteritis Survey II (NGSII), data from the water quality study (WQS), hospitalisation and mortality data from the Australian Bureau of Statistics (ABS).

The assumption informing that transition probability for worsening of IBS was based a cross-sectional study conducted in the UK (N=1,597) [168], where people with IBS were surveyed; one of the survey's components asked respondents about the effect on their working life. From this survey 12% (n=192) of people reported they had stopped working [168]. Although this study was conducted in 1999, it is the only study identified that has reported the number of people who ceased working due to IBS, where this study was identified from a narrative review published in 2014 [204]. In a more recently published systematic review [205] eight studies were identified that reported on the experience of working adults with IBS; of these only two qualitative studies [205] reported that a minority of people with IBS have difficulty keeping their job due to the severity of IBS symptoms, however these studies were qualitative studies with small sample sizes of less than 20 people [206, 207].

Time off work

Different instruments have been used to assess absenteeism and presenteeism (e.g., The Work Productivity and Activity Impairment (WPAI) questionnaire [208]; Work Limitations Questionnaire (WLQ) [209]; iMTA Productivity Cost Questionnaire (PCQ) [210]). Some of the surveys used for assessing the extent of absenteeism and/or presenteeism due to IBS have been bespoke [211, 212]. Most recently, absenteeism and presenteeism has been assessed using the Work Productivity and Activity Impairment (WPAI) questionnaire [164, 167, 181, 213-216] and has been validated for use in IBS i.e., the WPAI:IBS questionnaire [217]. Four scores are calculated using the WPAI: absenteeism (from work time), presenteeism (impairment at work), overall work productivity loss (absenteeism plus presenteeism), and daily activity impairment. Scores from the WPAI are conveyed as percentages and higher scores indicate higher productivity loss. For this reason, not all studies using these productivity questionnaires report time off work in units of time e.g., hours or days. Six studies were identified that reported absenteeism and/or presenteeism in a unit of time [167, 177, 213, 218-220]. A summary of the Tack et al. used to inform absenteeism and presenteeism in the model is provided in Table 13.

Table 13 Studies reporting time off work due to IBS

<table>
<tr><th>Source</th><th>Study design / population</th><th>Estimated time off work</th></tr>
<tr><td>Tack 2019 [167]</td><td><u>Study design</u>
Cross-sectional study; 12 month period (6 month retrospective + 6 month prospective); conducted from April 2012 to January 2014.

<u>Population</u>
• N=525;
• Patients ≥ 18y with moderate to severe IBS-C;
• France, Germany, Italy, Spain, Sweden and the UK.

<u>Outcomes</u>
• Direct costs per patient
• Productivity: WPAI</td><td>Days of sick leave over one year for employed patients
<table>
<tr><th>Country</th><th>N</th><th>Days (mean), n (95%CI)</th><th>Days per month[a]</th></tr>
<tr><td>France</td><td>59</td><td>64.1 (17.0, 111.2)</td><td>5.3</td></tr>
<tr><td>Germany</td><td>102</td><td>29.5 (10.5, 48.5)</td><td>2.5</td></tr>
<tr><td>Italy</td><td>112</td><td>11.6 (4.1, 19.2)</td><td>1.0</td></tr>
<tr><td>Spain</td><td>112</td><td>52.4 (0.0, 114.4)</td><td>4.4</td></tr>
<tr><td>Sweden</td><td>36</td><td>51.3 (0.0, 113.6)</td><td>4.3</td></tr>
<tr><td>UK</td><td>104</td><td>25.9 (12.7, 39.1)</td><td>2.2</td></tr>
<tr><td>All countries</td><td>525</td><td>35.2</td><td>2.9</td></tr>
</table>
a Results for all countries and days per month was calculated for this study.

No. of hours of work impairment
<table>
<tr><th>Country</th><th>N</th><th>Hours (mean), n (95%CI)</th><th>Hours per month[a]</th></tr>
<tr><td>France</td><td>59</td><td>69.1 (22.0, 116.1)</td><td>5.8</td></tr>
<tr><td>Germany</td><td>102</td><td>140.4 (88.8, 192.0)</td><td>11.7</td></tr>
<tr><td>Italy</td><td>112</td><td>83.2 (18.4, 148.0)</td><td>6.9</td></tr>
<tr><td>Spain</td><td>112</td><td>54.8 (34.0, 75.7)</td><td>4.6</td></tr>
<tr><td>Sweden</td><td>36</td><td>280.3 (146.5, 414.1)</td><td>23.4</td></tr>
<tr><td>UK</td><td>104</td><td>161.9 (103.6, 220.2)</td><td>13.5</td></tr>
<tr><td>All countries</td><td>525</td><td>115.8</td><td>9.6</td></tr>
</table>
a Results for all countries and days per month was calculated for this study.

Days off per month: ~6.2 days (2.9+1.2=4.1)
• Absenteeism: 2.9 days per month (range: 1.0 to 5.3)
• Presenteeism: 1.2 days off work per month (due to restricted activity; calc: 9.6/8 hours per day=1.2 days)</td></tr>
</table>

Utilities

Possible values for health state utilities could be informed from three different multi-attribute utility instruments (MAUIs):

- Euroqol-5 Dimensions (EQ-5D): A five item descriptive system recording the level of self-reported problems on each of the dimensions including: mobility, self-care, usual activities, pain/discomfort, anxiety/depression. The EQ-5D has been validated in people with IBS [181, 221].
- Short Form 6D (SF-6D): The SF-6D is derived from the Short Form 36 (SF-36). Dimensions included in the SF-36 include: physical functioning, role-physical, bodily pain, general health, vitality, role-emotional, social functions and mental health. The SF-36 has been validated in people with IBS [218, 220].
- Irritable Bowel Syndrome Quality of Life (IBS-QoL): A disease-specific health-related quality of life questionnaire containing 34 items in eight dimensions including: dysphoria, interference, body image, health worry, food avoidance, social reaction, and sexual relationships [222].

Sixteen studies were identified in the literature that could be used to inform utility for each health state.

- Three studies were identified that measured utility values in a general population in Australia [175, 176, 223]. Utility for full health across the studies reporting population norms in Australia ranged from 0.770 (SF-6D) to 0.92 (EQ-5D).
  Utility used in the model base case: 0.89 (using the EQ-5D).
- Five studies were identified reporting disutility for diarrhoea and vomiting [183-187]. These studies estimated disutility of adverse events for oncology treatments resulting in diarrhoea and/or vomiting using a standard gamble technique. These studies were used to inform the acute GI health state. Toxicities for oncology treatments have similar symptoms acute GI illness and thus provide reasonable proxy estimations. The estimated disutility ranged from 0.05 to 0.11.
  There was one study [156] that reported utility using the EQ-5D for associated with infection resulting in a foodborne illness, where experts (N=9) were asked to estimate the utility values for foodborne illness health states. Preferences elicited from a general population are generally considered to be more appropriate than those elicited from an expert panel.
  Disutility used in the model base case: -0.078 (average of five values reported).

- Eight studies were identified in patients with IBS [177-180, 182, 213, 220, 221]. Symptoms of IBS fluctuate over time, however it was assumed that quality of life does not change over time [179].
  Across the studies, utility values estimated ranged from 0.67 to 0.80 (range: six studies reporting EQ-5D, 0.675 to 0.80; three studies reporting SF-6D, 0.667 to 0.75; three studies reporting IBS-QoL, 0.614 to 0.754). Two studies reported differences between groups of people with IBS compared with controls [177, 213], where quality of life reported were lower for those with IBS compared with the controls (-0.064 (p<0.001) [213]; -13.5 (95%CI: -18.6, -8.0) [177]. However, these studies did not report the differences in utilities by severity of IBS. Only one study [221] reported utility values by severity of IBS, where based on the IBSSS score, people with mild and moderate illness had a utility of 0.80 and those with severe illness had a utility of 0.70.
  Utility used in the model base case: 0.719 (average of all EQ-5D values; SF-6D, 0.706; IBS-QoL, 0.695).

Team dynamic effects

Two studies have reported multipliers for absent workers by job type [189, 194]. These studies, where these studies were conducted in the USA, where the labour market is different to Australia e.g., sick leave benefits are different. As both studies were conducted by the same researchers, the results from the later study (2008) are used where the multipliers for absences are estimated. Estimated multipliers for absences ranged from 1.05 to 2.04 [189]. Absence multipliers have a lower bound of 1, which assumes that losses are either equal or greater than the wage costs. Occupations requiring a combination of requirements for team production, reduced availability of perfect substitute workers, and subject to outputs that were time-sensitive had higher absence multipliers. For the purposes of this case study, multipliers for five industries were selected. These five industries, along with the representative proportion of businesses they represent in Australia, and jobs within the industry where multipliers were estimated, are provided in Table 14.

Table 14 Absence multipliers

Industry, job type	Absence multiplier
Construction (Australian businesses: 17%)	**1.35**
Construction workers	1.35
Professional, scientific and technical services (Australian businesses: 12%)	**1.77**
Engineers	2.04
Paralegals	2.00
Legal secretaries	1.27
Transport, postal and warehousing (Australian businesses: 7%)	**1.50**
Truck drivers	1.50
Health care and social assistance (Australian businesses: 6%)	**1.41**
Registered nurses	1.52
Licensed Practitioner Nurses	1.52
Medical assistants	1.20
Accommodation and food services (Australian businesses: 4%)	**1.19**
Waiters/waitresses	1.10
Cooks	1.36
Hotel desk clerks	1.25
Hotel maids	1.05
Average across all job types	**1.43**

Source: ABS, 8165.0 Counts of Australian Businesses 8165.0 Counts of Australian Businesses, including Entries and Exits, Jun 2013 to Jun 2017, Table 1, Table 4, Table 13; URL http://www.abs.gov.au/ausstats/abs@.nsf/mf/8165.0). Data reported in this table is based on count of businesses operating at end of financial year 2016-2017; Pauly 2008 Table II and Table V [189].

Results: sensitivity analyses

Table 15 Sensitivity analyses of epidemiology, cost, efficacy assumptions: Model 1 base case

	Current	Intervention	Increment	Cost/QALY
Base case				
QALYs	7.042331	7.042462	0.000131	
Costs	$1.42	$8.91	$7.49	$57,323
Cost of intervention halves ($1.00→$0.50)				
QALYs	7.042331	7.042462	0.000131	$27,025
Costs	$1.42	$4.95	$3.53	
Cost of intervention doubles ($1.00→$2.00)				
QALYs	7.042331	7.042462	0.000131	$117,920
Costs	$1.42	$16.82	$15.40	
Intervention efficacy decreases (30% → 10%)				
QALYs	7.042331	7.042375	0.000044	$178,401
Costs	$1.42	$9.19	$7.77	
Intervention efficacy increases (30% → 50%)				
QALYs	7.042331	7.042549	0.000218	$33,108
Costs	$1.42	$8.62	$7.20	
Incidence of acute GI halves				
QALYs	7.042549	7.042614	0.000065	$118,247
Costs	$0.71	$8.41	$7.70	
Incidence of acute GI doubles				
QALYs	7.041894	7.042157	0.000263	$26,861
Costs	$2.85	$9.91	$7.05	
Incidence of acute IBS halves				
QALYs	7.042333	7.042463	0.000130	$57,586
Costs	$1.40	$8.89	$7.49	
Incidence of acute IBS doubles				
QALYs	7.042328	7.042459	0.000132	$56,803
Costs	$1.47	$8.94	$7.47	
Disutility of acute GI (-0.078 → -0.010)				
QALYs	7.042707	7.042724	0.000018	$425,910
Costs	$1.42	$8.91	$7.49	

Table 16 Models 2 to 5: Sensitivity analyses

	Model 2 HCA	Model 3 FCA	Model 4 FCA + WTP with SL	Model 5 WTP without SL
Base case	$20,431	$28,546	$27,344	$31,508
HCA/FCA assumptions				
Wage rate				
Increase wage by 10%	$16,742	$25,669	$24,468	$31,508
Decrease wage by 10%	$24,121	$31,422	$30,220	$31,508
Assuming 5-day work week	$6,083	$17,067	$15,865	$31,508
Acute GI				
Increase no. days absent (1→2)	-$15,087	$131	-$1,071	$31,508
IBS, unable to work some of the time				
Increase no. days absent (2.9→5.0)	$20,251	$28,401	$27,200	$31,508
Decrease no. days absent (2.9→1.0)	$20,595	$28,676	$27,474	$31,508
Increase in no. presenteeism hours (115.8→280.3)	$20,284	$28,428	$27,226	$31,508
Decrease in no. presenteeism hours (115.8→54.8)	$20,486	$28,589	$27,388	$31,508
FCA assumptions				
Multiplier for absences decreased (1.43→1.19)	$20,431	$14,556	$13,354	$31,508
Multiplier for absences increased (1.00→1.43)	$20,431	$13,121	$11,919	$31,508
Elasticity increased (0.8→1.0)	$20,431	$21,371	$20,170	$31,508
Elasticity decreased (0.8→0.6)	$20,431	$35,720	$34,518	$31,508
Ratio of managers/non-managers (25/75→75/25)	$20,431	$28,532	$27,330	$31,508
Friction period duration (10 weeks→26 weeks)	$20,431	$28,448	$27,246	$31,508
Friction period costs ($3,557→$10,000)	$20,431	$28,520	$27,319	$31,508
WTP assumptions				
Ratio of mild/severe cases (50/50→75/25)	$20,431	$28,546	$27,672	$30,768
Ratio of mild/severe cases (50/50→25/75)	$20,431	$28,546	$27,016	$32,248

Chapter 6: Exploring the Trade-Off Between Economic and Health Outcomes During a Pandemic: DCE of Lockdown Policies

6.1 Overview

During my candidature, an infectious outbreak of the novel coronavirus (COVID-19) was declared to be a pandemic by the World Health Organization (WHO) on the 11 March 2020 [224]. In April 2020, as COVID-19 infection rates increased, Australia went into lockdown and international borders closed. As the central theme of my thesis is to develop methods to enhance our understanding of the economic consequences associated with population-level diseases, the COVID-19 outbreak offered an opportunity to apply my newly acquired skills in stated preference-based research to answer a significant policy question – specifically, to explore the trade-offs individuals are prepared to make between the economic consequences and health outcomes under different lockdown policies. The catastrophic impact of an illness on productivity would have been considered inconceivable prior to the COVID-19 pandemic. Impacts of the pandemic are broad and more severe due to the impact on people who are well or healthy. Consideration of the COVID-19 restrictions reflects a contemporary health issue affecting productivity.

To reduce mortality from COVID-19, governments imposed stringent disease containment measures including limitations on travel, physical distancing restrictions and closures of schools and workplaces [225]. While these measures have been effective in reducing the spread of COVID-19, they significantly impacted the economy and led to reduced economic activity, business closures and unemployment [225, 226].

Implementation of these disease containment measures required compliance not only from people with COVID-19 but from everyone in the community [225, 226]. Trade-offs between the health risks (for self and for others) and productivity impacts (e.g., labour shortages, increasing unemployment and welfare payments) were prominent news headlines. The balance between managing health risks and maintaining economic outcomes, such as employment and income, is one of the biggest challenges the COVID-19 pandemic has presented for governments, businesses and individuals.

As in the foodborne illness case study, government intervention is required to reduce the negative health impacts of COVID-19. However, in contrast to the willingness to pay (WTP) to avoid a foodborne illness presented in Chapter 3, which examined trade-offs from the perspective of an individual person, this discrete choice experiment (DCE) study examines trade-offs between health and productivity from a national perspective. The scale of productivity impacts due to COVID-19 are also larger in scale than those of foodborne illness, where an outbreak is typically localised to a region.

In this study, I develop and implement a DCE to examine the interrelationship between policies used to manage and regulate public health risks which result in lost productivity and changes in freedom at a national level. I present a second case study using a DCE to examine health and productivity trade-offs at a national level. As part of the experiment, I design an experiment that trades off the policy options in hypothetical scenarios where individuals choose their preferred option. This allowed for an examination of what matters most to people with respect to managing public health risks on the one hand and impacts affecting productivity capacity for the overall economy on the other.

Publications details

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Author contribution: The research question and methodology and the design of the study were developed by KM, DS, PC, RV and SG. DS constructed the designed experiment. I performed the data analysis and interpretation of results and drafted the manuscript. All co-authors contributed to the interpretation of the results, reviewed the manuscript and approved the final version for publication.

Post publication notes:

During the development of the DCE there were many restrictions that were considered but not included in the experiment. The intention was not to value each restriction individually, but to compare different suites of restrictions, which were relevant at the time. Combining restrictions into a single attribute was done to reflect the levels of restrictions at the time, which were multifactorial. From a public health point of view, this reflects the policy reality – restrictions tend to be thought of as a package depending on the need to reduce risk of infection. For example, closing schools and preventing people going to work or to the shops were intertwined. Newly emerging information meant restrictions rapidly changed (for example restrictions relating to wearing masks, LGA travel limits, and curfews), which is a limitation that has been acknowledged in the paper. Additional refinement to include more restrictions may have increased the burden on the respondents completing the DCE. As restrictions did vary in locations around Australia - for example Victoria had stricter and longer restrictions compared to the rest of Australia - quotas were applied such that one third of respondents were from Victoria, one third from NSW, and the remaining from the rest of Australia. However, subgroup analyses by state did not show any meaningful or significant differences between these three regions in Australia, suggesting that exposure to different restrictions may not be important.

6.2 Publication/manuscript

The Patient - Patient-Centered Outcomes Research
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ORIGINAL RESEARCH ARTICLE

Exploring the Trade-Off Between Economic and Health Outcomes During a Pandemic: A Discrete Choice Experiment of Lockdown Policies in Australia

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Abstract

Background All countries experienced social and economic disruption and threats to health security from the COVID-19 pandemic in 2020, but the responses in terms of control measures varied considerably. While control measures, such as quarantine, lockdown and social distancing, reduce infections and infection-related deaths, they have severe negative economic and social consequences.

Objectives The objective of this study was to explore the acceptability of different infectious disease control measures, and examine how respondents trade off between economic and health outcomes.

Methods A discrete choice experiment was developed, with attributes covering: control restrictions, duration of restrictions, tracking, number of infections and of deaths, unemployment, government expenditure and additional personal tax. A representative sample of Australians ($n = 1046$) completed the survey, which included eight choice tasks. Data were analysed using mixed logit regression to identify heterogeneity and latent class models to examine heterogeneity.

Results In general, respondents had strong preferences for policies that avoided high infection-related deaths, although lower unemployment and government expenditure were also considered important. Respondents preferred a shorter duration for restrictions, but their preferences did not vary significantly for the differing levels of control measures. In terms of tracking, respondents preferred mobile phone tracking or bracelets when compared to no tracking. Significant differences in preferences was identified, with two distinct classes: Class 1 (57%) preferred the economy to remain open with some control measures, whereas Class 2 (43%), had stronger preferences for policies that reduced avoidable deaths.

Conclusions This study found that the Australian population is willing to relinquish some freedom, in the short term, and trade off the negative social and economic impacts of the pandemic, to avoid the negative health consequences.

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Supplementary Appendix:

Table 4 Best fit for number of classes for latent class analysis

Classes	LLF	Nparam	CAIC	BIC	AIC
2	-5065.91	43	10473.8	10430.8	10217.83
3	-5005.98	65	10528.89	10463.89	10141.97
4	-4943.61	87	10579.11	10492.11	10061.22
5	-4920.97	109	10708.79	10599.79	10059.94
6	-4919.4	131	10880.61	10749.61	10100.8
7	-4865.47	153	10947.7	10794.7	10036.93

Table 5 Mixed logit and latent class models (N=1,046)

	Mixed logit model		Latent class model	
			Class 1	Class 2
	β	SD	β	β
Attributes				
Restrictions (base: Level A)				
Level B	0.077		0.151**	0.075
Level C	-0.008	0.596***	0.121	-0.278*
Duration of restrictions (base: 1 month)				
3 months	0.029		0.09	-0.203
6 months	-0.158**		0.015	-0.525***
12 months	-0.382***	-0.706***	-0.130	-1.232***
Tracking (base: no tracking, contact tracing only)				
Tracking bracelet	0.167**	0.462***	0.221***	0.001
Mobile phone	0.134*	0.423***	0.048	0.164
Number of infections (base: 10,000)				
50,000	-0.161**		0.068	-0.819***
100,000	-0.193***		-0.059	-0.293*
500,000	-0.441***	-0.427**	-0.185**	-1.047***
Number of deaths (base 100)				
500	-0.442***		-0.077	-1.384***
1,000	-0.776***		-0.112	-2.218***
5,000	-1.583***	1.245***	-0.162	-4.307***
Number of people that lose their job (base: 500,000)				
1,000,000	-0.249***		-0.198**	-0.453**
1,500,000	-0.406***		-0.298***	-0.709***
3,000,000	-0.581***		-0.292***	-1.074***
Government spend (base: $50 billion)				
$100 billion	-0.149**		0.004	-0.595***
$200 billion	-0.181**		-0.072	-0.533***
$500 billion	-0.596***	0.535***	-0.316***	-1.097***
Additional income tax levy for the next 3 years (base: 1%)				
3%	-0.291***		-0.129*	-0.733***
5%	-0.473***	0.476***	-0.245***	-0.965***
Class membership parameters				
Constant	-		0.280	
Class share			0.570	0.430
Unconditional probability	-		0.514	0.620
Conditional probability	-		0.515	0.739
Model statistics				
Mean posterior probability	-		0.862	
Loglikelihood	-5152.4865		-5065.908	
BIC	10586.76		10430.78	
Observations	16,596		16,596	

legend: * p<.05; ** p<.01; *** p<.001

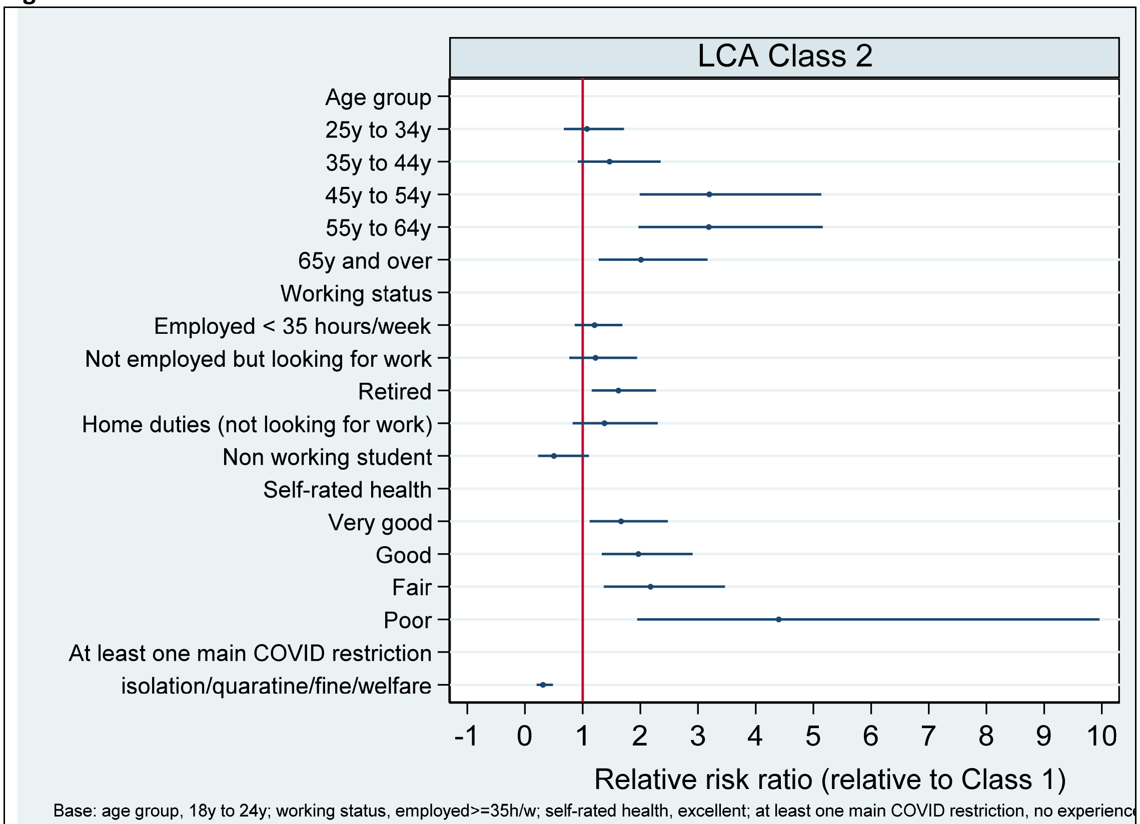
Table 6 Opinions and attitudes

n (%)	Respondents (N=1,046)
The government was quick to respond to the COVID-19 pandemic.	
Strongly disagree	53 (5.1)
Disagree	125 (12.0)
Neither agree nor disagree	178 (17.0)
Agree	468 (44.7)
Strongly Agree	193 (18.5)
Not reported	29 (2.8)
The social distancing, isolation and quarantine measures were excessive.	
Strongly disagree	344 (32.9)
Disagree	331 (31.6)
Neither agree nor disagree	146 (14.0)
Agree	116 (11.1)
Strongly Agree	80 (7.7)
Not reported	29 (2.8)
The impact of social distancing restrictions on the economy were too costly.	
Strongly disagree	187 (17.9)
Disagree	277 (26.5)
Neither agree nor disagree	273 (26.1)
Agree	183 (17.5)
Strongly Agree	97 (9.3)
Not reported	29 (2.8)
Australia's borders should remain closed to international visitors.	
Strongly disagree	24 (2.3)
Disagree	38 (3.6)
Neither agree nor disagree	127 (12.1)
Agree	321 (30.7)
Strongly Agree	507 (48.5)
Not reported	29 (2.8)
Restrictions have been eased too quickly.	
Strongly disagree	34 (3.3)
Disagree	115 (11.0)
Neither agree nor disagree	244 (23.3)
Agree	351 (33.6)
Strongly Agree	273 (26.1)
Not reported	29 (2.8)
I am worried about a second wave of COVID-19 cases.	
Strongly disagree	25 (2.4)
Disagree	38 (3.6)
Neither agree nor disagree	138 (13.2)
Agree	388 (37.1)
Strongly Agree	428 (40.9)
Not reported	29 (2.8)
I believe the economy will recover quickly.	
Strongly disagree	186 (17.8)
Disagree	287 (27.4)

n (%)	Respondents (N=1,046)
Neither agree nor disagree	260 (24.9)
Agree	194 (18.6)
Strongly Agree	90 (8.6)
Not reported	29 (2.8)
I trust most people in society to abide by the restrictions set by the government.	
Strongly disagree	88 (8.4)
Disagree	210 (20.1)
Neither agree nor disagree	265 (25.3)
Agree	344 (32.9)
Strongly Agree	110 (10.5)
Not reported	29 (2.8)
My employment is less secure due to the COVID-19 pandemic.	
Strongly disagree	144 (13.8)
Disagree	124 (11.9)
Neither agree nor disagree	372 (35.6)
Agree	242 (23.1)
Strongly Agree	135 (12.9)
Not reported	29 (2.8)
It has been easy for me to comply with the government's restrictions during the COVID-19 pandemic.	
Strongly disagree	12 (1.2)
Disagree	50 (4.8)
Neither agree nor disagree	146 (14.0)
Agree	480 (45.9)
Strongly Agree	329 (31.5)
Not reported	29 (2.8)
At the start of the pandemic I thought the risk of being infected with COVID-19 was high.	
Strongly disagree	54 (5.2)
Disagree	120 (11.5)
Neither agree nor disagree	240 (22.9)
Agree	388 (37.1)
Strongly Agree	215 (20.6)
Not reported	29 (2.8)
Currently, the risk of being infected with COVID-19 is high.	
Strongly disagree	48 (4.6)
Disagree	117 (11.2)
Neither agree nor disagree	267 (25.5)
Agree	383 (36.6)
Strongly Agree	202 (19.3)
Not reported	29 (2.8)
At the start of the pandemic I thought the risk of dying from COVID-19 was high.	
Strongly disagree	88 (8.4)
Disagree	173 (16.5)
Neither agree nor disagree	258 (24.7)
Agree	321 (30.7)
Strongly Agree	177 (16.9)

n (%)	Respondents (N=1,046)
Not reported	29 (2.8)
Currently, the risk of dying from COVID-19 is high.	
Strongly disagree	72 (6.9)
Disagree	190 (18.2)
Neither agree nor disagree	302 (28.9)
Agree	294 (28.1)
Strongly Agree	159 (15.2)
Not reported	29 (2.8)

Figure 5 **Assessment of latent class characteristics**



Summary of steps taken to produce final mixed logit model

1) Mixed logit model was run with levels for the attribute restriction level included as random parameters (Level A, Level B, Level C). The standard deviation for Level C was statistically significant.
2) Mixed logit model was run with levels for the duration of restriction included as random parameters (1 month, 3 month, 6 months, 12 months). The standard deviation for 12 months was statistically significant.
3) Mixed logit model was run with levels for the tracking of people included as random parameters (no tracking, tracking bracelet, mobile phone). The standard deviation for tracking bracelet and mobile phone were statistically significant.
4) Mixed logit model was run with levels for no. of people infected included as random parameters (10k, 50k, 100k, 500k). The standard deviation for 500k infections was statistically significant.
5) Mixed logit model was run with levels for no. of deaths included as random parameters (100, 500, 1000, 5000). The standard deviation for 5000 deaths was statistically significant.
6) Mixed logit model was run with levels for no. of jobs lost included as random parameters (500k, 1 million, 1.5 million, 3 million). The standard deviations were not significant for any of the job loss levels.
7) Mixed logit model was run with levels for additional government spend included as random parameters ($50 b, $100 b, $200 b, 500 b). The standard deviation for $500 billion was statistically significant.
8) Mixed logit model was run with levels for additional income tax levy included as random parameters (1%, 3%, 5%). The standard deviation for 5% was statistically significant.
9) The final model included the random parameters (which were assumed to be normally distributed) with statistically significant standard deviations.

Chapter 7: Discussion

7.1 Overview

Productivity loss due to illness can have negative impacts on individuals, firms and society. The overarching aim of this thesis was to explore and evaluate different methods used to value productivity losses, and to develop methods used for estimating and evaluating the opportunity costs of policy-related interventions preventing illnesses for Australia. In this thesis, I explored the characteristics influencing the relationship between health and productivity and the implications of this relationship for economic evaluation and health policy.

While there is debate about whether productivity impacts should be taken into account when making resource allocation decisions about health care interventions, there are many settings in which it is important to consider them to ensure that decisions maximise welfare. This is particularly the case for interventions at a population level which are aimed at reducing morbidity and mortality but which may themselves impact on the costs of production or where there are other unintended impacts on the wider community.

In Australia, government agencies typically rely on two main methods of economic evaluation to assess programs or interventions that have intangible benefits (i.e., CBA and CEA[16]) [43, 152, 153]. Cost-benefit analysis is the preferred method used by the Office of Impact Analysis (OIA) to assess proposals e.g., applications pertaining to infrastructure projects, as the method facilitate the evaluation of the social returns from privately owned resources as in regulation reviews [152]. However, CBA is unable to facilitate evaluations where cost and benefits are difficult to monetise e.g., improvements on quality of life or gain in life years. In these cases, the OIA recognise that other methods such as CEA may be more appropriate [152]. The Department of Health and Aged Care has a vast portfolio covering different areas of health [227]. Some of these government offices falling under the health portfolio may use CBA as the norm, however, since benefits of the interventions are difficult to monetise, CEA may be more appropriate to use. For example, Food Standards Australian and New Zealand (FSANZ) have previously used CBA to value the impact of FBI to Australia, however impacts of morbidity and mortality due to FBI are reported in units such as QALYS or disability adjusted life years (DALYs) [139, 156, 157, 201]. Whilst CEA is not normally used to value public health interventions, it is one of the main methods predominantly used in the assessment of

[16] Although cost-effectiveness analysis and cost-utility analyses are different methods of economic evaluation, both methods have all been included into one category under the term ‘cost-effectiveness analysis’. The main difference is the cost-utility analyses apply a quality of life adjustment to the physical unit being measured e.g., life years gained.

health technologies. Under the remit of the PBAC and MSAC, assessment of health technologies relies on CEA as the economic framework to guide investment decisions [42].

There are other issues affecting health that are not only a public health concern. As evidenced by the COVID-19 pandemic these issues can extend beyond the public health domain affecting general welfare. As part of the plan to ease COVID-19 restrictions in Australia, vaccine passports (or vaccine certificates) were introduced as a public health regulation to allow businesses to reopen while mitigating the spread of COVID-19 [228]. These public health measures also allowed individuals who were vaccinated to gain freedoms (such as dining in at restaurants, entering shopping centres). However, these measures increased production costs for businesses'. For example, additional staff were needed to validate COVID-19 certificates for patrons entering these facilities. It is possible that price increases may have been passed onto consumers; however, benefits in implementing these regulations meant to reduce risks of morbidity and mortality for individuals and avoid productivity loss.

If the aim of government intervention is to maximise the health or welfare of society, better information is required to assist the prioritisation and development of control measures designed to reduce the effects from illness. These measurements should be accurate and meaningful to help inform policy and investment decisions, and, importantly, the perspective that these evaluations take will also have impacts on how allocation decisions are made. This thesis explores two distinct case studies in which these trade-offs and policy questions are highly pertinent.

Trade-offs affecting health, welfare and productivity is explored using two key methods commonly applied in health economics, discrete choice experiments (DCEs) and economic evaluation. This thesis focussed on two case studies, foodborne illness and infectious disease, where different characteristics of an illness affect the valuation of health and productivity losses. In these case studies, public health interventions are used to manage and control illness, where implications from preventing these illnesses extend beyond the individual patient. Thus, intervention may be required from significant stakeholders at the government or from business levels. Furthermore, private costs of the impact from illnesses, and the benefits of production and consumption of the public health intervention are unlikely to be reflected in market transactions.

This chapter summarises the key findings from the research developed in this PhD and then discusses the potential policy implications.

7.1.1 Willingness to pay (WTP) to avoid foodborne illness (FBI)

Foodborne illnesses (FBIs) are mostly preventable. Interventions used to prevent FBI typically incur additional costs of production of goods and services (for example, through additional hygiene measures, packaging or monitoring), and considerable resources are expended by governments and businesses to reduce the impacts of FBI [134]. The health impacts of FBI are typically short-lived and self-limiting; however, in some individuals FBI can result in long-term sequelae [87, 229]. The duration and severity of the FBIs have different implications for an individual's health status and productivity [85, 156]. Time off work may be needed for workers infected with an FBI to help them recover if they are not well enough to work, which means that businesses are impacted when workers are absent [165]. Because of this, lost productivity is one of the largest costs associated with the burden of FBI [85]. For these reasons, FBI provides a good case study to explore this relationship between health and productivity.

Chapter 3 presented estimates of the willingness to pay (WTP) to avoid a FBI using DCE techniques [200]. The study included a range of FBIs, which allowed for an assessment of preferences for avoiding the health and loss of work disutility associated with different illnesses over short and long-terms using WTP. A potential advantage of using WTP compared with using market wages alone is that the individual's WTP incorporates the direct disutility of the illness to the individual as well as the effects of any loss of productivity (as measured by forgone wages). However, the extent to which the individual considers productivity impacts in their assessment of WTP may depend on their employment conditions, in particular whether they have paid sick leave [6]. The inclusion of an attribute that varied ability to work, with and without paid sick leave, allowed consideration of how these factors affect individuals' WTP. The extent to which paid and unpaid sick leave is a factor driving differences between the valuation of productivity losses as measured by wages and productivity losses as measured by WTP was captured and examined.

The findings from this DCE study illustrate that the important factors for respondents when valuing the productivity consequences of the FBI are the severity of the illness and whether the illness has long-term impacts. Interestingly, there were differences in preferences observed, which translated into substantial differences in WTP to avoid an illness once the availability of paid sick leave was considered. The increases in the WTP for mild and severe health states for each condition were ordered as expected, with smaller incremental costs being associated with the transition from not being ill for any time to a mild health state, compared with transitions from the mild to the severe health states. The largest influence on the WTP to avoid a specified illness was observed when respondents were asked to consider their ability to work within the context of availability of paid leave. For all conditions, when sick leave was not available participants expressed a stronger preference to avoid being ill and were willing to pay more to be able to reduce the effects of the disease (which translates to being willing to pay to avoid time off work).

As expected, lower costs of treatment and shorter durations of illness were preferred. In the vignette, respondents were asked to imagine that they had the illness described. The duration of illness was then presented as an attribute where the base levels were one day for an acute illness and one year for a chronic illness, consequently the mWTP could also be interpreted as reducing an acute illness for one day or one year for a chronic illness. Somewhat unsurprisingly, the results show that reducing the income loss associated with ill health reduces an individual's WTP to avoid a FBI, which has implications for estimating the burden and cost of FBI. The availability of paid sick leave entitlements reduces the WTP to avoid illness as individuals have the backup of paid leave. This suggests that entitlements are an important consideration in individuals' decision-making.

While paid entitlements have been identified as an important factor in measuring WTP, to avoid double counting it is important to note the factors included when valuation of WTP is being made. For example, the WTP to avoid illness with compensation (i.e., when paid sick leave is available) reflects the impact of ill health from an individual employee's perspective, while the WTP without compensation (i.e., when paid sick leave is not available) reflects, to some extent, the impact of an individual's income loss. The latter would result in double counting if the productivity losses faced by firms were also included; therefore, it may be more appropriate to estimate productivity losses separately.

These results have implications for estimating the burden and cost of FBI and suggest that income loss is tempered by availability of paid sick leave. Using WTP offers an alternative method for estimating productivity costs, noting that it is important that this considers the effects of employment conditions, which influence values differently for short-term and long-term illnesses. Reliable estimates of the economic costs of specific foodborne infections are needed for policy-makers to develop, prioritise and implement control measures with a net benefit to society. WTP estimates were derived for six different types of FBI in this study; this allows for evaluating the economic impact of pathogen-specific interventions to be considered. Given this flexibility, a pathogen-specific case study for a hypothetical intervention that reduces the risk of campylobacter was presented in Chapter 5.

7.1.2 How long does it take to replace a worker?

Another issue that needs to be considered when considering the relationship between health and productivity is the way loss of employment due to ill health affects the firm. In particular, it is important to understand the friction period and friction costs to obtain an accurate estimate of productivity impacts [59, 71].

In Chapter 4, estimates of the time taken to replace a worker (i.e., the duration of the friction period) and costs of replacing a worker (i.e., friction period costs) in Australia from a firm's perspective were derived [193]. These estimates are needed to inform the friction cost approach (FCA), which is one of the main methods used to value productivity loss in economic evaluation [59, 71]. The validity of these assumptions is important for deriving modelled estimates applicable for specific locations and settings. This was the first study to estimate these parameters in the Australian context.

The results from Chapter 4 showed the mean friction period or time to replace a worker was 12.3 weeks for a manager and 10.1 weeks for a non-manager. These Australian estimates are consistent with other international studies and with estimates applied in economic models in the literature, where the friction period duration is assumed (rather than measured) to be three months [73]. The time taken to train a worker was the largest time component associated with replacing a worker, and establishing this is a novel addition to the literature. Until now, the traditional approach used in the literature to estimate the duration of the friction period is to apply a period of 28 days to the vacancy duration to account for the recruitment decision and training [73]. The results from this study provide robust estimates which can be used to inform an economic model using the FCA in the Australian context.

The study also explored the impact of team dynamics on production. Production losses may be mitigated if workers in a firm can postpone work, if an individual's workload could be delegated to another worker or if businesses can draw on internal and external labour reserves. For this reason, a range of absentee timeframes were considered, ranging from one day to one year. There was substantial variability in the results pertaining to the effect on productivity in the business when team dynamics were considered. As expected, the longer the absence the more difficult it was to recover the work that had been delayed due to illness. Most businesses reported that they were able to continue functioning despite worker absence for short periods of time (i.e., one day to one month). However, when the duration of absence extended beyond six months or one year, postponing work was more difficult and additional effort would be expended by other workers during the absence of another employee.

7.1.3 Comparing methods of modelling productivity losses

In Chapter 5, the strands of research in the two previous chapters are brought together to explore the impacts of different approaches to considering productivity impacts of morbidity and mortality in economic evaluations of health care interventions. The overarching purpose of the economic evaluation presented in Chapter 5 was to comprehensively compare methods used to measure the economic cost of FBI in Australia. Findings from Chapter 3 (estimated WTP values from the foodborne illness DCE) and Chapter 4 (friction period duration and costs) were combined into the economic evaluation using a cost-utility analysis framework presented in Chapter 5.

Although considerable resources are expended by governments and businesses to reduce the impacts of FBI, these resources are limited and tough decisions need to be made to efficiently allocate resources [134]. Economic evaluations provide a framework where costs and benefits of interventions can be compared to guide these decisions [19]. With that in mind, a systematic comparison of approaches used to value productivity losses (human capital approach (HCA), FCA and WTP) to guide investment decisions for a hypothetical intervention that reduces the risk of campylobacter infection were explored. Chapter 5 follows on from Chapter 3, using FBI as a case study.

According to the US Panel on Cost-Effectiveness in Health and Medicine, quality adjusted life years (QALY), which is used to value the health benefits of an intervention, is assumed to capture both the intrinsic value to the person of their health and their productivity (because it is assumed implicitly that usual activities are captured in the QALY measure) [56]. Other researchers have contested the premise that the productivity costs (or income losses) are implicit in the QALY [195-197]. They found that there are no significant differences in the health state valuation scores between respondents that instinctively considered impacts of illness on income compared with respondents that did not think about income. These studies concluded that the impact of double counting productivity costs in the numerator of the incremental cost-effectiveness ratio (ICER) were likely to be minor; however, these studies comment, being asked to explicitly consider income effects did influence utility scores [195-197]. The impact of double counting of productivity losses is likely to be minor as respondents were explicitly asked to consider ability to work and benefits of sick leave pay.

Productivity costs were included in the numerators of the ICERs (for Models 2 to 5). The findings from this study demonstrate including productivity costs using different approaches can substantially influence the ICER, and the decision to adopt a new intervention. The key differences between the approaches were the perspective taken in the analysis, which influenced how the short-term and long-term productivity losses are treated. Productivity loss due to FBI were valued explicitly using four methods: the HCA (Model 2), FCA (Model 3), and WTP (Model 5), and a combination of the FCA and WTP methods (Model 4) to adjust for differences in the perspective of analysis. Methods explicitly including productivity costs were presented alongside a cost-utility analysis (CUA) (Model 1), as this is the main technique used for modelling health interventions in Australia [17].

This analysis assumed an ICER of $50k per QALY is the threshold in cost-effectiveness (CE) as the maximum cost per health outcome that a health system is willing to pay [53]. The highest ICER ($57k per QALY gained) were observed in the traditional CUA (Model 1), which takes the perspective of the health care system. Based on a $50k per QALY threshold, a hypothetical FBI intervention costing $1 per person per year that reduces incidence of campylobacter by 30% may not be suitable for funding from the health care system perspective. Inclusion of productivity costs (in Models 2 to 5) increased the total costs (in each model arm) by a factor of 9 to 12 times and reduced the ICER from $57k/QALY to $20k/QALY when using HCA (Model 2), $29k/QALY using FCA (Model 3), $27k/QALY using FCA plus WTP with paid sick leave (Model 4), and $32k/QALY using WTP without sick leave available (Model 5). By including productivity costs (Models 2 to 5), investing in an intervention that reduces campylobacter incidence by 30% is worthwhile based on the $50k/QALY threshold.

Economic models are generally used to argue that funding for certain policies should be given a higher priority. Hence it is important to understand what is being measured and valued in these models. In this case study, methods using the FCA and WTP generated ICERs within a similar range, which may imply that recommendation to adopt a policy or intervention may be somewhat aligned along the different perspectives representing businesses and employees. In this study, the ICERs were similar for models using the FCA (representing business perspective, Models 3 and 4) and the model using the WTP without sick leave (employee perspective, Model 5). Further research is needed to examine whether perspectives are consistent or divergent for other illnesses.

7.1.4 Exploring the trade-off between economic and health outcomes during a pandemic

Chapter 6 of the thesis takes a different approach to the overall consideration of health and productivity. The work in this chapter was motivated by the dramatic and sudden focus on the relationship between health and productivity brought about by the COVID-19 pandemic. Governments across the world were faced with the need to reduce economic activity and production of goods and services in order to protect the public from the risk of transmission of disease.

The COVID-19 pandemic forced the public to change their social behaviours and usual activities, and also impacted on the ability of people to work. The study presented in Chapter 6 explored the public’s attitudes and willingness to accept loss of productivity in order to reduce the risk of ill health. In particular, how respondents considered features of a policy where they are asked to trade-off among restrictions in freedom, mass unemployment, and other economic and health outcomes from a national perspective were examined. This study also explored the acceptability of different infectious disease control measures during the COVID-19 pandemic in Australia and how preferences across individuals and groups might differ.

Successful disease control requires acceptance of restrictions and consideration of the trade-offs between health, economic and social consequences for possible subsequent waves of infection. The results from this DCE showed that policies resulting in a high death toll were less acceptable than policies resulting in high unemployment, high government expenditure or a high tax levy. With regards to the restrictions, there were no differences with respect to tighter medium- to high-level restrictions (Level B or C) compared with low-level restrictions (Level A) allowing more freedom and movement, but there were clear preferences for shorter durations for restrictions. Respondents were indifferent to restrictions lasting three months compared with one month; however, restrictions extending beyond six months (compared with one month) were less desirable. The attribute for tracking people yielded interesting results as electronic methods were preferred over no tracking. The results suggest that in Australia there is an acceptance of polices using mobile phone and wearable devices to manage and contain disease spread.

The results of the DCE show there is an alignment between what the public were willing to endure and what they have been compelled to endure, and that policies returning society to a COVID-normal level could be implemented and may be possible when preferences are taken into account. To maximise health and welfare for society, policies requiring citizens to relinquish some autonomy and freedom were considered acceptable. As the risk of further outbreaks of COVID-19 is ongoing, policy decision-makers may find this study helpful in that people's willingness to accept restrictions on movement to avoid high mortality has been shown using these DCE methods.

7.2 Overall findings

The relationship between health and productivity investigated in this thesis has some important implications for health policy. The basis on which allocation decisions are made should be based on assessment of costs and benefits being transparent and understandable. Governments, businesses and individuals need to make investments in health that support individuals participating and contributing to productive activities, accordingly the methods used to value productivity is important as it impacts on the efficiency of resource allocation or implementation of policy.

As discussed in Chapter 1, economic evaluation using CEA is the predominant method used to inform decision-makers (e.g., the PBAC and the MSAC) about the efficiency of new health technologies (e.g., new medicines, devices, medical services and procedures) relative to a comparator [42, 43]. Economic evaluations conducted from the health care payer perspective are formalised in guidelines, which outline the preferred methods to be used [42, 43]. The guidelines specify that the base case does not include productivity costs; where productivity improvements are claimed, the guidelines also advocate using the FCA as the preferred method and requesting that valuations supporting this claim be provided in a separate analysis [42]. In the Netherlands, health technology assessment guidelines stipulate costs outside the health care system including productivity costs should be included in the base case [230]. Differences in these methods come down to the maximisation goal: in Australia, economic evaluations take the perspective of the health care payer, whereby decision-makers aim to maximise health, while in the Netherlands economic evaluations take a societal perspective, whereby decision-makers aim to maximise welfare. This position is similar to other government offices under the Australian health portfolio where the aim is to maximise welfare [152].

Although the decision to formalise a blanket recommendation including productivity losses in the health technology assessment guidelines may be controversial, including productivity losses and gains, and applying the appropriate valuation method, may be critical in some circumstances. As presented in Chapter 5, assuming an ICER threshold of $50k\QALY, the hypothetical intervention would not have been recommended, but would be recommended if productivity impacts were included in the evaluation. Prevention of FBI is one area where significant productivity losses are incurred in sectors outside the healthcare system. Intervention improves and protects access to safe food and many people benefit from accessing public goods, but incentives for the private market to invest are low. Although a regulatory authority such as Food Standards Australian and New Zealand (FSANZ) recommend policies that aim to prevent FBI, it is often businesses (e.g., suppliers in the food supply chain) or individuals that pay for the costs of the risk management. The costs associated with regulation are inexpensive for a government to implement, but the costs of intervention can be more expensive for a food supplying business. Using the alternative measures for valuing productivity costs (as derived in Chapter 3), such as WTP to avoid illness with sick leave, coupled with the FCA or the WTP to avoid illness without paid sick leave allows for different perspectives to be included in an economic evaluation (as derived in Chapter 5), and consideration of whether the interventions are worthwhile investments. These methods could assist in the evaluation of strategies of illnesses where prevention and management have a public good aspect.

Policy-makers need country-specific economic tools and measures to manage the growing burden of illness to justify funds for intensified preventative strategies. In some circumstances, market prices do not exist for costs or benefits of a proposed intervention. Quantitative techniques using stated preference methods are one way to determine market value of the benefits for these interventions, where input from the individuals about the impacts on health and productivity should be considered. Using approaches that explicitly ask individuals about the impacts on health and productivity caused by illness can potentially facilitate a more efficient allocation of public funds.

DCE techniques offer a valuable insight into how trade-offs are made when individuals are asked to consider trade-offs between being sick and losing income at an individual level – that is, the impact on themselves personally (Chapter 3) – but can also be used to assess health and productivity impacts at a national level (Chapter 6). The value in using a DCE approach is that as respondents make trade-offs, stating their preferences, they decide what is optimal for themselves, thus showing optimal social welfare. For these reasons, DCEs are tools that could be used to guide and support health policy. The public may be more inclined to cooperate, support and trust the decision-making process if their input has been considered.

7.3 Limitations and future work

Although the work generated from this thesis has the potential to inform policy relating to the evaluation of interventions preventing illness and the methods used to value productivity losses, there are limitations that need to be addressed and matters for future research that are discussed.

To estimate WTP values, valid and reliable income data should be collected as part of the survey; however, income data are often difficult to collect, as respondents may not wish to divulge their income information. The WTP estimates derived from DCEs assume that the marginal utility of income is constant, and in instances where this assumption is violated, concerns are raised about whether WTP estimates are valid welfare measures [231]. In the DCE presented in Chapter 3 (WTP to avoid an FBI) respondent characteristics could not be used to comprehensively explain differences in the WTP observed across the illnesses. Estimated WTP is constrained by the budget holder's income, and in this study, on average, respondents had lower incomes than the Australian median ($1,012 per week), and just over half (54%) were in employment. Theoretically, individuals with a higher income, would have a higher WTP to avoid an FBI. However, FBI disproportionately affects those who do not work (i.e., children and the elderly). Future work in this area may consider undertaking more qualitative research to understand the reasoning behind respondent's trade-off attributes in the choice tasks. To conduct such work alongside a survey including DCE techniques may help extricate the welfare changes with respect to WTP estimates derived.

True estimates of the WTP are conditional on taking up treatment [152]. It is also important to note that the range of WTP estimates are determined in part by the range of costs included in the study, and so it may not reflect the maximum value for consumers whose WTP is outside the average range in a market. In addition to this, the WTP estimates need to be considered in the context of the health system, which may have affected preferences in relation to health care costs. If the illness was severe, it may be perceived that healthcare costs could be covered by other means, such as Medicare (Australia's public subsidised health care) or via private health insurance. It is also possible that respondents inferred that the number of paid sick leave days available to a worker may be in excess of what employers typically provide e.g., 10 days for a full-time employee as mandated under the National Employment Standards [21].

The WTP values estimated in Chapter 3 are likely to be underestimated. As part of the background context given to respondents, they were asked to imagine having the illness. The duration of illness was not specified in the vignette, which forced respondents to make a choice. The base levels for the attribute duration of illness were set to one day and one year for a chronic illness. Accordingly, the marginal WTP for the duration of illness could be interpreted as a reduction to one day for an acute illness or to one year for a chronic illness. The marginal WTP for the duration of illness as estimated in this DCE does not consider the difference between absence of disease to one day or one year of disease, consequently the marginal WTP may be underestimated. This is an area that could benefit from future research to estimate the difference between the absence of illness compared to one day (acute illness), and one year (chronic illness) to obtain a more accurate estimate of the WTP.

The use of opt-outs in DCEs is common in settings where this is a realistic choice, and the exclusion of an opt-out in this thesis is a potential limitation in the design for the acute illness choice sets. Using a forced choice design may be implausible in a real market situation where people would be able to opt-out of paying for treatment. The choice format does have a bearing on the responses. Investigation into how to handle opt-out during design and data analysis, as well as implications for non-inclusion of opt-outs, is one of the current issues being examined in this field [232, 233]. Inclusion of an opt-out may make the choice more realistic since participants are not forced to choose between the designed alternatives, although the trade-off produces a lack of efficiency in responses. Inclusion of opt-outs are recommended where the research seeks to predict adoption of new interventions, medications, treatments, to allow for demand and market shares to be calculated [232]. Although, the inclusion of an opt-out depends on the research question. If the study aims to estimate marginal rates of substitution among attributes and to compare levels and attributes or alternatives of the choice experiments, an opt-out option may be unnecessary and so forced choice tasks could be applied [232]. For the DCE in Chapter 3, the reason that the design forced respondents to make a choice was to maintain a consistent frame across the choice sets. Although an opt-out could have been presented for the acute illnesses, opt-outs were not realistic for the chronic illnesses, and we did not want to confound the experiment by including an opt-out for the acute illness but not the chronic illnesses. It is also possible that respondents may have interpreted choice sets with $0 treatments as 'watch and wait' or 'no treatment' alternatives. The majority of respondents demonstrated trading behaviour between the two treatment profiles, but there was a small proportion of respondents who always chose the lowest cost (11%) or the shortest duration (4%).

There are some issues pertaining to use of the WTP to pay to avoid FBI estimate in Models 4 and 5 that should be acknowledged. Firstly, there is a double-counting of disutility of illness in Models 4 and 5. The ICER contains elements of disutility in numerator, in the WTP to avoid illness value, and in the denominator, in the QALY. The extent to which double-counting of disutility associated with illness affecting the ICER is unclear. This is a limitation in using the values derived from Chapter 3 in this cost-effectiveness analysis. Secondly, Model 4 included the employer perspective through the FCA, and employee perspective using WTP values estimated using a general population. There may be a mismatch between the employer and employee expectations. Advancement of this research could consider conducting a DCE assessing the WTP to avoid illness using a business panel or from employers.

In both DCEs, some characteristics of the sampled populations differed from the Australian population. Compared to the general population in Australia, the study samples had a lower income and were also more highly educated. Application of survey quotas based on age, sex, and location are often used to establish a sample that is comparable to the population in which the study is assumed to reflect. Although use of other characteristics such as type of employment or household income may have been more relevant in applying quotas, using these characteristics maybe more difficult fill if people are not comfortable sharing personal data [234]. Income data is often missing from population-based surveys [235]. The distribution of education attainment and income is a potential concern; however, this is a common limitation of conducting surveys using an online panel.

How respondents perceive the descriptions provided to them when they make their choices is difficult to ascertain in a DCE. Qualitative work is being applied to improve the face validity of DCEs [95, 114]. Qualitative work investigating DCE valuation of the EQ-5D has found that respondents perceive 'usual activities', and the severity levels 'severe' and 'extreme' very differently, which influences the decisions made [236]. The descriptors used in the DCE assessing the WTP to avoid a FBI (such as generally, may, can, most, few, often, and more frequent) are common terms that are used within the research field of eliciting stated preferences for health [236]. The number of sick leave days were not explicitly given to respondents, and it is possible that respondents may have inferred they had more paid sick leave days than otherwise entitled under the National Employment Standards outlined by the Fair Work Ombudsman [6]. The results indicated strong preferences against being unable to work without paid sick leave for the four chronic illnesses. However, these preferences were not consistent when respondents were unable to work some/most of the time with paid sick leave where some findings were not statistically significant. Interpretation of these points is dependent on context and perspective, where specifics behind these preferences pertaining to ability to work, and availability of paid sick leave could be investigated using qualitative research.

There are challenges with collecting survey data. One of the challenges is the trade-off between collecting more information versus participant drop out, which reduces the quality of information. Designing the survey requires collection of enough data to ensure that refinements can be made to analyses. However, these refinements would require a longer survey. The more onerous the survey is to understand or complete increases the cognitive load onto respondents. Consequently, this can lead to a lower response rate or a higher drop out as the survey progresses. It is important to ensure the survey is clear and easy to understand, which may mean limiting data collection. This was one of the challenges encountered in designing the survey for the friction period study. This was designed as a 'proof of concept' study to ascertain whether data could be captured through survey methods; whereas other studies [237-239] estimated the vacancy duration is obtained from National Statistics Offices. Although it would have been more desirable to further understand how the friction period is influenced by structural constraints in the labour market and explore the heterogeneity of skilled or unskilled labour, the survey was limited to enable completion within 10 to 15 minutes. In understanding the impacts of these factors, future research may focus on conducting face-to-face interviews, as a respondent's agreement to participate using this format may provide a better opportunity to delve into survey responses.

Another challenge in using survey methods pertains to how the survey is framed as background information and instructions given to respondents can influence the responses [240]. People can be biased when making their judgements if they have knowledge of the topic under investigation, or influenced externally, such as through the media when being asked about their public views. Frames in the survey can be in the introduction and be in the way the questions are phrased to respondents. For the friction period survey information were given to respondents to help them imagine the effect on productivity when workers were absent over various periods of time. Although enough information should be given so that respondents have a clear description of what is being valued, it is not always clear what is an appropriate amount of information. Although there appears to be no evidence of priming with respect to estimation of the friction period, it is possible that results may have been different if sections of the timeline were depicted as being of equal duration or not depicted at all. Priming effects may have also been induced by examples of manager and non-manager roles given to respondents in the vignettes.

The two studies using a survey incorporating a DCE were collected at a single point in time; consequently, there may be concerns that preferences may change over time, and data collected may be dated. One of the challenges when designing the study in Chapter 6 was the constantly evolving and uncertain course of the COVID-19 pandemic. As new information emerged, restrictions changed in line with recommendations that were being issued. For example, at the time the survey was launched, face mask usage was not commonplace.

Attributes for specific policies pertaining to financial aid and welfare were also not included e.g., JobKeeper [228] which was used to reduce income for individuals during times when restrictions were high. Implementation of specific financial aid and welfare policies may be more or less important for a person, depending on whether the sector in which a person is employed was affected by the restrictions. The impact of specific policies (such as JobKeeper) that were implemented cannot be addressed by the results of this DCE. Further to this, since this study has been published, vaccines have become available that reduce the risk of hospitalisation for COVID-19. New variants (where protection afforded by available vaccines is uncertain due to waning efficacy over time or ability for new variants to evade immune responses, leading to breakthrough infection), are also being identified. The DCE did not explicitly include the possibility of subsequent waves in the design, consequently, extrapolating the study findings to future waves may not be reasonable. One serious limitation of stated-preference research in health is the difficulty of finding opportunities to compare stated preferences with revealed preferences. Repeating the DCEs, and re-eliciting preferences, would establish whether the sentiments are consistent over time, and dynamically inform policy, in situations that are quickly evolving, as data for DCEs can be collected quickly.

If workers are absent due to illness, this does not always result in a production loss for a firm. If work can be postponed or delegated to another worker, or if businesses can draw on other labour reserves, production losses could be mitigated [191, 192]. Another input used to inform the FCA is the absence multiplier, which corrects for compensation mechanisms and team dynamics considers that losses are equal to or higher than wage costs. This thesis explored the impact of team dynamics on production when a worker is absent due to illness over timeframes ranging from one day to one year. However, a multiplier was not derived from the study. Modelling presented in Chapter 5 was sensitive to this parameter, and hence future work may include deriving estimates of the absence multiplier for the Australian context.

Research conducted for this thesis focused on productivity losses associated with paid work as a first step in comparing methods used to value productivity. Although a narrow focus, the reason for this is that evaluating impacts on paid work is that the current health technology assessment guidelines [42]. The PBAC guidelines recommends presenting other claimed benefits such as productivity loss as a sensitivity analysis with preference for the using the FCA. Productivity losses pertaining to unpaid work and leisure time are seldom included in economic evaluations. Future research could explore impacts on other types of productivity loss pertaining to unpaid work and leisure, which are also quite valuable.

7.4 Concluding remarks

The research presented in this thesis aimed to evaluate the different methods used to value productivity losses, and to develop a methodology for estimating and evaluating the opportunity costs of policy-related interventions preventing illnesses for Australia. Different aspects, such as the effect on valuation using different perspectives on the relationship between health and productivity, and the implications of this relationship for economic evaluation and health policy, were explored using two case studies. Policy-makers need country-specific economic tools and measures to manage the growing burden of illness to justify funds for intensified preventative strategies. A range of methods used to value health and productivity losses from different perspectives should be considered.

The applicability of the WTP approach is seldom used in the health technology assessments, however, population interventions aim to protect individuals by reducing the risk of morbidity or mortality. Other negative impacts, pertaining to loss of time, and costs and benefits of the implementing public health intervention can have broader impacts on society. Whilst noting that productivity losses were important factors for the case studies presented, this is still an area that may benefit from further research. Although the foodborne illness case study was a good starting point, the applicability of the WTP approach could benefit from further understanding how respondents perceived attributes relating to ability to work and availability of sick leave. Further work could investigate other aspects of productivity such as that relating to unpaid work and lost leisure time using DCE techniques. More research would need to be conducted around the effects of adopting one policy over others and implications across stakeholders including government, businesses and individuals.

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