Title: Preparing for future pandemics: a multi-national comparison of health and economic tradeoffs

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Abstract

Background: Government investment in preparing for pandemics has never been more relevant. The COVID-19 pandemic has stimulated debate regarding the trade-offs that societies around the world are prepared to make between population health and economic activity. What is not known is how much the public in different countries are prepared to pay in forgone GDP to avoid mortality from future pandemics, nor which government policies to prepare for and respond to the next pandemic they prefer.

Methods: We harness discrete choice experiment (DCE) survey methods, administered in representative samples of the tax-paying general public in the UK, the US, Canada and Australia. The choices made in the experiment are analysed using limited dependent variable modelling. We harness the resulting model of preferences in post-estimation analysis to calculate willingness to pay in forgone GDP to avoid one death and the relative importance of specific policy investment options.

Results: To avoid one death the tax-paying public is prepared to pay $4.85 million USD (Canada), $5.44 million USD (UK), $5.99 million USD (US) and $6.59 million USD (Australia) in forgone GDP. The health policies that taxpayers want to invest in to prepare for the next pandemic and the economic policies they want activated once the next pandemic hits are relatively consistent across the four countries, with some exceptions.

Conclusions: Such results can help inform Government investment in health and economic policies to prevent and reduce adverse impacts of the next pandemic.

Government investment of scarce tax dollars to prepare for and respond to future pandemics has never been more relevant. Preparation requires investing in health policies now to prepare for the future, plus consideration and investment in economic policy responses to be activated when the next pandemic occurs.

A pandemic itself, and the policy responses to mitigate resulting adverse health effects, can have a major negative impact on an economy. The COVID-19 pandemic has accentuated resource scarcity (even in our wealthiest societies) and emphasized trade-offs[1]. This has been palpable at all levels of decision-making, particularly at the broadest level of health versus the economy[2]. Different health policies can also be seen as competing with each other for policy attention and associated resources, and the same can be said for policies aimed at economic sustainability and stimulus. Different policies may have vastly different economic costs and health impacts so it is crucial to examine specific policies in the context of this trade-off[3].

What is not known is how the general public in different countries view such trade-offs. In this paper, we harness discrete choice experiment (DCE) survey methods[4,5], administered in samples of the tax-paying general public in the UK, the US, Canada and Australia, to provide evidence on: (1) preferences regarding the health-economy trade-off captured in the amount taxpayers are prepared to pay in forgone GDP per death avoided; and (2) which of nine health and six (fiscal, monetary and labour) economic policies they want their government to invest in to prepare for and manage the next pandemic. Such an approach involves asking survey respondents to choose between policy investment options and, in doing so, make trade-offs similar to those faced by policy-makers, given information on the implications of such investments on the expected number of cases and deaths, GDP, unemployment and other key

economic indicators, as well as the increase in personal income tax they would be required to pay to help fund the policy investment. This work acknowledges the importance of the views of the general public when setting priorities, e.g.[6-8]. We provide evidence on the relative importance of, and tolerance for, each policy option from the perspective of those who stand to benefit from and bear its burden. The effectiveness of a number of health-related policies, too, depends on their public acceptability.

There is a related but distinct emerging literature exploring preferences in relation to various aspects of the current COVID-19 pandemic, e.g.[9-11]. Where preferences over COVID-19 policy responses have been explored, a focus on health policies with limited simultaneous exploration of economic policies has been taken. None have explored preferences for *future* pandemics. We explicitly take a perspective of planning for future pandemics and in so doing consider a broad range of health and economic policy options across three continents. This work meets an appeal to systematically look beyond the current pandemic to future pandemics[12], as "… at some point, … the world will … have to systematically consider how to deal with similar scenarios in the future."[13]. Results from our study can help inform Government investment in pandemic preparedness and response.

Methods

We conducted a discrete choice experiment (DCE) to elicit preferences and values from a sample of the general public in the UK, US, Canada and Australia. DCEs are a stated preference approach[4,5] regularly used in applied economics (particularly in areas of health, environment, transport and marketing). A key appeal of such methods is they allow a range of research questions to be addressed, some of which could not otherwise be answered with

existing data sources. They have also been shown to have good external validity[14]. Survey respondents in our study choose their preferred option between pairs of policy investment options to prepare for and respond to the next pandemic (see Appendix Figure. S1). In every scenario respondents were asked to consider preparing for the next pandemic and told it would result in 150,000 cases per million and 3000 deaths per million, presented relative to the total population of the country where the respondent lived. Note that these are figures for a hypothetical future pandemic, not figures for the current COVID-19 pandemic. Each choice scenario contained two policy investment options between which respondents were asked to choose.

Attributes and levels

Each policy investment option was described by nine health policies, three types of economic policies, the resulting impact on cases, deaths and GDP if the policy investments are enacted and the cost to the individual in terms of an increase in the amount they pay in tax, described in Table 1 and in more detail in the Appendix.

[Insert Table 1]

Experimental design

The combinations of attributes and levels to form policy options A and B presented in the choice scenarios considered by survey respondents were determined by an experimental design generated through the software Ngene 1.1.2[15] using the Fedorov exchange method to optimize the d-efficiency. To increase the realism of the generated alternatives and avoid implausible

combinations of attribute levels, we applied constraints between certain levels (e.g., at least one health policy must be present in every scenario; the number of deaths cannot be greater than number of cases); the full list of constraints is provided in the Appendix. The efficient design generated allowed estimation of all attribute main effects and consisted of 144 scenarios blocked into 24 versions, each containing 6 choice scenarios. Respondents were randomly allocated to a block of 6 scenarios.

Survey design, sample and data collection

In addition to the choice scenarios, the survey contained a number of socio-demographic questions and questions about experience with COVID-19 as controls for current context on preferences for planning for future pandemics. The survey was administered online via Dynata panel in the UK, US and Australia and Advanis Inc. general population random sample in Canada. A relatively large total target sample size of approximately 1000 respondents per country was set. Simulations confirmed this was more than sufficient to estimate the models of interest for the experimental design we developed. The sampling frame was adult (aged 18 +) taxpayers in each country. We restricted the sample to taxpayers to ensure the realism of the DCE in which respondents chose between policy investment options that came at the cost of increased personal income tax. The sample was stratified by age and sex to account for potential differences between the online panels and population level distributions in demographic features (e.g., due to internet access), to ensure our sample reflected the population in each of the four countries. Effectively we targeted and achieved an online sample that had unit weights to allow expansion to the corresponding population. Within each category selection was random. The study was approved by the Australian National University Human Research Ethics Committee (ID: 2020/275).

Statistical Analysis

The choices made were analysed using discrete choice limited dependent variable models[16]. The estimated choice models reveal respondent preferences regarding the policy investment options and the importance of attributes that describe those options. We harnessed the resulting model of preferences in post-estimation analysis to calculate (1) willingness to pay in forgone GDP to avoid one death; (2) which policies respondents do/do not want to invest in and the relative importance of specific policy options; and (3) predicted public support for particular policy combinations. Further detail is provided in the Appendix.

Results

The survey was completed between 12 August and 4 October 2020 by taxpayers in Australia (n=980), Canada (n=980), UK (n=1002) and US (n=998).

Economy – mortality trade-offs

Choice model results (Appendix Table S1) were used to explore the tax-paying population's 'willingness to pay' in forgone GDP to avoid one death (Table 2). The percent reduction in GDP that people in each of the four countries would be willing to pay to avoid one death per million is presented in column 2 and in the total population in column 3, with the reduction in GDP they would be willing to pay to avoid one death presented in column 4.

[Insert Table 2]

Members of the public in all four countries were willing to pay considerable amounts in forgone GDP per death avoided in the population, ranging from 0.00019% to 0.00047% of GDP. This is equivalent to a reduction in GDP of $4.85million USD in Canada, $5.44 million USD in the UK, $5.99 million USD in the US and $6.59 million USD in Australia (column 4, Table 2).

Preferred policies for government investment

We explored which health and economic policies taxpayers do and do not want to invest in to prepare for the next pandemic as well as their relative importance. Figure 1 depicts the percentage change in predicted probability of choice for each policy along with their 95% confidence intervals. The underlying data are presented in Table S2 in the Appendix. The public do (do not) want to invest in policies depicted to the right (left) of the vertical zero line, with those further to the right being more strongly preferred. Where a confidence interval contains zero the value is not statistically significant at the 5% level, implying a judgement that additional investment is no better than the current level of investment in that policy.

[Insert Figure 1]

We summarise the rank order of relative importance across the policies from most to least preferred in Table 3. Among the health policies, the most important were health and social care system capacity in Australia and Canada, contact tracing in the UK and medical supply of facemasks in the US. Indeed, all three were consistently in the top four preferred policies across all four countries. Investment in the development of drug and other treatments was

important in all countries. Investment in vaccine development was the second most important policy in Canada, fifth in the US and UK, while Australians were indifferent between current and new investment. Respondents in the US and Canada want additional investment in handwashing and public use of masks, while in Australia and the UK respondents were indifferent to these.

Health department surveillance of infections, international travel bans and social distancing policies were consistently the least-preferred health policies across all four countries. Australia and the US did not want to invest in health department surveillance of infections while the US and UK did not want to invest in international travel ban preparedness. All four countries were indifferent to additional investment in social distancing.

Among the economic policies, cash transfers (a fiscal policy) was the only policy statistically significantly preferred to no new policy in all four countries. A cut in interest rates was also significantly preferred in the US.

[Insert Table 3]

Our results allow us to explore combinations of pandemic preparedness policies that enjoy broad public support. To illustrate, we predicted the approval level for the combination of health and economic policies that were statistically significantly supported for each country (policy mix depicted in bold italics in Table 3). These policy packages yielded high levels of support: 74% (Australia); 83% (Canada); 74% (UK) and 73% (US).

Discussion

As a first of its kind, this multi-national study quantifies preferences and trade-offs in relation to how the tax-paying public in the UK, US, Canada and Australia want their governments to prepare for and respond to the next pandemic, as well as how much they are willing to pay to fund this investment, summarised in terms of forgone GDP per death avoided.

For the majority of elements, our findings were remarkably consistent across the countries and we sought to ensure they were generalisable through a sample that is reflective of the tax-paying population in each country based on age and sex.

In all four countries, people were willing to accept a broadly similar trade-off between economic impact and deaths, ranging from $4.85 million USD (Canada) to $6.59 million USD (Australia) to avoid one death. Useful reference points are other values of human life used in government decision making: the value of a statistical life (VSL) or the value of a prevented fatality (VPF). The UK Government use a VPF of £1.6 million GBP ($2.11 million USD)[17]; Australia uses a VSL of $4.9 million AUD ($3.55 million USD)[18] and the US uses VSLs of $7.4 million USD[19] and $9.6 million USD[20]. The Canadian government does not publish a VSL but the literature puts this at just over $4 million CAD ($3.03 million USD)[21]. With the exception of the US, the monetary values from our study are larger than the respective VSL/VPF. VSL/VPF is the aggregation of values of small reductions in risk to life over a number of people. It is a value for a statistical life, not for an actual, identifiable person. Donaldson[22] outlines a number of additional reasons why *a priori* we could expect higher values of human life in a pandemic. Pandemics could invoke a 'rule of rescue' which

describes the imperative people feel to rescue identifiable individuals facing avoidable death[23] and can lead to larger willingness to pay to extend or save life[24]. Indeed, the UK Treasury's guidance[17] states that the VPF is not designed for situations of emergency or rescue; arguably, pandemics exhibit both. There may be an element of 'dread' associated with dying in a pandemic; and 'dread' has been shown to be more highly valued[25]. Given the infectious nature of viruses, the value of lives saved during a pandemic are not independent of, or indeed can include, the value of reducing the risk of death of others (positive externalities). The estimated US monetary value being less than the US VSLs is not unexpected given the latter are derived using compensating wage differentials from risky occupations which have been shown to generate higher values than methods that elicit social values (including the UK VPF), similar to those used here.

The health and economic policies in which taxpayers want to invest are relatively consistent across the four countries. For health policies, Australia and the UK had similar preferences (except the UK wanted to invest in vaccine development) while Canada and the US preferred the same policies (but in different rank order). The countries differed somewhat in health policies they did not want to further invest in. Given contact tracing relies on surveillance, it may be surprising that all countries wanted investment in the former but not the latter; this could relate to familiarly with 'test, trace and treat'. Uniquely, Australians were indifferent to additional investment in vaccine development for future pandemics, possibly influenced by the high control of COVID-19 infections locally through non-pharmaceutical means[26]. All countries were indifferent to new investment in social distancing which could be interpreted as viewing the current level of investment as adequate.

Preferences regarding economic policies were consistent across the four countries with investment focused on cash transfers (plus cut in interest rates in the US). For all other economic policies, respondents viewed additional investment as no better than the current level of investment; but none were actively opposed. Overall, there was a preference for investment in more health than economic policies which could relate to familiarity and/or a perception that investment now to minimise the health impact could minimise the need for a large economic response. Combining the policies that the samples wanted to invest in into a package yielded high levels of support, from 73% (US) to 83% (Canada).

Inevitably, the trade-offs taxpayers are prepared to make between and within health and economic domains when preparing for the *next pandemic* will be informed by, and have potential to inform, management of the *current pandemic*. To our knowledge, data on public preferences regarding investment in preparation for future pandemics do not currently exist beyond this study. Repeating our survey on an ongoing basis (and in other countries) would provide policy-makers with regular updates, aiding management of the current pandemic and inform in real time ongoing preparation for future pandemics.

Given delays in responding to a pandemic ultimately costs both lives and resources, the better prepared we are the better we will fare in the next pandemic. Preferred policies to invest in and quantification of the public's assessment of the required trade-offs is crucial in such preparation.

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Tables

Table 1 Attributes and levels describing policy investment options

Attributes	**Levels**
Investment in health policies to prepare for the pandemic	
Handwashing and public use of masks awareness campaign	Yes/No
Social distancing awareness campaign	Yes/No
Contact tracing	Yes/No
International travel bans and border security measures	Yes/No
Increase medical supply of face masks/medical stockpile	Yes/No
Improved health and social care system capacity	Yes/No
Improved health department surveillance of infections and investigation of outbreaks	Yes/No
Rapid development of vaccine	Yes/No
Rapid development of drug and other treatments	Yes/No
Additional economic policy response in the event of a pandemic	
Fiscal policy	Cash transfers to individuals Tax relief to firms

	No additional policy response
Monetary policy	Cut interest rates
	Injecting extra money into the system for banks to lend to businesses & individuals
	No additional policy response
Labour policy	Wage subsidy (job retention)
	Wider access to unemployment benefits/insurance
	No additional policy response
Cases	
Number of cases per million after policy investment/response	300
	5000
	20,000
	50,000
	100,000
	150,000
Deaths	
Number of deaths per million after policy investment/response	0
	20
	100
	500

	1000
	3000
Impact on the economy	
Impact on the economy compared to year prior to the pandemic	0.2% reduction GDP associated with Unemployment rate increasing from 5.2% to 5.4% 0.2% reduction in median house prices 2% decrease in the stock market 2% reduction GDP associated with Unemployment rate increasing from 5.2% to 7.3% 2% reduction in median house prices 21% decrease in the stock market 6% reduction GDP associated with Unemployment increasing from 5.2% to 11% 6% reduction in median house prices 50% decrease in the stock market 10% reduction GDP associated with Unemployment increasing from 5.2% to 15.5% 9% reduction in median house prices 50% decrease in the stock market
Cost to the individual	

Cost to you in terms of $ increase in income taxes per year (and per month)	Presented as both $ value % of taxable income: $ [income*0.0025] per year or $[(income*0.0025)/12] per month (0.25% of your taxable income) $ [income*0.01] per year or $[(income*0.01)/12] per month (1% of your taxable income) $ [income*0.02] per year or $[(income*0.02)/12] per month (2% of your taxable income) $ [income*0.03] per year or $[(income*0.03)/12] per month (3% of your taxable income)

Table 2 Willingness to pay in forgone GDP to avoid 1 death in Australia, Canada, the UK, and the US, 2020.

	% GDP reduction to avoid 1 death per million	% GDP reduction to avoid 1 death in the population	GDP reduction to avoid 1 death in the population (millions USD)
Australia	0.012	0.00047	6.59
	[0.01, 0.014]	[0.00038, 0.00056]	[5.37, 7.80]
Canada	0.010	0.00028	4.85
	[0.009, 0.012]	[0.00024, 0.0003]	[4.19, 5.50]
UK	0.013	0.00019	5.44
	[0.011, 0.015]	[0.00016, 0.00022]	[4.53, 6.36]
US	0.009	0.000028	5.99
	[0.008, 0.011]	[0.000023, 0.000033]	[4.93, 7.06]

95% confidence interval in [ ]

Table 3: Rank order of preferred policy investment (most to least preferred)*.

Rank	Australia	Canada	UK	US
Health policies				
1	***Health and social care system capacity***	***Health and social care system capacity***	***Contact tracing***	***Medical supply of face masks***
2	***Medical supply of face masks***	***Development of vaccine***	***Medical supply of face masks***	***Contact tracing***
3	***Contact tracing***	***Medical supply of face masks***	***Health and social care system capacity***	***Health and social care system capacity***
4	***Development of drug and other treatments***	***Contact tracing***	***Development of drug and other treatments***	***Development of drug and other treatments***
5	Handwashing and public use of masks	***Development of drug and other treatments***	***Development of vaccine***	***Development of vaccine***
6	Development of vaccine	***Handwashing and public use of masks***	Handwashing and public use of masks	***Handwashing and public use of masks***
7	Social distancing	International travel bans	Social distancing	Social distancing

8	International travel bans	Social distancing	Health department surveillance of infections	*International travel bans*
9	*Health department surveillance of infections*	Health department surveillance of infections	*International travel bans*	*Health department surveillance of infections*
Economic policies				
1	***Cash transfers to individuals***	***Cash transfers to individuals***	***Cash transfers to individuals***	***Cash transfers to individuals***
2	Wage subsidy (job retention)	Wage subsidy (job retention)	Cut interest rates	***Cut interest rates***
3	Cut interest rates	Cut interest rates	Wider access to unemployment benefits/insurance	Wage subsidy (job retention)
4	Injecting extra money into the system	Injecting extra money into the system	Injecting extra money into the system	Injecting extra money into the system
5	Tax relief to firms	Tax relief to firms	Tax relief to firms	Wider access to unemployment benefits/insurance

6	Wider access to unemployment benefits/insurance	Wider access to unemployment benefits/insurance	Wage subsidy (job retention)	Tax relief to firms

*Policies respondents wanted to invest in that are statistically significant are in bold italics; policies respondents did not want to invest in that are statistically significant are in italics; remaining policies (in neither bold nor italics) are not statistically different to no further investment.

Figures

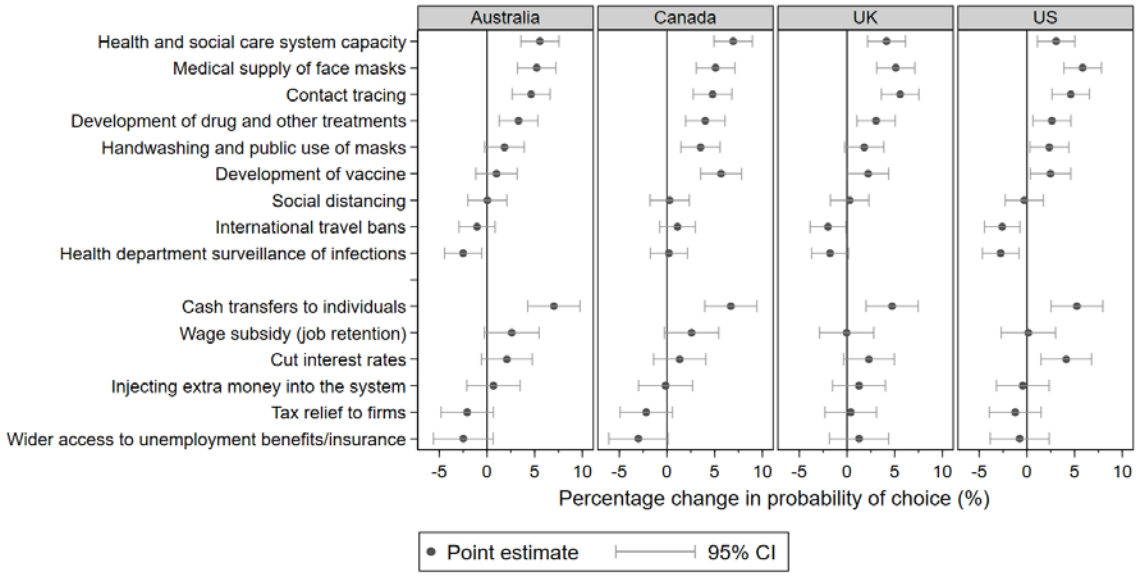

Figure. 1: Relative importance of policy options in Australia, Canada, the UK, and the US, 2020. Plots the percentage change in predicted probability of choice for each policy along with their 95% confidence intervals.

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Supplementary Appendix

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Methods – additional detail

Attributes and levels

A glossary explaining each attribute was presented to respondents in advance of completing the choice sets; further, when considering the choice scenarios respondents could remind themselves of the meaning of the attributes by clicking on the link to a glossary. The attributes and levels are described below.

Health Policies

Each of the nine health policies that could be invested in prior to the next pandemic were described by one of two levels: "yes" if that the policy was part of the investment package and "no" if it was not part of the investment package. These included:

1. Handwashing and public use of masks awareness campaign: Investment in developing and implementing awareness campaigns informing the public about the benefits of handwashing and may also include consideration of public use of masks if recommended.

2. Social distancing awareness campaign and infrastructure: Investment in awareness campaigns about the benefits and requirements of social distancing for in general and for closed settings (restaurants, function venues, workplaces, sporting events, etc.).

3. Contact tracing capabilities: Investment in infrastructure to test for infections, training a workforce to find 'contacts' of those infected, the development of apps to track location and close contacts of cases during a pandemic, and the ability to quarantine cases once identified (at home and in institutions such as hotels and boarding facilities).

4. Travel bans and border security measures: Investment in applying domestic and international travel restrictions and border security measures in preparation for the pandemic, including costs of policing/staffing those bans; training of border security health workforces; cost of mandatory quarantine in hotels.

5. Increase in medical supply of face masks/medical stockpile: Investment in stockpiling and maintaining personal protective equipment for the health sector and the public, as well as emergency medications, to prepare for future pandemics.

6. Improved health and social care system capacity: Investment to increase capacity in the existing health and social care system in preparation for a pandemic. This includes, for example, increasing beds, staffing, equipment and resources for intensive care units (ICU), care for older people, enabling telehealth services and purchasing medical equipment. Having greater capacity will mean less services reduced due to a pandemic, such as no need to pause elective surgery, usual care appointments and social care services.

7. Improved health department surveillance of infections and investigation of outbreaks: Investment to protect public health, including surveillance of infections, routine testing of laboratory specimens, genome sequencing, investigating outbreaks and educating the health workforce regarding what to look for to spot future pandemics to enhance surveillance and to enhance public health response capacity.

8. Rapid development of vaccines: Investment to prepare for a more flexible scientific infrastructure including investment in people and resources to fast-track the development and

distribution of a class of vaccines in preparation for likely pandemic scenarios.

9. Rapid development of drug and other treatments: Investment to prepare for a more flexible scientific infrastructure including investment in people and resources to fast-track the development and distribution of certain types of drug treatments and research in other related treatments in preparation for a pandemic.

Economic Policies

Pandemics can cause large negative shocks to an economy which can have elements of both a supply and demand shock, as is the case with the current COVID pandemic. We described the additional economic policy response in the event of a pandemic in terms of three attributes: fiscal policies; monetary policies; and labour policies. These were informed by policies enacted to stabilise and stimulate economies in response to economic shocks, including those commonly considered/enacted in the current pandemic. These included:

10. Fiscal policy: Fiscal policy is the means by which the government adjusts its spending levels and tax rates to influence the country's economy. Levels included cash transfers to individuals; tax relief for firms affected by a pandemic; or no additional policy response.

11. Monetary policy: Monetary policy is the economic policy laid down by the central bank to influence a country's supply of money. Monetary policy responses included: cutting interest rates to encourage borrowing to stimulate economic growth; 'quantitative easing' to inject extra money into the system for banks to lend to businesses and individuals (such that financial markets continue to function effectively); or no additional policy response.

12. Labour policy: providing a wage subsidy or payment to firms to help people keep their jobs; providing greater access to unemployment benefits or insurance; or no additional policy response.

Impact of the new policy investment on health and the economy

13. Number of cases and 14. Number of deaths: Describes the number of cases per million and deaths per million during the year of a future pandemic if the health and economic policy response options are implemented. We used a common set of four levels per million for each of cases and deaths across the four countries but also presented what these numbers meant in terms of the total population in each of the four countries to make the levels contextually relevant to each respondent.

For cases and deaths we proposed levels informed by real (minimum and maximum) values from a number of moderate to severe pandemics (including Spanish influenza A (H1N1), Asian influenza A (H2N2), COVID-19, Hong Kong influenza A (H3N2), SARS, MERS, Seasonal influenza) in Australia, the UK, the US and Canada and then used non-linear spacing of levels between the minimum and maximum values.

15. Impact on the economy compared to year prior to the pandemic: Describes the percentage reduction in GDP if the health and economic policy investment described in the policy option is implemented compared to the year prior to the pandemic. The levels were based on the literature[1]. The reduction in GDP was also described in terms of the associated increase in unemployment, percentage reduction in median house prices and percentage decrease in the stock market. Since the impact a given reduction in GDP has on unemployment, house and asset prices depends on where an economy is in its business cycle prior to the downturn in

GDP, the relationship between each and GDP was informed by the last five Australian recessions. For each recession the reduction in GDP and the associated change in each of these three variables were sourced and averaged to identify the proportional change in each for a given change in GDP. This was applied consistently across all four countries

16. Cost in terms of increase in income taxes: Described as the increase in respondent's income tax per year (also described per month) to provide the government with additional resources to implement the policy investment. While the four levels of percent increase in income taxes were the same for all respondents across all countries, we presented for each individual what that would mean for them in local currency based on their taxable income, provided earlier in the survey.

Experimental design constraints

The constraints imposed in the experimental design involve four types:

1. At least one health policy must be present in an option. This corresponded to excluding all options in which all health policies were jointly not available.
2. Less expensive policies must be accompanied with low tax increases. Such policies included investments in awareness campaigns including 'handwashing and public use of masks awareness campaign', and 'social distancing awareness campaigns'. This corresponded to imposing the following specific constraints:
    a. Options that only included awareness campaigns and no other health policy were only shown with tax increases of less than or equal to 1% per year;
    b. Options that only included investments in awareness campaigns and no additional economic policies were only shown with tax increases of less than or equal to 1% per year.

3. Cases and deaths:
    a. Within an option the total number of cases must be greater than or equal to the number of deaths;
    b. Within an option the combination of cases and deaths shown must have a case fatality rate (percentage of deaths to number of cases) within the range reported for past mild to severe pandemics (less than 6%).
4. Policies expected to have low (high) economic impact shown with low (high) percent reductions in GDP. Holding all else constant, policies classified as being expected to have low impact on GDP included: handwashing; contact tracing; increase in PPE supply, accelerate vaccine development, accelerate drug treatment. Holding all else constant, policies classified as being expected to have medium-high (classified as high) economic impact included: social distancing, travel bans, health and social care system capacity, public health response capacity. Once classified the following constraints were imposed:
    a. If an option included only one health policy investment and it is expected to have low economic impact, and no additional economic policy, GDP reduction must be less than 10% (i.e. less than worst designed level);
    b. If an option included only one health policy investment and it is expected to have low economic impact, and only one economic policy investment, it must be accompanied by a GDP reduction of less than 10% (i.e. less than worst designed level);
    c. If an option included only one health policy investment and it is expected to have high economic impact and no additional economic policy is included, GDP reduction must be greater than 0% (i.e. some non-zero impact on the economy).

Statistical Analysis

Discrete choice model

The statistical analysis of choice data generated in a DCE relies on random utility theory (RUT)[2] where each respondent faces a choice amongst J=2 options. The RUT framework proposes that utility can be separated into a systematic and random component.

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (1)$$

Here U_{ij} is the utility individual i derives from choice of option j, V_{ij} is the systematic component and ε_{ij} is the random component. Individuals are assumed to choose option j if and only if the utility derived from that option is greater than the utility derived from any other option in the choice scenario J. The probability respondent i will choose option 1 is represented as

$$Pr(U_{i1} > U_{ij}) = Pr(V_{i1} + \varepsilon_{i1} > V_{ij} + \varepsilon_{ij}) \; \forall j \neq 1 \quad (2)$$

Assuming ε_{ij} are identically and independently distributed (IID) extreme value type 1 produces the standard multinomial logit (MNL) specification

$$Pr(U_{i1} > U_{ij}) = \frac{\exp(V_1)}{\sum_{j \in J} exp(V_j)} \quad (3)$$

Assuming a linear functional form for the systematic component of the indirect utility function gives:

$$V_{ij} = \beta' X_{ij} + \varepsilon_{ij} \quad (4)$$

where X_{ij} is the vector of attributes (Table 1) of the *jth* choice as viewed by the *ith* individual. We estimate a main effects MNL model in all analyses.

We tested for statistical difference between the split sample on the basis of who the pandemic most affected (everyone, with a greater impact on children or the elderly) using a likelihood ratio test[3]. We found no statistical difference between the results of the two conditions confirming that the data could be pooled across conditions (Table S3). All results reported are therefore based on the pooled data for each country.

Compensating variation

The willingness to pay to avoid one death in the population in terms of a percentage reduction in GDP was calculated using the Hicksian Compensating Variation (CV) accounting for discrete data and random utility theory[4,5]:

$$CV = \frac{1}{MU_{GDP}} [\ln \sum_{j=1}^{J=2} exp(V_j{}^0) - \ln \sum_{j=1}^{J=2} exp(V_j{}^1)] \quad (5)$$

where MU_{GDP} is the marginal utility of GDP; $V_j{}^0$ and $V_j{}^1$ are the values of the indirect utility function for each choice option *j* before and after the change (in our case a decrease in deaths by 1), respectively. The Hicksian CV calculates the change in expected utility due to the change in number of deaths weighted by the marginal utility of GDP. That is, we compare an initial state of the world (where attributes are set to given levels described in Table S4) and a new state of the world (where all attributes are at the same levels as in the initial state of the world except for a decrease in the number of deaths by one). This produces the percentage GDP reduction to avoid one death per million, shown in Table 2 (column 2) of the body of

the paper. We scaled this by the country population to calculate the percentage GDP reduction to avoid one death in the population (column 3). Empirically we used the full population (not just taxpayers) as ultimately that is the projection of interest, analogous to the approach taken to generate value of a statistical life. Multiplying this by the country-specific GDP generates the GDP reduction to avoid one death in the population (column 4). Population and GDP values described in Table S5.

Probability analysis and relative importance of attributes

To measure the relative importance of each policy, we calculated the percentage change in the probability of choosing an option given a particular policy compared to the probability of the base case in which all attributes are set to their mean values.

In the case of an unlabelled experiment with two options per choice scenario, in the base case the indirect utility is equal for both alternatives, $V_1=V_2=V$, giving

$$Pr\big(U_{i1} > U_{ij}\big)_{base} = \frac{\exp(V_1)}{\exp(V_1)+\exp(V_2)} = 0.5 \quad (6)$$

The probability of choosing a particular alternative based on the policy of interest and setting all other attributes to the mean is calculated as

$$Pr(U_{i1} > U_{i2}|x_k, x_{K\neq k} = 0) = Pr(\beta_k x_k + \varepsilon_1 > \beta_k \overline{x_k} + \varepsilon_2)$$

$$Pr(U_{i1} > U_{i2}|x_k, x_{K\neq k} = 0\ ) = \frac{\exp(\beta_k x_k)}{\exp(\beta_k x_k)+\exp(\beta_k \overline{x_k})} \quad (7)$$

where x_k is the particular policy of interest, $\overline{x_k}$ is its mean and β_k is the associated beta-coefficient from the estimated choice model. In the case of effects coded attributes, the attribute mean $\overline{x_k}$ will be zero.

Finally, the percent change in the probability of choosing a particular alternative is calculated to measure the effect of each attribute over and above the base case. The percentage change in probability for the policy of interest x_k is given by

$$\%\,\Delta\, P_{x_k} = \frac{Pr(U_{i1}>U_{i2}|x_k, x_{K\neq k}=0\ ) - Pr\left(U_{i1}>U_{ij}\right)_{base}}{Pr\left(U_{i1}>U_{ij}\right)_{base}} \times 100$$

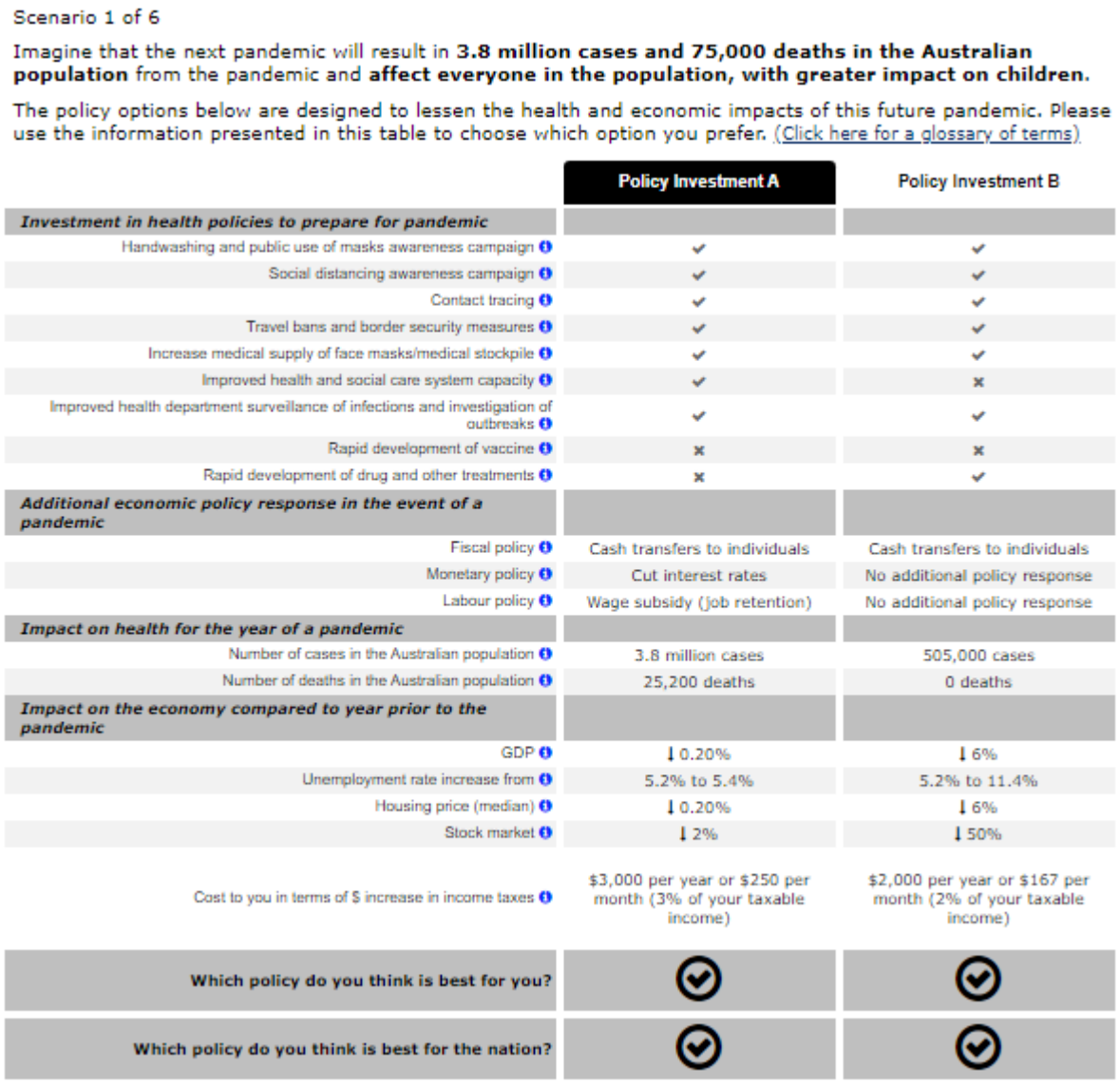
$$\%\,\Delta\, P_{x_k} = \frac{\frac{\exp(\beta_k x_k)}{\exp(\beta_k x_k)+\exp(\beta_k \overline{x_k})} - 0.5}{0.5} \times 100 \qquad (8)$$

Systematically repeating this procedure over all policies produces a rank ordering.

Predicted support for particular policy combinations was estimated using equation (3).

Figures

Figure S1 Example choice scenario*



Scenario 1 of 6

Imagine that the next pandemic will result in **3.8 million cases and 75,000 deaths in the Australian population** from the pandemic and **affect everyone in the population, with greater impact on children.**

The policy options below are designed to lessen the health and economic impacts of this future pandemic. Please use the information presented in this table to choose which option you prefer. (Click here for a glossary of terms)

	Policy Investment A	Policy Investment B
Investment in health policies to prepare for pandemic		
Handwashing and public use of masks awareness campaign	✔	✔
Social distancing awareness campaign	✔	✔
Contact tracing	✔	✔
Travel bans and border security measures	✔	✔
Increase medical supply of face masks/medical stockpile	✔	✔
Improved health and social care system capacity	✔	✖
Improved health department surveillance of infections and investigation of outbreaks	✔	✔
Rapid development of vaccine	✖	✖
Rapid development of drug and other treatments	✖	✔
Additional economic policy response in the event of a pandemic		
Fiscal policy	Cash transfers to individuals	Cash transfers to individuals
Monetary policy	Cut interest rates	No additional policy response
Labour policy	Wage subsidy (job retention)	No additional policy response
Impact on health for the year of a pandemic		
Number of cases in the Australian population	3.8 million cases	505,000 cases
Number of deaths in the Australian population	25,200 deaths	0 deaths
Impact on the economy compared to year prior to the pandemic		
GDP	↓ 0.20%	↓ 6%
Unemployment rate increase from	5.2% to 5.4%	5.2% to 11.4%
Housing price (median)	↓ 0.20%	↓ 6%
Stock market	↓ 2%	↓ 50%
Cost to you in terms of $ increase in income taxes	$3,000 per year or $250 per month (3% of your taxable income)	$2,000 per year or $167 per month (2% of your taxable income)
Which policy do you think is best for you?	✔	✔
Which policy do you think is best for the nation?	✔	✔

*Half of the sampled respondents in each country were told the pandemic would affect everyone, with a greater impact on children (Condition 1), and the other half that the pandemic would affect everyone, with a greater impact on the elderly (Condition 2). Allocation to conditions was random.

Tables

Table S1: Choice model (MNL) results. ^reference level = no additional policy

		AUS	CAN	UK	US
ASC interactions	Canada X alternative1				
	UK X alternative1				
	US X alternative1				
Health policy	Handwashing and public use of masks (ref no)	0.037	0.070***	0.036	0.047*
	Social distancing (ref no)	0.00076	0.0055	0.0057	-0.0056
	Contact tracing (ref no)	0.093***	0.096***	0.11***	0.092***
	International travel bans (ref no)	-0.021	0.022	-0.040*	-0.052**
	Medical supply of face masks (ref no)	0.10***	0.10***	0.10***	0.12***
	Health and social care system capacity (ref no)	0.11***	0.14***	0.083***	0.061**
	Health department surveillance of infections (ref no)	-0.050*	0.0041	-0.035	-0.055**
	Development of vaccine (ref no)	0.02	0.11***	0.044*	0.049*
	Development of drug and other treatments (ref no)	0.066**	0.080***	0.061**	0.052**
Fiscal policy^	Cash transfers to individuals	0.14***	0.13***	0.095***	0.10***
	Tax relief to firms	-0.042	-0.044	0.0078	-0.025
Monetary policy^	Cut interest rates	0.042	0.027	0.046	0.082**
	Injecting extra money into the system	0.014	-0.003	0.025	-0.0087
Labour policy^	Wage subsidy (job retention)	0.052	0.052	-0.00073	0.0029
	Wider access to unemployment benefits/insurance	-0.05	-0.06	0.025	-0.015
Cases	000's cases per million	-0.0012**	-0.0024***	-0.0011**	-0.00068
Deaths	000's deaths per million	-0.76***	-1.10***	-0.85***	-0.78***
Economy	% reduction GDP	-0.040***	-0.071***	-0.040***	-0.052***
Cost ($ taxes)	Cost ('000s USD)	-0.14***	-0.24***	-0.29***	-0.034**
Model fit	ρ^2	0.056	0.11	0.058	0.049
	Number of parameters	19	19	19	19
	Log likelihood	-3846.5	-3919.9	-3923.6	-3945.4

Table S2: Predicted probabilities describing relative importance.

	Probability of choice for alternative 1 by country				Percentage change in probability by country			
	AUS	CAN	UK	US	AUS	CAN	UK	US
Baseline[a]	0.5	0.5	0.5	0.5				
Health policy								
Health and social care system capacity	0.528 [0.518, 0.538]	0.535 [0.525, 0.545]	0.521 [0.511, 0.531]	0.515 [0.505, 0.525]	5.55 [3.55, 7.55]	6.94 [4.93, 8.95]	4.15 [2.15, 6.14]	3.06 [1.1, 5.02]
Medical supply of face masks	0.526 [0.516, 0.536]	0.525 [0.515, 0.536]	0.526 [0.516, 0.536]	0.529 [0.519, 0.539]	5.21 [3.2, 7.22]	5.1 [3.07, 7.12]	5.12 [3.12, 7.12]	5.84 [3.87, 7.82]
Contact tracing	0.523 [0.513, 0.533]	0.524 [0.514, 0.534]	0.528 [0.518, 0.538]	0.523 [0.513, 0.533]	4.63 [2.64, 6.62]	4.78 [2.76, 6.81]	5.58 [3.61, 7.55]	4.59 [2.64, 6.55]
Development of drug and other treatments	0.517 [0.506, 0.527]	0.52 [0.51, 0.53]	0.515 [0.505, 0.525]	0.513 [0.503, 0.523]	3.31 [1.28, 5.33]	4.02 [1.95, 6.08]	3.05 [1.04, 5.06]	2.62 [0.63, 4.61]
Handwashing and public use of masks	0.509 [0.499, 0.52]	0.518 [0.507, 0.528]	0.509 [0.499, 0.519]	0.512 [0.502, 0.522]	1.83 [-0.25, 3.91]	3.52 [1.47, 5.58]	1.81 [-0.24, 3.86]	2.35 [0.3, 4.39]
Development of vaccine	0.505 [0.494, 0.516]	0.528 [0.518, 0.539]	0.511 [0.5, 0.522]	0.512 [0.502, 0.523]	1 [-1.17, 3.16]	5.67 [3.53, 7.82]	2.22 [0.07, 4.36]	2.47 [0.34, 4.6]
Social distancing	0.5 [0.49, 0.51]	0.501 [0.491, 0.512]	0.501 [0.491, 0.512]	0.499 [0.489, 0.509]	0.04 [-2.01, 2.08]	0.28 [-1.78, 2.34]	0.28 [-1.73, 2.3]	-0.28 [-2.28, 1.73]
International travel bans	0.495 [0.485, 0.504]	0.506 [0.496, 0.515]	0.49 [0.481, 0.499]	0.487 [0.478, 0.496]	-1.05 [-2.93, 0.84]	1.1 [-0.77, 2.97]	-1.99 [-3.86, -0.11]	-2.6 [-4.45, -0.74]
Health department surveillance of infections	0.488 [0.478, 0.497]	0.501 [0.491, 0.511]	0.491 [0.481, 0.501]	0.486 [0.477, 0.496]	-2.5 [-4.45, -0.55]	0.2 [-1.74, 2.15]	-1.77 [-3.7, 0.16]	-2.76 [-4.68, -0.83]
Economic policy								
Cash transfers to individuals	0.535 [0.521, 0.549]	0.533 [0.52, 0.547]	0.524 [0.51, 0.537]	0.526 [0.513, 0.54]	7.01 [4.26, 9.77]	6.69 [3.96, 9.42]	4.74 [2.01, 7.47]	5.24 [2.52, 7.95]
Wage subsidy (job retention)	0.513 [0.499, 0.527]	0.513 [0.499, 0.527]	0.5 [0.486, 0.514]	0.501 [0.486, 0.515]	2.59 [-0.28, 5.47]	2.58 [-0.27, 5.43]	-0.04 [-2.88, 2.81]	0.15 [-2.71, 3]
Cut interest rates	0.51 [0.497, 0.524]	0.507 [0.493, 0.52]	0.512 [0.498, 0.525]	0.521 [0.507, 0.534]	2.08 [-0.58, 4.75]	1.33 [-1.4, 4.07]	2.31 [-0.36, 4.97]	4.12 [1.46, 6.77]

Injecting extra money into the system	0.503 [0.489, 0.517]	0.499 [0.485, 0.513]	0.506 [0.492, 0.52]	0.498 [0.484, 0.512]	0.68 [-2.12, 3.47]	-0.15 [-2.99, 2.69]	1.26 [-1.51, 4.04]	-0.43 [-3.19, 2.33]
Tax relief to firms	0.49 [0.476, 0.503]	0.489 [0.475, 0.503]	0.502 [0.488, 0.515]	0.494 [0.48, 0.507]	-2.08 [-4.82, 0.66]	-2.18 [-4.92, 0.57]	0.39 [-2.31, 3.1]	-1.23 [-3.94, 1.48]
Wider access to unemployment benefits/insurance	0.488 [0.472, 0.503]	0.485 [0.469, 0.501]	0.506 [0.491, 0.522]	0.496 [0.481, 0.512]	-2.48 [-5.62, 0.65]	-3 [-6.1, 0.1]	1.27 [-1.83, 4.37]	-0.76 [-3.86, 2.34]
10,000 cases decrease	0.477 [0.463, 0.491]	0.456 [0.442, 0.47]	0.48 [0.466, 0.494]	0.487 [0.474, 0.501]	-4.57 [-7.35, -1.79]	-8.85 [-11.61, -6.08]	-4.03 [-6.79, -1.27]	-2.51 [-5.24, 0.22]
10,000 deaths decrease	0.541 [0.534, 0.549]	0.528 [0.525, 0.532]	0.494 [0.493, 0.495]	0.471 [0.466, 0.476]	8.27 [6.84, 9.7]	5.68 [4.99, 6.37]	-1.22 [-1.41, -1.03]	-5.79 [-6.76, -4.83]
% reduction GDP	0.51 [0.507, 0.512]	0.518 [0.515, 0.52]	0.51 [0.507, 0.512]	0.513 [0.511, 0.515]	1.99 [1.5, 2.48]	3.56 [3.04, 4.07]	1.98 [1.49, 2.47]	2.59 [2.1, 3.08]
$1000 USD decrease taxes	0.536 [0.525, 0.546]	0.56 [0.547, 0.573]	0.572 [0.552, 0.592]	0.509 [0.503, 0.515]	7.16 [5.07, 9.25]	12.04 [9.46, 14.62]	14.43 [10.48, 18.38]	1.72 [0.53, 2.91]

95% Confidence intervals reported in [].

a. Baseline sets all attributes to their mean levels. For two unlabelled alternatives the probability of choice for an alternative is equal to zero.

b,c,d - The change in predicted probability for: b. A decrease of 10,000 cases in population from mean; c. A decrease of 10,000 deaths in population from mean; d. A 1% decrease in % reduction of GDP from mean; e. Decrease of $1000 USD in tax from mean. The change for cases and deaths were very small and has been rescaled to 10,000 in population.

Table S3: Test of poolability of conditions.

		POOLED	CONDITION 1	CONDITION 2
ASC interactions	Canada X alternative1	0.0665*	0.0483	0.0857*
	UK X alternative1	0.164***	0.185***	0.142***
	US X alternative1	0.169***	0.207***	0.131***
Policy Investment Levels	Handwashing and public use of masks (ref no)	0.0431***	0.0519***	0.0342*
	Social distancing (ref no)	-0.00645	-0.00608	-0.00645
	Contact tracing (ref no)	0.102***	0.0898***	0.114***
	International travel bans (ref no)	-0.0251**	-0.0209	-0.0292*
	Medical supply of face masks (ref no)	0.108***	0.104***	0.113***
	Health and social care system capacity (ref no)	0.0897***	0.0998***	0.0796***
	Health department surveillance of infections (ref no)	-0.0292**	-0.0175	-0.0414**
	Development of vaccine (ref no)	0.0756***	0.0687***	0.0822***
	Development of drug and other treatments (ref no)	0.0660***	0.0790***	0.0529***
Fiscal policy^	Cash transfers to individuals	0.120***	0.108***	0.133***
	Tax relief to firms	-0.0182	0.00208	-0.0391*
Monetary policy^	Cut interest rates	0.0473***	0.0468*	0.0484*
	Injecting extra money into the system	-0.01	-0.0076	-0.013
Labour policy^	Wage subsidy (job retention)	0.0195	0.0423*	-0.00485
	Wider access to unemployment benefits/insurance	-0.0337*	-0.0431	-0.0233
Cases	000's cases per million	-0.00151***	-0.00201***	-0.000982***
Deaths	000's deaths per million	-0.874***	-0.879***	-0.871***
Economy	% reduction GDP	-0.0492***	-0.0445***	-0.0542***
Cost ($ taxes)	Cost ('000s USD)	-0.119***	-0.129***	-0.110***
Model fit	ρ^2	0.0643	0.0657	0.0642
	Number of parameters	22	22	22
	Log likelihood	-15701.3	-8015.7	-7674.9
Test of poolability of survey arms/conditions	LRT	21.4		

	Degrees of freedom	22
	p-value	0.496

^reference level = no additional policy

Table S4: Scenario valued in calculation of the CV for deaths with GDP

Initial State of the World	
Health Policies	Handwashing and public use of masks awareness campaign Social distancing awareness campaign Contact tracing International travel bans and border security measures Increase medical supply of face masks/medical stockpile Improved health and social care system capacity Improved health department surveillance of infections and investigation of outbreaks Rapid development of vaccine Rapid development of drug and other treatments
Economic Policy	Cash transfers to individuals Cut interest rates Wage subsidy (job retention)
Impact on GDP	0.2% reduction in GDP
Tax increase	0.25% increase in income tax
Cases per million	5000
Deaths	20
New state of the world	Identical to initial state of the world but with 1 fewer deaths

Table S5: Population and GDP values. Source: World Bank "GDP(current US$)" World Development Indicators, The World Bank Group, 2019, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD. Accessed 16th Feb. 2020 World Bank "Population, total – World" World Development Indicators, The World Bank Group, 2019 https://data.worldbank.org/indicator/SP.POP.TOTL. Accessed 16th Feb. 2020

	2019 GDP (current US$)	2019 Population
Australia	1396567014733.23	25364307
Canada	1736425629519.96	37589262
United Kingdom	2829108219165.80	66834405
United States	21433226000000.00	328239523

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