

The macroeconomic costs of a global influenza pandemic

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1. Abstract

There is growing support for the theory that at some point in the near future there will be an outbreak of an infectious disease that will be of global concern. SARS could be considered an early warning of the potential impact of infectious disease on the modern globalised economy and with the possibility of human to human transmission of bird flu or other strains of influenza on the horizon the potential impact of more serious infectious disease outbreaks is unknown.

Pandemic influenza carries with it the possibility of widespread mortality and morbidity. Traditional health economic methods focus on the specific health sector impacts whilst the larger macroeconomic picture goes unnoticed. The fall in labour supply, avoidance of public places and events, potential closure of schools is bound to impact the global economy and therefore traditional methods of health cost estimation must yield to macroeconomic modelling in order to capture the true potential impact.

This paper unites disease parameters, pandemic planning policies and CGE modelling in an attempt to capture the potential cost to the global economy of a future influenza outbreak. The estimation uses a 16 region, 20 sector global equilibrium model in GAMS and is calibrated using GTAP data. The policies modelled include reduced labour supply due to morbidity, mortality and school closure. Attempts to combat an influenza pandemic may involve the use of antivirals and vaccinations.

The model reveals that although the impacts of a base disease scenario is quite small (GDP loss of approximately 0.5%), the policies introduced to mitigate disease spread, such as school

closure, yield unprecedented losses to the economy of up to 8% of GDP. Our results also suggest that, although the effectiveness of antivirals and vaccines is unknown, such interventions may prove to be extremely important in mitigating the high economic cost of school closures.

2. Introduction

The last 60 years have seen radical changes in human health and advances in medical science to combat health scares such that collective memory of endemic diseases and ill health is fading rapidly, indeed the number of people still alive who remember clearly the era before the advent of antibiotics is shrinking quickly. Despite these medical advances people remain concerned, often deeply so, about the threats posed by diseases, e.g., HIV/AIDS, Ebola fever, etc., and where a few years ago there was confidence that medical advances offered widespread protection this is being eroded by the appearance of antibiotic resistant bacteria, e.g., MRSA, etc.¹ Moreover these medical advances have not provided methods for combating the common cold and, to only a limited extent, influenza.

Recently the media publication of high pathogenic avian influenza viruses, most notable H5N1, which are capable of infecting humans, have raised fears that a global influenza pandemic is imminent – most commonly expressed as a professional opinion that such a pandemic is statistically overdue. Since previous pandemics have been associated with substantial death rates, especially among the old and young, and generated large adverse economic costs, there is understandable concern about how – medically - such a pandemic should be countered. But while the medical options are relatively well understood there is far less evidence as to the economic costs of such a pandemic. This is especially so with respect to the macroeconomic consequences: it is these costs together with the relative impacts of government policies that are the concern of this study.

The rest of this paper is organised as follows. The next section provides a brief overview of the impacts of previous pandemics. This is followed in section 4 by a review of the evidences about how a pandemic might strike and how countries might respond, while section 5 provides a brief description of the economic model and data used for this study. The scenarios analysed and the model configuration are detailed in section 6, which is followed by a presentation of the results in section 7 and a discussion of the results in section 8.

3. Back story

Influenza pandemics vary in severity with regard to both the number of people affected and the number of deaths. However, pandemics generally have a greater impact than the most severe winter epidemics. The ages of those most affected can vary as can the number of pandemic waves. It is therefore impossible to predict the form that any future pandemic will take, but we can examine

¹ The rise of antibiotic resistance is not a new concern – see the Swann Committee report (1969).

past pandemics in the hope that these will provide some indication of what might be expected in future pandemics.

The severity of an influenza pandemic can be expressed in terms of the clinical attack rate (CAR) and case fatality ratio (CFR). The CAR is an estimate of the number of individuals who are infected with the disease and the CFR expresses the percentage of infected individuals who die from influenza. Multiplying the CAR by the CFR provides the mortality rate for the population.

There were three influenza pandemics in the last century occurring in 1918 (A/H1N1), 1957 (A/H2N2) and 1968/69 (A/H3N2) (HPA 2006) and the clinical attack rates for these pandemics ranged from (approximately) 25% to 35%. The most serious of these pandemics was A/H1N1, known as “Spanish flu”, which occurred in 1918/19 causing serious illness and a high number of deaths: 20-40 million worldwide. The CFR for the 1918/19 pandemic was estimated to be between 2 and 2.5% (HPA 2006). However, whilst influenza often has the heaviest impact on the elderly or very young, the 1918/19 pandemic yielded peak mortality rates for those aged 20 to 45 (DoH 2007). Whilst Asia has been the source of most influenza pandemics, Spanish flu’s origin is unknown. The pandemic spread almost simultaneously in 3 distinct waves over a 12-month period in 1918–1919, in Europe, Asia, and North America (Taubenberger and Morens 2006). As such, Spanish flu stands out as different from the other 20th century pandemics. As well as being more serious from the health perspective, a pandemic such as the 1918/19 pandemic is would be of particular concern from the economic perspective because of the impact on the working population.

The other two pandemics, in 1957 and 1968/69 were less severe and had less impact on those of prime age with mortality occurring mainly amongst the elderly. The CFR was less than 0.5% for both pandemics and the 1957 pandemic consisted of one wave whereas the 1968/69 pandemic consisted of two waves. However, since influenza transmits rapidly where people are in close contact and since children have no residual immunity to past influenza pandemics infection rates tend to be high among children. Some reports suggest that in 1957 up to 50% of school children developed influenza and the CAR reached up to 90% in some residential schools (DoH 2007). A policy to reduce the spread of infection in schools is addressed in our model.

4. A twenty first century pandemic

Influenza pandemic

Whilst the source of any future influenza pandemic is unknown, some assumptions regarding the most likely form of a future pandemic must be made in order to attempt to model it. Sources

suggest that the most likely origin of the disease will be a mutation/strain of avian flu from China or the Far East (DoH and HPIH&SD 2005). As with previous pandemics (DoH and HPIH&SD 2005; HHS 2005) it is expected that the disease is most likely to occur in the winter and would be expected to attack the Northern Hemisphere countries first and spread later to the Southern Hemisphere countries; occurring worldwide within a year.

The assumption of one year's duration raises the issue of pandemic waves. The number of waves of a future pandemic is unknown and predictions vary: some reports suggest that there will be at least one wave (DoH and HPIH&SD 2005; HPA 2006; DoH 2007), others suggest two or more waves (HHS 2005; Public Health Agency of Canada 2006; HSE and DoH&C 2007). However, it is acknowledged that, whether one or more waves occur, the clinical attack rate will have a cumulative upper limit (DoH and HPIH&SD 2005; HPA 2006; Public Health Agency of Canada 2006; DoH 2007; HSE and DoH&C 2007) and that waves may be weeks or months apart (DoH and HPIH&SD 2005). Typically upper limits of 12 to 18 months are placed on pandemics of several waves (Public Health Agency of Canada 2006).

Not only is the timing of any pandemic unknown, the strain of influenza, and therefore its virulence, is unknown. Based on previous pandemics, the greatest effect on the working population occurred in the 1918 pandemic, and this may be considered the worst pandemic from an economic and epidemiological perspective. Nevertheless, several pandemic influenza plans suggest that a 50% clinical attack rate is a reasonable worst case scenario (DoH and HPIH&SD 2005; Public Health Agency of Canada 2006; DoH 2007) and such a pandemic would be more widespread than the 1918/19 pandemic. Globalisation may also play a significant role in disease spread: whilst modern medicine may be better equipped to cope with pandemic influenza than in previous pandemics, modern air travel enables the rapid international movements of a much larger number of people than was the case for previous pandemics which will enable the disease to spread more rapidly.

Pandemic Policies

In the event of an influenza pandemic it is likely that policies will be implemented in order to attempt to mitigate the spread of the disease. These policies may be imposed by government for the general good of the population or they may be the responses of individuals in an attempt to avoid infection. The most likely policies are considered below.

School Closure

In response to the rapid spread of influenza amongst school children, the policy that may be most likely to be introduced to mitigate disease spread is school closure and is mentioned in many

pandemic planning documents including (DoH and HPIH&SD 2005; HHS 2005; HPA 2006; Public Health Agency of Canada 2006; DoH 2007; HSE and DoH&C 2007). Dense gatherings of children at school enable rapid transmission of diseases, among a vulnerable group, and a decision may be made to close schools to mitigate the disease spread. However, the duration of school closure has not been determined and may vary between countries. Arguably the two most likely scenarios are to close schools for the entire duration of the pandemic or to close them during the peak of the pandemic when infection is most rapid and demand for health services is at a premium. Whilst school closure for the duration of the pandemic may be preferable from a health perspective it would cause considerable disruption to working parents and possibly impact on children's education and therefore closure for the peak of the pandemic only may prove a suitable alternative. Both (DoH 2007) and (DoH and HPIH&SD 2005) suggest that the pandemic (single wave) will last approximately 3-5 months and the peak will last approximately 2-3 weeks.

Even if governments do not impose school closures there is arguably a strong likelihood that *de facto* school closures will emerge. Since children, especially young children, are a vulnerable group many parents are likely to choose to keep their children off school during any pandemic. If that is the case it may be that the rational response from a government will be to sanction school closures, even if the perceived benefits are minimal.

Antivirals and vaccinations

A second policy to mitigate the disease effect is to use antivirals and/or vaccinations. These policies are government imposed and will not be uniform across the globe since some countries will not be able to afford them and quantities purchased in different countries will enable varying proportions of the population to receive them. Several countries have made conditional purchases of antivirals in preparation for a pandemic.

Vaccinations are used shortly before the arrival of pandemic influenza to prevent vaccinated individuals from becoming unwell or to reduce the severity of their illness and prevent deaths. However, since the strain of pandemic influenza cannot be known in advance of a pandemic's arrival, vaccinations may not match the disease precisely, which will reduce their effectiveness. Thus the effectiveness of vaccination campaigns are ill defined.

Antivirals are given to infected individuals and are expected to reduce hospitalisations and deaths by about 60% (Cooper, Sutton et al. 2003; Kaiser, Wat et al. 2003). Antivirals need to be taken within 48 hours of the onset of infection but ideally with 24 hours.

5. Model and Data

GLOBE Model

This study uses an application of the GLOBE model (McDonald, *et al.*, 2007). GLOBE is a global computable general equilibrium (CGE) model that is constructed in the form of a series single country CGE models that are linked through their trade relationships, which are calibrated using data derived from the Global Trade Analysis Project's (GTAP) database that is presented in the form of global Social Accounting Matrix (SAM) (McDonald, 2006). It is a multi-region model constructed as a series of single country CGE models that are linked through their trade relationships. For this application GLOBE is implemented in comparative static mode.

For a detailed explanation of the GLOBE model and its construction see (Thierfelder, McDonald et al. 2007)

The economic data

The data for this study are derived from the GTAP database version 6.0, which is benchmarked to the year 2001 (Dimanaran, 2006). The form of the database used for this study is a Social Accounting Matrix (SAM) representation of the Global Trade Analysis Project (GTAP) database version 6.0 (see McDonald and Thierfelder, 2004, for a detailed description of the core database). GTAP produces the most complete and widely available database for use in global computable general equilibrium (CGE) modelling; indeed the GTAP database has become generally accepted as the preferred database for global general equilibrium policy analysis and is used by nearly all the major international institutions and many national governments. Hertel (1997) provides an introduction to both the GTAP database and its companion CGE model. The precise version of the database used as the starting point for this study is a reduced form global SAM representation of the GTAP data.

The aggregation of the GTAP database for this study has 28 sectors (commodities and activities), 11 regions, and 4 factors. The accounts in the SAM are detailed in Table 1, and the aggregation mapping is provided in the Appendix. Because of the emphasis on food and agriculture in the DDA the aggregation seeks to provide a broad coverage of sectors with some bias to agriculture – 9 sectors – and food – 5 sectors – with a balanced coverage of the other trade sectors. The regional aggregation reflects more the specific objectives of this study; there are 5 African regions and 3 (broadly-defined) OECD regions. The relatively large number of regions for Africa allows for deeper insights into the impacts upon those economies of variations in the number of nests in the behavioural modelling of trade relations.

Table 1 **Model Accounts**

Sectors		Regions	
Crops	Utilities	Benelux	Australia, NZ & Oceania
Livestock products	Construction	France	China and Hong Kong
Minerals	Trade	United Kingdom	South and East Asia
Animal products	Sea transport	Germany	South Asia
Other food products	Air transport	Italy	Western Asia
Beverages & Tobacco	Other transport	Rest of the EU	Africa
Base industries	Communications	Rest of Europe	Canada
Manufacturing	Insurance		USA
Machinery	Other services		Rest of Americas
Luxury products			Rest of the World

The choice of regions was motivated by a combination of factors. First, since the focus of this research is on the EU and therefore multiple European countries were maintained. Moreover, since European countries have been the most keen to purchase antivirals, these countries are also of interest from the policy intervention point of view. Second, since it is expected that other wealthy countries are likely to respond in ways similar to the EU, the United States, Canada and Australia, New Zealand and Oceania have been separately identified. Third, since Asia is the most likely source a disaggregation of Asian regions has been included. And finally Africa and the rest of the Americas have been separated out from the rest of the World because of Africa's relative poverty and the America's relative isolation.

The main objective when determining the choice of sectors was to provide a balanced coverage of the main sectors of economic activity. However, some sectors are of specific interest. During the SARS outbreak there was a decline in the demand for luxury items, transport and tourism (see(Keogh-Brown and Smith 2008). Insurance may be affected in the event of a pandemic because of the increased number of deaths and re-insurance may be affected if there should be large losses to the economy. Whilst health services were not noticeably affected by the SARS outbreak (Keogh-Brown and Smith 2008) the more serious nature of pandemic influenza and potentially costly interventions via vaccination and antivirals will also be of interest.

6 Scenarios and Model Configuration

Scenarios

The scenarios implemented for this study are summarised in Table 2. A basic presumption is that the impacts of the disease will take place over a period approximating to a year, and there while a pandemic is modelled as a single wave this is equivalent to a multiple wave pandemic.

In essence two intensities of a pandemic are modelled, the 'base' case assumes a clinical attack rate (CAR) of 35% while the 'severe' case assumes a CAR of 46%, but these intensities are mitigated by school closures (SC) although the effects on the CAR are small as indicated by medical research/opinion.

School closures are assumed to take place for either 4 weeks or 13 weeks. But to translate the consequences of school closure into an effect on the economy we need to quantify impact on the working population. According to the UK focused study (Sadique, Adams EJ et al. 2008), an estimated 38% of the workforce has dependent children under the age of 16 years living within the household. Overall, 15.5% of the workforce is estimated to be comprised of women who have dependent children in the home and would be expected to provide childcare to their children in the event of school closure. A further 0.6% of the workforce is fathers with dependent children in the household, but with no other adults (lone fathers). Thus the aggregate level of absenteeism due to closing of school is estimated to be 16.1%. The rate of absenteeism in different sectors varies significantly. Figure 7 shows the estimated proportion of the workforce who are likely to be responsible for children <16 years of age by sector (the fishing sector, which accounts for less than 1% of absenteeism is not shown in the graph). The figure clearly shows that the health and social work sector is most likely to be affected by school closure – an estimated 31% of the workforce is responsible for dependent children in the home, roughly twice the national average, as this sector employs a high proportion of women (79%). The educational sector also employs a large proportion of women, and therefore the absenteeism rate is also very high (~31%). However, absenteeism in this sector would already be affected by the very nature of school closure.

Table 2 Scenarios

	Case Fatality Rate (%)	Clinical Attack Rate (%)	Mortality rate (%)	Days Lost	School Closure (weeks)
Base	0.04	35	0.01	5	0
Severe with SC	2.5	46	1.15	7	4
Base with 4 weeks SC	0.04	33	0.013	5	4

School Closure with increased CFR	2.5	33	0.825	5	4
Base with PA	0.04	35	0.014	5	0
Severe with SC and PA	2.5	44	1.1	7	13
Base with AV & SC	0.02	28	0.007	4.29	0
Severe with AV & SC	1.5	36	0.54	6.27	4
Base with Vaccine & SC	0.02	20	0.005	5	0
Severe with Vaccine (& SC)	1.5	27	0.405	7	4
Base with vaccine AV & SC	0.01	16	0.002	4.29	4
Severe with vaccine, AV & SC	0.9	20	0.18	6.27	4

Since a greater proportion of women work part-time compared with their male counterparts the absenteeism rates expressed in days (or whole-time equivalents) are lower than that measured in persons. The aggregate absenteeism rate in terms of days is 14.2%. The health sector is still the most affected with around 28% of working days lost through school closures.

Vaccinations are assumed to have a 25% efficacy and that 80% of the population will receive vaccination in time. We also assume that the basic reproductive rate of the infection is 2. As a result of these assumptions vaccination would reduce both illness and deaths by about 40%. Antivirals are expected to reduce hospitalisations and deaths by about 60% (Cooper, Sutton et al. 2003; Kaiser, Wat et al. 2003). It is assumed that two thirds of infected individuals receive antivirals in time and deaths are therefore reduced by 40%.

In order to reflect the anticipated availability of vaccines and antivirals we only consider their application in certain countries. The regions of the model are discussed in the Model and Data Section and we consider five antiviral/vaccination scenarios:

1. EU (Regions: UK, Italy, Germany, France, Benelux, EU)
2. Europe (Regions: as (1) but including the rest of Europe)
3. UK
4. EU, US, Canada and AUS
5. Europe, US, Canada, AUS

Model Configuration

Configuring the GLOBE model adequately reflect the impacts of a pandemic requires determining the appropriate macroeconomic closure and market clearing conditions so as to adequately capture the impacts of a pandemic in a comparative static context. An important consideration is therefore

to ensure that all costs are incurred within the solution period by avoiding any ‘manna from heaven’ effects, e.g., reductions in investment, increases in government debt, etc.

Hence all tax rates are left unchanged except for direct taxes on households: these are allowed to vary so that the budget deficits for governments are held constant in real terms. Similarly investment volumes are held constant as are the aggregate trade balances for each region – the exchange rates are free to vary and thereby ensure the trade accounts are cleared: hence savings rates by household need to be free so that the capital accounts are cleared in each and every region.

The most important consideration however is the treatment of the trade accounts. A flu pandemic is a once off event that does not reflect any changes in economic fundamentals, and therefore there are no reasons to expect decision makers to alter their expectations for the future, other than to the extent that they believe that mortality rates will be sufficiently high as to alter long run factor supplies. However since the estimated impacts on factor supplies are minimal, it is reasonable to assume that decision makers would treat a pandemic as a short run impact that would induce no changes in planned factor use. Hence it is assumed that the response of activities to a pandemic would involve no changes in planned employment. Moreover since each wave would be relatively short – a matter of weeks – and the time periods required for employing additional labour, even on temporary contracts, are likely to be longer than the duration of a wave, the impact of the pandemic on labour employment is assumed to be simple short run reductions in the employment of labour. Furthermore since the ability to substitute labour for capital in the short run is limited the elasticities of substitution between factors are constrained to be severely limited and in the extreme are assumed to be zero. Thus workers who suffer from a flu attack or who are removed from the labour force by school closures are assumed not to be replaced. Hence the pandemic is modelled as a short run reduction of the available labour force annualised over a year.

7 Results

To begin with, we consider the percentage impact on Gross Domestic Product GDP. Figure 1 shows GDP impact across EU countries for five of the disease scenarios in Table 2. The general pattern of relative severity between scenarios remains similar across all results. The base disease scenario (Base) exhibits the smallest impact with losses of approximately 0.4% or 0.5% to GDP and the largest plotted impact occurs for the scenario with base disease and four weeks of school closure with losses from 5.8% for Italy to 7.9% for the UK which would imply unprecedented economic losses. The effect of using antivirals, vaccines and both antivirals and vaccines to mitigate the

impact of the base disease scenarios with four weeks of school closure can also be seen from the plot. These three scenarios yield similar values, the antiviral scenario is the least effective, followed by the vaccine and combination vaccine and antiviral scenarios, but the difference between these policy impact is less than 0.2% of GDP. There are slight differences in impact between countries but these differences are less than 0.3% of GDP in all except the Base disease scenario with school closure with Italy exhibiting the smallest impact followed by France, Germany, “Rest of EU”, Benelux and the UK.

Domestic absorption is plotted in Figure 2 and shows similar patterns to GDP as well as similar values. The impacts for domestic absorption are smaller, but there is no notable change in scenario or country impacts from those outlined for GDP.

Household consumption, Figure 3, exhibits slightly different results from GDP and domestic absorption. The pattern of relative impacts across disease scenarios is similar to that of GDP- the smallest impacts occur for the base disease scenario followed by the school closure in combination with antivirals and vaccines, vaccines, antivirals and finally school closure scenario without vaccine or antiviral intervention. However, the percentage changes for household consumption are greater than those for GDP. There is also a change in the relative impacts across countries: Italy still exhibits the smallest impacts, losses of 0.6% for the base scenario, 1.2% to 1.4% for the antiviral and/or vaccine scenarios and 9.3% for the school closure scenario. France the UK and Germany have similar results, all of which constitute losses approximately one fifth larger than Italy’s, the rest of the EU exhibits household consumption losses approximately one quarter larger than Italy’s losses and Benelux’s losses are approximately one third larger than those of Italy.

The plot of exchange rates is given in Figure 4. The plot shows that the flu scenarios modelled are sufficient to impact notably on the exchange rates between countries. The relative sizes of the impacts across scenarios remains the same as for the previous results. From the region perspective the impacts on the “rest of the EU” are the smallest with losses less than 0.2% for all scenario. Italy’s exchange rate also exhibits very little effect- losses are almost zero in the base case, less than 0.02% for the antiviral and/or vaccine scenarios and approximately 0.4% for the school closure scenario. The largest losses are exhibited by the UK, although Benelux’s exchange rate exhibits similar losses: the base scenario losses are for the UK and Benelux are 0.11% and 0.09 respectively, the antiviral and/or vaccine scenario impacts are approximately 0.4% for the UK and 0.3% for Benelux, and the school closure impacts are 1.8% for the UK and 1.5% for Benelux. It is interesting to note from the figure that pandemic influenza might introduce exchange rate gains for France and Germany. France’s gains are negligible except for a 0.5% gain for the school closure scenario but Germany sees

increases in its exchange rate of 0.1-0.2% for antiviral and/or vaccine scenarios and 1.9% for the school closure scenario.

Government expenditure is plotted in Figure 5. The impacts on government expenditure are positive, but the magnitudes of the relative impacts of the scenarios follow a similar pattern to the other results. However, the relative impacts for each country differ from the patterns observed in the previous results. The smallest government expenditure impacts occur for Germany where all increases in expenditure are less than 1%. France impacts range from small Base disease impacts to impacts of approximately 0.6 for all other scenarios except the school closure scenario which shows a government expenditure increase of approximately 1.6%. Although the UK exhibited large GDP impacts relative to other countries its government expenditure increases are slightly smaller than Italy, Benelux and the rest of the EU, with percentage changes of 0.2% for the base disease scenario, 0.7% for the antiviral and/or vaccine scenarios and 3.2% for school closure. The largest increases in government expenditure occur in the rest of the EU, followed by Benelux and Italy. For these countries the base scenario impacts are between 0.2% and 0.3%, the antiviral and/or vaccine impacts are approximately 0.9% for Italy, 1% for Benelux and 1.2-1.3% for the rest of the EU. For the school closure scenarios the impacts are 3.8% for Italy, 4.5% for Benelux and 5.7% for the 'rest of the EU'.

Having considered the overall country impacts for various scenarios the final aspect of our analysis of results considers the sectoral impacts on the price for value added in the UK. The impacts of the scenarios, shown in Figure 6, are fairly similar across sectors but there are some differences. For the base scenario losses of between 0.2% and 0.5% occur in the first six sectors which broadly cover food, drink and minerals but the sectors entitled utilities, other transport and communications suffer similar losses. Some sectors exhibit increase in the price of value added, most notably machinery (0.45%), construction (1.1%) and sea transport (1.8%). For the base with antiviral, vaccine and school closure, most sectors suffer a loss of between 0.8% and 1.6% to the price of value added. The smallest impacts for this scenario occur to machinery, construction, trade, sea transport and insurance, but the price of value added for other services rises by 1.4%. Finally, for the school closure scenario the pattern of sectoral impacts for price of value added is similar to that of the base scenario, but the impacts are mostly between 15 and 20 times larger.

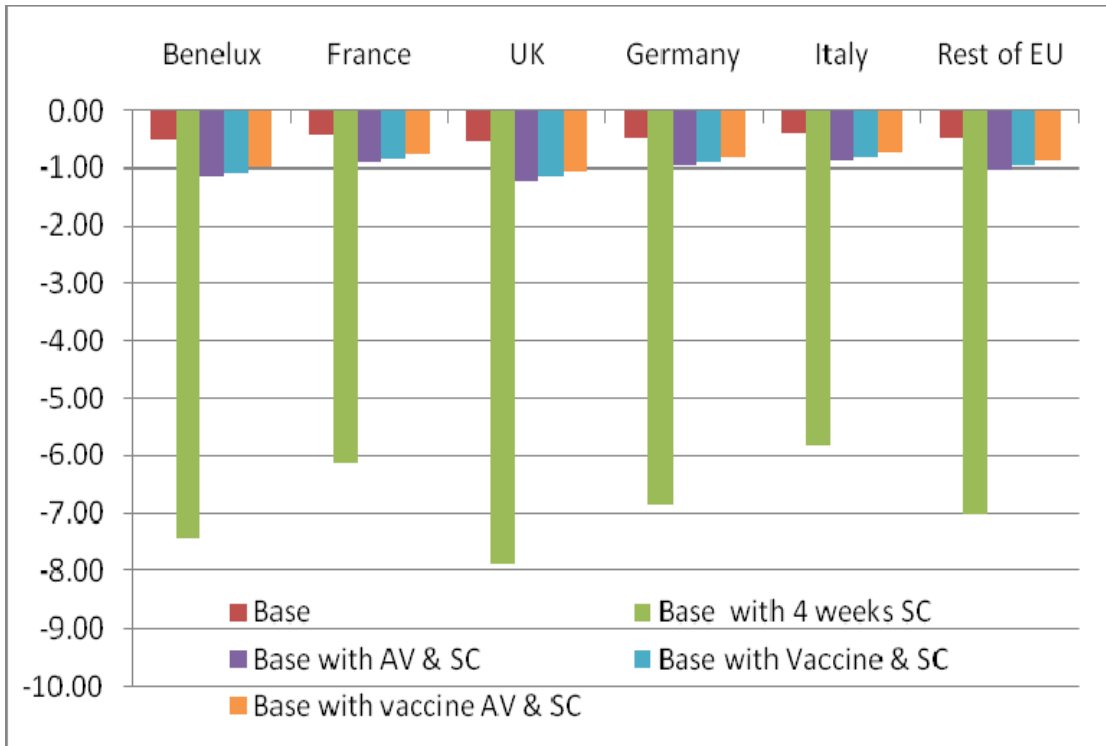


Figure 1 Gross Domestic Product (% changes)

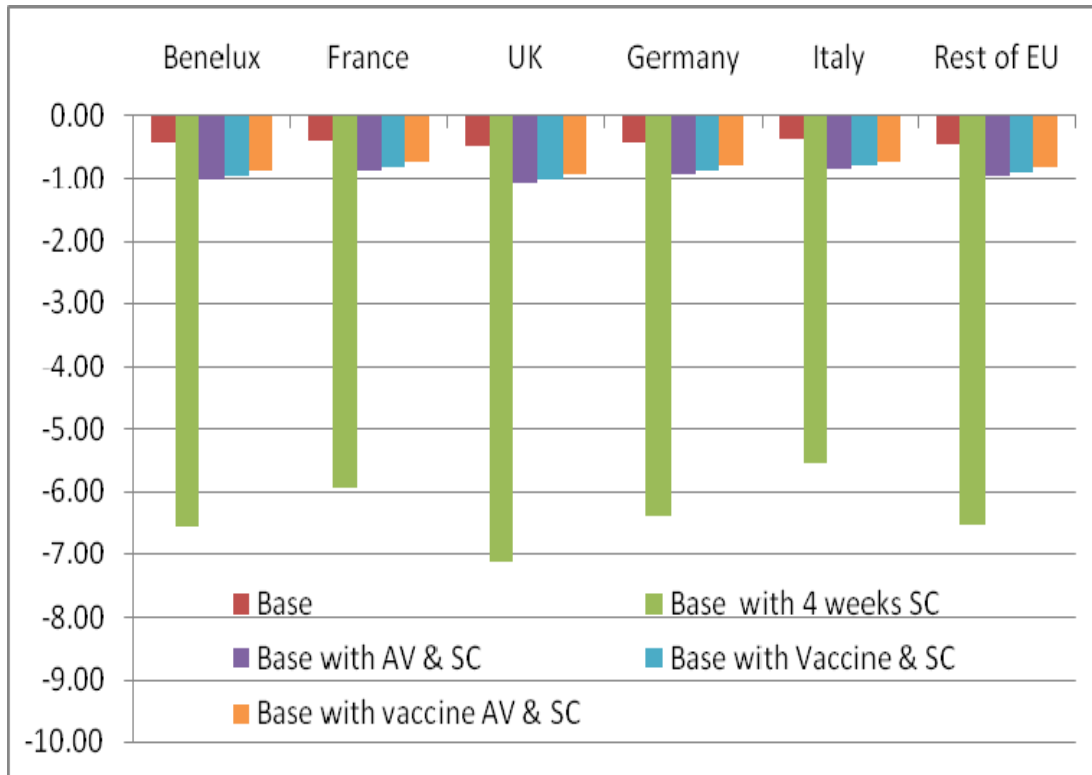


Figure 2 Domestic Absorption (% changes)

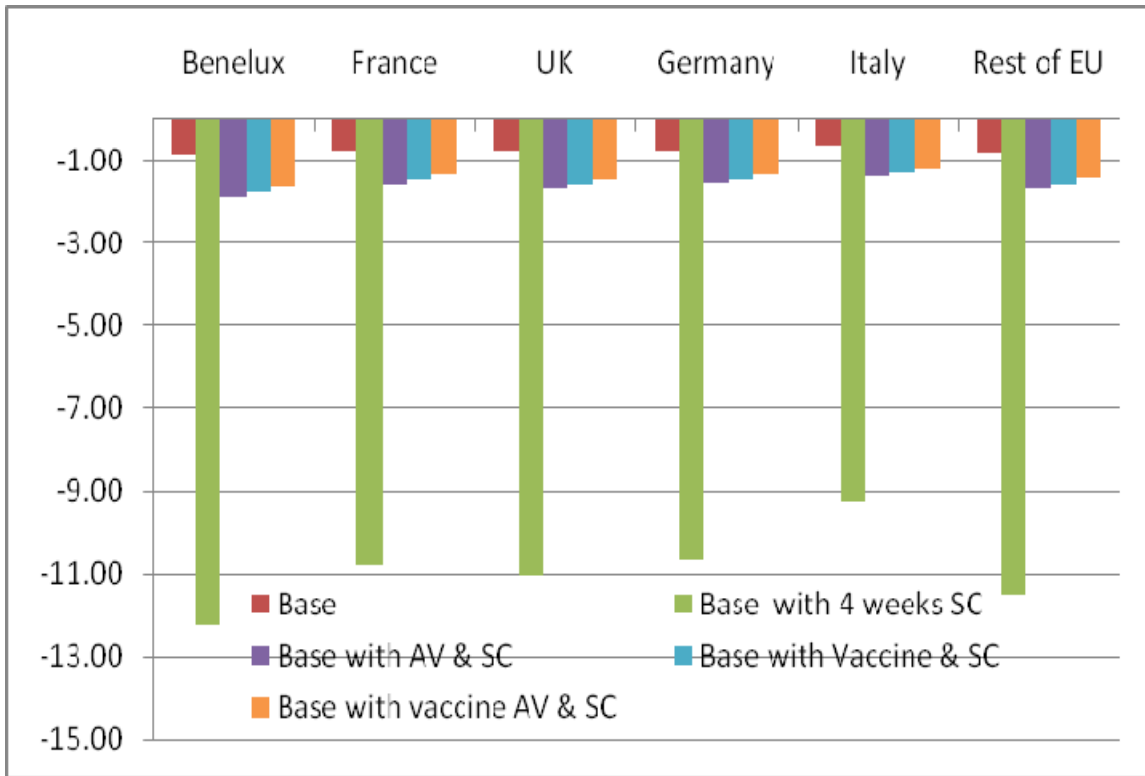


Figure 3 Household Consumption (% changes)

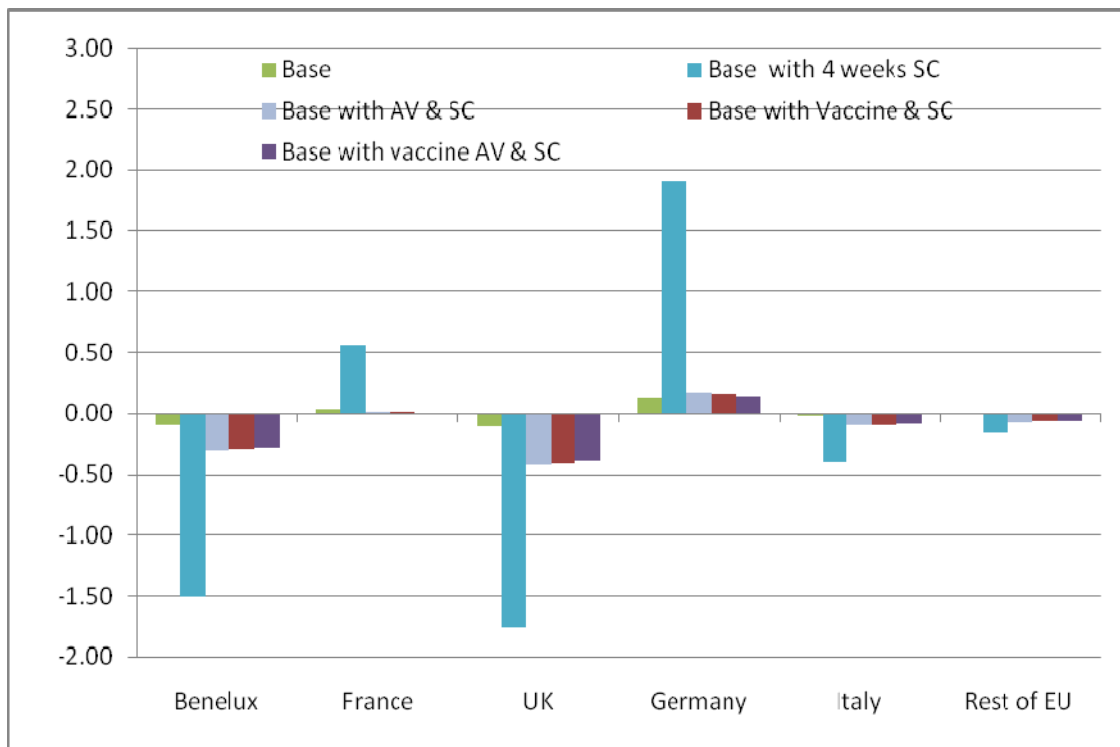


Figure 4 Exchange Rates (% changes)

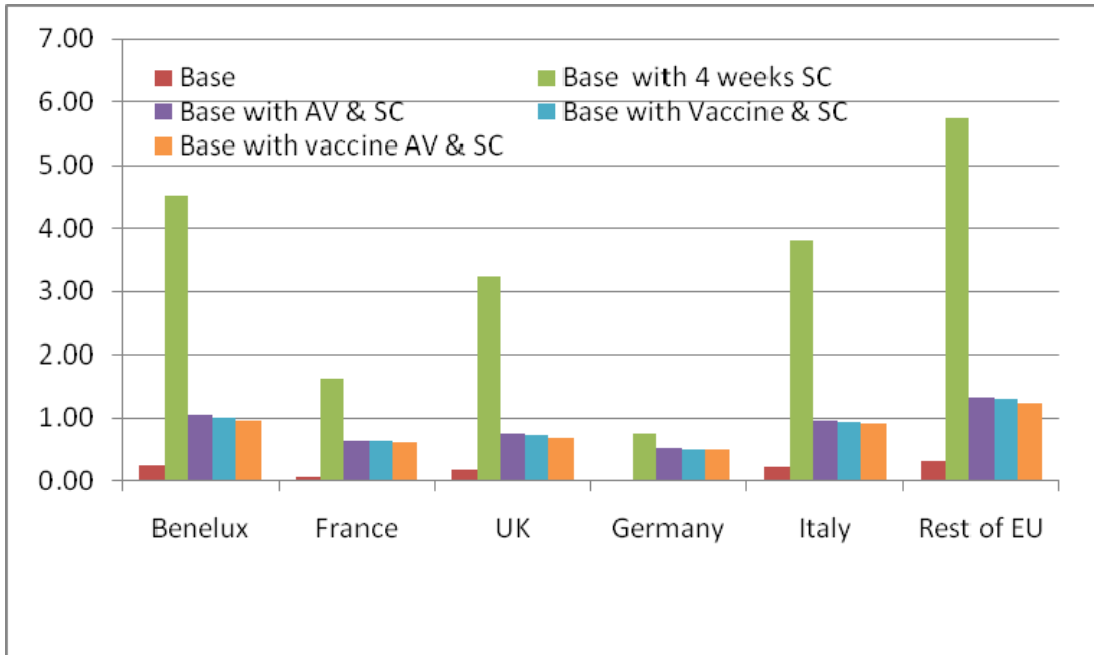


Figure 5 Government Expenditures

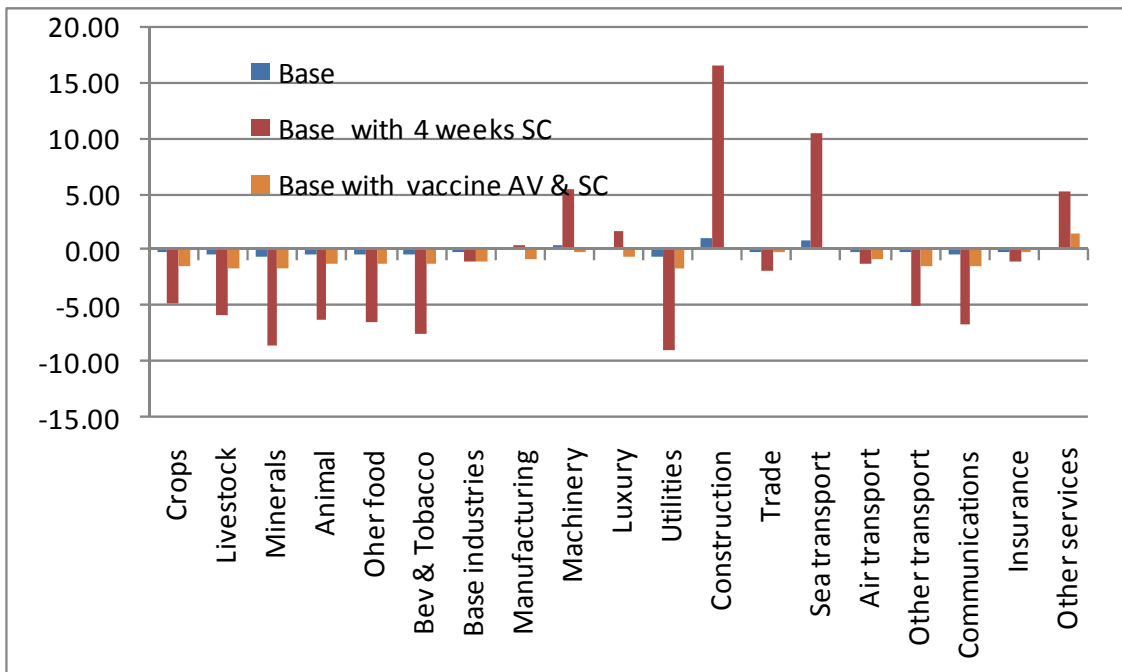


Figure 6 Price of Value Added (UK) (% changes)

8. Discussion

We have presented a selection of our model results to outline the potential impact of pandemic influenza. Our results suggest that a pandemic of the type experienced in 1957 or 1968/69 would have a negative impact on GDP of approximately 0.5% and would produce losses to household consumption of up to 1%, a small increase in government expenditure and some minor impacts on exchange rates. Sectoral impacts from our model are small so the overall economic impact of the pandemic itself would seem to be of relatively little concern.

However, the introduction of a school closure policy, even if restricted to the peak of the pandemic only, causes a large increase to the working population shock and greatly increases the economic impact of the pandemic. Under a peak pandemic school closure policy GDP losses of between 5% and 8% could result together with changes in the exchange rate of up to 2%. Whilst many countries share a common currency, adjustments in the economies of many countries will occur in response to these exchange rate effects. Household consumption could fall by almost 13% during the pandemic and government expenditure could rise by up to 6% in some countries. These results highlight the power of pandemic mitigation policies, however beneficial from the health perspective, to magnify the economic impact of a pandemic. The impact of school closure that we have modelled may prove a worst case scenario since, in reality, parents may make alternative arrangements for the care of their children that will enable them to return to work during school closure, thus reducing the school closure impact, but conversely school closures may be imposed for longer than the four weeks assumed in the results we have presented which would increase the economic impact and may reduce some parents' ability to find short-term care solutions that enable them to return to work.

Whilst some mitigation policies may have a detrimental effect on the economy, our results show that the use of antivirals and vaccines may prove very beneficial in dampening down the economic impact introduced by school closures. The economic impact of school closure together with antivirals and/or vaccines is approximately twice as large as the impact of the disease itself, but is much smaller than the economic impact of the scenario that considers school closure. The high rates of infection amongst school children, particularly if a pandemic is severe, is of great concern and it is therefore possible that the health benefits of school closure will take precedence over the economic cost and the effectiveness of antivirals or vaccines to mitigate the economic impacts may prove to be an important consideration. Our results for the antiviral/vaccine scenarios are limited

by our assumptions of their efficacy and the efficacy of such interventions will remain unknown until a pandemic arrives, but the relatively small increase in government expenditure presented in our results would seem to be justified in the light of the potential benefits of antivirals and/or vaccines.

Whilst there is much uncertainty surrounding the nature of future pandemics, the response of governments and individuals to the disease and the effectiveness of interventions, this study highlights the need for further investigation into the potential economic impact of pandemic influenza and for further analysis of the cost and effects of both policies and interventions to mitigate disease spread. Further research into this subject would provide a valuable insight to policy makers and form an important part of the preparedness plan for future pandemics.

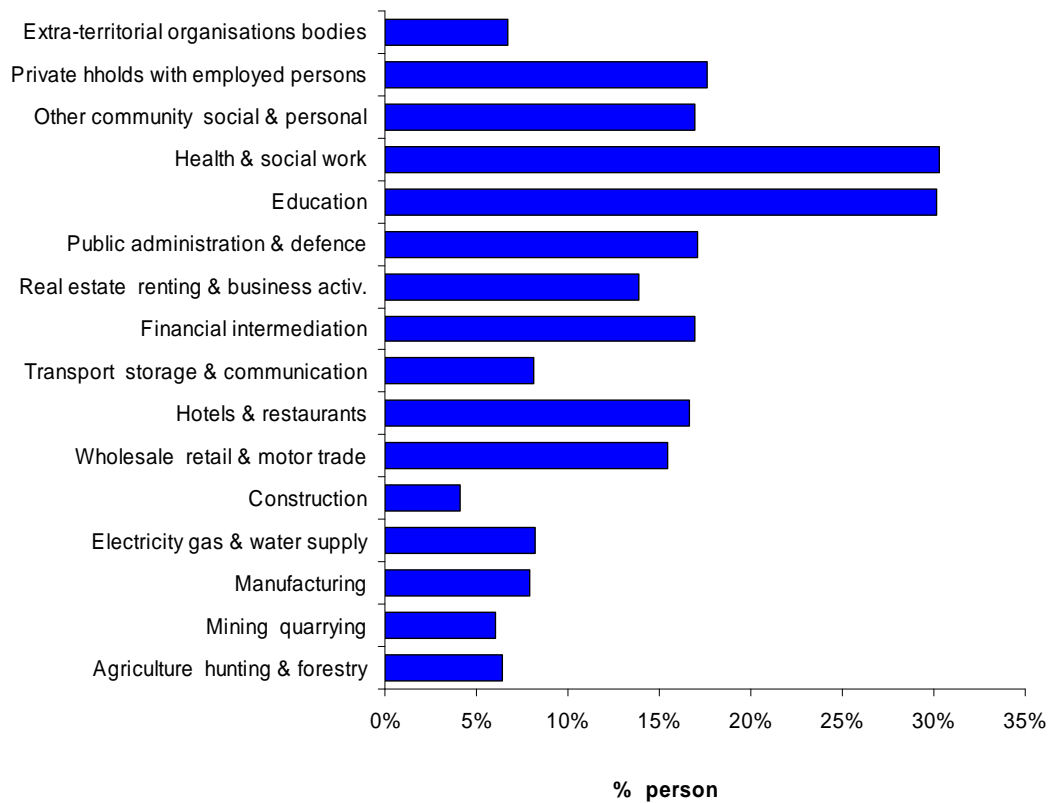


Figure 7 Proportion of workforce responsible for dependent children by sector

Table A11 Absenteeism rate in days

Industrial sector	Absenteeism rate (in days)
Agriculture, hunting & forestry	5.6%
Fishing	0.6%
Mining & quarrying	5.3%
Manufacturing	6.9%
Electricity, gas & water supply	7.2%
Construction	3.6%
Wholesale, retail & motor trade	13.8%
Hotels & restaurants	14.9%
Transport storage & communication	7.1%
Financial intermediation	15.1%
Real estate, renting & business activities	12.2%
Public administration & defence	15.2%
Education	27.6%
Health & social work	27.9%
Other community social & personal	15.1%
Private households with employed persons	15.9%
Extra-territorial organisations bodies	5.9%

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9. Appendices

Appendix A

Selection and aggregation of regions from GTAP

Oceania

- Australia
- New Zealand
- Rest of Oceania

China

- China
- Hong Kong

South East Asia

- Japan
- Korea
- Taiwan
- Rest of East Asia
- Indonesia
- Malaysia
- Philippines
- Singapore
- Thailand
- Viet Nam
- Cambodia
- Rest of Southeast Asia

South Asia

- Bangladesh
- India
- Sri Lanka
- Pakistan
- Rest of South Asia

Canada

- Canada

US

- United States of America

Rest of Americas

- Mexico
- Rest of North America
- Colombia
- Peru
- Venezuela
- Bolivia
- Ecuador
- Argentina

- Brazil
- Chile
- Uruguay
- Paraguay
- Rest of South America
- Nicaragua
- Central America
- Rest of Free Trade Area of the Americas
- Rest of the Caribbean

European Union

- Austria
- Denmark
- Finland
- Greece
- Ireland
- Portugal
- Spain
- Sweden
- Rest of EFTA
- Bulgaria
- Cyprus
- Czech Republic
- Hungary
- Malta
- Poland
- Romania
- Slovakia
- Slovenia
- Estonia
- Latvia
- Lithuania

Benelux

- Belgium
- Luxembourg
- Netherlands

France

- France

Germany

- Germany

UK

- United Kingdom

Italy

- Italy

Rest of Europe

- Switzerland
- Rest of Europe
- Albania
- Croatia
- Russian Federation
- Kazakhstan

- Kyrgyzstan
- Rest of Former Soviet Union
- Turkey

West Asia

- Iran, Islamic Republic of
- Rest of Middle East

Africa

- Morocco
- Tunisia
- Egypt
- Rest of North Africa
- Botswana
- South Africa
- Rest of South African Customs Union
- Malawi
- Mozambique
- Tanzania
- Zambia
- Zimbabwe
- Mauritius
- Rest of Southern African Development Community
- Madagascar
- Uganda
- Nigeria
- Senegal
- Rest of Sub-Saharan Africa

10. Appendix B

Selection and aggregation of sectors from GTAP

Ground Produce

- Paddy rice
- Wheat
- Cereal grains nec
- Vegetables fruit nuts
- Oil seeds
- Sugar cane sugar beet
- Plant-based fibers
- Crops nec
- Forestry

Livestock and Animal Products

- Cattle sheep goats horses
- Animal products nec
- Meat: cattle sheep goats horse
- Meat products nec

Dairy products

- Raw milk
- Dairy products

Other Animal Products

- Wool silk-worm cocoons
- Fishing

Minerals

- Coal
- Oil
- Gas
- Minerals nec

Other Food

- Vegetable oils and fats
- Processed rice
- Sugar
- Food products nec

Beverages and Tobacco Products

- Beverages and tobacco products

Manufacture

- Textiles
- Wearing apparel
- Wood products
- Paper products publishing
- Metal products
- Manufactures nec

Luxury Items (Non-Essentials)

- Leather products
- Motor vehicles and parts
- Electronic equipment

Base Industries

- Petroleum coal products
- Chemical rubber plastic prods
- Mineral products nec
- Ferrous metals
- Metals nec

Machinery

- Transport equipment nec
- Machinery and equipment nec

Utilities

- Electricity
- Gas manufacture distribution
- Water

Construction

- Construction

Trade

- Trade

Air Transport

- Air transport

Communication

- Communication

Other Transport

- Sea transport
- Transport nec

Health

- Public Administration, Defence, Health Education

Other Services

- Financial services nec
- Business services nec
- Recreation and other services
- Dwellings

Insurance

- Insurance