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THE POSSIBLE MACROECONOMIC IMPACT ON THE UK OF AN INFLUENZA PANDEMIC

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The possible macroeconomic impact on the UK of an influenza pandemic

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Abstract

Little is known about the possible impact of an influenza pandemic on a nation's economy. We applied the UK macroeconomic model 'COMPACT' to epidemiological data on previous UK influenza pandemics, and extrapolated a sensitivity analysis to cover more extreme disease scenarios. Analysis suggests that the economic impact of a repeat of the 1957 or 1968 pandemics, allowing for school closures, would be short-lived, constituting a loss of 3.35% and 0.58% of GDP in the first pandemic quarter and year respectively. A more severe scenario (with more than 1% of the population dying) could yield impacts of 21% and 4.5% respectively. The economic shockwave would be gravest when absenteeism (through school closures) increases beyond a few weeks, creating policy repercussions for influenza pandemic planning as the most severe economic impact is due to policies to contain the pandemic rather than the pandemic itself.

Accounting for changes in consumption patterns made in an attempt to avoid infection worsens the potential impact. Our mild disease scenario then shows first quarter/first year reductions in GDP of 9.5%/2.5%, compared to our severe scenario reductions of 29.5%/6%. These results clearly indicate the significance of behavioural change over disease parameters.

1. Introduction

Infectious disease outbreaks, such as Variant Creutzfeldt-Jakob disease, Foot and Mouth disease and Severe Acute Respirator Syndrome (SARS), quickly capture professional and popular attention (Blanke, Sinclair et al. 2001; Garner, Fisher et al. 2002; Thompson, Muriel et al. 2002; Smith 2006). More recently, bird flu (H5N1) has prompted renewed concerns about an influenza pandemic (Cooper and Coxe 2005). The focus of this attention tends to be on the health impact of such outbreaks, particularly mortality (Bartlett and Hayden 2005). Although there is awareness that the economic impact may potentially be large, the details of this are unclear. For instance, the economic impact of the SARS outbreak of 2003 was far greater in sectors other than healthcare (Keogh-Brown and Smith 2008); the bulk of the estimated US$30bn to US$100bn falling on the tourism and travel sectors (Fan 2003; Lee and McKibbin 2003; Smith and Sommers 2003; Knapp, Rossi et al. 2004). Overall, there is little empirical work on the likely impact of an influenza pandemic on a nation’s economy, how this might vary with different potential epidemiological features, or what the significant variables are that affect the impact.

This paper seeks to address these issues through the application of an established macroeconomic model of the UK economy, using epidemiological data from past influenza pandemics, in order to estimate the possible economic impact on the UK economy if such a pandemic were to occur today. Treating the mild disease scenario (based on the latter two pandemics of the 20^{th} century) as a base case, we then construct further disease scenarios by increasing the severity of the disease parameters to investigate what the economic effect of a more severe influenza pandemic might be.

2. Methods

2.1. COMPACT Model

COMPACT is a quarterly macroeconomic model of the UK, developed with support from the UK's Economic and Social Research Council. Its structure reflects current macroeconomic theory (such as a consumption function derived explicitly from intertemporal optimisation), and most of its parameters are econometrically estimated rather than calibrated. It has been used to address a number of macroeconomic issues, such as the impact of fiscal policy on the exchange rate (Wren-Lewis, Darby et al. 1996). The model uses aggregate variables and is therefore ideally suited to modelling an economic shock based on changes to the entire working population, such as those produced by pandemic influenza. A complete description of the model is available elsewhere (Darby, Ireland et al. 1999).

COMPACT has two specific advantages for our purposes. First, it is a structural econometric model, making the identification and application of specific shocks much more tractable than in a model based on a vector autoregressive (VAR) approach. Most policy making institutions use structural models for their core modelling purposes (see (Holder 2004) for example). (For a discussion of these difficulties, and a novel attempt to apply structural shocks to a VAR model of the UK, see (Jacobs and Wallis 2005), who apply their technique to the model of (Garratt, Lee et al. 2003), and compare their results to COMPACT.) Second, it is based on recent, 'microfounded' macroeconomic theory, and therefore shares many of the desirable characteristics of Computable General Equilibrium models (Smith, Yago et al. 2005). For example, consumption decisions derived from intertemporal optimisation mean that most consumers are likely to smooth the impact of any transitory loss in income that might result from a short-lived pandemic; although COMPACT does allow for an estimated proportion of consumers (around 15%) where credit constraints may prevent such smoothing. In addition, the model includes a labour market where the impact of changes in the working population on wages of the type identified by (Garrett 2008) will be present. Finally, COMPACT is estimated and solved under the assumption that expectations are rational, which reduces the impact of the 'Lucas critique' (Lucas 1976) on its results.

2.2. Influenza Pandemic Scenarios

There were three influenza pandemics of the 20th century: 1918, 1957 and 1968/69. Each was characterised by the rapid global spread of influenza. In the UK (and many other countries), there were three distinct waves of the 1918 pandemic, each lasting

10-15 weeks (Ministry of Health 1920), with the largest occurring in the autumn of 1918. The 1957 pandemic occurred in the autumn of that year and comprised a single wave of about 15 weeks (Ministry Of Health 1960). The 1968/69 pandemic affected the UK somewhat late in the normal influenza season resulting in a small first wave in March 1969, and a main wave in midwinter of 1969/70 (Cooper, Pitman et al. 2006).

Clinical Attack Rates (CAR), representing the proportion of the population experiencing influenza like symptoms, during the 1918 pandemic were published by the Ministry of Health. When combined with data from block census enumerations made in a number of English cities a cumulative attack rate of 25% is indicated. Higher clinical attack rates were recorded for the 1957 (e.g. >30% (Woodall, Rowse et al. 1957)) and 1968/69 (>45%(Davis, Caldwell et al. 1970)) pandemics. In these latter two pandemics the clinical attack rates appear to have been highest in children, whereas the highest recorded incidence in the 1918 pandemic was in young adults (Ministry of Health 1920).

The Case Fatality Rate (CFR) of the disease gives the proportion of infected individuals who die from influenza. Although the morbidity patterns appeared broadly similar for the three pandemics, there were dramatic differences in the mortality patterns. By fitting a low-frequency sine-wave (Serfling 1963) to the age-specific weekly mortality data around the time of the pandemics it is possible to estimate the excess deaths by age associated with the new strains of influenza.

Such analyses suggest that the pandemic of 1918 resulted in about 201,000 excess deaths in England and Wales (out of a population of about 40 million), whereas the 1957 and 1968/69 pandemics ‘only’ resulted in about 18,000 and 46,000 deaths respectively (Edmunds, Siddiqui et al. 2007). In addition, these latter two epidemics largely resulted in deaths in the elderly (in 1969 an estimated 86% of deaths occurred in those over 65 years of age), whereas in 1918 deaths were more evenly spread across all age groups (indeed the death rates were highest in those aged 25-35 years of age) (Edmunds, Siddiqui et al. 2007).

Changes in societal behaviour in the modern world, together with changes in public health policy mean that it is not possible to accurately estimate the economic impact of a recurrence of the 1918 pandemic today. However, by using the more recent pandemics as a base case for disease scenarios and extrapolating beyond the severity of more serious pandemics, such as 1918, it is possible to generate some useful hypotheses and stimulate thinking on the potential economic impact of infectious disease outbreaks (Beutels, Edmunds et al. 2008). Whilst past pandemics cannot be used as a definitive guide in predicting the future, historical data provide a useful first attempt to illustrate the potential severity of an otherwise unpredictable disease.

Thus, for the purposes of this study, the base-case assumes a CAR of 35% as was the case for the 1957 and 1968 influenza pandemics. The epidemic is assumed to last one quarter, which was also true of the other 20th century influenza pandemics, and also of SARS, and since COMPACT is a quarterly model this is the most sensible timescale to use. The duration of illness for future strains of influenza is unknown, however it is reasonable to assume that the illness duration of pandemic influenza will be at least as long as for seasonal influenza (which is five days (Postma, Jansema et al. 2005)) and longer for more severe pandemics. Those affected are therefore assumed to take an average of five days off work. To allow for increased severity, we also permit a value of 50% for the CAR for some scenarios, which would result in a further increase in deaths (as the proportion who die is simply the CAR*CFR). This upper bound on CAR is based on data from (Davis, Caldwell et al. 1970). The most severe scenarios have high CAR and CFR and are assumed on average to result in seven days off work per infected individual.

Table 1 summarises the epidemiological scenarios modelled using scenarios which vary the disease parameters. Table 2 gives the numbers of deaths by age that would be expected based on past influenza pandemics using the current population structure of the UK[1].

Tables 1 and 2 about here

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[1] Unpublished analysis by the Health Protection Agency

2.3. The ‘Shock’ – impact on the working population

The shock to the working population is expressed as deaths, direct absenteeism (caused by infection) and indirect absenteeism (caused by school closure and ‘prophylactic’ avoidance of work).

2.3.1. Deaths

Deaths apply a permanent shock to the working population and, as presented in Table 1, are estimated as the product of the CAR and the CFR for the working-age population. The CFR for the mild (base-case) scenario is calculated from the average of age-specific estimates for 1957 and 1969 (0.04%,(Edmunds, Siddiqui et al. 2007)). For the more severe scenario, we use a 2.5% CFR (similar to that observed in 1918).

2.3.2. Direct Absenteeism

The duration of illness for influenza is quite short and people feel unwell for a short while afterwards (Postma, Jansema et al. 2005). The CAR of 35% combined with the assumed duration of absence (Table 1) means that, for the quarter affected by the pandemic, 3% (five days) or 4% (seven days) of working days will be lost due to direct absenteeism in the base and severe scenarios respectively.

2.3.3. Indirect Absenteeism

During an outbreak of pandemic influenza it is probable that schools will be closed for a few weeks to reduce disease spread, but since the duration of this closure is unknown, we assume three scenarios. The first involves no closure of schools during the pandemic, the second involves closing schools for four weeks at the height of the pandemic and the third involves closure for the entire pandemic (13 weeks). Analysis of the Labour Force Survey (2005) suggests that there are a total of 25,245,000 individuals aged 16-64 who are in paid employment. Of these 3,900,000 are women who are either the head of the household or the spouse of, or cohabiting with, the head of the household and have dependent children in the household <16 years of age. That is, 15.5% of the workforce comprises women who are probably responsible for dependent children (Sadique, Adams et al. 2008). Assuming school closure will last four weeks, an average of 4.8%[2] of working days will be lost in the quarter of the pandemic due to school closure. In the event of schools closing for the duration of the pandemic this figure would increase to 15.5[3]%.

2.3.4. Prophylactic Absenteeism

A further possibility in the event of an influenza pandemic is that of prophylactic absenteeism where healthy workers remove themselves from their workplace in an attempt to avoid infection. Such absenteeism is limited in its duration since unjustified absence will not be tolerated by most employers and therefore prophylactic absentees would be forced to take annual leave (as longer term sick-leave usually requires GP authorisation and these individuals are, by definition, not

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[2] Since four weeks of school closure results in absence of 15.5% of the workforce for 30.1% of the quarter: 0.301*15.5 = 4.8

[3] Since closing schools for the duration of the pandemic results in absenteeism by 15.5% of the workforce for the entire quarter.

sick). It is therefore reasonable to assume that such absenteeism is likely to last four weeks or less.

Prophylactic absenteeism in the event of a major pandemic was surveyed in (Sadique, Edmunds et al. 2007). The results of this survey state that 34% of workers would take prophylactic absenteeism in the event of an influenza pandemic, of which 3.75% were women who had children at school and would therefore overlap with the school closure absenteeism. However, the remaining 30% represent the additional shock due to prophylactic absenteeism[4]. It should be highlighted that there is some uncertainty as to whether individuals who state an intention to take prophylactic absenteeism would, in reality, carry out this intention, so this shock could be seen as a worst case scenario.

2.3.5. Mitigating Factors

In reality the impact on production is likely to be less than the shock induced by summing our estimates for direct and indirect absenteeism. Substitution among the workforce, where those who are not ill work additional hours, will reduce the impact of absenteeism, though at some (friction) cost to the firm (Brouwer and Koopmanschap 2005). Equally, firms or plants in parts of the UK which are less affected at the time of the pandemic will be able to make up for the production lost

[4] It is interesting also to note that, in the absence of this survey data and applying the assumption made for the whole workforce to the prophylactic absentees, 15.5% of the prophylactic absentees would be assumed to overlap with the school closure individuals, which yields a 29% prophylactic absenteeism shock which is very similar to the survey results.

elsewhere, although again at some cost to particular firms. Another possibility is that firms may reduce the impact of a lower labour input on production by substituting capital (in COMPACT the production technology has a vintage structure, so the scope for direct substitution is very small, but firms will be able to use their remaining workforce on the more productive machines). Finally, to the extent that firms hold stocks of final goods (either directly or through wholesalers and retailers), they may be able to make good some of the decline in stocks caused by lost production within the quarter of the pandemic. Whilst it is unlikely that completely making good lost stocks in this way would be optimal, the extent of this kind of substitution is likely to be greater in the base scenario compared to the more severe pandemic scenarios.

2.3.6. Consumption

Those who are ill are likely to consume fewer goods, such as food and alcohol, and services, such as travel (Sadique, Edmunds et al. 2007), but since these consumption effects are small and would only last for the duration of illness (5 or 7 days) they have not been modelled. However, there is some evidence to suggest that there will be declines in consumption by those who are seeking to avoid illness. However, since any such consumption shock is uncertain and would depend on unpredictable features of the pandemic we have considered just two scenarios with consumption impacts.

In the survey conducted in (Sadique, Edmunds et al. 2007) it was revealed that approximately 75% of people would avoid making purchases in the areas of leisure, transport, furnishings, clothes, cars and tourism during a pandemic. The losses to transport and leisure are not likely to be made up after the pandemic since those who avoid public transport, watching sports events etc are unlikely to increase consumption of those items after the pandemic. Moreover, consumption losses for furnishings, clothes, cars and tourism are more likely to be deferred during the pandemic rather than lost altogether. However, this precautionary behaviour is only applicable to those who are well and have not had flu, since those who have been infected cannot be re-infected and so are likely to behave normally. We therefore need to apply our consumption shocks to the proportion of those who do not get flu (1-CAR) and apply the consumption shock to those who are infected for the period before their infection. For convenience we assume that individuals are likely to be infected, on average, halfway through the pandemic and therefore apply the consumption shocks to the proportion of infected individuals (CAR) for half of the pandemic.

For utilisation in the COMPACT model we translate our consumption shocks into the following sectors:

- Food, Drink, Alcohol and Tobacco
- Clothing and footwear
- Housing, heating etc
- Goods and services (furniture etc)
- Transport

- Recreation and Culture
- Restaurants, Hotels and net tourism
- Miscellaneous (incl health, communication education)

We assume no significant effect on food or housing or to the miscellaneous category of items.   However, as some proportion of clothing and footwear can be bought alongside food etc, we assume a reduction of 50% in purchases in this category as a result of precautionary behaviour by the well, all of which is made up for in subsequent quarters. Goods and services, in contrast, usually involve specialised purchases and we therefore allow an 80% postponement in this category.

Approximately one third of transport involves car purchase, and the remainder is the use of services and car use. We assume complete postponement of car purchase. Some proportion of car and service use is likely to continue for travel to work and we therefore assume a reduction of 50%, none of which is recouped in subsequent quarters.

Just under 30% of recreation and culture involves the purchase of durables. A similar share is ‘games and pets’, and again sport and culture, with a residual 10% being newspapers and books. For simplicity, we assume the proportion due to sport and culture is permanently lost, and that the durables element is postponed, with no effect on the remainder.

Finally, we assume that all of spending on restaurants etc is lost.

The total bounce back[5] will be around 18% of consumption (i.e. just over 5% of a quarter's consumption is lost forever). We assume that a small part of this 18% bounce back takes place a year after the pandemic (e.g. annual holidays), and that the remainder occurs mainly in the subsequent quarter.

Translating these figures into aggregate shocks that are applied in the model we obtain the estimates tabulated in Table 3.

Note that the assertions in this section and the model assumptions we make on their basis, concur with consumption patterns observed during and shortly after the 2003 SARS outbreak in Beijing (Beutels, Jia et al. 2009).

[5] After a shock to the economy has passed, losses can be partially or completely recouped in subsequent periods, we refer to this as 'bounce back'

Table 3 about here

2.4. Other Influences

Investment involving construction is likely to be hit directly by the reduction in hours worked. Investment in plant and machinery may be postponed in the very short term as a result of the uncertainty generated by the pandemic. Overall investment within the model is assumed to fall by varying amounts proportional to the number of days lost in each scenario.

Government consumption may see small influences from the school closure and increased health costs, but these are likely to be small as the health service operates at close to maximum capacity, so the extra cases largely displace routine health care (Beutels, Edmunds et al. 2008). For simplicity we assume no net effect. There may be a long-term gross effect caused by those patients whose treatment was postponed. These costs may be captured by a detailed dynamic sectoral model, but our assumption is reasonable based on the non-sectoral nature of COMPACT and the timescale chosen.

As noted above, another impact of the pandemic will be to increase firms' costs. In most cases, any reduction in output caused by absenteeism will not be reflected in a fall in the wage bill, so costs per unit of output will rise. As noted earlier, the impact on production is likely to be less than the shock induced by summing our estimates for direct and indirect absenteeism, however the impact on firms costs is proportional to the number of days lost and additional overtime that must be paid for.

For simplicity we also assume that the overseas output and demand reductions occur at a similar time to the UK. A recent analysis (McKibbin and Sidorenko 2006) broadly suggests that the impact would be less in the USA, but larger in more open economies (note that we have made no allowance for any impact on the value of Sterling, as it seems reasonable that any concern about the currencies of 'exposed' countries would have little impact on Sterling *relative* to the currencies of our major competitors). It is therefore reasonable to suggest that the impact of the pandemic overseas would be similar to the UK impact.

3. Results

Results for all scenarios except those with the additional consumption shock are tabulated in Table 4. All results are calculated as deviations from a no-pandemic base.

TABLE 4 ABOUT HERE

3.1. Disease only scenarios

The most basic illness scenario (the first column of Table 4, labelled 'base case') has GDP falling by 1.24% in the quarter of the attack. In subsequent quarters GDP is slightly higher than it would have been without the attack, as firms replenish stocks and investment recovers slightly. For the year as a whole, GDP is reduced by just 0.22%. The fall in consumption is small, reflecting in part the impact of lower GDP on incomes, and the impact of higher costs on inflation is also modest.

When increasing the CFR from the base scenario, the impact on GDP is more than doubled to 3.22%. The GDP loss for the year is increased by a factor of almost five to 1.03%, although inflation is little changed. The higher mortality of this scenario has a clear impact on the outcome since this scenario differs from the base case only in the extent of fatalities that result from the pandemic. The loss of nearly 1% in the working population will have a permanent impact on the supply of output, and a permanent reduction in consumption. The impact on investment is more drawn out than in the base case, although after a few quarters we see some recovery as capital is substituted for labour. Although firms' costs increase more in this scenario, because more working days are lost, the impact on inflation is hardly changed, because more depressed demand lowers profit margins.

Increasing the CAR from the base scenario also has a significant effect, although here the pattern in the base is retained. The GDP and consumption impacts for the first quarter are 2.2% and 0.68% respectively, and the GDP impact for the year is a

0.26% loss. This raises the number of days lost through illness. (We would get similar effects if we kept the CAR rate at 35%, but instead raised the number of working days lost per ill person from five to seven.) Despite the larger fall in GDP, the impact of the pandemic in this scenario is short-lived, with some bounce-back in GDP in subsequent quarters (not shown). The value for year two (the first pandemic-free year after the shock) is small but positive showing that the effect has dissipated.

3.2. Base Case Disease With School Closure Scenarios

Introducing school closure (the most likely policy option) to the base scenario causes a further decline in labour supply. Here working days are lost as an indirect result of the illness, as parents (in the main) stay at home to look after their children. Four weeks of school closure (at the height of the pandemic) generate a GDP loss of 3.35% for the first quarter and 0.58% for the first year. This is higher for the first quarter than the increased CFR and CAR scenarios, but falls to a lower level than the former at one year. Inflation, however, is affected more strongly than the previous scenarios with a 0.46% impact at year one.

Closing schools for 13 weeks (the duration of the epidemic) increases the economic impact. First quarter GDP loss is up to 8.1%, first year GDP loss is 1.44% and consumption declines by 2.56%. Inflation also increases to 1.07% at one year.

3.3. Base Case Disease With Prophylactic Absenteeism Scenarios

The introduction of prophylactic absenteeism, as with school closures, imposes an additional fall in labour supply. For the scenario where some individuals take one week of absence the loss to GDP is 2.43% in the first quarter and 0.42% at year one; both of which are less serious impacts than in the previous non-base scenarios. The impact on consumption is 0.78%, and inflation rises to 0.34%. Overall the addition of one week of prophylactic absenteeism is similar to the impact of increasing the CAR to 50%.

For the scenario where individuals take four weeks of prophylactic absenteeism the impact on GDP is 6.01% in the first quarter and 1.06% at the first year. The impact at the first quarter is quite large but sharply declines to levels similar to those of increased CAR and CFR. Consumption falls by 1.92% at the first quarter, slightly less than in the increased CFR and 13 week school closure scenarios. Inflation rises by 0.82%.

Overall, whilst prophylactic absenteeism has a notable short-term effect, this impact declines considerably by the first year. However some inflation effects remain which will impact in the longer term.

3.4. Base Case Disease With School Closure and Prophylactic Absenteeism

In the scenarios where schools are closed *and* prophylactic absenteeism is taken, there is a large reduction in the labour supply and some fall in consumption. If 13 weeks of school closure is combined with one week of prophylactic absenteeism, the first quarter impacts on GDP and consumption are 9.14% and 2.89% respectively. However, by the first year, the GDP loss has declined to 1.64% whilst inflation suffers, rising by 1.19%. This scenario represents the most serious impact so far and includes a longer-term effect on inflation.

In the more severe case where schools close throughout the pandemic and prophylactic absenteeism lasts for four weeks the impacts are larger still: losses of 12.27% to GDP and 3.84% to consumption in the first quarter, and at one year the impact on GDP remains at 2.23% loss. Inflation also increases by 1.54%.

3.5. School Closure Scenarios

Under the assumption that schools will most likely be closed only for four weeks at the height of a pandemic, we consider scenarios based around that assumption. Combining four weeks of school closure with an increased CFR combines a larger number of deaths with the decreased labour supply resulting from school closure. This generates a loss of 5.83% to GDP in the first quarter and 1.47% at the first year. Consumption also falls by 3.4% in the first quarter and inflation rises by 0.49%. The short-term effect of this scenario is slightly worse than that caused by increasing the CFR alone, but is not very different in the long-term.

Similarly, an increased CAR combined with school closure results in a short-term impact that is slightly worse than the scenario with an increased CFR alone, with first quarter impacts on GDP and consumption 4.8% and 1.47% respectively. After one year these impacts are 0.81% to GDP and 0.57% to inflation.

We also considered (not shown) combining four weeks of school closure with one and four weeks of prophylactic absenteeism. The impacts of these scenarios are similar to, though less serious than, the scenarios with 13 weeks of school closure combined with prophylactic absenteeism.

3.6. Severe Disease Scenarios

The severe disease scenarios represent increased CFR and CAR from the base case. We also consider the impact of school closure and prophylactic absenteeism in combination.

The estimated impact of the severe disease by itself (without school closure or prophylactic absenteeism) is a loss to GDP of 5.49% for the first quarter and 1.55% for the first year. Consumption in the first quarter falls by 3.16% and inflation rises by 0.39% for the first year. Although this scenario concerns disease only, the fall in consumption is greater than most of the previously considered scenarios because of the greater number of sicknesses and deaths. The GDP impact is similar to, though slightly more severe than, the base case disease scenario combined with four weeks of prophylactic absenteeism. The inflation impact is twice that of the base case disease scenario.

Introducing a four-week school closure policy in addition yields an 8.51% loss to GDP in the first quarter and 2.06% loss at the first year. Consumption falls by 4.03% in the first quarter and inflation rises by 0.68%. This is the highest impact considered so far, with the exception of those with 13-week school closures.

Combining 13 weeks of school closure with the severe disease scenario yields a fairly catastrophic first quarter GDP loss of 15.14%. However, by the first year, this loss averages out to 3.24% and inflation rises by 1.22%. During the first quarter consumption falls by 5.9%.

One week's prophylactic absenteeism combined with severe disease yields GDP loss impacts of 7.17% and 1.84% at the first quarter and first year respectively. Consumption falls by 3.65% in the first quarter and inflation rises by 0.56% in the first year. If the prophylactic absenteeism is increased to four weeks, the GDP losses for the first quarter and year rise to 12.33% and 2.75% respectively, consumption falls by 5.11% and inflation rises to 1%.

Combining severe disease with a full quarter's school closure and one week of prophylactic absenteeism yields GDP losses of 9.96% at the first quarter and 2.31% at the first year. Consumption falls by 4.44% and inflation rises by 0.8%.

The most extreme scenario combines severe disease with one quarter of school closure and four weeks of prophylactic absenteeism. This yields GDP impacts for the first quarter and first year of 21.25% and 4.45% respectively. Consumption falls by 7.61% and inflation rises by 1.64%. This impact on GDP in the quarter of the pandemic is unprecedented. There is now significant persistence in both investment and consumption changes in subsequent quarters, in part because of the large increase in interest rates that would result in response to a rise of 1.6% in inflation. For the year as a whole, GDP is nearly 5% lower, a decline which again is unprecedented.

3.7. Precautionary Consumption Scenarios

Applying the precautionary consumption shocks mentioned earlier yields the results given in Table 5. Introducing a consumption shock to the base disease scenario increases the GDP impact in the first quarter from 1.24% to 9.52% - more than seven times larger. For the most severe scenario, first quarter GDP impact increases from 21.25% to 29.45%. The first year GDP impact for the base scenario is 2.52% - more than ten times the original value and for the severe scenario it is 6.05% - an increase of nearly 2%. Not surprisingly the consumption impacts are large. For the base scenario the consumption impact is multiplied by a factor greater than 50 yielding 24.92%, for the severe scenario the consumption effect is more than three times larger at 29.22%. The inflation impact for the base scenario is smaller than the original, at 0.12%, as is the severe scenario inflation effect, at 1.09%. This suggests a smaller long-term impact, but very large losses in the short term if our estimates of consumption decline are realised. The rise in inflation may seem surprising since the negative demand shock is larger than the negative supply shock. However, whilst unemployment rises, and wage inflation falls a little as a result, this is more than counteracted by a sharp rise in costs, as firms retain labour (knowing the output reduction is temporary) well in excess of that required to produce the lower level of output. A small part of this increase in costs is passed on, but it is enough to raise inflation (although by an amount that is small relative to GDP movements).

TABLE 5 ABOUT HERE

Not only is the impact of the pandemic much greater with this scale of precautionary consumption losses, but its economic character also changes. In the simulations shown in Table 4, the economy essentially suffers a temporary supply shock, which reduces output but also raises costs. In the two simulations in Table 5, we add an additional, and much larger, demand shock, as consumers reduce or postpone consumption. This negative demand shock adds to the decline in GDP, but it does not raise costs, and so the impact on inflation is mitigated.

3.8. Comparison With Existing Studies

There is little literature providing specific cost estimates of pandemic influenza. This is partly due to the scarcity of economic data from previous pandemics of 1918, 1957 and 1968-9. However, it is interesting to compare the results presented here with papers that broadly concern the long-term economic impact of influenza.

In (Almond 2006) the author attempts to establish the economic impact of the 1918-19 influenza pandemic on individuals who were *in utero* during the pandemic. Their results suggest that affected individuals were up to 15% less likely to graduate from high-school, wages of men were 5–9% percent lower, socioeconomic status was substantially reduced and the likelihood of being poor rose as much as 15%. Clearly there are issues with establishing such a causal relationship. Nonetheless, although these impacts may be significant for the *individuals* affected, these accrue long after the time of the pandemic, and the proportion of the working population thus affected remains very small. Therefore, these results have little relevance to our analysis.

Garrett (2008) seeks to combine the economic impact of the 1918-19 influenza pandemic with the mortality effects of WWI. His conclusion is that the reduction in manufacturing labour supply resulted in a 1.93% increase in real manufacturing wage growth. Again, this study does not provide an illustration of the overall macroeconomic impact of the pandemic and thus is not comparable to our analysis.

Brainerd and Siegler (2003) also consider the economic effect of the 1918-19 influenza pandemic, concluding that there is a significant positive correlation between the prime-age mortality of the influenza pandemic and business failure rates. They also state that the “influenza pandemic was likely to have been a contributing factor to the immediate post- WWI recessions” and that the total mortality rate from influenza and pneumonia in 1918 and 1919 is significantly and positively correlated to the growth in income per capita from 1919-21 to 1930 across US states. This is the most comparable analysis to ours, although whilst it highlights the long-term impact on GDP per capita, it does not capture the short term effects that we estimate with the COMPACT model.

In James and Sargent (2006), the authors estimate the cost of past influenza pandemics and the more recent SARS outbreak to various countries including Canada and the US. Rather than using economic modelling, the authors estimate the impact on various sectors and indicators of the economy. The authors conclude the paper with a section estimating the cost of a future pandemic. They do not use a structural economic model, but rather estimate individual morbidity, mortality and absenteeism impacts. For example, they use labour force impacts, a production function and elasticity parameters to calculate disease effect before adding their assumptions. Two disease scenarios are used, one based on the 1918 pandemic with 25% CAR, causing seven days of absence from work for infected individuals and a mortality rate of 0.43%, the other scenario, based on 1957, uses a 35% CAR, causes five days of absence from work for infected individuals and has a mortality rate of 0.04%. Mortality effects on GDP are estimated by applying the respective age-specific mortality impacts to the current structure of the Canadian labour force yielding an aggregate hours worked impact of –0.38 per cent in the 1918 scenario and a near zero impact in the 1957 scenario. GDP mortality impacts are obtained from an aggregate Cobb-Douglas production with an output-hours elasticity of 0.6 resulting in –0.23 per cent GDP impact in the 1918 scenario.

Morbidity effects on GDP are estimated by applying the respective age-specific morbidity impacts to the current structure of the Canadian labour force and from assumptions regarding the impact of absenteeism on output yielding a morbidity estimate on GDP of –0.28 per cent. The authors also estimate the absenteeism of those caring for the sick on hours worked as –0.05 per cent in the 1918 scenario and –0.06 per cent in the 1957 scenario, equivalent to GDP impacts of –0.03 per cent given a high output elasticity of .6 and –0.01 per cent given a low elasticity of 0.2. James and Sargent also use the British Columbia teachers strike in October 2003 to estimate absenteeism from school closures but conclude no discernable effect on the working population. The authors also estimate peak all-cause industry specific illness rates for an individual city which are then used to estimate flu impacts. A model of prophylactic absenteeism is used which begins with an estimate of 35% absence, similar to our 34% assumption, but declines with time as more people become infected and then immune. The workplace avoidance across industries is calculated to be no higher than summer holiday peaks and would not be sufficient to cause breakdowns in goods transportation, etc. Although we do not estimate absenteeism due to caring for sick relatives, many of our disease and absenteeism estimates are similar. The overall GDP estimates are quoted as with/without work avoidance absenteeism as follows (without/with workplace avoidance absenteeism):

- High absenteeism impact on output with no demand reallocation -0.92/-1.1%
- High absenteeism impact on output with full demand reallocation -0.55/-0.73%
- Low absenteeism impact on output with no demand reallocation -0.7/-0.77%
- Low absenteeism impact on output with full demand reallocation -0.34/-0.4%

The smaller impacts match the base disease estimates from our model, but the larger absenteeism estimates are much smaller than the estimates produced by the COMPACT model with prophylactic absence and school closure absence. Part of the reason for this is explained by James and Sargent's assumption that school closure impacts would be very small, but the authors have not used a structural economic model and therefore have calculated the impact of several individual policies/behaviours on the economy rather than solving simultaneously for the various shocks, as in our COMPACT model application.

Jonung and Roeger (2006) use the QUEST model to consider the impact on the European economy of a mild and severe influenza pandemic in 2006 lasting one quarter. They assume a severe influenza scenario similar to the pandemic that occurred in 1918: their mild scenario uses a CAR of 25% (less than our assumed CAR) and a CFR of 1.14% (larger than our CFR). Their severe scenario uses CAR and CFR of 30% and 2.5%, which is very similar to our “increased CFR” scenario. As well as disease effects, the authors consider an 80% reduction in demand for tourism and entertainment sectors including restaurants, bars and cinemas, which is very similar to our assumed consumption shock. Without the demand effect, the authors estimate a first year impact on GDP of 1.1% (similar to our “increased CFR” estimate of 1.07%. The demand effect increases this impact to 1.6% which is smaller than our consumption impact. The authors state that their impact estimates would be larger if prophylactic absenteeism were considered, but do not attempt to quantify this.

In McKibbin and Sidorenko (2006), the authors present a multi-country model, G-Cubed, with sectoral breakdown to estimate the macroeconomic cost of influenza. The authors consider various shocks: like our COMPACT application they use morbidity and mortality labour force shocks based on 1918, 1957 and 1968-69 scenarios. They also estimate the sector specific shocks based on the share of various service sectors to GDP and make separate assumptions on those with high human contact and a risk premium for countries based on the quality of government response, a health policy index and an index of financial risks. Shocks to demand in response to changes in income and wealth are also applied, where spending is decreased, and the money saved for future expenditure. This is not dissimilar from our consumption shocks.   Overall, their UK impacts are estimated as mild (1968/69 like) -0.72%, moderate (1957-like) -2.38%, severe (1918-like) -5.83% and ultra (based on 1918 but with more severe elderly mortality) -11.11%. The mild impact is larger than our -0.22% base result, the moderate impact is larger than all of our first year disease scenarios. It is not until the introduction of school closure and prophylactic absence (which McKibben and Sidorenko do not model) that our COMPACT estimates approach the moderate G-cubed estimates. Even our most severe disease scenario with quarter school closure and prophylactic absence does not reach the severe or ultra scenarios. Our estimate does not include the sectoral impacts, but assumes school closure.

Overall, our study presents a model application that is not mirrored elsewhere. Table 6 outlines the GDP impacts from other studies that might be compared witho the results presented in this paper. The use of a structural model with scenarios representing disease together with prophylactic absence and school closure shocks is a useful contribution to the existing literature and whilst the COMPACT model does not study the sectoral impact, and the policy/behavioural shocks may not be fully realised in practice, it provides a helpful overall estimate of the potential impact on the UK economy.

TABLE 6 ABOUT HERE

4. Discussion

If the pandemic does not modify consumption patterns of uninfected people, our base case (mild) pandemic scenario predicts GDP to fall by around 1.25% during the quarter of the pandemic. There is no significant impact in the quarter after the attack, and subsequently there is a small rebound in output. For the year as a whole, output is estimated to fall by 0.22%. This result fits well with the figures for annual GDP for the late 1950s and 1960s (corresponding to the base pandemic scenario) which are plotted in Figure 1 and Figure 2. These figures show no appreciable loss that might be attributed to the pandemic.

Figures 1 and 2 about here

A feature of the simulations without any precautionary cuts in consumption is that the fall in consumption is relatively small, particularly when the number of deaths is also small. This reflects the important role of 'consumption smoothing' in this model: most consumers are able to cushion the impact of lower incomes in a single quarter due to the pandemic by borrowing or running down their savings. However, there is still some fall in consumption for two reasons. First, as we noted earlier, COMPACT assumes that a proportion of consumers are credit constrained, and so will not be able to borrow to cushion consumption. Second, higher interest rates designed to combat inflation lead consumers who are not credit constrained to shift some of their spending into the future, as the rewards from saving have increased.

Would our results be very different if we assumed more consumers were credit constrained? Some experiments suggest not, for the following reason. While raising the number of credit constrained consumers would mean more had to cut consumption when their income fell, there would be correspondingly fewer consumers who would be reducing consumption because interest rates were higher, and in COMPACT these two effects largely offset each other.

An important caveat, however, is that we assume a ‘standard’ response of the Bank of England to a rise in inflation, so that interest rates rise in an attempt to mitigate the impact of cost increases on inflation. In the circumstances of a pandemic it is possible that the Bank might well decide to ignore this inflation increase, and as a result the indirect declines in consumption, both immediately and in subsequent quarters, would be reduced. Investment begins to recover in the quarters after the pandemic (which reflects ‘Tobin’s q’ theory of investment embodied in COMPACT). We assumed that there would be no net effect on government consumption as a result of the attack. This assumption is not critical. Even if we assumed that government consumption rose by 0.5% in the quarter of the attack, this would only add about 0.1% to GDP.

Whilst an increase in the CFR and CAR has a notable effect on GDP and consumption in the short-term, the long-term impacts are less significant, reflecting the contrast between the effect on health and that of the economy. However, if school closures were to last for the duration of the pandemic, inflation increases and long-term economic effects persist well beyond the end of the pandemic.

Clearly, these results are indicative rather than definitive. However, the analysis does suggest some general conclusions. First, the macroeconomic impact of a ‘mild’ outbreak is mainly felt through morbidity rather than mortality whilst, for the severe attack, the overall impact on annual GDP (a fall of around 1.55%) is perhaps trivial compared to the mortality involved (300,000 deaths). Second, whilst absenteeism is limited to the peak of the pandemic, the macroeconomic impact is likely to be concentrated in the period of the attack and once the attack is over, the economy returns to approximately where it would have been if there had been no attack. Similar behaviour to this was observed for many sectors in the SARS outbreak of 2003 (Keogh-Brown and Smith 2008).

Whilst the disease impacts do not present a major cause of economic concern, the real economic danger occurs when policy and behavioural change in response to the pandemic occur. When absenteeism (through school closures) increases beyond a few weeks it causes inflation to rise during the pandemic, interest rates also rise, reducing consumption and investment, and these economic effects no longer rapidly disperse once the pandemic is over. Thus, the important consideration is the policy adopted in response to the pandemic at least as much, if not more, than the pandemic itself.

Precautionary changes in consumption patterns also present some alarming economic prospects. Whilst the inflation effects are smaller to those of the high absenteeism scenarios, the GDP impacts are very large and both absenteeism and precautionary consumption shocks suggest historically unprecedented economic losses. Whilst the size of these losses might promote some scepticism with regard to their validity, it may also be worth considering the differences between today's economic world and that of 1918. Today workers have much more scope to take days off work, and a much greater proportion of consumption is of items that have a high 'social' aspect and can therefore be easily postponed or abandoned. This means that modern economies may be much more vulnerable to sharp, but temporary, declines in activity than they were a century ago.

In order to illustrate these GDP impacts, it is helpful to bear in mind that in 2006 UK GDP per capita was £21,200. Therefore, the economic impacts for the base scenario, high CFR, high CAR, and severe scenarios equate to per capita effects of £47, £218, £226, and £329 respectively for the first year. To illustrate the impact of prophylactic absenteeism for one week and four weeks, the base cost to GDP per capita of £47 would increase to £89 and £225 respectively, whilst for four week school closures the cost would be £123. Finally the cost to GDP per capita in the severe disease scenario would be £437, and if a quarter of school closure were combined with four weeks of prophylactic absenteeism were also included the cost would be £934. Impacts for the consumption shocks in terms of GDP per capita would be £534 for the base scenario and £1283 for the severe.

In an attempt to put these costs in context, it has been estimated that the discounted cost of a course of antivirals (including stockpiling over a 30 year period, and administration) is approximately £90 (Siddiqui and Edmunds 2008).

It is unknown whether the anticipated prophylactic absenteeism as recorded in (Sadique, Edmunds et al. 2007) will be realised, and the anticipated impact of school closures may be mitigated as working mothers may make alternative arrangements for care of their children, particularly if school closure is to last 13 weeks. However, the potential impact of these policies and practices is notable and may prove helpful in informing policy.

In terms of limitations and further research, the key assumption is that regarding the duration of absence from work. If an average of three weeks rather than one was assumed (CBO 2005), the macroeconomic numbers would be scaled up by a substantial amount; although not by as much as three because the duration of school closure would not rise threefold. The effect of an increase in absenteeism is illustrated in the longer school closure scenarios. Further, COMPACT does not permit a detailed sectoral analysis of the potential impacts of pandemic influenza. Further research into the detailed impacts on the UK and other economies using a more sensitive model would be beneficial (Smith et al, 2005; 2006) and is currently being undertaken by the authors.

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Table 1 Morbidity and mortality estimates

	Case Fatality Ratio % (Working Population)	Clinical Attack Rate % (Working Population)	Working Population Mortality rate %	Days Lost	School Closure (weeks)	Prophylactic Absenteeism (weeks)
Base	0.04	35	0.01	5	0	0
Increased CFR	2.5	35	0.88	5	0	0
Increased CAR	0.04	50	0.02	5	0	0
Base with 4 weeks SC	0.04	35	0.01	5	4	0
Base with Quarter SC	0.04	35	0.01	5	13	0
Base with Mild PA	0.04	35	0.01	5	0	1
Base with PA	0.04	35	0.01	5	0	4
Base with Quarter SC and mild PA	0.04	35	0.01	5	13	1
Base with Quarter SC and PA	0.04	35	0.01	5	13	4
School Closure with increased CFR	2.5	35	0.88	5	4	0
School Closure with increased CAR	0.04	50	0.02	5	4	0
School Closure with Mild PA	0.04	35	0.01	5	4	1
School Closure with PA	0.04	35	0.01	5	4	4
Severe Disease (no SC or PA)	2.5	50	1.25	7	0	0
Severe Disease with SC	2.5	50	1.25	7	4	0
Severe Disease with Quarter SC	2.5	50	1.25	7	13	0
Severe Disease with mild PA	2.5	50	1.25	7	0	1
Severe Disease with Severe PA	2.5	50	1.25	7	0	4
Severe Disease with Quarter SC and Severe PA	2.5	50	1.25	7	4	1
Severe Disease with Quarter SC and Severe PA	2.5	50	1.25	7	13	4

Table 2 Deaths by age group

Age (years)	Deaths in severe (1918-like) scenario	Deaths in 1957/69 (Base) scenario
<15	55,400	300
15-24	39,200	200
25-34	40,700	200
35-44	46,800	300
45-54	38,800	3,200
55-64	35,200	2,900
65-74	25,600	18,200
75+	23,400	16,600
Total	305,100	41,900

Table 3 Breakdown of consumption assumptions (2006 data)

Category	% share of average person	Permanent loss of precautionary agents as % of their total	Delay by precautionary agents as % of their total
Food, Drink, Alcohol and Tobacco	12.51	0	0
Clothing and footwear	5.81	0	2.91
Housing, heating etc	19.98	0	0
Goods and services (furniture etc)	5.7	0	4.56
Transport	14.64	4.83	4.98
Recreation and Culture	12.3	3.69	3.69
Restaurants, Hotels and net tourism	13.07	0	13.07
Misc (incl health, communication education)	15.99	0	0
Total	100	8.52	29.21

Table 4 Percentage impacts on GDP, consumption and inflation

	GDPQ1	Consumption Q1	GDP Y1	Inflation Y1
Base	-1.24	-0.4	-0.22	0.17
Increased CFR	-3.22	-2.62	-1.03	0.19
Increased CAR	-2.20	-0.68	-0.37	0.26
Base with 4 weeks SC	-3.35	-1.07	-0.58	0.46
Base with Quarter SC	-8.1	-2.56	-1.44	1.07
Base with Mild PA	-2.43	-0.78	-0.42	0.34
Base with PA	-6.01	-1.92	-1.06	0.82
Base with Quarter SC and mild PA	-9.14	-2.89	-1.64	1.19
Base with Quarter SC and PA	-12.27	-3.84	-2.23	1.54
School Closure with increased CFR	-5.83	-3.4	-1.47	0.49
School Closure with increased CAR	-4.8	-1.47	-0.81	0.57
School Closure with Mild PA	-4.41	-1.41	-0.77	0.61
School Closure with PA	-7.58	-2.41	-1.35	1.01
Severe Disease (no SC or PA)	-5.49	-3.16	-1.55	0.39
Severe Disease with SC	-8.51	-4.03	-2.06	0.68
Severe Disease with Quarter SC	-15.14	-5.9	-3.24	1.22
Severe Disease with mild PA	-7.17	-3.65	-1.84	0.56
Severe Disease with Severe PA	-12.33	-5.11	-2.75	1
Severe Disease with Quarter SC and Severe PA	-9.96	-4.44	-2.31	0.8
Severe Disease with Quarter SC and Severe PA	-21.25	-7.61	-4.45	1.64

Table 5 Percentage impacts of disease scenarios with consumption shock

	Base with Consumption Shock	Severe disease with Quarter SC and Severe PA and consumption shock
GDP		
Q1	-9.52	-29.45
Q2	0.95	1.78
Q3	-1.11	1.74
Y1	-2.52	-6.05
Y2	0.59	1.04
Consumption		
Q1	-24.92	-29.22
Q2	9.9	8.50
Q3	-0.44	-1.1
Y1	-3.95	-5.73
Y2	0.44	-1.00
Investment		
Q1	-0.95	-16.18
Q2	0.24	0.77
Q3	0.09	0.02
Y1	-0.12	-4.06
Y2	0.1	0.43
Inflation		
Q1	0.59	2.8
Q2	-0.24	0.4
Q3	0.09	0.62
Y1	0.12	1.09
Y2	0.05	-0.24

Table 6 Overview of relevant GDP estimates from other studies

Country/Region	Author	Negative % GDP impact range (min to max)
Canada	(James and Sargent 2006)	0.9 to 0.28 (illness) 0.34 to 0.92 (Total without workplace avoidance) 0.4 to 1.1 (Total with workplace avoidance)
EU-25	(Jonung and Roeger 2006)	1.1 to 1.6
UK	(McKibbin and Sidorenko 2006)	0.72 to 11.11
UK	**This Study**	**0.22 to 4.5 (without consumption impact)** **2.52 to 6.05 (with consumption impact)**

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