Effects on the U.S. of an H1N1 Epidemic: 
Analysis with a Quarterly CGE Model

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Effects on the U.S. of an H1N1 Epidemic: Analysis with a Quarterly CGE Model

Peter B. Dixon, Bumsoo Lee, Todd Muehlenbeck, Maureen T. Rimmer, Adam Rose, and George Verikios

Abstract

We simulate the effects of a hypothetical H1N1 epidemic in the U.S. using a quarterly CGE model. Quarterly periodicity allows us to capture the short-run nature of an epidemic. We find potentially severe economic effects in the peak quarter. Averaged over the epidemic year, the effects are considerably damped. Our results indicate that the macroeconomic consequences of an epidemic are more sensitive to demand-side effects, such as reductions in international tourism and leisure activities, than to supply-side effects, such as reductions in productivity. This suggests that demand stimulus policies might be an appropriate economic response to a serious epidemic.

KEYWORDS: influenza epidemic, quarterly CGE model

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1. INTRODUCTION

In mid-2009 it seemed likely that the U.S. would face an H1N1 influenza epidemic in the winter of 2009-10. Fears were held that the epidemic could be as serious as those of 1957 and 1968 which caused approximately 70,000 and 34,000 deaths respectively in the U.S., and possibly even as serious as the 1918 epidemic which killed 500,000 U.S. residents. Such epidemics are not only a medical crisis, but may have significant economic effects. This paper explores these potential economic effects. Fortunately, it now appears that H1N1 will not be as devastating in 2010 as was first feared. Nevertheless, investigation of the economic effects of a major epidemic is still of interest as an input to contingency planning.

In our investigation, we use a dynamic, computable general equilibrium (CGE) model of the U.S. This is not the first time that a CGE model has been applied in quantifying the potential effects of an epidemic. McKibbin and Sidorenko (2006) provide a survey of the relevant modeling literature and report simulation results from a global CGE model of the effects of pandemics of various degrees of severity. Unlike McKibbin and Sidorenko (McKS), we focus entirely on the U.S. This narrower focus allows for more detail in two dimensions: industries and periodicity. Whereas the McKS model distinguishes six sectors, the model used in this paper identifies 39 sectors, including Medical services and Inbound and Outbound tourism that are particularly relevant to the study of the economic effects of epidemics. With respect to periodicity, our model is quarterly, whereas the models of all other CGE contributors to this literature are annual. Quarterly periodicity is a major advantage in modeling epidemics which tend to have sharp effects over periods much shorter than a year.

The remainder of the paper is organized as follows: section 2 describes the USAGE model which we use in our simulations; section 3 describes the shocks that we apply; and section 4 sets out and explains the results. A summary of results together with concluding remarks are in section 5.

2. BACKGROUND ON THE USAGE MODEL

USAGE3 is a detailed, dynamic, CGE model of the U.S. It has been developed at the Centre of Policy Studies, Monash University, in collaboration with the U.S.

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1 This is also the focus of CBO (2006) which looks at the effects on the U.S. of two Avian influenza scenarios. While quantitative, the CBO report does not use a formal model.
2 Bloom et al. (2005) undertake a pandemic analysis with a quarterly model. However their model is macro econometric (no industry dimension) rather than CGE.
3 U.S. Applied General Equilibrium.
The theoretical structure of USAGE is similar to that of the MONASH model of Australia (Dixon and Rimmer, 2002). However, in both its theoretical and empirical detail, USAGE goes beyond MONASH. USAGE can be run with up to 500 industries, 700 occupations and 51 regions (50 States plus the District of Columbia). In the application reported in this paper we use a version of the model in which there are 39 industries.

USAGE includes three types of dynamic mechanisms: capital accumulation; liability accumulation; and lagged adjustment processes. Capital accumulation is specified separately for each industry. An industry’s capital stock at the start of period t+1 is its capital at the start of period t plus its investment during period t minus depreciation. Investment during period t is determined as an increasing function of the expected rate of return on the industry’s capital. Liability accumulation is specified for the public sector and for the foreign accounts. Public sector liability at the start of period t+1 is public sector liability at the start of period t plus the public sector deficit incurred during period t. Net foreign liabilities at the start of period t+1 are specified as net foreign liabilities at the start of period t plus the current account deficit in period t plus the effects of revaluations of assets and liabilities caused by changes in price levels and the exchange rate. Lagged adjustment processes are specified for the response of wage rates to gaps between the demand for and the supply of labor by occupation.

In a USAGE simulation of the effects of policy and other shocks, we need two runs of the model: a baseline or business-as-usual run and a policy run. The baseline is intended to be a plausible forecast while the policy run generates deviations away from the baseline caused by the shocks under consideration (e.g. an outbreak of H1N1 influenza). The baseline incorporates trends in industry technologies, household preferences and trade and demographic variables. These trends are estimated largely on the basis of results from historical runs in which USAGE is forced to track a piece of history. Most macro variables are exogenous in the baseline so that their paths can be set in accordance with forecasts made by expert macro forecasting groups such as the Congressional Budget Office. This requires endogenization of various macro propensities, e.g. the average propensity to consume. These propensities must be allowed to adjust in the baseline run to accommodate the exogenous paths for the macro variables.

The policy run in a USAGE study is normally conducted with a different closure (choice of exogenous variables) from that used in the baseline. In the policy run, macro variables must be endogenous: we want to know how they are affected by the policy shocks. Correspondingly, macro propensities are exogenized at the values they had in the baseline. More generally, all exogenous variables in the policy run have the values they had in the baseline, either

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4 Prominent applications of USAGE by the ITC include USITC (2004, 2007 and 2009).
endogenously or exogenously, with the exception of the variables of interest. Comparison of results from the policy and baseline runs then gives the effects of shocking the variables of interest away from their baseline values. For this paper, the baseline and policy runs differ in the values given to exogenous variables in the policy run representing an outbreak of H1N1 influenza. The differences between the baseline and the policy results are the effects of the outbreak.

In previous applications, the USAGE model produced annual results. For the current application, the model has been modified so that it produces quarterly results. This modification is important because it is likely that an epidemic will have sharp effects over a short period. An annual model tends to smooth out effects leading to potential underestimation of disruption. For example, if an epidemic caused an 80 per cent loss of inbound international tourism for a particular quarter, then the adjustment path of the tourism industry would be quite different from that in a situation in which international tourism declined by 20 per cent for a year. Similarly, a 4 per cent increase in a single quarter in demands for medical services caused by an H1N1 outbreak would place more stress on the medical system than a 1 per cent increase spread over a year.

3. USAGE simulations: setting the shocks

We consider a hypothetical H1N1 epidemic that causes 88.6 million people to be infected in the first two quarters of 2010. Of these, 59.8 million experience symptoms. This scenario is derived from agent-based modeling by Josh Epstein of Johns Hopkins University and includes not only these aggregate figures but also a breakdown by age group. Epstein’s scenario is similar to the two scenarios in CBO (2006) in which 75 and 90 million people are infected by Avian influenza.

Reed et al. (2009) gives detailed statistics on medical treatment, hospitalization and death in the U.S. from H1N1 over the four-month period April 2009 to July 2009. During this period about 3 million U.S. residents experienced symptomatic infection. Based on the experience reported by Reed et al., we estimate that if 59.8 million people were to become symptomatic then 29.9 million (half those experiencing symptoms) would seek medical attention. Of these, 269,000 would be hospitalized with 16,000 deaths.

An H1N1 epidemic that caused symptomatic infection for 59.8 million U.S. residents over a six month period would impart a number of shocks to the U.S. economy. The most important would be: a reduction in both inbound and outbound international tourism (which we will refer to as shock S1); a loss of labor input per employed worker (S2); an increase in medical expenditures (S3); and a reduction in expenditures on leisure activities involving public gatherings

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5 More detail on the material contained in this section can be found in Dixon et al. (2010).
It is impossible to be precise on the size of these shocks. However, we can hypothesize about magnitudes and use our economic model to work out which shocks are likely to be the most significant. For concreteness we make the following assumptions:

**S1)** Inbound and outbound tourism fall 34 and 17 per cent respectively below their baseline levels in 2010.Q1 and Q2 and then recover smoothly to their baseline levels over the next four quarters. In setting the shock for inbound tourism we considered the experiences with inbound tourism to Asia during the Asian SARS epidemic of 2003 and to Mexico during the H1N1 outbreak in Mexico in April to July 2009. These episodes suggest that regions suffering a widespread influenza infection can incur reductions in inbound tourism in the range 20 to 70 per cent during the peak infection period. For our hypothetical H1N1 epidemic, a disease with generally mild symptoms and low lethality, we adopt a number (34 per cent) towards the lower end of this range. One possibility for outbound tourism is a zero effect consistent with no U.S. residents being dissuaded from vacationing overseas. However, it is reasonable to suppose that some potential U.S. travelers would be dissuaded from international travel by fears of becoming symptomatic on vacation: they may already be infected but not yet symptomatic; they may contract influenza from a fellow passenger; or they may contract influenza on arrival at their destination as the epidemic spreads. While we would not expect the effect of a U.S.-centered epidemic on outbound tourism to match that on inbound tourism, we would expect a significant shrinkage in outbound tourism. For illustrative purposes we assume that the outbound effect is half that of the inbound effect. We also assume that U.S. residents who are dissuaded from international tourism save their tourism budget implying a reduction in the average propensity to consume by the household sector of 0.238 per cent.

**S2)** Labor input from employed workers falls 0.41 per cent below its baseline level in 2010.Q1 and Q2 and then recovers to its baseline level in 2010.Q3. In arriving at this shock, we assumed that during 2010.Q1 and Q2 there would be a loss of 74.0 million days work directly related to H1N1 through sickness of workers and absence from work due to taking care of sick children. With about 150 million workers in the U.S. contributing 120 days each in a six-month period, this loss of work days amounts to a 0.41 per cent loss of labor input \( 0.41 = 100 \times 74.0 / (150 \times 120) \). Table 1 shows our calculation of work days lost. The first column is derived from Epstein’s scenario. The factors in the second column show lost workdays per person in the first column. For working age people (18-64) these factors were suggested by Molinari et al. (2007) in their study of...
seasonal influenza. For children (0-17), we follow Molinari et al. in assuming that missed childcare and school days for symptomatic children conform to the same pattern as missed workdays for adults. Then based on data from the American Community Survey on the proportion of children in families with no non-working parent, we assume that each missed childcare/school-day results in 0.7 missed workdays for a caring parent if the child is at home and 0.35 missed workdays if the child is hospitalized. The final column in Table 1 is the product of the previous two columns. As well as a 0.41 per cent reduction in labor input per employed worker, shock (S2) introduces a permanent reduction in the supply of labor of 0.0053 per cent. This represents the effect on the workforce of H1N1-related deaths. The economic effect of this reduction in labor supply is negligible.

<table>
<thead>
<tr>
<th>Table 1. Calculation of lost workdays</th>
</tr>
</thead>
<tbody>
<tr>
<td>People aged 18-64 (millions)</td>
</tr>
<tr>
<td>----------------------------------</td>
</tr>
<tr>
<td>Symptoms, but no medical treatment</td>
</tr>
<tr>
<td>Medical treatment without hospitalization</td>
</tr>
<tr>
<td>Hospitalized</td>
</tr>
<tr>
<td>People aged 0-17 (millions)</td>
</tr>
<tr>
<td>Symptoms, but no medical treatment</td>
</tr>
<tr>
<td>Medical treatment without hospitalization</td>
</tr>
<tr>
<td>Hospitalized</td>
</tr>
<tr>
<td>Total workdays lost</td>
</tr>
</tbody>
</table>

(S3) Medical expenditures move 2.41 per cent above their baseline levels in 2010.Q1 and 2010.Q2 and then return to their baseline level in 2010.Q3. As shown in Table 2, we estimate for our H1N1 scenario that medical expenditures would be increased by $14.15 billion (2003$s) in the six-month epidemic period, which in current prices is 2.41 per cent of half a year’s medical expenditures. The cost-per-person figures in Table 2 are taken from Molinari et al. (2007).

(S4) Expenditures by households on leisure activities involving public gatherings move 10 per cent below their baseline levels in 2010.Q1 and 2010.Q2 and then return to their baseline level in 2010.Q3. Following CBO (2006) we assume that these expenditures represent 4 per cent of GDP and cover arts, entertainment, accommodation and food service. In setting the 10 per cent shock, we also followed CBO (2006) who, in their mild-Avian-influenza scenario, assumed a 20 per cent cut in these expenditures for a single quarter (10 per cent for two quarters). As in (S1) we assume that U.S. residents who refrain from expenditures because of H1N1 save their money, implying a further reduction in the average propensity to consume by the household sector of 0.549 per cent.

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6 Molinari et al.’s estimates take account of workforce participation rates.
7 About 8,000 deaths of people in the workforce out of a total workforce of 150 million.
4. RESULTS

This section reports USAGE results for the effects of the shocks described in section 3. We start with macro and industry effects of the four sets of shocks combined. Then we analyse the results for aggregate employment in more detail by describing the effects of each set of shocks individually.

Table 2. Calculation of medical expenditures ($2003)

<table>
<thead>
<tr>
<th>People (millions)</th>
<th>Cost per person ($)</th>
<th>Total cost ($billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms, but no medical treatment</td>
<td>29.907</td>
<td>3</td>
</tr>
<tr>
<td>Medical treatment without hospitalization</td>
<td>29.622</td>
<td>293</td>
</tr>
<tr>
<td>Hospitalized and survived</td>
<td>0.254</td>
<td>18,298</td>
</tr>
<tr>
<td>Hospitalized and died</td>
<td>0.016</td>
<td>46,120</td>
</tr>
<tr>
<td>Total</td>
<td>59.80</td>
<td>14.15</td>
</tr>
</tbody>
</table>

Employment and GDP

Effects of the shocks on aggregate employment and GDP are shown in Chart 1. The main effects occur in 2010.Q2 when employment and GDP fall by 2.1 and 2.6 per cent below baseline. The decline in GDP relative to employment mainly reflects the loss in labor input per employed worker imposed in (S2). On average through 2010, the epidemic reduces aggregate employment by 1.3 per cent and GDP by 1.6 per cent. Both aggregate employment and GDP are a little higher in 2011 with the epidemic than they would have been without it. Through 2011, Chart 1 shows average positive deviations for employment and GDP of 0.3 per cent and 0.2 per cent. As indicated in Chart 1, the epidemic-related reduction in employment in 2010 causes real wage rates to be lower than they otherwise would have been. This allows the U.S. to arrive in 2011 with enhanced international competitiveness (a lower real exchange rate) so that when tourism recovers and the other epidemic-related shocks disappear, employment and output move above their baseline values.

Investment and capital

Chart 2 shows that the hypothetical epidemic reduces investment: by 0.7 per cent in 2010.Q1; by 4.3 per cent in 2010.Q2; and by 4.9 per cent in 2010.Q3. In 2010.Q1, investment falls below the baseline because demand-contracting [(S1) and (S4)] and cost-increasing [(S2)] shocks reduce the rental value of capital. This damps expected rates of return and thereby reduces investment. It is also true that in 2010.Q1 the epidemic causes excess capacity to appear in some industries, particularly those related to tourism and construction. Excess capacity in 2010.Q1
has a strongly negative effect on investment in 2010.Q2. Weak investment in 2010.Q2 causes further excess capacity to appear, explaining weak investment in 2010.Q3. In 2010.Q3, much of the pick up in demand for capital associated with the recovery in the demand for leisure activities and the start of the recovery in tourism is satisfied by working down the excess capacity that appeared in 2010.Q1 and 2010.Q2. By 2010.Q4 investment starts to move back towards the baseline. This is because excess capacity in 2010.Q3 is declining as capital in existence adjusts down and capital in use adjusts up. By 2011.Q2, excess capacity is eliminated (that is, capacity utilization is at normal levels).

**Chart 1. Effects of the hypothetical epidemic on employment, GDP, real wages and real exchange rate (percentage deviations from baseline)**

The real exchange rate is measured by movements in the U.S. price level compared with the price level of trading partners expressed in a common currency. Negative movements indicate improvements in the international competitiveness of the U.S.
Chart 2. Effects of the hypothetical epidemic on aggregate investment and capital (percentage deviations from baseline)

Expenditure components of GDP

Chart 3 shows epidemic-induced movements in the real expenditure components of GDP. Exports decline sharply in 2010.Q1 reflecting the 34 per cent reduction in inbound tourism (S1). Although inbound tourism does not fully recover until 2011.Q2, aggregate exports move back close to their baseline path by 2010.Q3. The recovery of exports is assisted by real devaluation (Chart 1). Imports decline sharply in 2010.Q1 and 2010.Q2. This reflects the reduction in outbound tourism, real devaluation and the decline in GDP. Private consumption closely follows real GDP. Public consumption is treated exogenously and assumed not to be affected by the epidemic.

Industry outputs

USAGE results for the effects of the hypothetical epidemic on outputs of groups of selected industries are given in Charts 4 to 9. Chart 4 covers industries that are directly impacted by the epidemic. Output of Medical services is stimulated in the first half of 2010 by about 2 per cent through (S3). Inbound and Outbound tourism contract in the first half of 2010 by about 34 and 17 per cent through (S1). Miscellaneous services contracts by about 4 per cent through the shock applied in (S4) and through the general contraction in economic activity.
Chart 5 shows sharp short-run contractionary effects for industries supplying inputs to investment. In 2010.Q3, output of construction is about 5.3 per cent below its baseline and remains below baseline until 2011.Q2. Other investment-supplying industries benefit from their trade exposure. For example, the outputs of Machinery, Electrical machinery, Computers and Transport equipment are above their baselines by 2010.Q4, even though aggregate investment is still well below its baseline (Chart 2). This reflects a low real exchange rate (Chart 1) which facilitates exports of the products of these industries and inhibits imports.

Charts 6 and 7 show that import-competing industries are adversely affected in the short run by the hypothetical epidemic. This is mainly through the contraction of economic activity. By 2010.Q3, output of most of these industries is above baseline: real devaluation improves their competitive position against imports. Exceptions are Mining (mainly crude oil) and Petroleum products which do not return to baseline until 2011.Q1. Output of these products is related mainly to economic activity, with import shares in the domestic market responding only sluggishly to changes in the real exchange rate.

**Chart 3. Effects of the hypothetical epidemic on expenditure components of GDP (percentage deviations from baseline)**
Chart 4. Effects of the hypothetical epidemic on output of directly impacted industries (percentage deviations from baseline)

Chart 5. Effects of the hypothetical epidemic on output of investment-related industries (percentage deviations from baseline)
Chart 6. Effects of the hypothetical epidemic on output of highly protected import-competing industries (percentage deviations from baseline)

Chart 7. Effects of the hypothetical epidemic on output of other import-competing industries (percentage deviations from baseline)
Chart 8. Effects of the hypothetical epidemic on output of government-related service industries (percentage deviations from baseline)

Chart 9. Effects of the hypothetical epidemic on output of private-sector service industries (percentage deviations from baseline)
Charts 8 and 9 show results for service industries. With two exceptions, output of these industries dips below baseline in 2010.Q1 and Q2, recovers in the second half of 2010 and moves above baseline in 2011. The first exception is Government services. This industry shows zero output deviations because its sales are to government consumption which we assume is unaffected by the epidemic. The second exception is Ownership of dwellings, the output of which is shelter provide by the housing stock in use. Unlike other service industries, for Ownership of dwellings the macro recovery in the second half of 2010 and in 2011 is insufficient to move the output above baseline. The reason is that the epidemic-related investment slump in 2010 leaves the housing stock, and therefore the output of the Ownership industry, below baseline in 2011.

Relative importance of individual shocks for aggregate employment

Chart 10 indicates the relative importance of the different shocks in determining the overall employment effects. We introduce the shocks sequentially with the effect of each set of shocks being revealed by comparison of results in successive simulations. The S1 line shows the effects of the collapse of international tourism alone. The S12 line shows the effects of the tourism and labor-input shocks combined. The S123 line shows the effects of the tourism, labor-input and medical-expenditure shocks while the S1234 line shows the combined effects of all four sets of shocks. The order in which the shocks are introduced is arbitrary. We have experimented with different orderings and found that the ordering is not important in the calculation of the effects of each set of shocks.

The chart indicates that the tourism shocks are a major contributor to the short-run employment effects of the hypothetical epidemic. Out of the 2.1 per cent employment reduction in 2010.Q2 (Chart 1), 1.0 percentage points are contributed by these shocks. Comparison of the S1 and S12 lines shows that the labor-input shocks (S2) are a relatively minor contributor to the aggregate employment result. In 2010.Q2 the labor-input shocks move employment down by an extra 0.2 percentage points, from -1.0 to -1.2 per cent.
Comparison of the S12 line with the S123 line shows that increased medical expenditures initially (that is, in 2010.Q1) have almost no effect on aggregate employment, but then in 2010.Q2 to 2011.Q1 they have a small negative effect, and finally in 2011.Q2 to 2012.Q2 they have a small positive effect.

The fact that increased medical expenditures have only a negligible effect on aggregate employment in 2010.Q1 is not surprising. In our modeling we assume that households finance extra medical expenditures by diverting expenditures away from other goods and services, with no direct change in aggregate household demand. This switch in expenditures has a minor positive effect on employment because medical services are labor-intensive relative to other consumer goods and services. However, in our simulation this minor positive effect is offset by a minor negative effect: we assume that with an upsurge in the demand for medical services there is an increase in hours of work per medical employee which damps job creation in the medical sector.

The diversion of household expenditures towards medical services causes additional excess capacity to appear in other consumer sectors in 2010.Q1. This reduces investment in these sectors in subsequent quarters. We assume that there is no offsetting effect from the medical sector where it is recognised that the upsurge in demand for medical services is temporary. Thus there is a net reduction in aggregate investment. In the quarterly version of USAGE, aggregate employment in the short run is determined mainly by movements in aggregate
demand. The net reduction in aggregate investment then explains why the S123 line in Chart 10 lies below the S12 line from 2010.Q2 to 2011.Q1.

Reduced investment in 2010 leaves the economy short of capital in 2011. Thus, the diversion in 2010 of expenditures towards medical services causes aggregate investment to be stronger in 2011.Q2 to 2012.Q2 than it otherwise would have been. This takes S123 line for this period above the S12 line.

Consistent with the short-run results being demand driven, Chart 10 indicates that diversion of household expenditures on leisure activities into savings (S4) has a significant negative effect on employment in the first half of 2010: for 2010.Q2 the S1234 line lies 0.8 percentage points below the S123 line. The wage mechanism, explained earlier, means that when demand for leisure activities recovers in the second half of 2010, employment temporarily moves above where it would have been without the contraction in demand for these activities, that is, the S1234 line moves above the S123 line.

5. SUMMARY AND CONCLUDING REMARKS

In this paper we used a quarterly CGE model to simulate the effects of a hypothetical H1N1 epidemic infecting about 90 million Americans and causing symptoms of various levels of severity in about 60 million. The use of a model with quarterly periodicity rather than the usual annual periodicity allowed us to capture the short-run nature of an epidemic. Such an event would have its economic effects concentrated over no more than one or two quarters.

Specifically, we assumed that the epidemic lasts for two quarters and causes: reductions of 34 and 17 per cent in inbound and outbound international tourism; a loss of 0.4 per cent in labor input per employed worker; a 2.4 per cent surge in demand for hospital and other medical services; and a 10 per cent cut in expenditures by households on leisure activities involving public gatherings. Table 3 is a summary of our macroeconomic results. It shows quite severe effects at the height of the epidemic (peak quarter) including a 2.1 per cent reduction in employment. Averaged over the epidemic year, the effects are considerably damped. In the year following the epidemic, the macroeconomic effects are

<table>
<thead>
<tr>
<th>Variable</th>
<th>Peak quarter</th>
<th>Epidemic year</th>
<th>Next year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>-2.1</td>
<td>-1.3</td>
<td>0.3</td>
</tr>
<tr>
<td>GDP</td>
<td>-2.6</td>
<td>-1.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Private consumption</td>
<td>-3.2</td>
<td>-2.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Investment</td>
<td>-4.3</td>
<td>-3.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Exports</td>
<td>-4.7</td>
<td>-2.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Imports</td>
<td>-5.7</td>
<td>-4.5</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

Table 3. USAGE results for the effects of an H1N1 epidemic
(Percentage deviations from baseline)
mostly positive. By reducing wage rates, the epidemic improves the competitive position of the U.S. economy in the post-epidemic year. It also boosts investment in the post-epidemic year. This is explained by a capital shortage reflecting reduced investment in the epidemic year.

Our modeling showed substantial direct epidemic-related effects on several industries: positive for medical services; negative for inbound and outbound tourism; and negative for miscellaneous services which includes leisure activities involving public gatherings. For other industries, the results were fairly uniform with variations reflecting macroeconomic effects. Construction was particularly adversely affected in the short run by weakness in investment. Trade-exposed industries showed rapid recovery facilitated by real devaluation. For nearly all industries, the epidemic produced a sharp but short-lived downturn.

Although we looked at only one epidemic scenario, our analysis can be extended to cover other scenarios. This can be done by using the results for individual shocks presented in the last part of section 4. For example, Chart 10 implies that cuts of 34 and 17 per cent in inbound and outbound tourism (S1) sustained over two quarters would cause reductions in aggregate employment in the two quarters of 0.8 and 1.0 per cent. While responses from models such as USAGE are not completely linear, we can be confident that if the tourism cuts were 50 per cent greater (51 and 25.5 per cent rather than 34 and 17 per cent) then our model would imply additional reductions in aggregate employment of approximately 0.4 and 0.5 per cent. Similarly, Chart 10 implies that a loss of labor input per employed worker of 0.41 per cent sustained over two quarters (S2) would cause reductions in aggregate employment in the two quarters of 0.1 and 0.2 per cent (the gaps between the S1 and S12 lines). If the labor-input loss were 50 per cent greater (0.615 per cent rather than 0.41 per cent) then there would be additional reductions in aggregate employment of approximately 0.05 and 0.10 per cent. Overall, our results for individual shocks indicate that the macroeconomic consequences of an epidemic are much more sensitive to demand-side effects such as reductions in international tourism and leisure activities than to supply-side effects such as reductions in labor input per employed worker. This suggests that demand stimulus policies might be an appropriate economic response to a serious epidemic.
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