# Economic Modeling for the Analysis of Pandemic Influenza

## Supplement to the National Population and Infrastructure Impacts of Pandemic Influenza Report

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# List of Acronyms and Abbreviations

| | |
|---|---|
| BEA | Bureau of Economic Analysis |
| BMO | Bank of Montreal |
| BSE | Bovine Spongiform Encephalopathy |
| CBO | Congressional Budget Office |
| CDC | Centers for Disease Control and Prevention |
| CIPDSS | Critical Infrastructure Protection Decision Support System |
| CMG | Community Management Guidance |
| CMG-SE | Community Management Guidance – Selected Elements |
| DHS | U.S. Department of Homeland Security |
| EpiSimS | Epidemiological Simulation System |
| GDP | gross domestic product |
| IMF | International Monetary Fund |
| NAICS | North American Industrial Classification System |
| NBER | National Bureau of Economic Research |
| NISAC | National Infrastructure Simulation and Analysis Center |
| PI | pandemic influenza |
| REMI | Regional Economic Model, Inc. |
| SAR | Special Administrative Region (Hong Kong) |
| SARS | severe acute respiratory syndrome |
| SIC | Standard Industrial Classification |
| TLC | targeted layer containment |
| U.S. | United States |
| UK | United Kingdom |
| WWI | World War I |

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# 1. Background

Pandemic influenza (PI) could cause significant short-term and permanent impacts on U.S. households and industrial output. Not only would a wide range of industries, including infrastructures, incur short-term disruptions, but the nation's population and workforce would decrease in absolute terms. Consumer spending reductions could also result from the psychological impact of the outbreak. In the long-term, the U.S. economy has proven resilient to disasters (including past pandemics), and it would likely return to its previous growth rate trend. However, due to mortality (loss of human capital resources) associated with a pandemic, the base from which growth occurs would be smaller.

A fraction of the population contracting PI would die. Loss of population over and above the normal and regular factors (births, deaths, and migration) would represent a shock with short-term and long-term effects to the national economy. As seen with the severe acute respiratory syndrome (SARS) outbreak in East Asia and the post-9/11 decline in air travel, a major economic impact could be attributed to the immediate response of consumers to the outbreak itself together with the associated uncertainty. Economic analysis of recent cataclysmic events suggests that consumers could also delay expenditures for big-ticket items such as furniture, major appliances, automobiles, and housing due to uncertainty of near-term economic conditions such as loss of income and/or employment or possible increased spending on healthcare.

Industries with significant person-to-person transactions such as mass-transportation, restaurants, and tourism might see a sharp decrease in customers and overall demand as people try to reduce their risks of exposure. Economists and other scholars continue to debate the existence and magnitude of consumer response associated with psychology of this type of event. While some economists argue that the psychological impact of PI would be negligible in terms of actual realized/observed changes in consumption, others expect it would continue to be a factor in the overall economic response. For this reason the National Infrastructure Simulation and Analysis Center (NISAC) devoted a significant portion of the literature review to this debate.

As the pandemic advances, NISAC projects that absenteeism in the work place would increase due to actual illness, care for individuals who are ill, and voluntary quarantine due to fear of becoming ill. For this analysis, NISAC assumed that the supply shock and consumer spending reductions for each scenario would be contained within the first year of the pandemic. Sensitivity analysis can evaluate this assumption.

The actions of governments could influence the effects of a pandemic on the economy. Attempts to quarantine people would probably amplify any reductions in trade, travel, and tourism.

## 1.1 Economic History of Public Health Crises

The impact of a pandemic disease on the economy is complex and dependent on many factors. Such factors include the specific population group(s) most at risk, duration of the pandemic, and method of transmission. Many types of influenza affect primarily the elderly and the very young; however, with past pandemics, the demographic stratum most affected was the working-age population (bubonic plague [Black Plague], 1918 Influenza). Opinions vary as to how the loss of a large segment of the working-age population would affect the macro-economy. Economists studying past pandemics—mainly the Black Plague and 1918 Influenza—found the impacts would range from per-capita income gains to no significant impacts on output.

### 1.1.1 Black Plague

The Black Plague of the middle ages killed one-quarter of Europe's population between 1346 and 1352, with death tolls up to 70 percent in some cities.[1] The guilds of the time preserved detailed financial records of business transactions and work contracts, allowing economists to empirically study how the Black Plague affected the economy. The guilds also maintained the accounts and wage rates, which were best preserved in Western Europe. These historical records provided the basis for the following empirical studies.

Clive Bell and Maureen Lewis found through research of historical records that, while the Black Plague left behind devastatingly high mortality rates throughout villages and towns of Europe, survivors found expanded employment opportunities and declines in prices for food stuffs. Entire villages were wiped out of existence, leaving more land available for cultivation. As the value of the land fell, so did the marginal cost of agricultural production, which led to an abundance of food supplies.[2] If individuals did not have farming knowledge, there were employment opportunities in other villages and towns where labor shortages existed. These individuals would have enjoyed an increase in wages due to labor scarcity.[3]

Economists widely accept that the negative shock to the working population led to a rise in real wages that persisted until the 15th Century.[4] However, Bloom and Mahal examined the effects of the Black Plague and found a positive but statistically insignificant relationship between real wages and population growth.[5]

In contrast to previous studies of the Black Plague, John Munro and Gregory Clark do not believe the Black Plague was a catalyst for rising wages.[6] Munro found that real wages in England did not rise in the immediate aftermath of the Black Plague. He finds that wages were depressed following the Great Famine (1315–1320) and remained so until around 1370, almost 30 years after the Black Plague. Clark analyzed and tried to quantify the effects of the Black Plague on land, labor, and capital prices. He found that toward the end of the Black Plague, around 1350, land rents began to fall and the return to capital fell. Clark closely analyzed wage effects for this period and found that wages did not rise immediately following the conclusion of the Black Plague. Similar to Munro, Clark found that wage increases did not manifest until 1370. Although, he argues that this could be the result of English laws that effectively froze wages in the years immediately following the Black Plague, he asserts that wages could have been other than monetary. Clark found that, in the long run, the Black Plague had an insignificant impact on output.

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[1] Diamond, Jared, 1999, *Guns, Germs, and Steel: The Fates of Human Societies*, W.W. Norton & Company, ISBN 039331752, April

[2] Bell, Clive, and Maureen Lewis, 2005, "The Economic Implications of Epidemics Old and New," *World Economics* **5**(4), October (hereinafter referred to as Bell and Lewis, 2005)

[3] Ibid.

[4] Hirschleifer, Jack, 1987 *Economic Behaviour in Adversity*, Chicago: The University of Chicago Press, ISBN 0226342824

[5] Bloom, David E., and Ajay S. Mahal, 1997, "AIDS, Flu, and the Black Plague: Impacts on Economic Growth and Well-being," *The Economics of HIV and AIDS: The Case of South and South East Asia*, Bloom, D., and P. Godwin, eds, Delhi: Oxford University Press, pp. 22-52 (hereinafter referred to as Bloom and Mahal, 1997)

[6] Munro, John, 2004, "Before and After the Black Plague: Money, Prices, and Wages in Fourteenth-Century England," Institute for Policy Analysis, University of Toronto, Working Paper No. 24, December; Clark, Gregory, 2003, "Microbes and Markets: Was the Black Plague an Economic Revolution?" University of California, Davis

### 1.1.2 The 1918–19 Influenza Pandemic

Appenzeller estimates that 50 million people worldwide died from the flu pandemic of 1918, more than 3 times the deaths of World War I (WWI).[7] Influenza left no part of the world untouched. The 1918 influenza disproportionately killed healthy men and women, ages 15–44, during their prime productivity and wage earning years.[8]

Data on the 1918–19 pandemic and U.S. data in general from this period are somewhat limited. Due to the insufficiency of data, Elizabeth Brainerd and Mark V. Siegler[9] built their econometric model by relying on previous work by Easterlin[10] and Lindert. [11] Easterlin created nominal estimates of state income per capita at 20-year intervals, and Lindert generated regional price indexes from available data to deflate Easterlin's nominal estimates. From this, Lindert was able to construct real estimates of personal income per capita after taxes for each state. Brainerd and Siegler also relied on one of the few broad data sets from this period, Dun's business failure-rate data. However, the sample size is quite limited for authors studying the 1918 pandemic. Death reporting during this period is not comprehensive; only 30 states reported influenza and pneumonia deaths for 1918 and 1919. Influenza and pneumonia are combined because many deaths reported as pneumonia were actually attributable to influenza.

The objective of Brainerd's and Siegler's model was to quantify the effects of the 1918–19 pandemic on the U.S. economy. They found that the mortality rate of the 1918–19 pandemic and the mortality rate of the working-age population were positively correlated with subsequent business failure rates in 1919, 1920, and 1921; however, these correlations were not statistically significant. Brainerd and Siegler estimated that the correlation between the mortality rate of the 1918 flu and the change in average deposits per depositor from 1918 to 1919 was 0.445, reflecting a possible increase in the savings rate (reduction in consumption). Additionally, they found that both measures of the flu were positively and significantly related to growth in real income per capita from 1919 to 1930. Brainerd and Siegler suggested that the growth in real income per capita in 1930 might simply be a return to the long-run trend. An examination of the National Bureau of Economic Research (NBER) business cycle chronology reveals that a peak in August 1918, followed by a trough in March 1919, closely mirrors the beginning of the pandemic in August 1918 and its conclusion by March 1919. Brainerd and Siegler asserted that, regardless of the debate surrounding how far below trend the economy was from 1919 through 1921, there certainly is no doubt that the economy was below trend during this period.

Barro and Sala-i-Martin found that for years immediately following the 1918 pandemic, specifically the 1920s, the states with large shares of agriculture experienced slower growth.[12] Additionally,

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[7] Appenzeller, Tim, 2005 "The Next Killer Flu: Can We Stop It?" *National Geographic*, March, pp. 8-31

[8] Barry, J. M., 2004, *The Great Influenza: The Epic Story of the Deadliest Plague in History*, Viking Press, New York

[9] Brainerd, Elizabeth, and Mark V. Siegler, 2003, "The Economic Effects of the 1918 Influenza Pandemic," Centre for Economic Policy Research, International Macroeconomics, London, United Kingdom, Discussion Paper No. 3791, February

[10] Easterlin, Richard A. (1957) "State Income Estimates," *Population Redistribution and Economic Growth, United States, 1870-1950*, Vol. 1, Everett S. Lee, Ann Ratner Miller, Carol Brainerd, et al., eds, The American Philosophical Society, Philadelphia, Pennsylvania, pp. 702–759

[11] Lindert, Peter H., 1978, *Fertility and Scarcity in America*, Princeton University Press, Princeton, New Jersey

[12] Barro, Robert J., and Xavier Sala-i-Martin, 1992 "Convergence," *Journal of Political Economy* **100**(2): 223–251

these states experienced decreases in land values and farm prices. These results are similar to what Bell and Lewis found for the Black Plague.[13]

Thomas A. Garret attempted to quantify the effect of WWI and the 1918 influenza pandemic on manufacturing wage growth between the years 1914 and 1919. WWI and the 1918 pandemic resulted in a large number of deaths; the demographics of both events led to a significant labor shortage in manufacturing. Garret relied on state-level data and the U.S. census of manufacturers for information on the number of manufacturing jobs, the percentage change in real manufacturing wages, and influenza and pneumonia deaths (only 30 states reporting). Additionally, Garret converted annual wages per worker to 1914 prices. Garret estimated the effects of influenza pandemic and WWI mortalities together and individually.[14]

Garret found the coefficient on the aggregated mortalities to be positive and significant, supporting the hypothesis that the decrease in manufacturing labor supply resulted in real wage growth. He also found that states involved with wartime production experienced an average 10-percent growth in manufacturing wages compared to nonproduction states. Real wages in the manufacturing sector increased an average of 0.70 percent. According to Garret, states with higher value-added per worker in 1914 experienced a slower rate of real wage growth from 1914 to 1919. Garret investigated regional differences and found that average manufacturing wages in Southern and Midwestern states increased by 20 percent and 9 percent, respectively, when compared to Western and Northeastern states. The aggregate effect of age 20 to 49 influenza mortalities and WWI mortalities was a 1.41-percent increase in real manufacturing wage growth.

Garret estimated the effects of an increase in mortality, as compared with the mean, of an additional 1,000 deaths for both WWI and the 1918 pandemic. He also estimated that an additional 1,000 deaths from WWI would have resulted in a predicted 6.5-percent growth in real manufacturing wages; an additional 1,000 deaths from influenza for ages 20 to 49 would have increased real manufacturing wages by 1.25 percent. According to Garret, it appears that the marginal effect of an additional WWI mortality on manufacturing wage growth was greater than that of the 1918 influenza pandemic.

Garret then estimated the effects of influenza mortalities on real wage growth. Garret found the estimated coefficient of influenza deaths to be positive with a statistically significant effect on real manufacturing wage growth. Specifically, the coefficient for deaths of those aged 10 to 49 had a positive and significant impact on manufacturing wage growth. However, when he considered influenza deaths separately from WWI mortalities, he found the coefficient on influenza deaths was no longer positive and lost its statistical significance.

Other authors of studies on the economic impact of the 1918 pandemic analyzed countries other than the U.S. At the time of the 1918 pandemic, India was almost entirely an agrarian society; therefore, analysts employed methods other than measuring per-capita income to quantify the impact.[15] Schultz used the decennial census of 1921 to estimate that the agricultural workforce dropped by 8 percent during the pandemic, and the output fell by 3.3 percent; his results implied an increase in per-capita output. Bloom and Mahal examined the relationship between changes in acreage sown and the

[13] Bell and Lewis, 2005 (See Footnote 2)

[14] Garret, Thomas A., 2006, “War and Pestilence as Labor Market Shocks: Manufacturing Wage Growth 1914-1919,” Federal Reserve Bank of St. Louis, Working Paper 1006-018A, March

[15] Schultz, Theodore W., 1964, *Transforming Traditional Agriculture*, Yale University Press, New Haven, Connecticut

decline in population in 13 infected Indian provinces.[16] As was the case with their results for the Black Plague, they found no significant relationship.

### 1.1.3 Severe Acute Respiratory Syndrome (SARS)

At the beginning of the 21st Century, spanning the winter of 2002 and spring of 2003, Asia was the hotbed of an outbreak of SARS, a potential pandemic. Asia and the world were shocked by the emergence of this infectious disease. At the time, SARS was not only completely unknown but highly contagious, uncontrollable, and deadly. Although a global health crisis was avoided, according to some researchers, economic disruptions were not.

Jong-Wha Lee and Warwick J. McKibbin provided an assessment of the impacts on Hong Kong and China.[17] To generate their empirical estimates, they used economic modeling software called the G-cubed (Asia-Pacific) model. Lee and McKibbin used data collected by banks, analysts, and financial analysts during the SARS outbreak to calibrate the G-Cube model. Lee and McKibbin revealed that the retail-service sector and travel industry suffered the greatest decline in consumer demand. They estimated that the consumption shock to the retail-service sector was as high as a 15-percent reduction in consumer demand within a 6-month outbreak period. Additionally, Lee and McKibbin found that SARS increased employers' costs of disease prevention in the retail-service, sales, and travel industries. They approximated the increased costs at 5 percent during the 6-month outbreak. They generally considered medical costs during the outbreak to be minimal, given the small number of infected patients. The uncertain nature of the disease affected confidence in the future health of these economies. To account for this uncertainty, Lee and McKibbin increased the country risk premium to 200 basis points.[18] To reflect the 6-month duration of the outbreak, they scaled the shocks by 50 percent.

Lee and McKibbin estimated the shocks transmitted to other countries through the flow of goods, services, and capital. To model the SARS impact on other countries, they calibrated a number of variables based on tourist flows, geographical distance to China and Hong Kong, health expenditures, sanitary conditions, government response, climate, per-capita income, and population density. Their results from the simulation indicated the following percentage changes in gross domestic product (GDP): Hong Kong, -2.63 percent; China, -1.05 percent; Taiwan, -0.49 percent; and Singapore, -0.47 percent.

Using the Oxford Forecasting Model, the *Asian Development Outlook 2003 Update* estimated the changes in key economic variables between the first and second quarters of 2003 for East and Southeast Asia.[19] The authors ran a counterfactual simulation, which estimated what GDP growth, consumer spending, and other variables might have been if the SARS epidemic had not occurred. According to the authors, the counterfactual simulation provided an estimate of the total cost of SARS to East and Southeast Asian economies in terms of overall GDP losses and allowed for the repercussions of consumer spending on investment, exports and imports of goods, employment, and prices. They estimated the GDP losses for 2003 to be $18 billion, or 0.6 percent of GDP, and the total final expenditure costs to be $60 billion, or 2 percent of GDP. In general, the consumption

[16] Bloom and Mahal, 1997 (See Footnote 5)
[17] Lee, Jong-Wha, and Warwick McKibbin, 2003, "Globalization and Disease: The Case of SARS," Brookings Institution Working Paper, May (hereinafter referred to as Lee and McKibbin, 2003)
[18] Ibid.
[19] Asian Development Bank, 2003, "Assessing the Impact and Cost of SARS in Developing Asia," *Asian Development Outlook 2003 Update*, ISSN 1655-4809 (hereinafter referred to as Asian Development Bank, 2003)

results were better than expected due to delayed consumption; sales began to recover as the SARS outbreak began to subside around June of 2003. The impact of SARS appeared to be moderate; the authors attributed this result to high government spending, strong investment, and buoyant exports offsetting the adverse impact on consumption and tourism.

When reviewing statistics for countries affected by SARS, it is obvious there were costs beyond those of the health sector, even assuming that the outbreak had little or no repercussions beyond the second quarter of 2003. GDP weakened sharply in the second quarter across most of Asia, which can be attributed mostly to the SARS outbreak of 2003. The authors found that the economic impacts were not confined to the countries with confirmed cases. In 2003, the Asian Development Bank reported that Thailand's economy was badly hurt; tourists feared contracting SARS anywhere in Asia and promptly sought other holiday destinations.[20] As reported in many studies regarding SARS, tourism plummeted across all of Asia. Consumer spending dropped, but primarily only in the countries with confirmed cases and only for one quarter. This would be a possible threat especially considering a more malicious disease.

Alan Siu and Y. C. Richard Wong reported the economic impacts of the SARS outbreak on Hong Kong in 2003 data collected by the Census and Statistics Department of Hong Kong Special Administrative Region (SAR) Government and CEIC Data Company Ltd.[21] In late March 2003, retail sales figures dropped 6.1 percent from 2002, and in April 2003, retail sales dropped 15.2 percent from the 2002 figures. Siu and Wong observed that, as the number of new cases declined, consumption patterns began to change, with video rental shops and supermarkets doing more business than the previous year. As the SARS outbreak began to taper off after May 2003, sales began to improve and by July 2003 retail sales were back to pre-outbreak levels. Passenger travel to Hong Kong began to drop in mid-March 2003, with total visitor arrivals falling by 10.4 percent. However, April 2003 had the largest drop in visitor arrivals when compared with March 2003: airline passenger arrivals declined by 77 percent, people traveling by land fell by 52 percent, and sea travel dropped by 72 percent. Travel began to return to normal levels by May for residents and June for visitors.

Across the developed world and in global travel and tourism hotspots, the economic impacts of public health risks posed by high profile contagious diseases such as SARS would be likely to dwarf costs from a purely healthcare perspective, as demonstrated by Lee and McKibbin.[22]

Rossi and Walker reported that tourism is the world's largest industry. Out of total world GDP of $35–40 trillion, tourism accounted for an estimated $3 trillion.[23] This new-found discretionary spending is much more volatile than the typical basket of goods from 30–40 years ago. This spending is not essential for survival; therefore, consumers are quick to hold back on discretionary spending when uncertainty increases. Lee and McKibbin attempted to demonstrate that international trade and investment would likely be affected by SARS with the effects distributed globally.[24] Some drawbacks would come with the easy movement of trade and investment. Global news and

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[20] Asian Development Bank, 2003 (See Footnote 19)

[21] Siu, Alan, and Y. C. Richard Wong, 2004, "Economic Impact of SARS: The Case of Hong Kong," The University of Hong Kong, School of Economics and Finance, April

[22] Lee and McKibbin, 2003 (See Footnote 17)

[23] Rossi, Vanessa, and John Walker, 2005, "Assessing the Economic Impact and Costs of Flu Pandemics Originating in Asia," Oxford Economic Forecasting Group, May

[24] Lee and McKibbin, 2003 (See Footnote 17)

information would be widely available and at almost no cost; news of an outbreak could have quick and far-reaching impacts.

Collectively, this evidence explains, in part, why a relatively small public health problem such as SARS, which actually had a limited impact on the traditional health sector cost analysis (namely labor productivity and medical care), could generate a significant overall economic loss in the affected region.

Experience with SARS provides some insight into the potential economic impact of PI. The main impact of SARS was on the demand side, as consumption and the demand for services contracted. This reflects both the psychological and real impact of the outbreak and the need to limit contact to prevent infection. However, a flu pandemic might also affect the supply side, as members of the labor force get sick and, in some cases, die. Human and physical capital could be destroyed, possibly reducing the affected region’s long-run growth potential.

### 1.1.4 Other Pandemic Influenza Studies

Analysts have conducted a number of studies assessing the possible economic ramifications of a PI. Previous studies tended to model the economic impact of a pandemic by separating the changes to supply and demand. Table 1-1 provides an overview of findings from other PI studies. Each study used slightly different assumptions of attack rates, deaths, and consumer response that might occur in a pandemic. As a result, the findings for possible GDP impacts were not directly comparable without further discussion and consideration of differing assumptions. Even so, readers can see the wide ranges in expected economic impact, an indication of the wide range of opinions and uncertainty involved with such an event. Table 1-1 summarizes the main findings of the studies reviewed. Some of the more significant studies and their assumptions are discussed in the text following the table.

**Table 1-1: Previous pandemic influenza economic impact studies**

| Pandemic Influenza Economic Studies | Scope | First year GDP Impact (%) | |
|---|---|---|---|
| | | Low | High |
| Asian Development Bank[25] | Asia (excl. Japan) | 2.6 | 6.8 |
| Lowy/Brookings Institute[26] | U.S. | 0.6 | 5.5 |
| BMO-Nesbitt Burns[27] | Global | 2 | 6 |
| Congressional Budget[28] | U.S. | 1 | 4.25 |
| Douglas, Szeto, and Buckle[29] | New Zealand | 5 | 10 |
| James and Sargent[30] | Canada | 0.3 | 1.1 |
| Jonug and Roeger[31] | Europe | -1.6 | |
| Kennedy, Thompson, and Vujanovic[32] | Australia | 6 | |
| NISAC/CIPDSS (Baseline) | U.S. | 0.2 | 3.5 |

Notes: BMO = Bank of Montreal, CIPDSS = Critical Infrastructure Protection Decision Support System, GDP = gross domestic product, NISAC = National Infrastructure Simulation and Analysis Center

The Congressional Budget Office (CBO) released one of the first studies focusing on the U.S. and has received much attention.[33] The CBO admitted that many of their assumptions, especially regarding the demand-side impact, were "very rough," as there is much uncertainty around what might actually occur. They estimated that a severe pandemic might reduce GDP about 4.5 percent, while a milder pandemic might reduce GDP by closer to 1 percent. In either case, they noted that the economic shocks would be temporary, with productivity and consumption patterns returning to previous levels after the pandemic passes.

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[25] Bloom, E., V. de Wit, and M. J. Carangal-San Jose, 2005, "Potential Economic Impact of an Avian Flu Pandemic on Asia," Economics and Research Department Policy Brief, Asian Development Bank, http://www.adb.org/Documents/EDRC/Policy_Briefs/PB042.pdf (hereinafter referred to as Bloom et al., 2005)

[26] McKibbin, W., and A. Sidorenko, 2006, "Global Consequences of Pandemic Influenza," Brookings Institution, Lowy Institution for International Policy, February, www.lowyinstitute.org/Publication.asp?pid=345 (hereinafter referred to as KcKibbin and Sidorenko, 2006)

[27] Cooper, S., 2006, "The Avian Flu Crisis: an Economic Update," BMO-Nesbitt Burns, March, www.bmonesbittburns.com/economics/reports/20060313/report.pdf (hereinafter referred to as Cooper, 2006)

[28] CBO (Congressional Budget Office), 2005, "A Potential Influenza Pandemic: Possible Macroeconomic Effects and Policy Issues," December, revised July 2006, www.cbo.gov/ftpdocs/69xx/doc6946/12-08-BirdFlu.pdf (hereinafter referred to as CBO, 2005)

[29] Douglas, J., Szeto, K. and Buckle, B. (March 2006), "Impacts of a Potential Pandemic on New Zealand's Macroeconomy," New Zealand Treasury Policy Perspectives Paper 06/03. Online: www.treasury.govt.nz/workingpapers/2006/pp06-03.asp

[30] James, Steven, and Timothy Sargent, 2006, "The Economic Impact of an Influenza Pandemic," Economic Analysis and Forecasting Division, Department of Finance, Government of Canada, June (hereinafter referred to as James and Sargent, 2006)

[31] Jonung, Lars, and Werner Roeger, 2006, "The Macroenomic Effects of a Pandemic in Europe – A Model-Based Assessment," European Commission Directorate-general for economic and financial affairs, Economic Papers: www.europa.eu.int/comm/economy_finance (hereinafter referred to as Jonung and Roeger, 2006)

[32] Kennedy, S., J. Thomson, and P. Vujanovic, 2006, "A Primer on the Macroeconomic Effects of an Influenza Pandemic," Treasury of Australia, February, www.treasury.gov.au/contentitem.asp?NavId=&ContentID=1069

[33] CBO, 2005 (See Footnote 28)

Additional studies have been released calculating worldwide economic impacts, or impacts focused on other countries. The Asian Development Bank conducted an early study focusing solely on the impact to Asia (excluding Japan), which ranged from 2.6 to 6.8 percent.[34] They based many of the demand-side assumptions for a pandemic on evidence gathered from a 2003 study by Fan on the impact of SARS.[35] Fan found that "the main impact of SARS was on the demand side, as consumption and the demand for services contracted." As a result, for this study, NISAC assumed a large consumer response, much greater than the supply-side reductions due to ill workers.

The Brookings Institute, in conjunction with the Lowy Institute, released a report that analyzed 4 possible global scenarios.[36] The range of economic impacts for the U.S. was from a loss of 0.6 percent of GDP under a mild pandemic to a 5.5-percent loss under an "ultra" pandemic scenario. They used an annual model and adjusted all shocks to an annual rate. The Brookings Institute/Lowy model generates endogenous shifts in spending patterns because of the changes in incomes, wealth, and relative prices caused by the various shocks imposed. The Brookings Institute/Lowy model assumed an overall fall in spending, which resulted in an increase in savings or future spending. The shift in consumption would be confined to agriculture, manufacturing, and services.

Sheri Cooper from The Bank of Montreal (BMO)-Nesbitt Burns released an economic update report on avian influenza in March 2006.[37] She used the CBO assumptions as a starting point. Her results are merely suggestive, estimating that a mild pandemic would reduce GDP by 2 percent and a severe pandemic would result in a loss of 6 percent. Cooper also predicted dire situations in the event of a pandemic: shortages would occur very quickly, the electricity grid might fail for extended periods of time, the financial sector would not function, gasoline supplies would run out.[38] The study also highlighted limitations of the current medical facilities to accommodate such a surge in demand. However, Cooper also stressed that even in a pandemic, roughly 99 percent of the world's population would survive. Additionally, public reaction might not be entirely a negative shock. To the extent that people take preventative mitigation measures, the fear of illness might help lessen the attack rates for all types of contagious illness.

The International Monetary Fund (IMF) formed a working group early in 2006 to discuss the potential global economic and financial impacts of an avian flu pandemic and issued a report to document their analysis and findings.[39] The IMF working group suggested that comparisons made between the 1918 pandemic and a future pandemic may be appropriate. However, information about the 1918 epidemic is limited "in part because the epidemic broke out during WWI, but also because national economic accounting was in its infancy." Indeed, the GDP was not officially maintained by the Bureau of Economic Analysis (BEA) until 1929. While the IMF working group did not estimate a reduction in GDP, they did discuss the likely responses in the market. They discussed the possibility of disruptions due to high absenteeism; however, they noted these responses would be temporary. Similarly, Milan Brahmbhatt of the World Bank discussed the likely socioeconomic impacts. He noted that "the most immediate economic impacts of a pandemic might arise not from

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[34] Bloom et al., 2005 (See Footnote 25)

[35] Fan, Emma Xiaoqin, 2003, "SARS: Economic Impacts and Implications." ERD Policy Brief No. 15, Asian Development Bank, May

[36] McKibbin and Sidorenko, 2006 (See Footnote 26)

[37] Cooper, 2006 (See Footnote 27)

[38] Ibid., pp. 14–15

[39] IMF (International Monetary Fund), 2006, "The Global Economic and Financial Impacts of an Avian Flu Pandemic and the Role of the IMF," Avian Flu Working Group, February 28, http://www.imf.org/external/pubs/ft/afp/2006/eng/022806.pdf

actual death or sickness but from the uncoordinated efforts of private individuals to avoid becoming infected."[40]

A recent study by Steven James and Timothy Sargent estimated that a severe pandemic would actually be much milder than others have predicted.[41] They used data, where available, from SARS, the 1918 pandemic, and subsequent milder pandemics as a basis for their analysis of how an influenza pandemic might affect Canada. They found that, assuming a severe pandemic such as 1918, output would decline by only about 1 percent whereas a milder pandemic would have negligible impacts. They found no basis for large supply-side or consumer spending reductions. Their upper-bound estimates indicated that peak absenteeism would not be sufficient to halt supply chains or disrupt critical infrastructure services. Furthermore, they criticized other studies that predicted a large negative impact resulting from fear or consumer response because they claimed that fear does not imply widespread behavioral changes. The authors found almost no basis from other disasters in history for such assumptions. They concluded by suggesting that loss of life and illness would dominate any economic concerns in the event of a pandemic and economic output should not be the metric to judge disasters.

Jonung and Roeger estimated a macroeconomic impact of a pandemic for the European economy.[42] They estimated a total loss of output of 1.6 percent in the pandemic year and a sustained reduction due to deaths of 0.75 percent. Of the total loss, they attributed 0.5 percent to the consumer spending reduction and the remaining 1.1 percent to supply-side reductions. They assumed a smaller demand effect than supply effect, because their model included a monetary policy reaction to counter the potential negative consumer response. In addition, they noted that consumption patterns likely would return to normal very quickly after the pandemic.

[40] Brahmbhatt, Milian, 2005, "Avian Influenza: Economic & Social Impacts" World Bank, 23 September, http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20663668~pagePK:34370~piPK:42770~theSitePK:4607,00.html
[41] James and Sargent, 2006 (See Footnote 30)
[42] Jonung and Roeger, 2006 (See Footnote 31)

# 2. Modeling Inputs and Assumptions

NISAC used the Regional Economic Model, Inc. (REMI), state-level model with 67 industry sectors as the base model to generate macroeconomic simulations. This model was required because of NISAC's intent to use estimates of workplace absenteeism generated by a detailed epidemiological model.

## 2.1 Background Assumptions

NISAC conducted this analysis without considering the costs of formulation, implementation, or enforcement of the actions that implicitly comprise the scenarios. The cost is likely directly related to the number of provisions involved with the scenario. For example, the anticipated intervention and targeted layered containment (TLC) scenarios call for multiple interventions including school closures, quarantine, and prophylactic treatment, the sum of which is likely to be costly. Future studies could investigate these costs, compute cost-benefit ratios, and evaluate the cost effectiveness of the scenarios.

***Note: After this supplemental document was completed, the Centers for Disease Control and Prevention (CDC) changed the designations of the TLC and TLC Lite scenarios to Community Management Guidance (CMG) and Community Management Guidance – Selected Elements (CMS-SE), respectively.***

## 2.2 The Regional Economic Model, Inc. (REMI), Model

REMI is a structural set of equations that model the U.S. macroeconomy, including the aggregate production of goods and services, employment levels and movement across industries, consumer spending, effects of wage and price changes, and international trade. As illustrated in Figure 2-1, the equations model economic variables such as output, prices, and consumer spending, via theoretical and empirical relationships.[43] These relationships, developed into parameters with publicly available historical data,[44] model the fundamentally dynamic and circular nature of the real economy: output generates employment, employment generates income, income generates demand for and spending on new output, new output generates new employment, and so on.

Variables are grouped to reflect their part in the causal linkages. The output block contains variables representing the amount of goods produced; the variables are divided both by Standard Industrial Classification (SIC) industry; that is, SIC 35, Industrial Machinery and Equipment, and by the "demand category" of the good; that is, consumption, investment, government spending, or net exports. Within the output block, an input-output matrix determines inter-industry demand and final demand, by industry.

[43] Treyz, G. I., D. S. Rickman, and G. Shao, , 1992, "The REMI Economic-Demographic Forecasting and Simulation Model," *International Regional Science Review*, **14**( 3): 221–253, 1992

[44] For example, GDP measures are obtained from the BEA and the *Survey of Current Business* (http://www.bea.gov/scb/). Data on employment, wages, and personal income come from the BEA and the Bureau of Labor Statistics. The cost of capital is computed from data in the *Quarterly Financial Report for Manufacturing (*http://www.census.gov/csd/qfr/) and from the *Survey of Current Business*. State and U.S. corporate profits tax rates are obtained from the *Government Finances (Revenue)* and the *Survey of Current Business*.

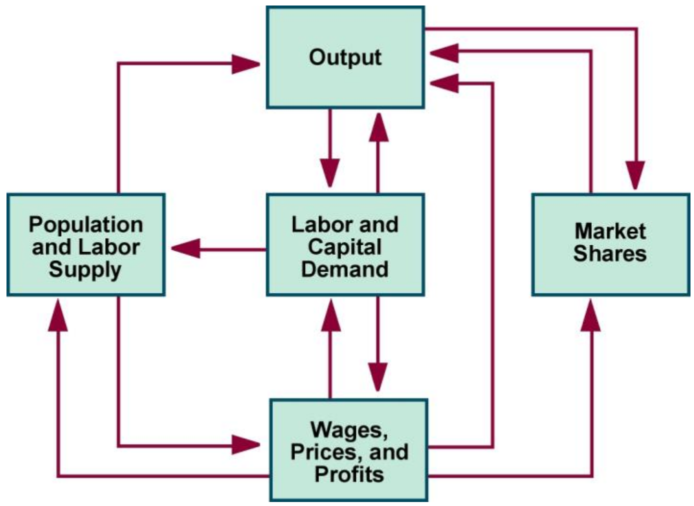


**Figure 2-1: Regional Economic Model, Inc. (REMI), model structure**

In Figure 2-1, The Population and Labor Supply block contains variables that track population levels and migration trends between regions of the country. The Labor and Capital Demand block contains variables that track the factors that affect a firm's decisions about how much product to produce, how many workers to employ, and how much equipment and other capital to acquire. The Market Shares block contains variables that track, by industry, the supply-side and demand-side market shares; that is, the fractions of U.S. production sold to domestic and foreign customers and the fractions of U.S. demand satisfied by domestic production and foreign goods. The bottom block, Wages, Prices, and Profits, contains price-related variables such as the wage rate, the cost of producing goods, the profitability of firms, and the sales prices of goods. All of these variables are used to simulate an economic change or "shock" and to measure the impacts of it.

There are 3 types of economic relationship in the model:

- A technical relationship; for example, how much of the aluminum castings industry's output is used by the automobile industry as an input
- A definitional relationship; for example, what are the national income accounts
- A behavioral relationship; for example, how does consumer demand for cars respond to changes in personal income or automobile price

For example, the arrow pointing from Output down to Labor and Capital Demand represents a technical relationship stating that industry output determines industry employment. The arrow pointing from Output to Market Shares represents definitional relationships stating that changes in output affect the market shares of industries. The arrow pointing from Wages, Prices, and Profits represents behavioral relationships, such as demand curves, stating that changes in prices affect market shares.

Modelers carry out a REMI analysis in 2 steps: first, a baseline forecast is computed, in which there is no change to the economy; and second, an alternative forecast is generated, in which a set of simulation variables model a change in the economy. As illustrated in Figure 2-2, the economic impact of the change in the economy is measured as the differences between the baseline and alternative forecasts. Consider an event, such as PI, that increases income of healthcare workers. One outcome of this income increase is an increase in consumption spending that increases domestic personal disposable income (the income available to workers). The lower, solid line in the figure shows the baseline forecast of personal disposable income over the 1996–2001 period (without the healthcare worker income increase); the upper dashed line shows the alternative forecast of income (with the new income levels). REMI measures the impact of the new exports as the difference between the alternative and baseline forecasts, in this case based on personal disposable income.

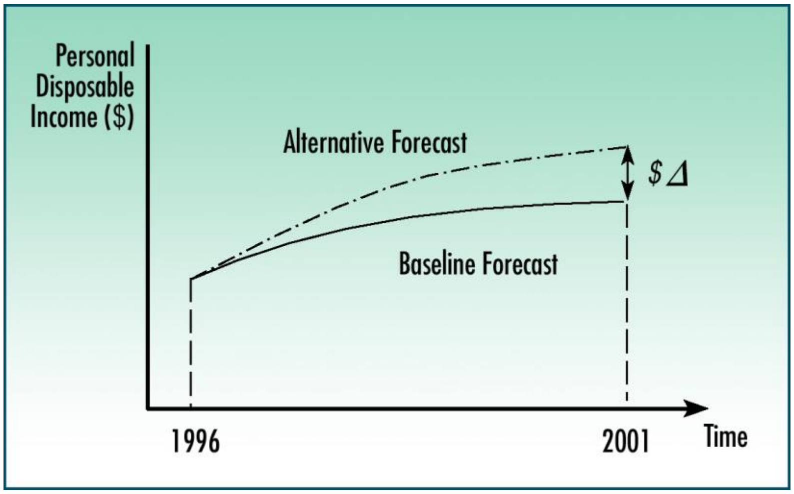


**Figure 2-2: Economic impacts, measured as the difference between alternative forecasts and baseline forecasts**

### *2.2.1 Limitations of Using the Regional Economic Model, Inc. (REMI)*

Whereas a pandemic might only affect a specific geographic area for a period of several weeks to several months, inputs to REMI have to be annualized because the model is developed for annual data. This may mask peak swings in output and consumption that are likely to happen in the event of a pandemic. Because the duration for all the scenarios is less than a year, an annual model would mask or smooth many of the effects that would be seen with a model of higher temporal resolution.

Counterbalancing forces might cause the output of some industries to decline while that of others could increase. REMI does not model the detailed resolution of firm dynamics. For example, poultry farmers might suffer quite dramatically in an avian influenza pandemic, but the beef, pork, and fish producers might benefit. In aggregate, it is unlikely that people would change their eating habits or their allocation of income spent on food; thus, essentially there would be no change.

Capacity constraints could limit increases in output. Increased demand on the health sector could reflect the additional money that would be allocated to medical services, but would not limit the ability of the medical sector to provide for those services. REMI does not model the actual details of whether and how the medical industry could respond to meet the increased demand.

### 2.2.2 Regional Economic Model, Inc. (REMI), Inputs and Assumptions

#### 1.1.1.1 Transformations on Epidemiological Results

NISAC conducted detailed epidemiological modeling for the 6 counties comprising the Los Angeles Basin. These results generated morbidity and mortality data by week during the PI period. This section summarizes the approach taken to translate the epidemiological results, which estimate worker absenteeism for Southern California, by industry, into worker absenteeism categorized by critical infrastructure and industry. This section also discusses how estimates of absenteeism for Southern California were transformed into estimates of absenteeism for the U.S. as a whole and for each state. The process involved the following steps:

- SIC industry codes were mapped to North American Industrial Classification System (NAICS) industries codes, using the mapping provided by the U.S. Bureau of Labor Statistics
- Each set of weekly absentees, initially broken down by SIC industry and then translated into NAICS industry, was assigned to 1 of the 17 critical infrastructures, based on the U.S. Department of Homeland Security (DHS) taxonomy
- Weekly absentees, broken down by critical infrastructure, were aggregated into summaries indicating the weekly number of absentees for each critical infrastructure
- Absentee rates for Southern California were scaled into estimated weekly absentee rates by critical infrastructure, as a whole, using weekly absentee rates for the U.S. Similarly, absentee rates for Southern California were scaled into estimated weekly absentee rates, by critical infrastructure, using weekly absentee rates for each state.
- The estimated weekly absentee rates were applied to estimates of workers by critical infrastructure to obtain estimates of absentees by critical infrastructure for the U.S. as a whole and for each state. The scaling was necessary because the actual absentee rates and the temporal pattern of absenteeism in each state differ from those estimated for Southern California.
- Using similar methods, weekly absentee rates were estimated for the U.S. and for each state, by 2-digit NAICS industries code

NISAC modeled 7 intervention scenarios, representing a variety of potential population response and intervention strategies:

- Baseline
- Fear-based self-isolation (Fear-40)
- TLC
- TLC Lite
- Antiviral treatment and prophylaxis
- Partially effective vaccine (not analyzed in this study)
- Anticipated intervention

For purposes of this economic analysis, the partially effective vaccine scenario was not modeled. Therefore, only 6 scenarios are discussed.

The length of the pandemic varies among scenarios. In the interest of continuity, the normal economic timeframe spans 322 days, but the scenario lengths are Baseline = 189 days, Fear-40 = 231 days, TLC = 322 days, TLC Lite = 245 days, antiviral treatment and prophylaxis = 217 days, and anticipated intervention = 322 days. This accounts for the zeros that occur during the latter weeks of all but the TLC and anticipated intervention scenarios. NISAC did this to facilitate the construction of the spreadsheets.

Summaries of estimated absentee rates for the U.S. under the baseline and 5 alternative scenarios are included in the report "Workforce Participation during an Influenza Pandemic."[45]

#### 1.1.1.2 Mapping from Industries to Critical Infrastructures

The mapping of industries to critical infrastructures uses the infrastructure taxonomy developed by the DHS to determine the critical infrastructure within which to place the absentees reported in the epidemiological results. These are based on taking the epidemiological results, which were given by SIC code, translating the SIC code into the appropriate NAICS industries code, and then assigning the absent workers directly to the critical infrastructure given in the taxonomy. The following summarizes which NAICS industries codes make up each of the critical infrastructures.

- The agricultural and food critical infrastructure is composed of the following industries: agriculture, forestry, fishing, and hunting; manufacturing; wholesale trade; retail trade; transportation and warehousing; accommodation and food services; and public administration
- The banking and finance critical infrastructure includes finance and insurance and public administration
- The chemical and hazardous materials critical infrastructure is represented by the following industries: manufacturing, wholesale trade, transportation and warehousing, other services, and public administration
- The defense industrial base critical infrastructure is represented by utilities and manufacturing
- The energy critical infrastructure is represented by mining, utilities, manufacturing, wholesale trade, retail trade, transportation and warehousing, other services, and public administration
- The emergency services critical infrastructure is represented solely by public administration
- The information critical infrastructure is composed of the following industries: manufacturing, information, finance and insurance, and real estate rental and leasing
- The telecommunications critical infrastructure is composed of information and public administration

[45] Flaim, Silvio J., and Brian K. Edwards, 2006, "Workforce Participation During an Influenza Pandemic," Los Alamos National Laboratory, 11 October

- The postal and shipping critical infrastructure is composed of transportation and warehousing, exclusively
- The health critical infrastructure is composed of the following industries: manufacturing; wholesale trade; retail trade; finance and insurance; professional, scientific, and technical services; educational services; healthcare and social assistance; other services; and public administration
- The transportation critical infrastructure is made up of mining, utilities, wholesale trade, retail trade, transportation and warehousing, real estate and rental and leasing, other services, and public administration
- The water critical infrastructure is composed of utilities, other services, and public administration
- The national monuments and icons critical infrastructure is composed of public administration, exclusively
- The commercial assets critical infrastructure includes manufacturing; retail trade; information; real estate and rental and leasing; professional, scientific, and technical services; administration and support of waste management and remediation services; educational services; arts, entertainment, and recreation; accommodation and food service; other services; and public administration
- The nuclear critical infrastructure is made up of utilities; manufacturing; professional, scientific, and technical services; administration and support of waste management and remediation services; other services; and public administration

There is no representation of the hydroelectric dams as a critical infrastructure among the 2-digit NAICS industries codes.

NISAC transformed the absenteeism data derived from the process just described for direct entry as REMI input parameters. NISAC treated absenteeism as the result of 2 phenomena: true absenteeism wherein workers were absent from their jobs, and a reduction of productivity due to absenteeism. The smaller of the 2 phenomena is a direct reduction in employment, which is approximately one-third of the overall reduction in the workforce. The second input is a reduction in labor productivity, which accounts for the remaining two-thirds of the estimated number of workers absent. NISAC made the division to account for the absent employees who would not necessarily lose an income if they remained home from work for some time. This division implicitly does not account for the likely increases in labor productivity that could occur among the remaining workers in the event of a high rate of absenteeism.

#### 1.1.1.3 Separating Morbidity and Mortality

Because the plan was to treat mortality directly in the REMI population dynamics model (by reducing the survival rate), NISAC needed to obtain or estimate mortality separately from morbidity. In other words, NISAC needed to determine the number of deceased individuals for each scenario from the total of morbidity and mortality. Because REMI can directly model effects of increased deaths, it is necessary to separate the absenteeism due to deaths from the other absenteeism reasons. This is not straightforward because deaths are reported separately only at the population-wide or aggregate-age-group levels, not by employed members of the workforce. So, NISAC implemented methods for each scenario to approximate the number dead, by industry, and the period during which the deaths occur. NISAC then subtracted the deaths from the total absent population. Differences in the scenarios required somewhat different approaches to separating the number of deceased from the total. Table 2-1 contains a summary of the methods and assumptions pertinent to each scenario.

**Table 2-1: Method and assumptions used to separate mortality and mortality**

| Scenario | Method | Assumptions Required |
|---|---|---|
| Baseline | To determine weeks when deaths occur:<br>• Calculate percent of total mortality by week<br>• Apply fraction obtained in the first bullet to industry data | • Number of deceased contained in last week (confirmed)<br>• % of mortality by week for employed is same as % of mortality for total population<br>• % deceased by week is constant across industries |
| Fear-based self-isolation (Fear-40) | Same as Baseline | Same as Baseline |
| TLC | • Use mortality for total population as mortality by industry<br>• Allocation to weeks same as for Baseline | • Mortality by industry proportional to mortality in total population |
| TLC Lite | Same as TLC | Same as TLC |
| Antiviral | Same as Baseline | Same as Baseline |
| Anticipated intervention | Same as TLC | Same as TLC |

Note: TLC = targeted layered containment

Subsequent to implementing the methods listed in Table 2-1 to estimate total national mortality and running the models based on calculated mortality, NISAC was able to obtain total mortality directly from the epidemiological modeling results. This provided the opportunity to compare NISAC's mortality estimates with an independent source. The comparison is contained in Table 2-2. Calculated mortality estimates were higher than direct summation from the epidemiological simulation system (EPISimS) model for 3 of the 6 scenarios (baseline, antiviral, and Fear-40) and lower than the EPISimS results for the remaining 3 scenarios (TLC Lite, anticipated intervention, and TLC).

**Table 2-2: Comparison of calculated mortality and epidemiological (EPI) model mortality**

| Scenario Name | Calculated Estimate | Direct Summation |
|---|---|---|
| Baseline | 1,787,258 | 1,478,224 |
| Antiviral | 1,557,832 | 1,388,120 |
| Fear-based Self-Isolation (Fear-40) | 1,431,624 | 1,208,813 |
| TLC Lite | 198,876 | 547,964 |
| Anticipated Intervention | 18,048 | 51,640 |
| TLC | 10,156 | 25,545 |

Note: TLC = targeted layered containment

It is not clear why these differences occurred. In future studies, REMI simulations will be re-run with the EPISimS mortality calculations. For the 10-year results, the rankings might change or, at least, the differences between the scenarios would likely change.

### 2.2.3 Consumer Response Literature

Many studies estimating an economic impact from an avian influenza pandemic discuss the possibility of shifts in consumer spending. In a recent presentation given at the Brookings Institution in October 2006, Warwick McKibbin explained that, for his results, "in the minor scenarios, it is actually the human response rather than the labor changes that drive the economic changes."[46] Indeed, almost all recent studies assume fairly significant behavioral shifts on the part of consumers.

Table 2-3 summarizes the reductions in GDP caused by consumer spending reductions for various pandemic studies. These studies are not entirely comparable as they have used different approaches, models, and assumptions regarding the nature of the disease. However, the summary does indicate that most researchers assumed a consumer spending reduction or reallocation, which led to a reduction in GDP.

[46] McKibbin and Sidorenko, 2006 (See Footnote 26)

**Table 2-3: Gross domestic product (GDP) losses attributable to consumer spending reductions**

| Pandemic Influenza Economic Studies | Scope | Annualized reduction of GDP (%) | |
|---|---|---|---|
| | | Low | High |
| Asian Development Bank | Asia (excl. Japan) | 1.15 | 6.5 |
| Lowy/Brookings Institution[a] | U.S. | 0.01 | 0.8 |
| BMO-Nesbitt Burns | Global | 0.7 | 2.3 |
| Congressional Budget[b] | U.S. | 0.5 | 2 |
| Douglas, Szeto, and Buckle[c] | New Zealand | 3.6 | 4.5 |
| James and Sargent | Canada | 0.4 | 0.4 |
| Jonug and Kroger | Europe | 0.5 | |
| Kennedy, Thompson, and Vujanovic | Australia | 1.6 | |
| NISAC/CIPDSS (Baseline) | U.S. | 0.2 | 2.2 |

Notes:
[a]Confined to agriculture, manufacturing, and services
[b]Actual amount varies by industry
[c]One scenario was conducted; the range represents the industry range
BMO = Bank of Montreal, CIPDSS = Critical Infrastructure Protection Decision Support System, GDP = gross domestic product, NISAC = National Infrastructure Simulation and Analysis Center

Other analysts justify an expected consumer response by explaining that individuals would “avoid infection by minimizing face-to-face interactions, resulting in temporary reductions in consumer expenditures for services such as tourism, mass transportation, retail sales, hotels and restaurants.” Most studies rely, in part, on evidence from SARS when determining the magnitude of behavioral changes. In the Forster and Tang analysis of SARS, they describe the outbreak as a “crisis of fear” wherein “the infrastructure of Hong Kong was fully functional but the normal activities of citizens were severely curtailed by fear of infection.”[47]

Bovine Spongiform Encephalopathy (BSE), or Mad Cow Disease, hurricanes, and the 9-11 events in the U.S. also provide evidence of a quantifiable change in consumer behavior. In a study on consumer reactions to BSE, the authors note that “behavior of consumers in a crisis situation is not always consistent with the true level of risk they face.”[48] Pennings and others collected survey data from shoppers in the U.S., Germany, and the Netherlands.[49] The authors were focused on why consumers change their behavior and whether marketers or policymakers would have any influence to contain the reaction. They decoupled consumers’ choices on beef consumption into differences among risk perceptions and risk attitudes. If the probability of an event is accurately known, then

[47] Forster, P. W., and Y. Tang, 2005, "The Role of Online Shopping and Fulfillment in the Hong Kong SARS Crisis," *System Sciences*, 2005, proceedings for the 38th Annual Institute of Electrical and Electronics Engineers Hawaii International Conference, available online at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1385795

[48] Pennings, Joost M. E., Brian Wansink, and Matthew T. G. Meulenberg, 2002, “A note on modeling consumer reactions to a crisis: The case of the mad cow disease,” *International Journal of Research in Marketing* **19**:2 pp. 91–100, March

[49] Ibid.

risk perception is likely to have a greater influence on consumer behavior. For this NISAC PI study, analysts assumed that public policy and marketers would have the opportunity to influence decisions through providing clear information regarding the risks. However, if risk attitudes dominate decisions, there is little that can be done to change consumer behavior, other than eliminate the risk. Another study on BSE found evidence that scientists had a greater avoidance of beef products following the BSE outbreak than the public at large, suggesting that a more informed consumer would be more risk adverse.[50]

A study by the Food Policy Institute in 2003 analyzed economic factors involved with agro-terrorism. While noting the importance of risk, they also noted that there is evidence that eliminating all sources of uncertainty would not be sufficient to regain consumer confidence and return demand to initial levels. The authors commented on the potential limited ability to generalize this statement to non-food products because of the strong link that is often made between eating a food product and becoming sick. Researchers studied a case of decline in demand for raspberries after a Cyclosporiasis outbreak was discovered in Guatemala. Despite many controls placed by Guatemala and the U.S., the perceived risk outstripped the benefit even when raspberry prices were heavily discounted. By 2000, only 77 out of 369 Guatemalan raspberry farms remained.[51]

This evidence suggests that consumers do change their behavior in response to changes in their perceived risks. However, the underlying assumptions concerning the magnitude and extent of behavioral changes are by no means certain, especially when trying to tie the fear that people would have during a pandemic to hypothetical changes that people make in actual purchases and work habits. Few studies have attempted to quantify the assumptions of consumer behavior with non-survey data.

One exception is the recent study by Sargent and James, who took a thorough look at the available data from SARS, the 1918 pandemic, and other less-severe pandemics. While the authors acknowledged, without a doubt, that people must have been scared during these outbreaks, they found little evidence to suggest that consumers dramatically changed their spending habits. They found that, for the1918 pandemic, there was little effect on retail sales, external trade, financial markets, or bankruptcies. Other researchers support the Sargent and James findings that humans are exceptional at adapting to extreme circumstances. The positive responses that must occur after the negative effect are likely to even outweigh the initial shock. They criticize research that predicts large negative impacts because the analysis “rarely considers the response to disaster impacts as part of the same event.”

Ultimately, the wide range of opinions regarding possible consumer behavior changes illustrates the uncertainty that prevails with anticipating human response. There is sufficient reason to believe a behavioral adjustment would occur in the event of a pandemic, but there is also evidence that the behavioral adjustment would not be as large as initially anticipated. Based on evidence uncovered in the literature, NISAC assumed, for purposes of these simulations, that consumers would change expenditures in the categories and magnitudes shown in Table 2-4 on an annualized basis. NISAC acknowledges the possibility of a zero response of consumer spending and may investigate this in future studies.

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[50] Ishida, Takashi, Noriko Ishikawa, and Motosugu Fukushige, 2006, “Impact of BSE and Bird Flu on Consumer’s Meat Demand in Japan,” Osaka School of International Public Policy, Discussion Paper 06-01, January

[51] Calvin. L., W. Foster, L. Solorzano, J. D. Mooney, L. Flores, and V. Barrios, 2002, “Response to a Food Safety Problem in Produce: A Case Study of a Cyclosporiasis Outbreak,” *Global Food Trade and Consumer Demand for Quality*, B. Krissoff, M. Bohman, and J. A. Caswell, eds, Kluwer Academic/Plenum Publishers, New York

### Table 2-4: Assumed Reductions in Consumer Expenditure

| Category of Consumer Spending | Percent Change in Expenditures | |
|---|---|---|
| | Lower Estimate | Upper Estimate |
| Vehicles and parts | -4 | -8 |
| Computers and furniture | -4 | -8 |
| Other durables | -4 | -8 |
| Clothing and shoes | -4 | -8 |
| Transportation | -4 | -8 |
| Other services | -4 | -8 |
| Medical care | +4 | +9 |

## 2.3 Data Limitations

NISAC made assumptions, and limitations remain in the effort to obtain absenteeism by industry. The main limitation at the time the economic analysis was completed was the extrapolation of the detailed epidemiological results of the Southern California region to all states. This implies the percent of workers who are dead or absent across the nation would be the same for all areas and would vary by industry, as indicated in the Southern California region.

Another notable factor that NISAC did not include in the economic analysis is the cost of implementing these different response strategies. Presumably, the baseline would have the least cost, but NISAC made no effort to estimate the costs incurred by the government in the process of formulating, implementing, and enforcing the provisions that partially defined each of the scenarios the team examined. Furthermore, NISAC did not include a possible monetary response from the Federal Reserve among the adopted assumptions. The policy analysis did not include investigating the possibly large costs of implementing any of the scenarios.

The supply and demand for imports and exports might be affected during a pandemic. Products imported from countries hit harder by the pandemic likely would be subjected to delays, or orders might be entirely canceled. NISAC captured some of the effect of slowed or cancelled imports and exports in the model through the assumptions regarding the magnitude of changes in consumer spending patterns. However, the team did not consider, in these results, the impact of increased inspection of goods and people entering the country.

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# 3. Results of Economic Simulations

## 3.1 National Economic Impact Summary Results

To estimate the impacts of a pandemic, NISAC used 2 independent models, NISAC REMI and Critical Infrastructure Protection Decision Support System (CIPDSS) National Economic, to examine 3 distinct economic impacts or "shocks" to the economy:

- Supply shock: a temporary reduction in the working population due to own illness, illness of family members, fear of the threat of illness, or staying at home to care for children
- Consumer spending reduction: a temporary reduction and reallocation of consumption of particular goods and services
- Population shock: a permanent loss of population and the workforce due to mortality

NISAC also assumed that the supply shock and consumer spending reductions resulting from each scenario would occur in the first year of the pandemic and that the population shocks would cause structural adjustments that would last indefinitely.

A total of 6 sets of macroeconomic simulations, 1 for each of the 6 different pandemic scenarios, were conducted using 2 models: the CIPDSS National Economic model and the NISAC REMI model.[52] The CIPDSS model captures the daily effect of worker absenteeism on national output (but does not include consumer spending reductions), while the NISAC model captures, on an annual basis, the sectoral, regional, and temporal response of the national economy. Both models provide the same rank ordering of all the scenarios based on year 1 lost GDP.

Table 3-1 lists the economic impacts of each scenario, measured as changes in U.S. GDP in year 1 and over the 10-year period based on the NISAC REMI model runs. The impacts listed for each scenario reflect variations in the consumer spending reduction, from a 4-percent to an 8-percent decrease in demand for selected consumer spending sectors.

As indicated by the bold text in Table 3-1, the TLC Lite scenario would have the lowest economic impacts for year 1, and the TLC scenario would have the lowest economic impacts over the long-term (years 1–10). In year 1, the baseline scenario economic impacts would be between $110 and $320 billion (1 percent to 3 percent of the U.S. GDP), depending on the assumption about consumer demand.

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[52] The NISAC REMI model is a 51-region (50 states plus Washington, D.C.), 66-sector, dynamic-econometric model of the U.S. economy.

**Table 3-1: Losses in national gross domestic product (GDP) by scenario for year 1 and years 1–10**

| Pandemic Scenario | Year 1 (2000 Constant Dollars) | Cumulative Years 1–10 (2000 Constant Dollars) |
|---|---|---|
| Baseline | | |
| Level ($billion) | ($110 to $320) | ($740 to $1,000) |
| % GDP | (1.0% to 3.0%) | (0.6% to 0.8%) |
| Fear-based Self-Isolation (Fear-40) | | |
| Level ($billion) | ($130 to $370) | ($710 to $960) |
| % GDP | (1.2% to 3.5%) | (0.5% to 0.7%) |
| Antiviral | | |
| Level ($billion) | ($110 to $310) | ($650 to $880) |
| % GDP | (1.0% to 2.9%) | (0.5% to 0.7%) |
| Anticipated Intervention | | |
| Level ($billion) | ($130 to $370) | ($390 to $530) |
| % GDP | (1.2% to 3.5%) | (0.3% to 0.4%) |
| TLC Lite | | |
| Level ($billion) | **($85 to $250)** | ($280 to $380) |
| % GDP | **(0.8% to 2.3%)** | (0.2% to 0.3%) |
| TLC | | |
| Level ($billion) | ($95 to $280) | **($270 to $370)** |
| % GDP | (0.9% to 2.6%) | **(0.2% to 0.3%)** |

Note: GDP = gross domestic product, TLC = targeted layered containment

The summary of results contained in Table 3-1 is based on dollar and percentage changes to GDP, comparing the 6 different scenarios with the REMI control simulation. Many other metric variables can be selected to display similar results. For example, Table 3-2 shows the results of the 6 simulations in terms of employment losses and percentage of employment losses. The ranking of scenarios using employment losses over the 10-year period is exactly the same as the 10-year ranking by GDP losses. GDP and employment are the 2 most commonly reported measures of economic impact and are 2 independent measures of the same variable; that is, losses (or gains, as the case may be) of economic output.

### Table 3-2: Employment losses by scenario

| Pandemic Scenario | Year 1 (2000 Constant Dollars) | Cumulative Years 1–10 (2000 Constant Dollars) |
|---|---|---|
| Baseline | | |
| Level (000) | (1,549 to 5,063) | (9,971 to 13,932) |
| % EMP | (0.9% to 3%) | (0.6% to 0.8%) |
| Fear-based Self-Isolation (Fear-40) | | |
| Level (000) | (1,574 to 5,144) | (8,983 to 12,551) |
| % EMP | (0.9% to 3.1%) | (0.5% to 0.7%) |
| Antiviral | | |
| Level (000) | (1,496 to 4,891) | (8,808 to 12,307) |
| % EMP | (0.9% to 2.9%) | (0.5% to 0.7%) |
| Anticipated Intervention | | |
| Level (000) | (1,514 to 4,947) | (4,475 to 6,253) |
| % EMP | (0.9% to 3.0%) | (0.3% to 0.4%) |
| TLC Lite | | |
| Level (000) | (1,191 to 3,892) | (3,815 to 5,331) |
| % EMP | (0.7% to 2.3%) | (0.2% to 0.3%) |
| TLC | | |
| Level (000) | (1,285 to 4,200) | (3,566 to 4,983) |
| % EMP | (0.8% to 2.5%) | (0.2% to 0.3%) |

Note: EMP = employment, TLC = targeted layered containment

There is relatively little difference between the scenarios in terms of short-term economic impacts for a given assumption regarding the demand shock. The real differences are in the long-term impacts and they are between 2 groups of scenarios. The higher economic impacts are for those scenarios that have high mortality rates (Baseline, Fear-40, and Antiviral) with relatively little difference for a given assumption regarding the demand shock.

### 3.1.1 Sector Impacts

The component economic shocks (population, supply, and demand) would have different impacts across economic sectors. As shown by Figure 3-1, the hardest-hit sectors would be manufacturing, which would lose an estimated $95 billion in output, followed by finance and insurance ($40 billion) and retail trade ($32 billion). Most of the manufacturing losses are attributed to the consumer spending reduction, followed by the supply and population shocks.

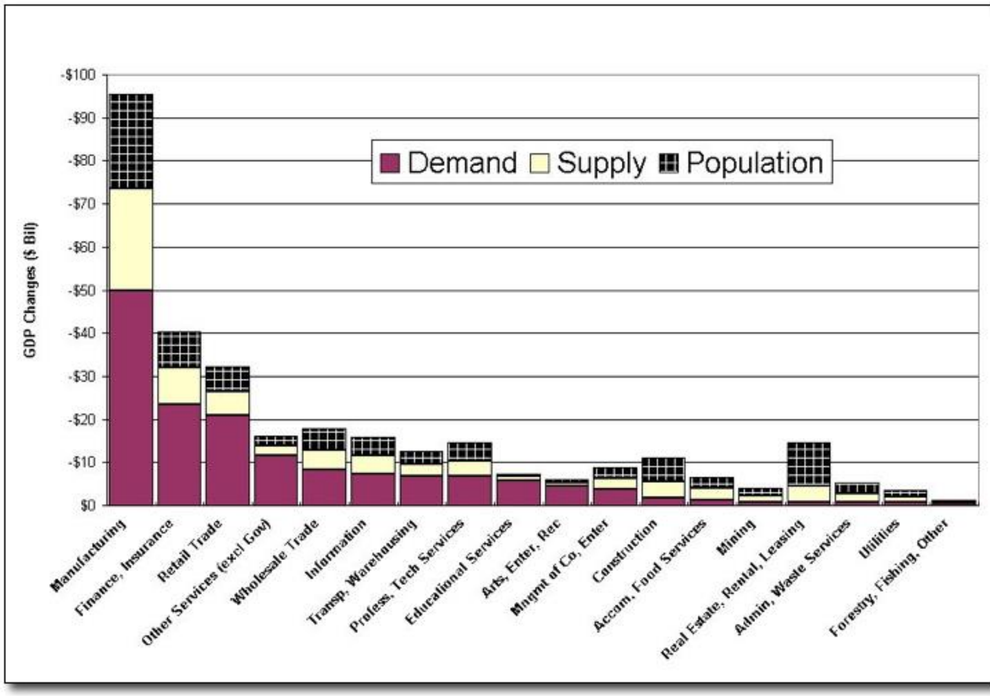


**Figure 3-1: Average gross domestic product (GDP) losses, by type of shock and industry: year 1, baseline scenario**

Among the 3 types of shock (supply, demand, and population), demand would have a strong impact across many of the sectors; for example, demand would be specifically reduced in a number of the manufacturing sectors that produce final goods for consumers (the direct economic impacts). Indirectly, other sectors that provide goods and services to manufacturing would see lost sales (the indirect impacts), and the lost manufacturing wages would reduce purchases across consumer spending categories (the induced impacts).

The effects of the absenteeism-based supply shock would be greatest in manufacturing where many jobs exist, followed by finance and insurance, retail trade, wholesale trade, real estate, and construction. Unlike the consumer spending reduction, the supply shock would be distributed across sectors based on employment levels, so the supply shock-based impacts in and between sectors would be direct, indirect, and induced. The population effect would likewise be strongest in manufacturing, followed by real estate and finance and insurance, reflecting the combined effects of large numbers of employees in manufacturing and labor intensity in the finance and insurance and real estate sectors.

### *3.1.2 Regional Impacts*

Similar to sector-specific impacts, the year 1 impacts would vary regionally across the country. Figure 3-2 shows the percent change in GDP for each state in year 1. California, Michigan, Indiana, New York, and some New England states would bear the brunt of the GDP percentage reductions.

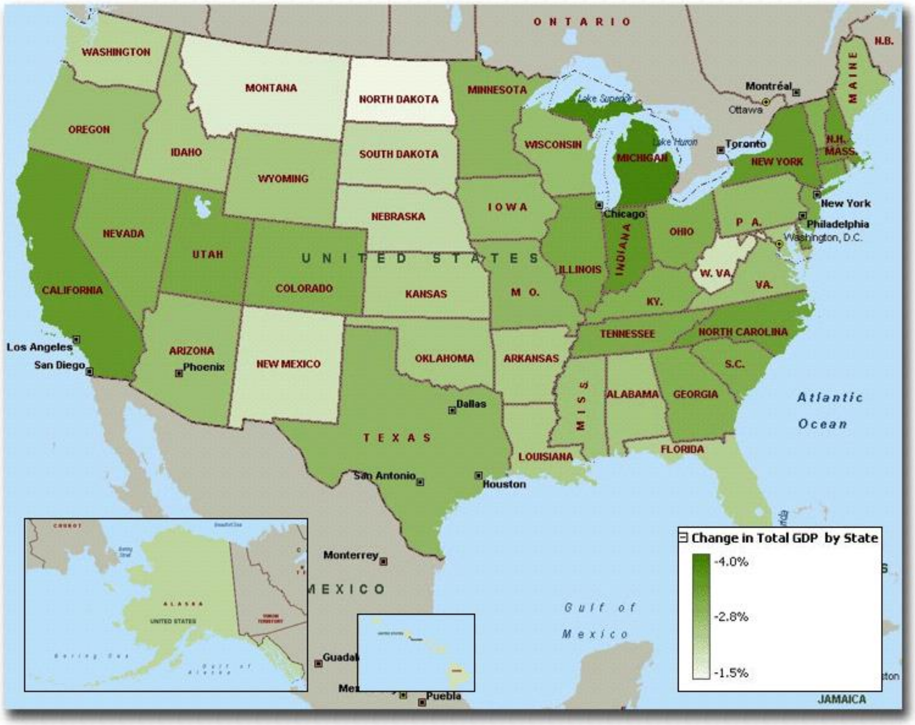


**Figure 3-2: Percent changes in gross domestic product (GDP) by state: baseline scenario, year 1**

GDP losses correlate with the levels of population and manufacturing activity; for example, the large impacts in California and Michigan likely would be due to the combined effects of the population shock and the consumer spending reduction. Both states have significant manufacturing sectors and would experience significant losses of demand for consumer durables. Other highly populated states, such as Florida, would experience lower-than-average impacts due to lower-than-average manufacturing activity.

## 3.2 Factor Analysis

To supplement the analysis of each scenario, NISAC also performed 5-year simulations using the 6 scenario assumptions for each shock factor (absenteeism, mortality, and consumer spending), employed independently in each successive simulation. The single-factor results for consumer spending reductions, mortality, and supply shock were each generated independently. For the baseline scenario, NISAC also performed simulations for 4-percent consumer spending reductions in selected categories of consumer spending. All other factor analysis results employed the assumption of an 8-percent reduction in consumer spending. Results for each of the simulations are summarized in Figures 3-3 through 3-6.

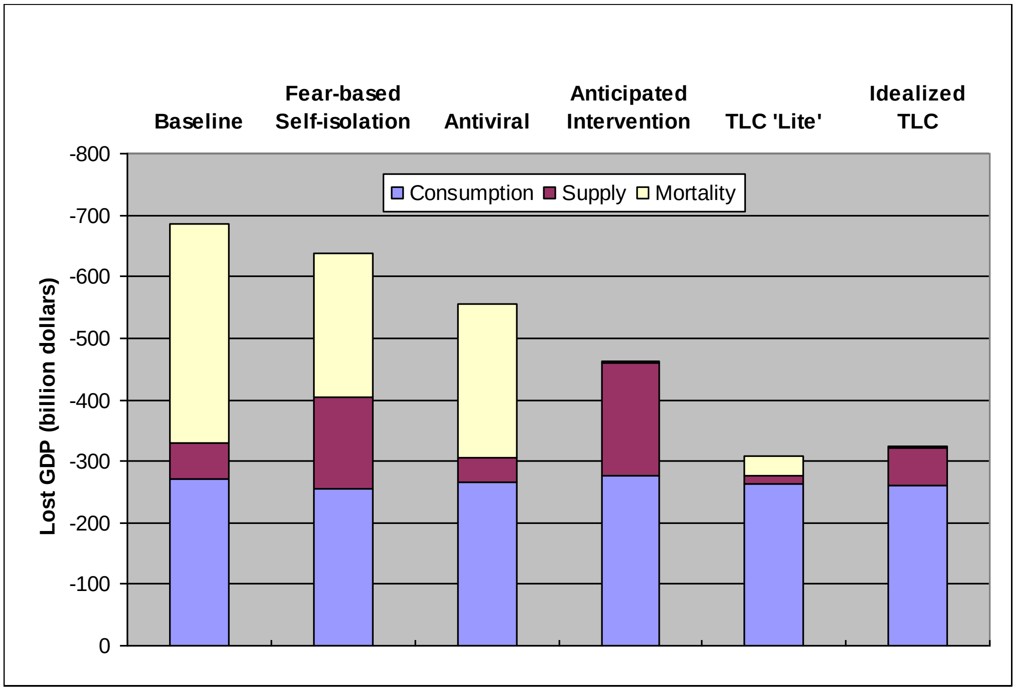


**Figure 3-3: 5-year cumulative gross domestic product (GDP) losses for 6 scenarios**

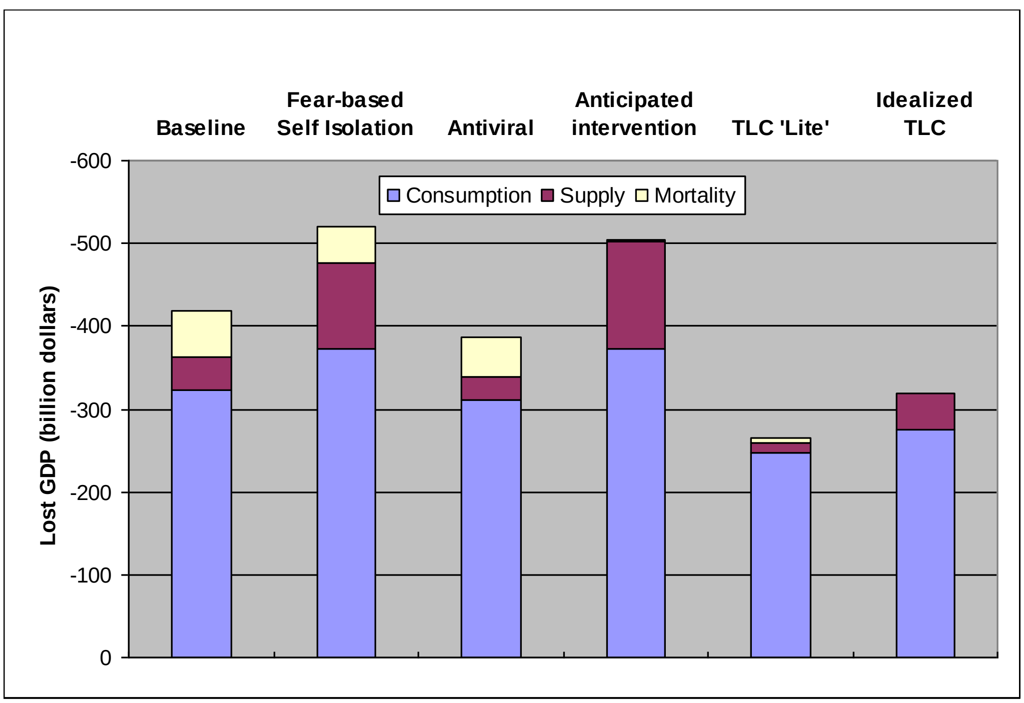


**Figure 3-4: Year 1 gross domestic product (GDP) losses for 6 scenarios**

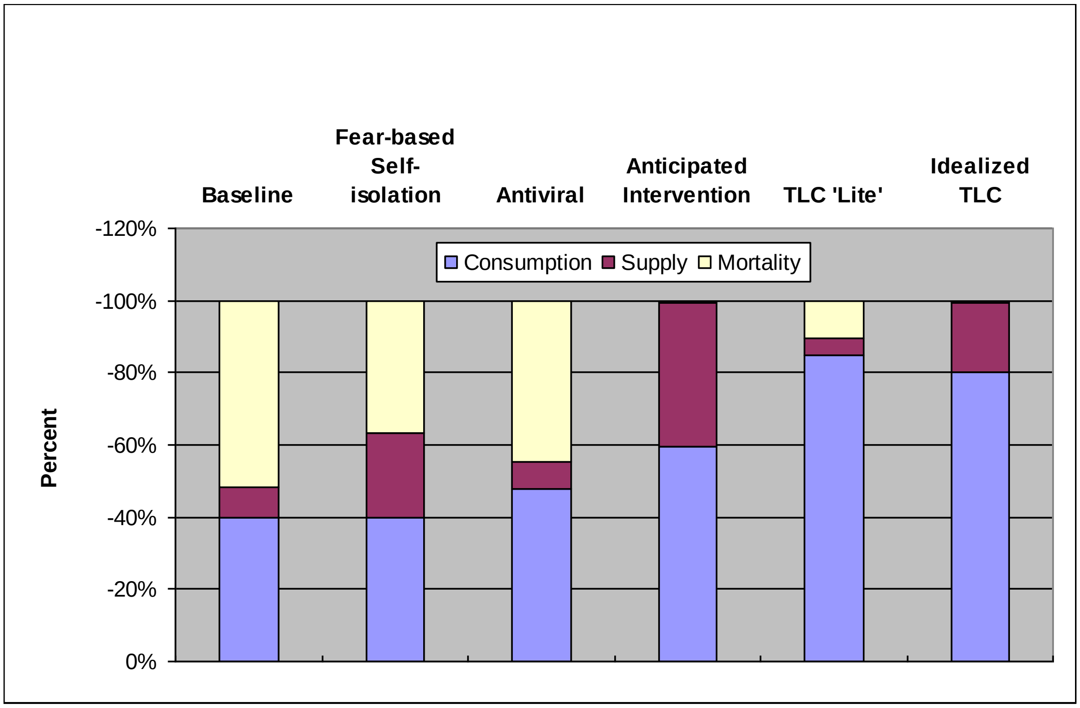


**Figure 3-5: 5-year cumulative percentage gross domestic product (GDP) losses for 6 scenarios**

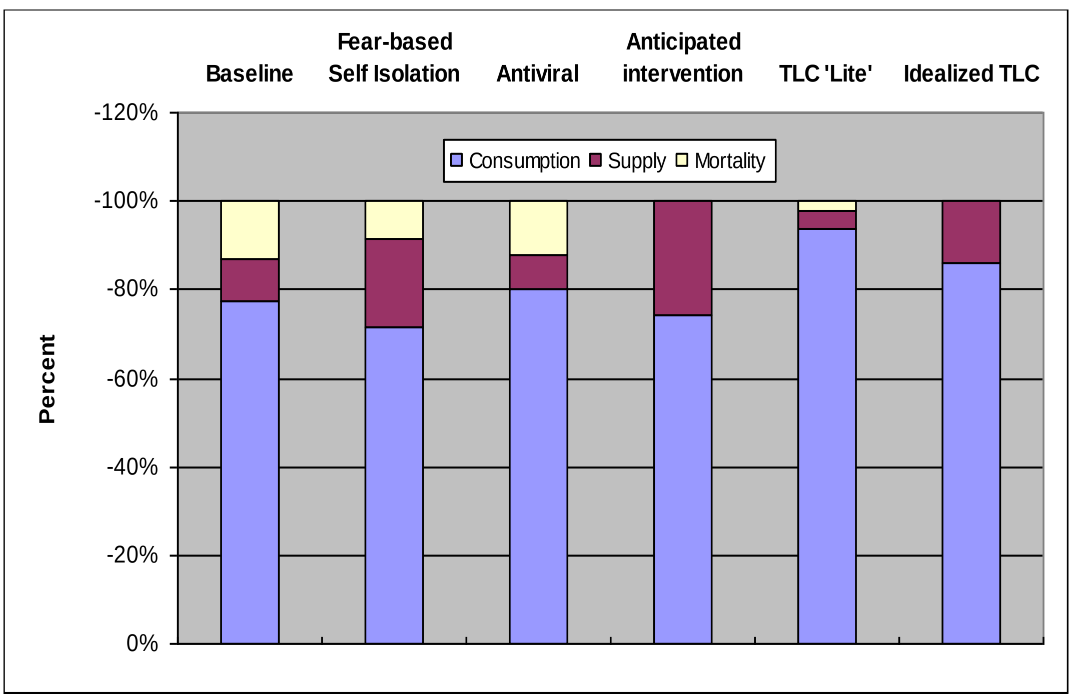


**Figure 3-6: Year 1 percentage gross domestic product (GDP) losses for 6 scenarios**

Figure 3-3 shows cumulative 5-year GDP losses for each scenario with the scenarios ranked left-to-right in descending order of total GDP losses (for years 1–10). Notice that in the Baseline, Fear-40, and Antiviral scenarios, mortality dominates, or at least is one of the most significant contributors to GDP losses. For the year 1 result of these same scenarios shown in Figure 3-4, consumer spending dominates as a GDP loss factor. Absenteeism (supply shock) has a lesser effect on GDP losses. Notice also that the first-year consumer spending reductions (Figure 3-4), though the same percentage in all scenarios, have a differential impact in each scenario. The dynamics of REMI explain this result. The scenarios with the largest supply shock also have the highest consumer spending impact. This is due to the assumption that absent workers (absent for any reason) are not being paid; therefore, their consumption must decline. Thus, the consumer spending shock is positively related to the total number of absent workers, and the consumer spending decline of this group is over and above the 8-percent consumer spending reduction in selected categories.[53]

A final observation about the bar charts in Figures 3-3 and 3-4 is that the ranking of the scenarios by GDP losses is different for 5 years than for 10 years. The lesson from this observation is that, for scenarios with multi-year economic impacts, a dynamic analysis is warranted. The mortality effect is essentially forever; therefore, as more years are included in the analysis, the GDP losses mount and increasingly dominate as a factor explaining the total GDP losses. A more complete intertemporal analysis would run the results out for a longer period—say 30 years—and discount the results to a present value using an acceptable discount rate. This was deemed beyond the scope of the present analysis.

The percentage representation of results, shown in Figures 3-5 and 3-6, supports many of the same conclusions as the results in dollar terms shown in Figures 3-3 and 3-4. For the first year, the consumer spending reduction dominates, comprising over 70 percent of total GDP losses and, for 2 scenarios, over 80 percent. For the Baseline, Fear-40, and Antiviral scenarios, the percentage contribution of absenteeism is about the same in both charts. However, for the Anticipated Intervention and TLC scenarios, the absenteeism supply shock percentage increases over the 5 years as absenteeism remains a factor beyond the first year.

NISAC has documented the controversy concerning the existence and magnitude of a potential consumer response to a pandemic. Few historical examples are available from which to draw data, and there is some debate about extending other more recent events to a pandemic situation. In this analysis, changes in consumption patterns would be the largest first-year change, but that effect would dissipate after the first year. This seems reasonable because it is unlikely that a PI would permanently change consumption patterns. Table 3-3 shows the percentage effect of consumer spending reductions on both GDP and employment for the 5-year simulation of the baseline case.

**Table 3-3: Percentage effect of consumer spending on gross domestic product (GDP) and employment**

| | Outbreak | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| GDP | -2.2% | -0.1% | -0.1% | -0.1% | -0.1% |
| Employment | -2.3% | 0.0% | 0.0% | -0.1% | 0.0% |

Note: GDP = gross domestic product

[53] It is interesting to note that had NISAC assumed a nonexistent consumer spending response, this phenomenon would not have been observed.

The lasting impact and the component that would dwarf all other impacts over the long-run is the lost output resulting from the number of people who would die in the pandemic. The economy would stay at a lower level of output for the duration of the scenario and beyond as this would be a permanent effect from which the economy would never recover. Because of the constructs of the REMI model, the growth rate would always converge to the long-term growth path, but actual output levels would be lower due to the loss in productive assets (human capital). Thus, when modeled, the population shock would only affect the levels, not the growth rate of the economy. However, there is some debate among economists and demographers as to the long-term impacts of a population reduction on growth trends.

The supply-side impacts of a pandemic are input in 2 components in REMI. The smaller is a direct reduction in employment, which is approximately one-third of the overall reduction in the workforce. The second input is a reduction in labor productivity, which accounts for the remaining two-thirds of the estimated number of workers absent. NISAC made the division to account for the absent employees who would not necessarily lose an income if they remained home from work for some time. This division implicitly does not account for the likely increases in labor productivity that could occur among the remaining workers because of a high rate of absenteeism. Table 3-4 is a breakdown of the impacts.

**Table 3-4: Supply-side percent change in gross domestic product (GDP) for productivity and employment components**

| | Outbreak | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Productivity effect | -0.38% | -0.07% | -0.04% | -0.02% | -0.02% |
| Employment effect | -0.04% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Combined supply shock** | **-0.42%** | **-0.07%** | **-0.04%** | **-0.02%** | **-0.02%** |

## 3.3 Sensitivity Analysis

In addition to factor analysis, NISAC conducted sensitivity runs to explore the impact of some input assumptions. In 1 test, NISAC included more digits in the input file to test for sensitivity to rounding or to determine the benefit of additional resolution. This had very little effect on the results; it indicates that the additional level of detail does not add much resolution to the findings. NISAC conducted another test to examine the importance of variation in absenteeism across industry. The team conducted this test by holding absenteeism constant at the industry average. These results support the conclusion that the differences in absenteeism, by industry, smoothed over a year, are not large and do not add to the overall and industry-level results.

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