Globalization and Disease:
The Case of SARS*

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Abstract

The purpose of this paper is to provide an assessment of the global economic impacts of severe acute respiratory syndrome (SARS) as well as to provide a more comprehensive approach to estimating the global consequences of major disease outbreaks. Our empirical estimates of the economic effects of the SARS epidemic are based on a global model called the G-Cubed (Asia Pacific) model. Most previous studies on the economic effects of epidemics focus on the disease-associated medical costs or forgone incomes resulting from disease-related morbidity and mortality, but the most significant real costs of SARS have been generated by changes in spending behavior by households and firms in affected countries. This study estimates the cost of the SARS outbreak by focusing on the impacts on consumption and investment behavior through changes in the cost and risk of doing business. Through increased economic interdependence, these changes in behavior have wide-ranging general equilibrium consequences for the world economy that can lead to economic losses well in excess of the traditional estimates of the cost of disease.

1. Introduction

Severe acute respiratory syndrome (SARS) has put the world on alert. The virus appears to be highly contagious and is fatal for about 10 percent of patients. In the 6 months after the first outbreak in the Chinese province of Guangdong in November 2002, SARS spread to at least 28 countries, including Australia, Brazil, Canada, South Africa, Spain, and the United States. As of 14 July 2003, the number of probable SARS cases had reached 8,437 worldwide (table 1). By the apparent end of the outbreak in July 2003, the death toll had reached 813, including 348 in China and 298 in Hong Kong.

Scientists do not know all the details about the coronavirus that causes SARS. The precise mechanism by which this atypical pneumonia is spread is still unclear. Many countries successfully contained the SARS outbreak and local transmission, but the disease might recur in 2004.[1] Experts predict that the likelihood of discovering a vaccine or treatment for SARS in the foreseeable future is very low.

The purpose of this paper is to provide a preliminary assessment of the global economic impacts of SARS. We update our estimates from an earlier version of this paper, dated May 2003, with final information on the number of SARS cases and the knowledge that the SARS epidemic lasted approximately 6 months rather than the full year originally assumed. Our empirical estimates of the economic effects of the SARS epidemic are based on a global model called the G-Cubed (Asia Pacific) model. Most previous studies of the economic effects of epidemics focus on economic costs involving the disease-associated medical costs or forgone incomes resulting from disease-related morbidity and mortality. However, the direct consequences of the SARS epidemic in terms of medical expenditures or demographic effects seem to be rather small, particularly when compared with those of other major epidemics such as HIV/AIDS or malaria. A few recent studies, such as Chou, Kuo, and Peng (this issue), Siu and Wong (this issue), and Hai et al. (this issue), provide some estimates for the economic effects of SARS on individual Asian countries such as China, Hong Kong, and Taiwan. These studies focus mainly on assessing the damages caused by SARS in affected industries, such as tourism and the retail service sector.

Calculating the number of canceled tourist trips and the decline in retail trade, however, is not sufficient to provide a full picture of the impact of SARS, because there

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1 See Hanna and Huang (this issue) and the World Health Organization's SARS Web site (www.who.int/csr/sars/en/).

Table 1. Cumulative number of reported probable cases of SARS, as of 11 July 2003

Country	Cumulative number of cases[a]	Number of deaths	Number recovered[b]	Date last probable case reported	Date for which cumulative number of cases is current
Australia	5	0	5	12 May 2003	27 June 2003
Brazil	1	0	1	9 June 2003	1 July 2003
Canada	250	38	194	9 July 2003	10 July 2003
China	5,327	348	4,941	25 June 2003	11 July 2003
China, Hong Kong	1,755	298	1,433	11 June 2003	11 July 2003
China, Macao	1	0	1	21 May 2003	10 July 2003
China, Taiwan	671	84	507	19 June 2003	11 July 2003
Colombia	1	0	1	5 May 2003	5 May 2003
Finland	1	0	1	7 May2003	20 May 2003
France	7	1	6	9 May 2003	11 July 2003
Germany	10	0	9	4 June 2003	23 June 2003
India	3	0	3	13 May 2003	14 May 2003
Indonesia	2	0	2	23 April 2003	19 June 2003
Italy	4	0	4	29 April 2003	8 July 2003
Kuwait	1	0	1	9 April 2003	20 April 2003
Malaysia	5	2	3	20 May 2003	4 July 2003
Mongolia	9	0	9	6 May 2003	2 June 2003
New Zealand	1	0	1	30 April 2003	25 June 2003
Philippines	14	2	12	15 May 2003	11 July 2003
Republic of Ireland	1	0	1	21 March 2003	12 June 2003
Republic of Korea	3	0	3	14 May 2003	2 July 2003
Romania	1	0	1	27 March 2003	22 April 2003
Russia	206	32	172	18 May 2003	7 July 2003
Singapore	1	0	0	31 May 2003	31 May 2003
South Africa	1	1	0	9 April 2003	3 May 2003
Spain	1	0	1	2 April 2003	5 June 2003
Sweden	3	0	3	18 April 2003	13 May 2003
Switzerland	1	0	1	17 March 2003	16 May 2003
Thailand	9	2	7	7 June 2003	1 July 2003
United Kingdom	4	0	4	29 April 2003	30 June 2003
United States	75	0	67	23 June 2003	9 July 2003
Vietnam	63	5	58	14 April 2003	7 June 2003
Total	8,437	813	7,452	—	—

Source: *World Health Organization, CSR Severe Acute Respiratory Syndrome (SARS) home page. Available at http://www.who.int/csr/sars/en*

Note: *The cumulative number of cases includes the number of deaths. As SARS is a diagnosis of exclusion, the status of a reported case may change over time. This means that previously reported cases may be discarded after further investigation and follow-up. The start of the period of surveillance has been changed to 1 November 2002 to capture cases of atypical pneumonia in China that are now recognized as being cases of SARS. As of 14 July 2003, WHO no longer publishes a daily table of the cumulative number of reported probable cases of SARS.*

a. A decrease in the number of cumulative cases and the discrepancies in the difference between cumulative number of cases of the last and the current WHO updates are attributed to the discarding of some cases that turned out not to be SARS.

b. Includes cases that are "discharged" or "recovered," as reported by the national public health authorities.

are linkages within economies across sectors and across economies in both international trade and international capital flows. The economic costs from a global disease such as SARS go beyond the direct damages incurred in the affected sectors in the disease-inflicted countries. This is not only because the disease spreads quickly across countries through networks related to global travel, but also because any economic shock to one country is quickly spread to other countries through the increased trade and financial linkages associated with globalization. As the world becomes more integrated, the global cost of a communicable disease like SARS is

expected to rise. Our global model is able to capture many of the important linkages across sectors as well as across countries, through the trade of goods and services and capital flows, and hence provides a broader assessment of the costs of SARS.

The G-Cubed model also incorporates rational expectations and forward-looking intertemporal behavior on the part of individual agents. This feature is particularly important when one is interested in distinguishing the effects of a temporary shock from those of a persistent shock. For instance, if foreign investors expect that SARS or other epidemics of unknown etiology could break out in some Asian countries not only in the current year but also persistently for the following few years, they will demand a greater risk premium from investing in affected economies. Their forward-looking behavior would have immediate global impacts. Because we take into account the interdependencies among economies and the role of investor confidence, our cost estimates of the SARS outbreak are larger than many of those that have recently appeared in the media.

2. Economic impacts of SARS

Despite the catastrophic consequences of infectious diseases such as malaria and HIV/AIDS, the impact of epidemics has been considerably underresearched by economists.[2] Traditionally, most studies have attempted to estimate the economic burden of a widespread illness based on the private and nonprivate medical costs associated with the disease or the demographic consequences of the epidemic.[3] To date the number of probable SARS cases is small compared with the number of victims of other major historical epidemics. Unlike that in cases of HIV/AIDS, the duration of hospitalization of SARS patients is short, with more than 90 percent of the patients recovering to full health in a short period, thereby rendering the medical costs very low (comparatively speaking). The SARS-related demographic or human capital consequences are also currently estimated to be insignificant. The fatality rate of the SARS coronavirus is high, but considering that fewer than 1,000 people

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2 An exception is the work of the Commission on Macroeconomics and Health (2001).

3 For example, a standard neoclassical growth model would predict that a negative shock to population growth can lead to a faster accumulation of capital and subsequently faster output growth, but the empirical studies present conflicting results on this proposition. Brainerd and Siegler (2003) show that the Spanish influenza epidemic of 1918–19, which killed 675,000 people in the United States, had a positive effect on per capita income growth across U.S. states in the 1920s. In contrast, Bloom and Mahal (1997) show no significant impact of the 1918–19 influenza epidemic on acreage sown per capita in India across 13 Indian provinces. Researchers simulating the effect of HIV/AIDS on growth in southern African countries find that HIV/AIDS has had significant negative effects on per capita income growth, mainly through the decline in human capital (e.g., Haacker 2002).

have died from SARS so far, the death toll is tiny compared with the 3 million who died of AIDS in 2002 or the (at least) 40 million people worldwide who died of the Spanish influenza epidemic over 10 months in 1918–19. Therefore, forgone incomes associated with morbidity and mortality as a result of SARS appear to be insignificant. If SARS became endemic in the future, it would substantially increase private and public expenditures on health care and would have more significant impacts on the demographic structure and human capital of the economies of infected countries. Based on information to date, however, this is unlikely to happen.

Although SARS-associated medical expenditures and demographic consequences are generally considered insignificant, SARS has apparently caused substantial economic effects through other important channels. We summarize three mechanisms by which SARS influences the global economy.

First, fear of SARS infection leads to a substantial decline in consumer demand, especially for travel and retail sales services. The fast speed of contagion makes people avoid social interactions. The adverse demand shock becomes more substantial in regions that have much larger service-related activities and higher population densities, such as Hong Kong or Beijing. The psychological shock, however, ripples around the world rather than affecting only the countries suffering from local transmission of SARS, because the world is closely linked by international travel.

Second, the uncertain features of the disease reduce confidence in the future of the affected economies. This effect seems potentially very important, particularly in China, which is a key center of foreign investment. The response by the Chinese government to the 2003 SARS epidemic was fragmented and nontransparent. China's greater exposure to the unknown disease and the less-than-effective government responses to the outbreaks, compared with the case numbers and official reactions in other Asian countries, must have increased concerns about China's institutional quality and future growth potential. Although it is difficult to measure directly the effects of diseases on the decision making of foreign investors, the loss of foreign investors' confidence would have had potentially tremendous impacts on foreign investment flows, which in turn would have had significant impacts on China's economic growth. The effect would also have been transmitted to other countries competing with China for foreign direct investment.

Third, SARS undoubtedly increases the costs of disease prevention, especially in the most affected industries, such as the travel and retail sales service sectors. These costs may not be substantial, at least in global terms, as long as the disease is transmitted only through close human contact. However, the global costs could become

Table 2. Countries and sectors included in the G-Cubed (Asia Pacific) model, version 50N

Countries or regions	Sectors
United States	Energy
Japan	Mining
Australia	Agriculture
New Zealand	Durable manufacturing
Indonesia	Nondurable manufacturing
Malaysia	Services
Philippines	
Singapore	
Thailand	
China	
India	
Taiwan	
South Korea	
Hong Kong	
Rest of OECD	
Non-oil-producing developing countries	
Eastern Europe and Russia	
OPEC	

enormous if the disease were found to be transmitted by other channels, such as through international cargo.

Given the important linkages between countries in the affected region, through the trade of goods and services and capital flows, any analysis of the implications of SARS for the global economy needs to be undertaken with a model that adequately captures these interrelationships. The G-Cubed (Asia Pacific) model, based on the theoretical structure of the G-Cubed model outlined in McKibbin and Wilcoxen (1999), is ideal for such analysis, incorporating both a detailed country coverage of the region and rich links between countries through goods and asset markets.[4] Table 2 provides a list of the countries and sectors that the model covers.

The model is based on explicit *intertemporal* optimization by the agents (consumers and firms) in each economy,[5] in contrast to static computable general equilibrium models. However, the behavior of agents is modified to allow for short-run deviations from optimal behavior due either to myopia or to restrictions on the ability of households and firms to borrow at the risk-free bond rate on government debt. There is an explicit treatment of the holding of financial assets, including money. The model distinguishes between the stickiness of physical capital within sectors and within countries and the flexibility of financial capital, which immediately flows to where expected returns are highest. This important distinction leads to a critical difference between the *quantity of physical capital* that is available at any time

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4 Full details of the model, including a list of equations and parameters, can be found online at www.gcubed.com

5 See Blanchard and Fischer (1989) and Obstfeld and Rogoff (1996).

to produce goods and services and the *valuation of that capital* as a result of decisions about the allocation of financial capital.

3. Designing the simulations

We make two alternative assumptions in generating the range of scenarios. In our original paper we assumed in the first scenario that the SARS shock lasted for a year. To capture the fact that the SARS outbreak actually lasted 6 months, we now scale down the shocks by 50 percent to capture this shorter duration. This is called a temporary shock. In the second scenario, the assumption is that the shocks in the first year are the same magnitude as the 6-month temporary shock, but they are more persistent and fade out equiproportionally over a 10-year period. These assumptions permit us to determine the impact of expectations (concerning the future evolution of the disease) on the estimated costs in 2003 and to provide some insight into what might happen to the region if the SARS outbreak is the beginning of a series of annual epidemics emerging from China.

We first calculate the shocks to the Chinese and Hong Kong economies and then work out some indexes that indicate how these shocks are likely to occur in other economies. There are three main shocks, based on observations of financial market analysts about the existing data emerging from China and Hong Kong. These shocks are consistent with those identified in the papers presented at the Asian Economic Panel meeting in May 2003 that focused on the impacts of SARS on particular countries.

3.1 Initial shock to China and Hong Kong

In the model we specify three broad shocks to China and Hong Kong:

1. Increase in country risk premium: 200 basis points.[6]
2. Sector-specific demand shock to retail sales sector: 15 percent drop in demand in the exposed industries of the service sector.
3. Increase in costs in the exposed activities in the service sector: 5 percent.

These shocks are scaled to last 6 months rather than 1 year.[7]

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6 In the May 2003 version of this paper we assumed a 300-basis-point shock. We follow the updated figures in the *Economic Roundup Winter 2003* of the Commonwealth Treasury of Australia in adjusting this shock to 200 basis points.

7 We could also consider several other shocks, such as the impact on health expenditure and fiscal deficits. Because it is not clear how to estimate the magnitude of such shocks, or even

Table 3. Health expenditure, tourist arrivals, and sanitation indicators for selected countries and regions

Country or region	Total health expenditure (% of GDP)	Health expenditure per capita (current US$)	Tourist arrivals (million)	Tourist arrivals/population (%)	Adequate sanitation facilities (% of population)
China	5.3	45	33.2	3	29
Hong Kong	4.4	950	13.7	203	100
India	4.9	23	2.5	0	16
Indonesia	2.7	19	5.2	2	47
North Korea	2.1	18	n.a.	n.a.	99
South Korea	6.0	584	5.1	14	63
Malaysia	2.5	101	12.8	53	n.a.
Philippines	3.4	33	1.8	4	74
Singapore	3.5	814	6.7	163	100
Thailand	3.7	71	10.1	16	79
Vietnam	5.2	21	1.4	2	29
United States	13.0	4,499	n.a.	n.a.	100
Japan	n.a.	n.a.	4.8	4	n.a.
High-income OECD countries	10.2	2,771	377.6	n.a.	n.a.
World	9.3	482	696.5	n.a.	55

Source: *CEIC, World Development Indicators: Asian Economic Outlook and Strategy. Data in this table are re-cited from parts of table 1 in Hanna and Huang (this issue, p. 108).*

Note: n.a. = not available.

3.2 Shocks to other countries

We refer to the person-to-person transmission of SARS, as distinct from its economic transmission through global markets, as the global exposure to SARS. The speed of spread is likely to depend on (1) tourist flows, (2) geographical distance to China (and Hong Kong), (3) health expenditure and sanitary conditions, (4) government response, (5) climate, (6) per capita income, and (7) population density. There are more than 33 million annual visitors to China. Hong Kong's annual tourist arrivals amount to over 200 percent of the local population. Total health expenditure as a percentage of GDP is not small in Asian countries, but health expenditure per capita per annum is only US$45 in China, compared with US$585 in South Korea, US$814 in Singapore, and US$950 in Hong Kong. Table 3 presents indicators on health expenditure, tourist arrivals, and sanitary conditions for selected countries.

For the purposes of this paper we construct a rough measure of the intensity of exposure to SARS, based on the above information and the cumulative number of cases of SARS in 2002–03 for each country. These "indexes of global exposure to SARS" are shown in figure 1. They are used to scale down the country risk shocks calculated for China and Hong Kong to apply to all other countries and regions. For

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how to determine what the sign of the shocks should be, we have ignored the fiscal impacts of SARS in this paper.

Figure 1. Index of global exposure to SARS: Intensity of transmission
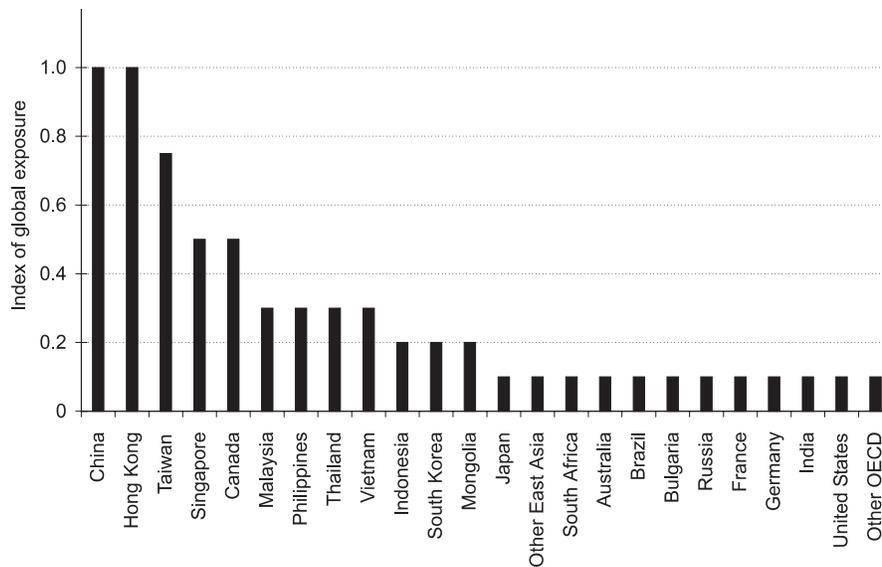
example, if a country has a global exposure index of 0.5, the country risk premium shock will be the Chinese shock of 2 percent adjusted by the index of its global exposure to SARS, which gives a shock of 1 percent.

For the shocks to the service industries, before applying the global exposure index to each country, we need to adjust the sector-specific shocks. Because we have only an aggregate service sector in the model, we need to take account of the structural differences within the service sectors of each country. We do this by creating "indexes of sectoral exposure to SARS." These indexes are assumed to be proportional to the share of service sector industries that were affected by the 2002–03 SARS epidemic. Industries such as tourism, retail trade, and airline travel were hit severely in that outbreak. We use the Global Trade Analysis Project (GTAP) version 5 database to calculate the share of exposed sectors in the total services sector for each country. We define the exposed sectors based on GTAP definitions: wholesale and retail trade, hotels and restaurants, land transport, and air transport. The relative values of the indexes of sectoral exposure to SARS for several countries and regions are shown in figure 2. These indexes are applied to the sector-specific shocks we developed for the Chinese economy. We then apply the index of global exposure to SARS to the resulting shocks. For example, the shock applied to costs in the service sector in Singapore is the shock of 5 percent increase in costs, multiplied by 0.31 for the

Figure 2. Index of sectoral exposure to SARS: Share of retail sales and travel industry in service sector
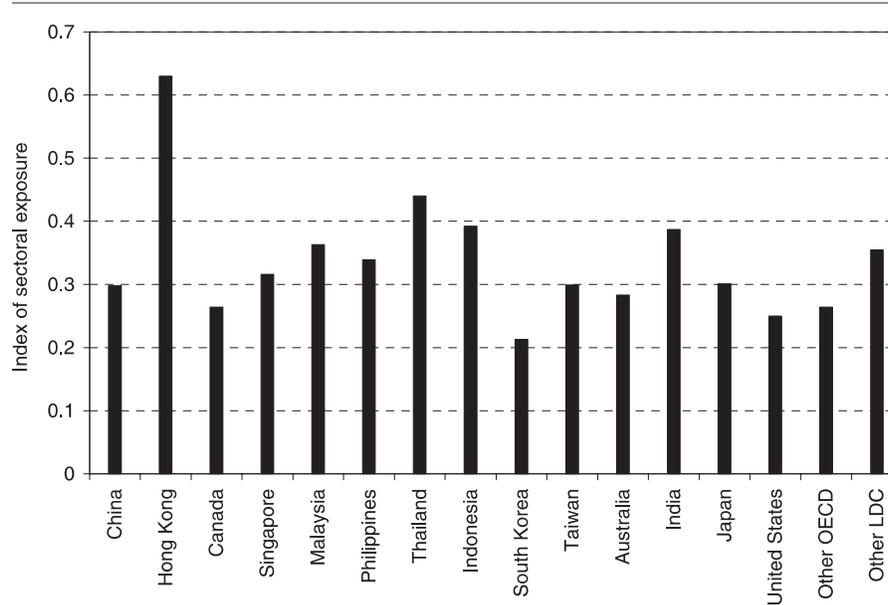
sectoral exposure to SARS, multiplied by 0.5 for the global exposure to SARS. This gives a shock to costs in the service sector in Singapore of 0.775 percent.

4. Simulation results

4.1 Baseline business-as-usual projections

The first step is to make base case assumptions about the future path of the model's exogenous variables in each region. For all regions we assume that the long-run real interest rate is 5 percent, tax rates are held at their 1999 levels, and fiscal spending is allocated according to 1999 shares. Population growth rates vary across regions according to 2000 World Bank population projections.

The baseline assumption in the G-Cubed (Asia Pacific) model is that the pattern of technical change at the sector level is similar to the historical pattern for the United States (where data are available). In regions other than the United States, however, the sector-level rates of technical change are scaled up or down in order to match the region's observed average rate of aggregate productivity growth over the previous 5 years. This approach attempts to capture the fact that the rate of technical change varies considerably across industries, while also accounting for regional differences in overall growth.

4.2 Results of the simulation

We apply the shocks outlined in the previous section to the global economy. We begin the simulation in 2003, assuming that the SARS outbreak in 2003 was completely unanticipated. Both the temporary and persistent shocks are assumed to be understood by the forward-looking agents in the model. Clearly this is problematic when it comes to a new disease such as SARS, because there is likely to be a period of learning about the nature of the shock. Yet what alternative approach might exist and be viable is not clear. In our defense it is worth pointing out that only 30 percent of agents have rational expectations and 70 percent of agents are using a rule of thumb when they adjust to contemporaneous information about the economy.

Table 4 shows the model's predictions for the percentage change in GDP in 2003 as a result of the temporary and permanent SARS shocks, as well as the contribution of each component (i.e., demand decline for services, cost increase for services, and country risk premium). Focusing on the GDP results, it is clear that there are interesting differences among the various components of the overall shock as well as between the temporary and permanent shocks. The temporary shock has its largest impact on China and Hong Kong, as expected. The loss to Hong Kong of 2.63 percent of GDP is, however, much larger than the corresponding loss of 1.05 percent for China. This primarily reflects the larger role of the service sector in Hong Kong, the larger share of impacted industries within the service sector, and the greater reliance on trade. Taiwan is the next-most-affected region, losing 0.49 percent of GDP in 2003, followed closely by Singapore, with a loss of 0.47 percent of GDP. For Hong Kong, the increase in costs in the service sector is by far the largest contributing factor to the loss of GDP. In China it is evenly spread across the three factors.

A persistent SARS shock, according to the results, is even more serious for Hong Kong and China. The primary impact is from the persistence in the rise of the country risk premium. Although this risk premium is the same in 2003 as it is for the temporary shock, the persistence of the country risk premium causes much larger capital outflows from China and Hong Kong than from other regions studied. This capital outflow, which causes real interest rates to rise, affects short-run aggregate demand through a sharp contraction in investment and leads to a persistent loss in production capacity through a resulting decline in the growth of the capital stock. The extent of capital outflow is discussed below.

Interestingly, when SARS is expected to be more persistent, the difference in GDP loss in 2003 distinguishes two groups of countries. China, Hong Kong, Malaysia, the Philippines, Singapore, and Taiwan experience a larger loss, and the OECD economies and others experience a smaller GDP loss. This reflects the greater capital outflow from the most affected countries into the least affected countries, which

Table 4. Predicted percentage change in GDP in 2003 resulting from SARS

Country or region	Impact on GDP from temporary SARS shock (%)				Impact on GDP from persistent SARS shock over 10 years (%)			
	Total effects	Demand shift for services	Cost rise for services	Country risk premium	Total effects	Demand shift for services	Cost rise for services	Country risk premium
United States	−0.07	−0.01	−0.06	0	−0.07	−0.01	−0.06	0
Japan	−0.07	−0.01	−0.06	0	−0.06	−0.01	−0.06	0.01
Australia	−0.07	0	−0.06	0	−0.06	0	−0.06	0.01
New Zealand	−0.08	0.01	−0.08	0	−0.08	0	−0.08	0
Indonesia	−0.08	0.01	−0.09	0	−0.07	0.01	−0.08	0
Malaysia	−0.15	0.01	−0.16	0	−0.17	0.01	−0.15	−0.02
Philippines	−0.10	0.04	−0.14	0	−0.11	0.03	−0.13	−0.02
Singapore	−0.47	−0.02	−0.45	0	−0.51	−0.01	−0.44	−0.05
Thailand	−0.15	0	−0.15	0	−0.15	0	−0.15	0
China	−1.05	−0.37	−0.34	−0.33	−2.34	−0.53	−0.33	−1.48
India	−0.04	0	−0.09	0	−0.07	0.01	−0.08	0.01
Taiwan	−0.49	−0.07	−0.41	−0.01	−0.53	−0.07	−0.39	−0.07
South Korea	−0.10	−0.02	−0.08	0	−0.08	−0.01	−0.08	0
Hong Kong	−2.63	−0.06	−2.37	−0.20	−3.21	−0.12	−2.37	−0.71
Rest of OECD	−0.05	0	−0.05	0	−0.05	0	−0.05	0
Non-oil-producing developing countries	−0.05	−0.01	−0.04	0	−0.05	0	−0.04	0
Eastern Europe and Russia	−0.06	−0.01	−0.05	0	−0.05	−0.01	−0.05	0
OPEC	−0.07	−0.01	−0.05	0	−0.09	−0.01	−0.06	−0.02

Source: G-Cubed (Asia Pacific) model, version 50N.

would tend to lower the GDP of those countries losing capital and to raise the GDP of those countries receiving capital. The countries in the first group that are less affected by SARS are nonetheless worse off when a more persistent outbreak is expected because of their trade links with Hong Kong, China, and Singapore.

The various linkages have many dimensions, but a global model is able to help untangle some of the more important factors. The results for GDP illustrate how the estimated costs of SARS in 2003 can be very different depending on expectations of how the disease will unfold. It is also interesting to examine the change in economic impacts over time. We present three figures, each containing six charts (figures 3–5). The variables in each chart are expressed as deviations from the underlying baseline of the model projections. They show how key variables change relative to what would have been the case without SARS. On the left-hand side of figures 3 and 4, the results of the temporary SARS shock are shown, and on the right-hand side of these figures, the impacts of the more persistent SARS shock are presented. This enables one to compare the impacts of the two shocks on real GDP, investment, exports, capital flows, trade balance, and exchange rates. Figure 5 presents the results for the financial and sectoral impacts of a persistent SARS shock.

Figure 3 shows the results for the effects on real GDP, investment, and exports of both the temporary and persistent SARS shocks. The loss in GDP from the temporary shock is largely confined to 2003. The persistent shock not only has a larger impact on GDP in 2003, because of expectations about future developments, but also has a persistent impact on real GDP for several years. Investment falls more sharply in 2003, when compared with the temporary shock, even though the shock in 2003 is the same for both the persistent and temporary shocks. This larger fall in investment is the source of the larger GDP loss.

The results for exports are particularly interesting. In the case of the temporary shock, exports from Hong Kong fall sharply. Yet, in the more persistent case, exports from Hong Kong fall by less in 2003. The reason for this difference is that the more persistent the shock, the larger the capital outflow from affected economies. A capital outflow will be reflected in a current account surplus and a trade balance surplus. For this to occur, either exports must rise or imports fall, or both. This can be seen clearly in figure 4.

In the case of the temporary SARS shock, the net capital outflow from China and Hong Kong (relative to the baseline projection) is around 0.3 percent of GDP by the second year of the shock. When the shock is more persistent, however, this capital outflow (top left panel) rises sharply to 1.4 percent of GDP for Hong Kong and to 0.8 percent of GDP for China by the second year. This capital outflow is reflected in

Figure 3. Predicted impacts of temporary versus persistent SARS shocks on real GDP, investment, and exports
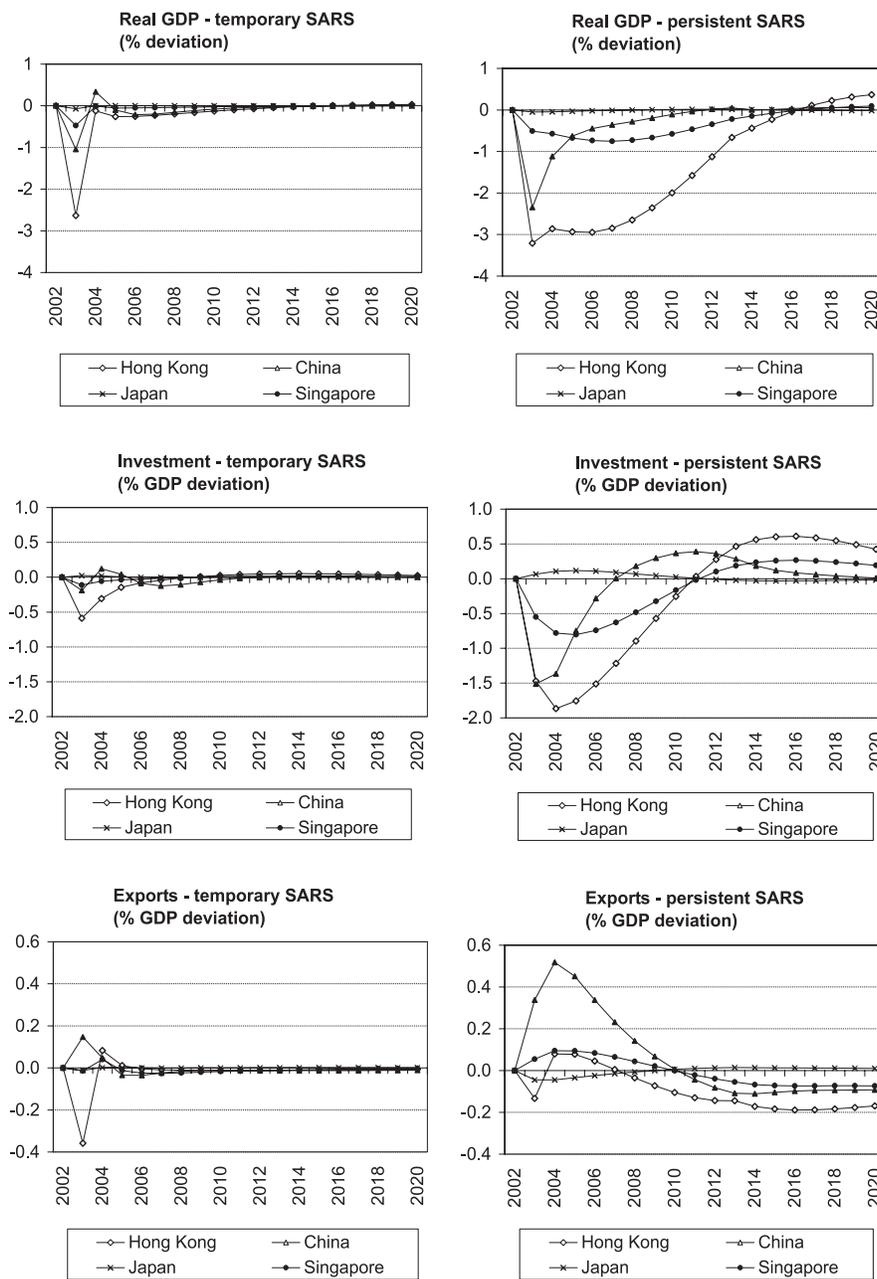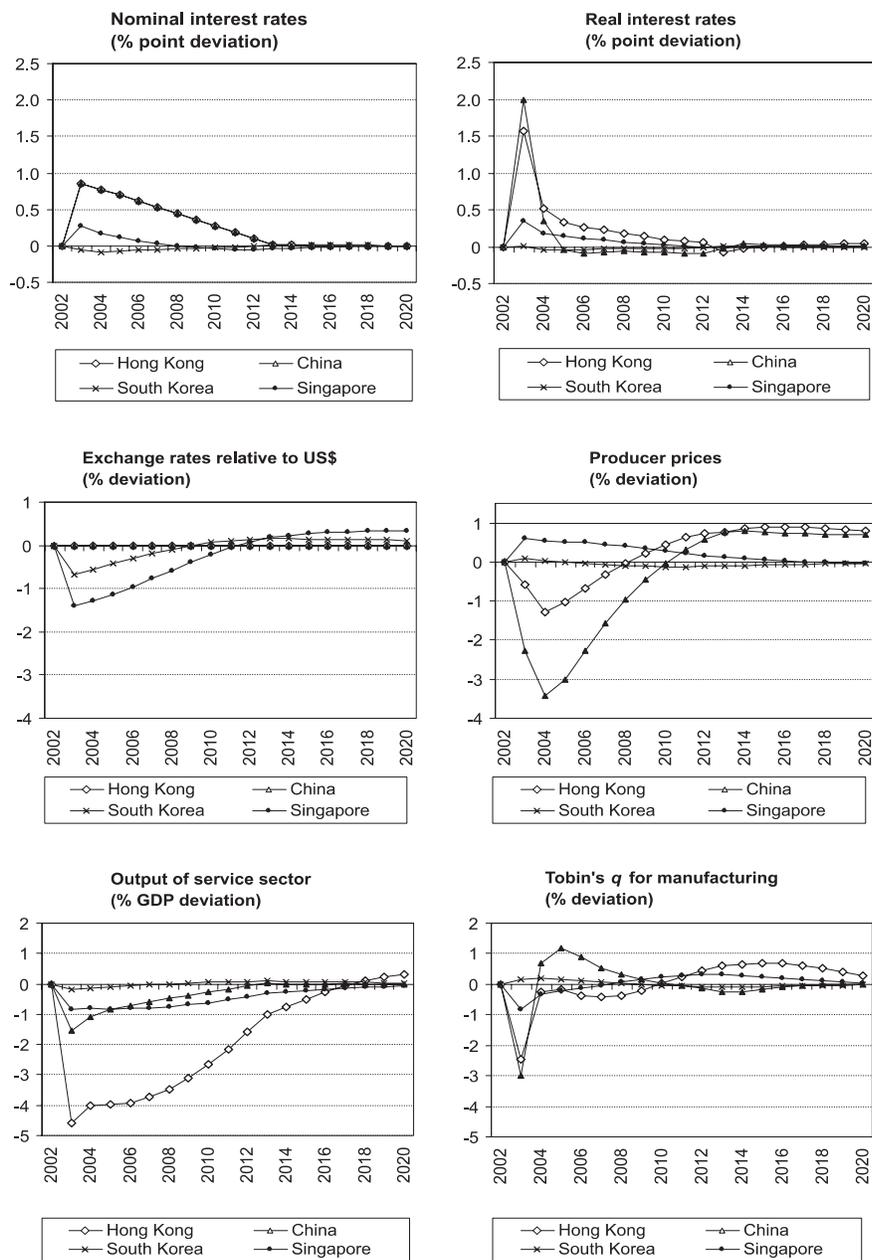
Source: *G-Cubed (Asia Pacific) model, version 50N.*

Figure 4. Predicted impacts of temporary versus persistent SARS shock on capital flow, trade, and exchange rates
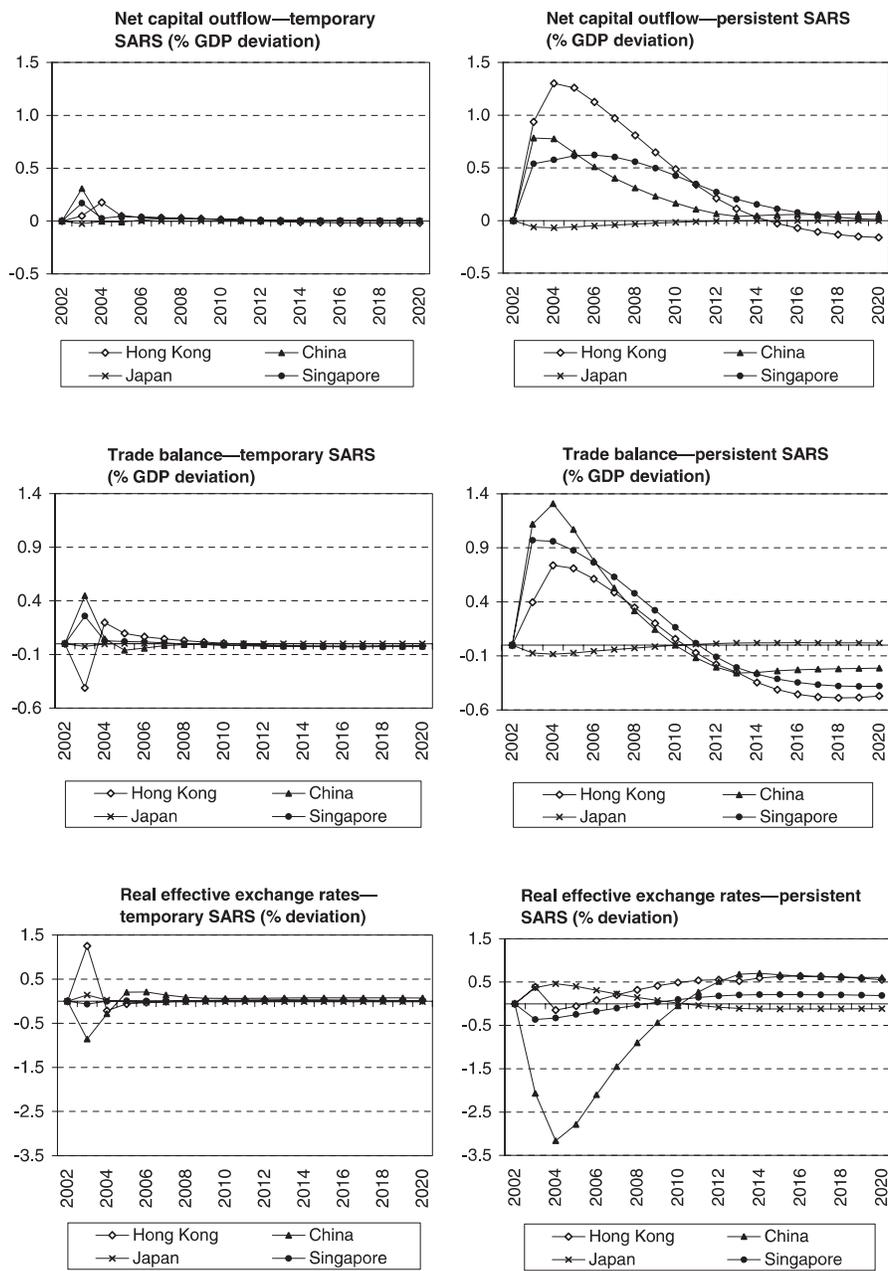
Source: G-Cubed (Asia Pacific) model, version 50N.

Figure 5. Predicted financial and sectoral impacts of a persistent SARS shock

the trade balance surplus in both countries. This shift in the trade balance is achieved by means of the capital outflow's substantially depreciating the real exchange rate of both China and Hong Kong.

For this model we assume that the monetary authorities in both economies maintain a tight peg to the U.S. dollar. Figure 5 shows that the inevitable real exchange rate depreciation is achieved through falling prices (again relative to the underlying baseline projection) that are induced by very high real interest rates. In order to maintain the interest parity condition, the expected depreciation in turn induces high real interest rates. This is similar to what occurred in the aftermath of the 1997 Asian crisis in Hong Kong and in the aftermath of the bursting of the asset bubble in Japan in the early 1990s, when the lack of nominal yen depreciation against the U.S. dollar (through policy intervention) induced the required real economic adjustment through a fall in prices, which, through persistent policy errors, developed into deflation.

We see in figure 5 that both South Korea and Singapore experience nominal exchange rate depreciations that limit the extent of price declines in those economies, even though China is experiencing falling prices. One important lesson from these results is that the popular myth, particularly prevalent in Japan, that China is the cause of global deflation involves a complete misunderstanding of the difference between the change in relative prices and the change in overall prices within economies and among economies. Deflation within an economy reflects the decisions of the monetary authorities of that country and not the change in prices within other economies. This is not just a curiosity from the model but is perfectly consistent with the observation that countries such as Canada, Australia, and New Zealand, which trade extensively with China, can have inflation while Japan and Hong Kong experience deflation. This phenomenon cannot be explained by low-cost Chinese production.

We also see in figure 5 that the problems in the service industries in China and Hong Kong are reflected in the share market valuations in the manufacturing sectors in these economies (lower-right-hand chart, summarized in Tobin's q). The SARS outbreak is predicted to have widespread economic impacts beyond the declines in the most-affected service industries.

5. Conclusion

The impact of SARS on the economies of China and Hong Kong, as estimated by the G-Cubed (Asia Pacific) model, is large. This impact is not a consequence of the disease itself for the affected people but is rather the effect of the disease on the behav-

ior of many people within these economies. The economic impact of SARS depends on the adjustment of expectations about the disease, reflected in integrated real and financial markets. The more persistent the SARS outbreak is expected to be, the larger are the expected negative economic impacts in 2003, and the smaller the expected impacts in countries outside the core countries.

An important aspect of the costs estimated in this paper is the fixed-exchange-rate regimes in China and Hong Kong, which increase the costs of SARS. The real depreciation induced by SARS occurs through lower prices in these economies, which, through sticky labor markets, results in increased unemployment. The regional impacts are also significant as a result of trade linkages as well as through the direct transmission of the disease.

These results support the point that the true cost of disease is far greater than the cost to a health budget for treatment of patients. The more persistent shock in this paper can be thought of as the 2002–03 SARS epidemic's having lasted longer than anyone feared, but it can also be interpreted as a recurring series of annual epidemics emerging from China and infecting the world through increased globalization. Such annual outbreaks would not be a new phenomenon: influenza viruses have been emanating from China since at least 1918–19, when the Spanish flu spread worldwide. If the threat of recurring SARS or SARS-like diseases from China is real, then the estimated risk to economic activity in the region and the world, as calculated in this paper, could be very large. The estimates of our model suggest that there is a strong economic case for direct intervention in improving public health in China and other developing countries in which there is inadequate expenditure on public health and insufficient investment in research on disease prevention to avoid the future outbreak of a major pandemic.

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