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GLOBALIZATION AND DISEASE: THE CASE OF SARS

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Globalization and Disease: The Case of SARS[*]

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1. Introduction

SARS (severe acute respiratory syndrome) has put the world on alert. The virus appears to be highly contagious and fatal. In the six months after its first outbreak in China in Guangdong province last November, the SARS disease has spread to at least 30 countries/regions including Australia, Brazil, Canada, South Africa, Spain, and the United States. By the apparent end of the outbreak on July 14 2003, the number of probable cases reached 8,437 worldwide (see Table 1 and Figure 1). The disease kills 10 % or so of those infected. The death toll reached 813 including 348 in China and 298 in Hong Kong.

Scientists still do not know details about coronavirus that causes SARS. The precise mechanism by which this atypical pneumonia is spread is still unclear. Many countries have successfully contained the SARS outbreaks and local transmission, but the disease may re-occur later this year.[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 an assessment of the global economic impacts of the SARS disease. We update our estimates from the 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 on the economic effects of epidemics focus on the economic costs involving the disease-associated medical costs or forgone incomes as a result of the 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, in particular compared to other major epidemics such as HIV/AIDS or malaria. A few recent studies including Chou, Kuo and Peng (2003), Siu and Wong (2003), and Wen (2003) provide some estimates for the economic effects of SARS on individual Asian countries such as China, Hong Kong, and Taiwan. But, these studies focus mostly on assessing the damages by SARS in affected industries such as tourism and retail service sector.

However, just calculating the number of canceled tourist trips and declines in retail trade etc is not sufficient to get a full picture of the impact of SARS because there 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 goes beyond its direct

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1 See Hanna and Huang (2003), and WHO SARS website (www.who.int/csr/sars/en/).

damages incurred in the affected sectors in the disease-inflicted countries. This is not just because the disease spreads quickly across countries through networks related to global travel, but also 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 SRAS 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 provide a broader assessment of the costs.

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 we are interested in distinguishing the effects of a temporary shock from those of a persistent shock. For instance, when foreign investors expect SARS or other epidemics of unknown etiology can break out in some Asian countries not just this year but persistently for the next few years, they would demand a greater risk-premium from investing in affected economies. Their forward-looking behavior would have immediate global impacts.

Needless to say, our empirical assessment is preliminary and relies on our limited knowledge about the disease and constrained methodology.   With the SARS epidemic apparently over for now it is worth evaluating the cost. There is speculation that even if it diminishes in the Northern Hemisphere summer, it could re-emerge in even more deadlier form in the next influenza season. There is no consensus yet on the likely developments of the epidemic and the precise mechanism by which the SARS affects economic activities. Although a global model is better than simple back of the envelope calculations, it is a coarse representation of a complex world. Nonetheless the simple calculations are important inputs into the model. We saw that with the Asian Crisis of 1997 where the transmission of the shocks in the Asia to the rest of the world and the adjustment within economies in Asia were poorly predicted when only trade flows where considered[2]. Thus it is important to go beyond the rough estimates that currently permeate the commentary of economic consequences of SARS. Because we take into account the interdependencies between economies and the role of confidence, our costs are larger than many of the estimates that currently appear in the media.

2. Economic Impacts of SARS

Despite the catastrophic consequences of infectious diseases such as malaria and HIV/AIDS,

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2 See McKibbin (1998) for a study of the Asia crisis that included the critical role of capital flow adjustment.

the impact of epidemics has been considerably under-researched in economics[3].

Traditionally, studies have attempted to estimate the economic burden of an epidemic based on the private and non-private medical costs associated with the disease. The costs include private as well as public expenditures on diagnosing and treating the disease. The costs are magnified by the need to maintain sterile environments, implement prevention measures, and do basic research. The economic costs can be substantial for major epidemics such as AIDS. According to UNAIDS (the Joint United Nations Programme on HIV/AIDS), at present 42 million people globally live with HIV/AIDS. The medical costs of various treatments of HIV patients, including highly active antiretroviral therapies (HAARTs) are estimated to be more than $2,000 per patient per year. In the Southern African regions, the total HIV-related health service costs, based on assumed coverage rate of 10 percent, ranges from 0.3 to 4.3 percent of GDP (Haacker 2002).

The costs of disease also include incomes forgone as a result of the disease-related morbidity and mortality. Forgone income is normally estimated by the value of lost workdays due to the illness. In the case of mortality, forgone income is estimated by the capitalized value of future lifetime earnings by the disease-related death, based on projected incomes for different age groups and age-specific survival rates. This cost can be substantial for some epidemics. Malaria kills more than one million people a year. The HIV/AIDS disease is estimated to claim 3.1 million lives in 2002.

Previous researchers have also focused on the long-term effects from the demographic consequences of epidemics. The first and foremost impact of epidemics is a negative shock to population and labor force. But, economic theory provides conflicting predictions regarding the economic effects of negative population shocks. A disease that kills children and elderly mostly without affecting economically active population aged 15-54, can lead to an initial increase in GDP per head. Even when the disease mostly attacks prime earners, its long-term economic consequence is not unambiguous. Standard neoclassical growth model predicts that a negative shock to population growth can lead to a faster accumulation of capital and subsequently faster output growth (see Barro and Sala-I-Martin 1995). Conversely, an exogenous, one-time reduction in labor force raises capital-labor ratio and lowers rate of return to capital, which subsequently leads to slower capital accumulation and thereby lower output growth. Empirical studies also present conflicting results. Brainerd and Siegler (2002) show that Spanish flu epidemic of 1918-19 that killed at least 40 million people worldwide and 675,000 in the United States had a positive effect on per capita income growth across

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3 Exceptions can be found in the Commission on Macroeconomics and Health (2001).

states in the United States in 1920s. In contrast, Bloom and Mahal (1997) show no significant impact of the 1918-1919 influenza epidemic on acreage sown per capita in India across 13 Indian provinces.

Epidemics can have further effects on demographic structures by influencing fertility decisions of households. According to the 'child-survivor hypothesis,' parents desire to have a certain number of surviving children. In this theory, risk-averse households raise fertility by even more than expected child mortality. Evidence shows that high infant and child mortality rates in African regions of intense malaria transmission are associated with a disproportionately high fertility rate and high population growth (Sachs and Malaney, 2002). Thus, the increase in fertility has further negative impact on long-term growth.

Aside from the direct demographic consequences of an epidemic, another important mechanism by which a disease has an adverse impact on the economy's long-term growth is the destruction of human capital. Human capital, the stock of knowledge embodied in the population, is considered as an important determinant of long-term growth (Barro and Sala-I-Martin 1995). Furthermore, the decline in 'health capital', as measured in general by life expectancy, has negative effects on economic growth (Bloom, Canning and Sevilla, 2001). Epidemics also adversely affect labor productivity by inhibiting the movement of labor across regions within a country as well as across countries. Restricted mobility inhibits labour from moving to the places where it is most productive. Researchers simulating the effect of AIDS on growth in Southern African countries find that AIDS has had significant negative effects on per capita income growth mainly through the decline in human capital (Haacker 2002).

While previous studies emphasize the economic cost of disease associated with private and non-private medical costs, this doesn't seem to be the case for SARS. The number of probable SARS cases is still small, compared to other major historical epidemics. Furthermore, unlike AIDS, the duration of hospitalization of the infected patients is short, with more than 90 percents of the patients recovering to full health in a short period, thereby rendering the medical costs very low. 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, with fewer than about 813 known SARS deaths so far, the death toll is tiny compared with the 3 million who died of AIDS last year or at least 40 million people worldwide in just 10 months died of Spanish flu epidemic of 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 healthcare and would have more significant impacts on demographic structure and human capital of the infected economies. But, based on

information to date, this is unlikely to happen with the SARS epidemic.

While the SARS-associated medical expenditures or its demographic consequences are insignificant, SARS has apparently already caused substantial economic effects by 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 service. The fast speed of contagion makes people avoid social interactions. The adverse demand shock becomes more substantial in the regions, which have much larger service related activities and higher population densities, such as Hong Kong or Beijing, China. The psychological shock ripples all around the world, not just to the countries of local transmission of SARS, since the world is so closely linked by international travel.

Second, the uncertain features of the disease reduces confidence in the future of the affected economies. This effect seems to be potentially very important, particularly as the shock rages in China, which has been a key center of foreign investment. The response by the Chinese government to the epidemic has been fragmented and non-transparent. The greater exposure to the unknown disease and the less effective government responses to the disease outbreaks must have raised more concerns about the China's institutional quality and future growth potential. Although it is difficult to directly measure the effects of diseases on decision-making of foreign investors, the loss of foreign investors' confidence would have potentially tremendous impacts on foreign investment flows, which will have in turn significant impacts on China's economic growth. The effect is also transmitted to other countries competing with China for FDI.

Third, SARS undoubtedly increases the costs of disease prevention, especially in the most affected industries such as travel and the retail sales service industries. This cost may not be substantial, at least in global terms, as long as the disease was transmitted only by close human contact. However, the global cost could become enormous if the disease is found to be transmitted by other channels such as through international cargo.

3. **The G-Cubed (Asia Pacific Model)**

Given the important linkages between affected countries in the region, through the trade of goods and services and capital flows, any analysis of the implications of SARS on 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 having both a detailed country coverage of the region and rich links between countries through goods and asset markets. [4] A number of studies—summarized in McKibbin and Vines (2000)—show that the G-cubed model has been useful in assessing a range of issues across a number of countries since the mid-1980s.[5]   A summary of the model coverage is presented in Table 2. Some of the principal features of the model are as follows:

●   The model is based on explicit *intertemporal* optimization by the agents (consumers and firms) in each economy[6]. In contrast to static CGE models, time and dynamics are of fundamental importance in the G-Cubed model.

●   In order to track the macro time series, however, the behavior of agents is modified to allow for short run deviations from optimal behavior either due to myopia or to restrictions on the ability of households and firms to borrow at the risk free bond rate on government debt. For both households and firms, deviations from intertemporal optimizing behavior take the form of rules of thumb, which are consistent with an optimizing agent that does not update predictions based on new information about future events. These rules of thumb are chosen to generate the same steady state behavior as optimizing agents so that in the long run there is only a single intertemporal optimizing equilibrium of the model. In the short run, actual behavior is assumed to be a weighted average of the optimizing and the rule of thumb assumptions. Thus aggregate consumption is a weighted average of consumption based on wealth (current asset valuation and expected future after tax labor income) and consumption based on current disposable income. Similarly, aggregate investment is a weighted average of investment based on Tobin's q (a market valuation of the expected future change in the marginal product of capital relative to the cost) and investment based on a backward looking version of Q.

●   There is an explicit treatment of the holding of financial assets, including money. Money is introduced into the model through a restriction that households require money to purchase goods.

●   The model also allows for short run nominal wage rigidity (by different degrees in

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different countries) and therefore allows for significant periods of unemployment depending on the labor market institutions in each country. This assumption, when taken together with the explicit role for money, is what gives the model its "macroeconomic" characteristics. (Here again the model's assumptions differ from the standard market clearing assumption in most CGE models.)

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

As a result of this structure, the G-Cubed model contains rich dynamic behavior, driven on the one hand by asset accumulation and, on the other by wage adjustment to a neoclassical steady state. It embodies a wide range of assumptions about individual behavior and empirical regularities in a general equilibrium framework. The interdependencies are solved out using a computer algorithm that solves for the rational expectations equilibrium of the global economy. It is important to stress that the term 'general equilibrium' is used to signify that as many interactions as possible are captured, not that all economies are in a full market clearing equilibrium at each point in time. Although it is assumed that market forces eventually drive the world economy to a neoclassical steady state growth equilibrium, unemployment does emerge for long periods due to wage stickiness, to an extent that differs between countries due to differences in labor market institutions.

4. Designing the Simulations

We make two alternative assumptions in generating a range of possible scenarios. In our original paper we assumed in the first scenario that the shock lasted for a year. To capture the fact that the shock lasted 6 month in reality we now scale down the shocks by 50% to capture the shorter duration. This is called a temporary shock. The second assumption is that the shocks are the same magnitude in the first year as the temporary shock, but there are more persistent in that they fade out equi-proportionately over a ten-year period. This illustrates the impact of expectations of the future evolution of the disease on the estimated costs in 2003. It also gives some insight into what might happen to the region if the SARS virus is considered the beginning of a series of annual epidemics emerging from China.

We first calculate the shocks to the Chinese and Hong Kong economies, which were most heavily hit by the disease, and then work out some indexes summarizing 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 are also consistent with other papers on particular countries presented at the Asian Economic Panel in May 2003.

a. Initial shock to China and Hong Kong

There are three broad shocks to China and Hong Kong:

- Increase in country risk premium: 200 basis point[7];
- Sector-specific demand shock to retail sales sector: 15% drop of demand for the exposed industries in the service sector;
- Increase in costs in the exposed activities in the service sector of 5%.

These shocks are then scaled to only last 6 months rather than 1 year.

We could also consider several other shocks such as the impact on health expenditure and fiscal deficits. It is not clear how large this shock should be or for the persistent shock, nor even the sign. Since SARS kills a higher proportion of vulnerable people in a very short period it may be that the large amount of expenditure for these people will be reduced as a result of SARS. There might also be a reaction of medical authorities with substantial investments in public health. We are forced to abstract from all of these considerations given current information. We therefore explicitly ignore the fiscal impacts of SARS in this version of the paper.

b. Shocks to Other Countries

The transmission of SARS, as distinct form the economic transmission through global markets depends on a number of factors. We refer to this as the global exposure to SARS. The speed of spread is likely to depend on (i) tourist flows (ii) geographical distance to China (and Hong Kong), (iii) health expenditures and sanitary conditions, (iv) government response, (v) climate, (vi) per capita income, (vii) population density, and so on. Table 3 presents indicators on health expenditures, tourist arrivals and sanity conditions for selected countries.

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7 In the May version of this paper we assumed a 300 basis point shock. We follow the updated research of Australian Treasury (2003) in adjusting this shock to 200 basis points.

There are more than 33 million annual visitors to China. Hong Kong has annual tourist arrivals that are over 200 % of the local population. Overall health expenditure as a ratio to GDP is not small in Asian countries but health expenditure per capita is only $45 in China.

With more data we could do some econometric estimation to capture these influences. Lacking that data currently, for the purposes of this paper we construct a rough measure of the intensity of exposures to SARS, based on the above information and the number of cumulated cases of SARS for each country.

This index of "global exposure to SARS" is contained in Figure 2. This will be used to scale down the country risk shocks calculated for all other countries. For example if a country has an index of 0.5, the country risk premium shock will be the Chinese shock of 2% adjusted by the "global exposure to SARS" index which gives a shock of 1%.

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 only have an aggregate service sector in the model, we need to take account of the structural difference within the services sector of each country. We do this by creating an "index of sectoral exposure to SARS". This index is assumed to be proportional to the share of affected industries within the service sector to SARS. Industries like tourism, retail trade, airline travel etc have been impacted severely. We use the GTAP5 database to calculate the share of exposed sectors to total services for each country. We define the exposed sectors based on GTAP definitions as wholesale and retail trade, and hotels and restaurants (TRD), land transport (OTP) and air transport (ATP).   The "index of sectoral exposure to SARS" is shown in Figure 3.   This index is applied to the sector-specific shocks we developed for the Chinese economy. We then apply the "global exposure to SARS" to the resulting shocks.

The direct impact on any economy will be a function of a number of factors. An important aspect of the impact will be the size of the service sector in the economy as well as the relative indexes of exposure. Figure 4 shows the size of the service sector relative to total output in each economy in the model.

5. Simulation Results

a. Baseline Business-As-Usual Projections

To solve the model, we first normalize all quantity variables by each economy's endowment of effective labor units. This means that in the steady state all real variables are

constant in these units although the actual levels of the variables will be growing at the underlying rate of growth of population plus productivity. Next, we must make base-case assumptions about the future path of the model's exogenous variables in each region. In all regions we assume that the long run real interest rate is 5 percent, tax rates are held at their 1999 levels and that fiscal spending is allocated according to 1999 shares. Population growth rates vary across regions as per the 2000 World Bank population projections.

A crucial group of exogenous variables are productivity growth rates by sector and country. The baseline assumption in G-Cubed (Asia Pacific) is that the pattern of technical change at the sector level is similar to the historical record for the United States (where data is 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 past 5 years. This approach attempts to capture the fact that the rate of technical change varies considerably across industries while reconciling it with regional differences in overall growth. This is clearly a rough approximation; if appropriate data were available it would be better to estimate productivity growth for each sector in each region.

Given these assumptions, we solve for the model's perfect-foresight equilibrium growth path over the period 2002-2081. This a formidable task: the endogenous variables in *each* of the 80 periods number over 7,000 and include, among other things: the equilibrium prices and quantities of each good in each region, intermediate demands for each commodity by each industry in each region, asset prices by region and sector, regional interest rates, bilateral exchange rates, incomes, investment rates and capital stocks by industry and region, international flows of goods and assets, labor demanded in each industry in each region, wage rates, current and capital account balances, final demands by consumers in all regions, and government deficits.8 At the solution, the budget constraints for all agents are satisfied, including both intra-temporal and inter-temporal constraints.

b. The simulations

We apply the shocks outlined in the previous section to the global economy. We begin the simulation in 2003 assuming in 2003 that the SARS outbreak 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 anew disease like

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8 Since the model is solved for a perfect-foresight equilibrium over a 80 year period, the numerical complexity of the problem is on the order of 80 times what the single-period set of variables would suggest. We use software summarized in McKibbin and Sachs (1991) Appendix C, for solving large models with rational expectations on a personal computer.

SARS when there is likely to be a period of learning about the nature of the shock. In this case rational expectations might not be a good way to model expectations. Yet an alternative approach is not clear. In our defense it is worth pointing out that only 30% of agents have rational expectations and 70% of agents are using a rule of thumb in adjusting to contemporaneous information about the economy.

Table 4 contains results 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).

The full dynamics of adjustment will be outlined shortly. Focusing on the GDP results it is clear that there are interesting differences between 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% of GDP is however much larger than that of 1.05% 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 in Hong Kong and the greater reliance on trade within the region of Hong Kong. Taiwan is next most affected losing 0.49% of GDP in 2003 followed closely by Singapore with a loss of 0.47% 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. The temporary increase in the country risk premium of a 200 basis point is estimated to lower GDP by 0.33% for China and by 0.20% for Hong Kong. Interestingly, the risk premium shock has very negligible impacts, of less than 0.01% of GDP, on the other countries such as Taiwan and Singapore which adopt floating exchange rate regimes although they are also subject to a substantial rise in the country risk premium by 150 and 100 basis point respectively. The difference comes from the fact that exchange rate depreciation helps Taiwan and Singapore to avoid a rise in real interest rate and subsequent output decline. The persistent SARS shock is also much more serious for Hong Kong and China. The primary impact is from the persistence in the rise of the country risk premium. Although the same in 2003 as for the temporary shock, the persistence of the country risk premium causes are much larger capital outflow from China and Hong Kong. This impacts on short run aggregate demand through a sharp contraction in investment and a persistent loss in production capacity through a resulting decline in the growth of the capital stock which reduces the desirability of investment. The extent of capital outflow will be discussed below.

Interestingly, the difference in GDP loss in 2003 when SARS is expected to be more

persistent distinguishes between two groups of countries. China, Hong Kong, Malaysia, Philippines, Singapore, Taiwan experience a larger loss in 2003 when SARS is expected to be more persistent, whereas the OECD economies and others experience a lower GDP loss. This reflects the greater capital outflow from the most affected countries into the least affected countries which tend to lower the GDP of those countries losing capital and raises the GDP of those countries receiving capital. The countries in the first group that are less affected by SARS nonetheless are worse off with a more persistent disease 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 just illustrated how the costs of SARS can be very different in 2003 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 sets of figures containing 6 charts within each figure. These results are all expressed as deviation from the underlying baseline of the model projections. They show how key variables change relative to what would have been the case without SARS. Figures 5 and 6 give results down the left column for the results of the temporary SARS shock and down the right for the results of the more persistent SARS shock. This enables a comparison between the two for the impacts on the real economy and trade flows. Figure 8 gives more detailed financial outcome for the persistent SARS shock.

Figure 5 contains results for real GDP, investment and exports for both the temporary and persistent SARS shock. 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 it has a persistent impact on real GDP for a number of years. Investment falls more sharply in 2003, which is the source of the larger GDP loss.

The results for exports are interesting. In the case of the temporary shock, exports from Hong Kong fall sharply. Yet, in the more persistent case, exports from Hong Kong rise 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 6.

In the case of the temporary SARS shock the net capital outflow from China and Hong Kong (relative to base) is around 0.3% of GDP. However, when the shock is more persistent this capital outflow (top left panel) rises sharply to 1.4% of GDP for Hong Kong and 0.8% of GDP for China. This capital outflow is reflected in the trade balance surplus in both. This shift in the trade balance is achieved by the capital outflow depreciating the real exchange rate of both China and Hong Kong substantially.

What is interesting is that we assume in the model that the monetary authorities in both economies maintain a tight peg to the US dollar. Figure 7 shows that the real exchange rate depreciation that is inevitable, is achieved through very high real interest rates inducing falling prices (again relative to base). The real exchange rate depreciation and the increased real interest rate will maintain the interest parity condition taking into account the higher risk ppremium. This is similar to the aftermath of the 1997 Asia crisis in both countries and the aftermath of the bubble bursting in Japan in the early 1990s where the lack of nominal Yen depreciation against the US dollar though 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 7 that both Korea and Singapore experience nominal exchange rate depreciations which 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 in Japan, that China is the cause of global deflation is a complete misunderstanding of the difference between the change in a relative price and the change in overall prices within economies and between 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 like Canada, Australia and New Zealand which trade extensively with China, can have inflation while Japan and Hong Kong experience deflation. This phenomena cannot be explained by low cost Chinese production.

We also see in figure 7 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 decline in the most affected service industries.

6. Conclusion

The impact of SARS is estimated to be large on the affected economies of China and Hong

Kong. This impact is not due to the consequence of the disease itself for the affected people, but the impact of the disease on the behavior of many people within these economies. It also depends on the adjustment of expectations reflected in integrated real and financial markets to the disease. The more persistent SARS is expected to be, the larger the negative economic impacts in 2003 in affected economies but the smaller 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 illustrate that the true cost of disease is far greater than the cost to a health budget of treatment of the cases involved. The more persistent shock in this paper can be thought of as SARS lasting longer than anyone hopes, but it can also be interpreted as a recurring series of annual epidemics emerging from China and infecting the world through increased globalization. This is not a new phenomenon, since influenza viruses have been emanating from China since at least the 1918/19 Spanish Flu. Fortunately most have been less devastating than the well-known major outbreaks. A key point of this paper is an attempt to evaluate the true underlying cost of these diseases to the globe. 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 might be very large. The estimates of this paper suggests that there is a strong economic case for direct intervention in improving public health in China and other developing countries where there are inadequate expenditures on public health and insufficient investments in research into disease prevention. And, as we observed from the Asian financial flu in 1997 and SARS in 2003, there is an important role for global monitoring and coordination mechanisms in containing these epidemics.

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Table 1. Cumulative Number of Reported Probable Cases of SARS, As of July 11, 2003

Country	Cumulative number of case(s)[2]	Number of deaths	Number recovered[3]	Date last probable case reported	Date for which cumulative number of cases is current
Australia	5	0	5	12/May/2003	27/Jun/2003
Brazil	1	0	1	9/Jun/2003	1/Jul/2003
Canada	250	38	194	9/Jul/2003	10/Jul/2003
China	5327	348	4941	25/Jun/2003	11/Jul/2003
China, Hong Kong	1755	298	1433	11/Jun/2003	11/Jul/2003
China, Macao	1	0	1	21/May/2003	10/Jul/2003
China, Taiwan	671	84	507	19/Jun/2003	11/Jul/2003
Colombia	1	0	1	5/May/2003	5/May/2003
Finland	1	0	1	7/May/2003	20/May/2003
France	7	1	6	9/May/2003	11/Jul/2003
Germany	10	0	9	4/Jun/2003	23/Jun/2003
India	3	0	3	13/May/2003	14/May/2003
Indonesia	2	0	2	23/Apr/2003	19/Jun/2003
Italy	4	0	4	29/Apr/2003	8/Jul/2003
Kuwait	1	0	1	9/Apr/2003	20/Apr/2003
Malaysia	5	2	3	20/May/2003	4/Jul/2003
Mongolia	9	0	9	6/May/2003	2/Jun/2003
New Zealand	1	0	1	30/Apr/2003	25/Jun/2003
Philippines	14	2	12	15/May/2003	11/Jul/2003
Republic of Ireland	1	0	1	21/Mar/2003	12/Jun/2003
Republic of Korea	3	0	3	14/May/2003	2/Jul/2003
Romania	1	0	1	27/Mar/2003	22/Apr/2003
Russia	206	32	172	18/May/2003	7/Jul/2003
Singapore	1	0	0	31/May/2003	31/May/2003

South Africa	1	1	0	9/Apr/2003	3/May/2003
Spain	1	0	1	2/Apr/2003	5/Jun/2003
Sweden	3	0	3	18/Apr/2003	13/May/2003
Switzerland	1	0	1	17/Mar/2003	16/May/2003
Thailand	9	2	7	7/Jun/2003	1/Jul/2003
United Kingdom	4	0	4	29/Apr/2003	30/Jun/2003
United States	75	0	67	23/Jun/2003	9/Jul/2003
Viet Nam	63	5	58	14/Apr/2003	7/Jun/2003
Total	8437	813	7452		

Notes: Cumulative number of cases includes 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. As of 14 July, WHO no longer publishes a daily table of the cumulative number of reported probable cases of SARS.

1. 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.

2. A decrease in the number of cumulative cases and discrepancies in the difference between cumulative number of cases of the last and the current WHO update are attributed to the discarding of cases.

3. Includes cases who are "discharged" or "recovered" as reported by the national public health authorities.

Source: World Heath Organization, CSR Severe Acute Respiratory Syndrome (SARS) homepage (http://www.who.int/csr/sars/en/)

Table 2: The G-Cubed (Asia Pacific) Model version 50N

Countries:

    United States

    Japan

    Australia

    New Zealand

    Indonesia

    Malaysia

    Philippines

    Singapore

    Thailand

    China

    India

    Taiwan

    Korea

    Hong Kong

    ROECD

    non Oil Developing countries

    Eastern Europe and Russia

    OPEC

Sectors:

    Energy

    Mining

    Agriculture

    Durable Manufacturing

    Non-Durable Manufacturing

    Services

Table 3. Health Expenditure, Tourist Arrivals and Sanitation Indicators for Selected Countries

	Health Expenditure, Total (% of GDP)	Health Expenditure per Capita (Current US$)	Tourist Arrivals (million)	Tourist Arrivals/ Population (%)	Improved 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
US	13.0	4499	n.a.	n.a.	100
Japan	n.a.	n.a.	4.8	4	n.a.
High income OECD	10.2	2771	377.6	n.a.	n.a.
World	9.3	482	696.5	n.a.	55

Source: CEIC, World Development Indicators. Recited from Hanna and Yiping (2003)

Table 4: Percentage Change in GDP in 2003 Due to SARS

	Temporary Shock				Persistent Shock over 10 years			
	Total Effects	Demand Shift	Cost Rise	Country Risk	Total Effects	Demand Shift	Cost Rise	Country Risk
United States	-0.07	-0.01	-0.06	0.00	-0.07	-0.01	-0.06	0.00
Japan	-0.07	-0.01	-0.06	0.00	-0.06	-0.01	-0.06	0.01
Australia	-0.07	0.00	-0.06	0.00	-0.06	0.00	-0.06	0.01
New Zealand	-0.08	0.01	-0.08	0.00	-0.08	0.00	-0.08	0.00
Indonesia	-0.08	0.01	-0.09	0.00	-0.07	0.01	-0.08	0.00
Malaysia	-0.15	0.01	-0.16	0.00	-0.17	0.01	-0.15	-0.02
Philippines	-0.10	0.04	-0.14	0.00	-0.11	0.03	-0.13	-0.02
Singapore	-0.47	-0.02	-0.45	0.00	-0.51	-0.01	-0.44	-0.05
Thailand	-0.15	0.00	-0.15	0.00	-0.15	0.00	-0.15	0.00
China	-1.05	-0.37	-0.34	-0.33	-2.34	-0.53	-0.33	-1.48
India	-0.04	0.00	-0.04	0.00	-0.04	0.00	-0.04	0.00
Taiwan	-0.49	-0.07	-0.41	-0.01	-0.53	-0.07	-0.39	-0.07
Korea	-0.10	-0.02	-0.08	0.00	-0.08	-0.01	-0.08	0.00
Hong Kong	-2.63	-0.06	-2.37	-0.20	-3.21	-0.12	-2.37	-0.71
ROECD	-0.05	0.00	-0.05	0.00	-0.05	0.00	-0.05	0.00
non Oil Developing countries	-0.05	-0.01	-0.04	0.00	-0.05	0.00	-0.04	0.00
Eastern Europe and Russia	-0.06	-0.01	-0.05	0.00	-0.05	-0.01	-0.05	0.00
OPEC	-0.07	-0.01	-0.05	0.00	-0.09	-0.01	-0.06	-0.02

Source: G-Cubed (Asia Pacific) Model version 50n

Figure 1: Probable Cases of SARS, worldwide, China , Hong Kong, and Taiwan

Probable cases of SARS by week of onset
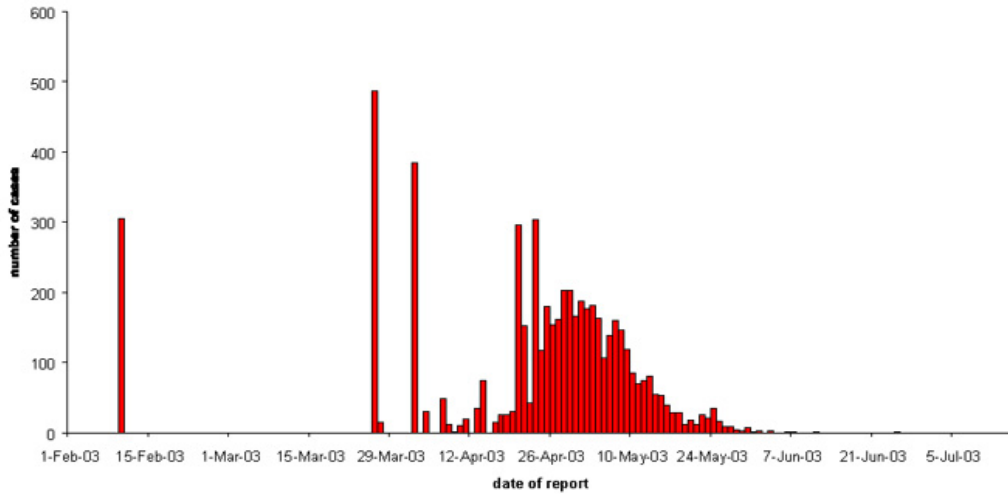**Worldwide* (n=5,910), 1 November 2002 - 10 July 2003**
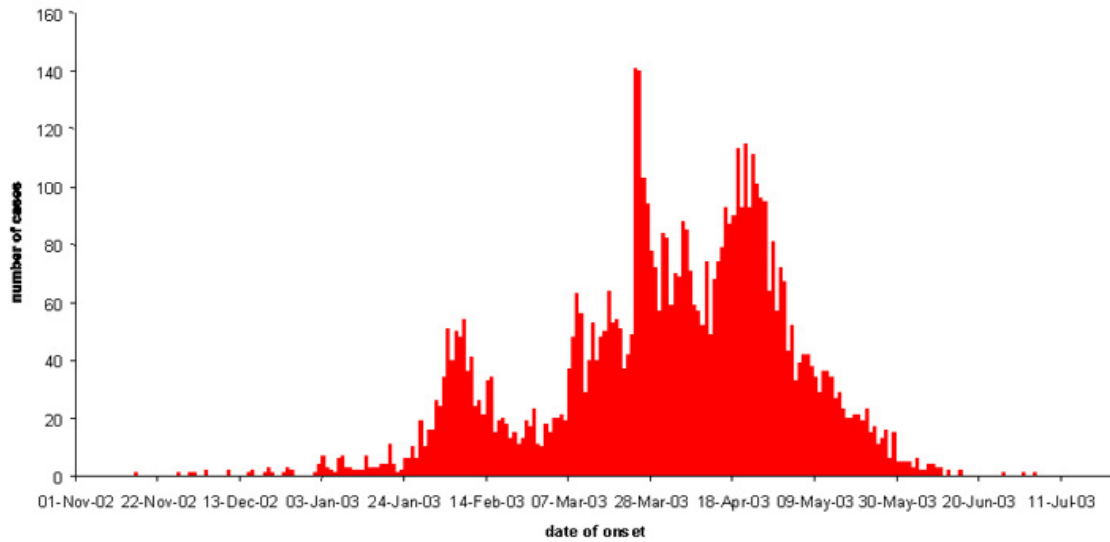
* This graph does not include 2,527 probable cases of SARS (2,521 from Beijing, China), for whom no dates of onset are currently available.

Probable cases of SARS by date of report
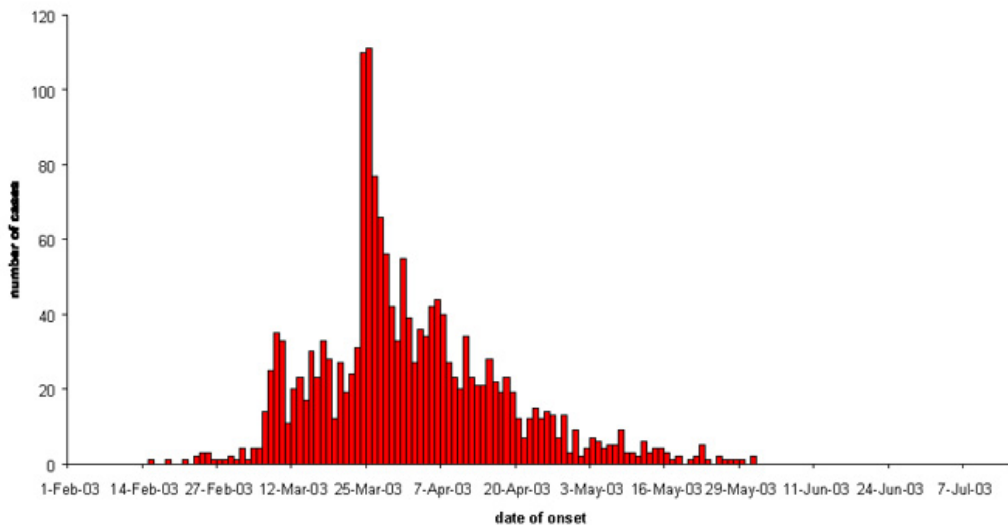**Worldwide* (n=7,588), 1 March - 10 July 2003**
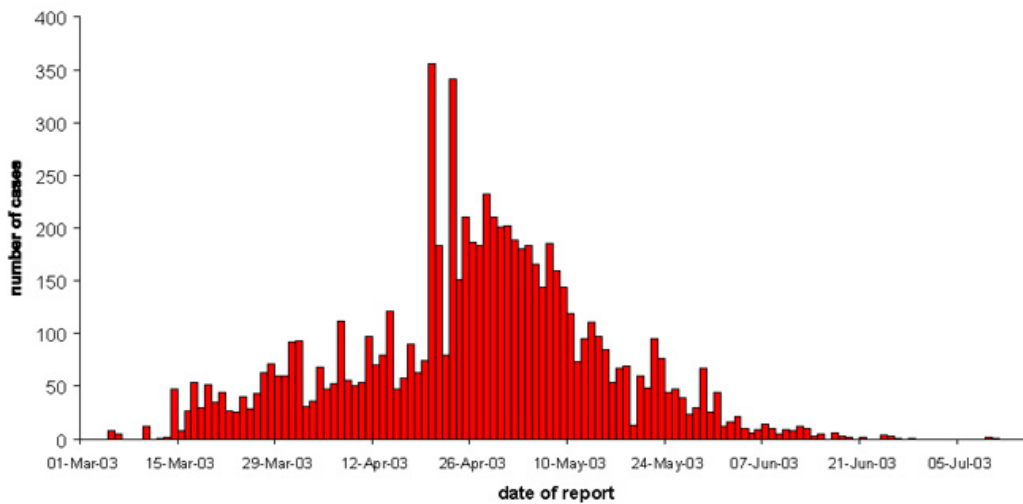
* As of 10 July 2003, 8,437 probable cases of SARS have been reported to WHO.
This graph includes all cases from Hong Kong SAR, Macao SAR and Taiwan, China, but only those cases elsewhere in China reported after 3 April 2003 (1,190 cases between 16 November 2002 and 3 April 2003 not shown). Also includes 341 probable cases of SARS who have been discarded and for whom dates of report could not be identified. The United States of America began reporting probable cases of SARS to WHO on 20 April 2003

Probable cases of SARS by date of report
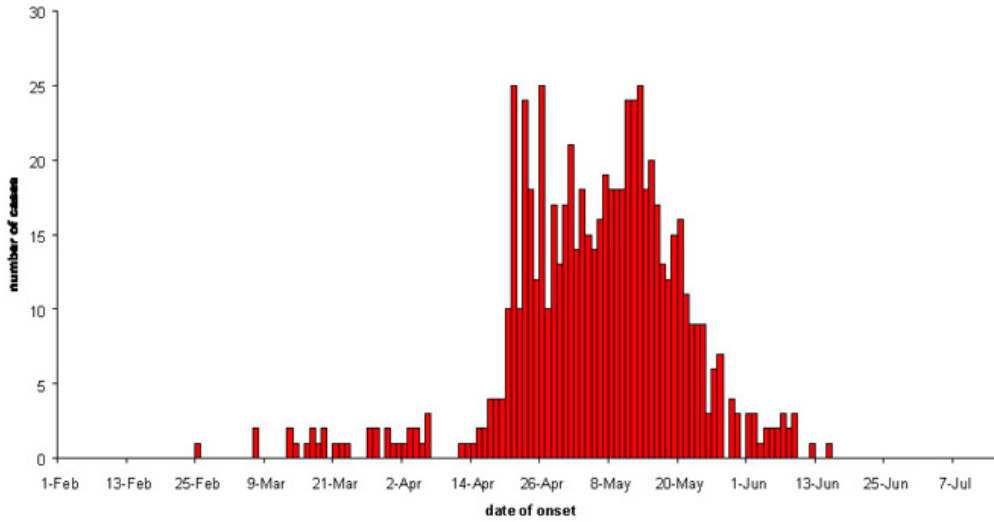## China, 1 February - 10 July 2003 (n=5,550*)

Probable cases of SARS by date of onset
Hong Kong SAR, China, 1 February - 10 July 2003 (n=1,734*)

Probable cases of SARS by date of onset
Taiwan, China, 1 February - 10 July 2003 (n=671)

Source: CDC Taiwan, China and WHO

Source: World Heath Organization, Epidemic curves - Severe Acute Respiratory Syndrome (SARS)**.** http://www.who.int/csr/sars/epicurve/epiindex/en/
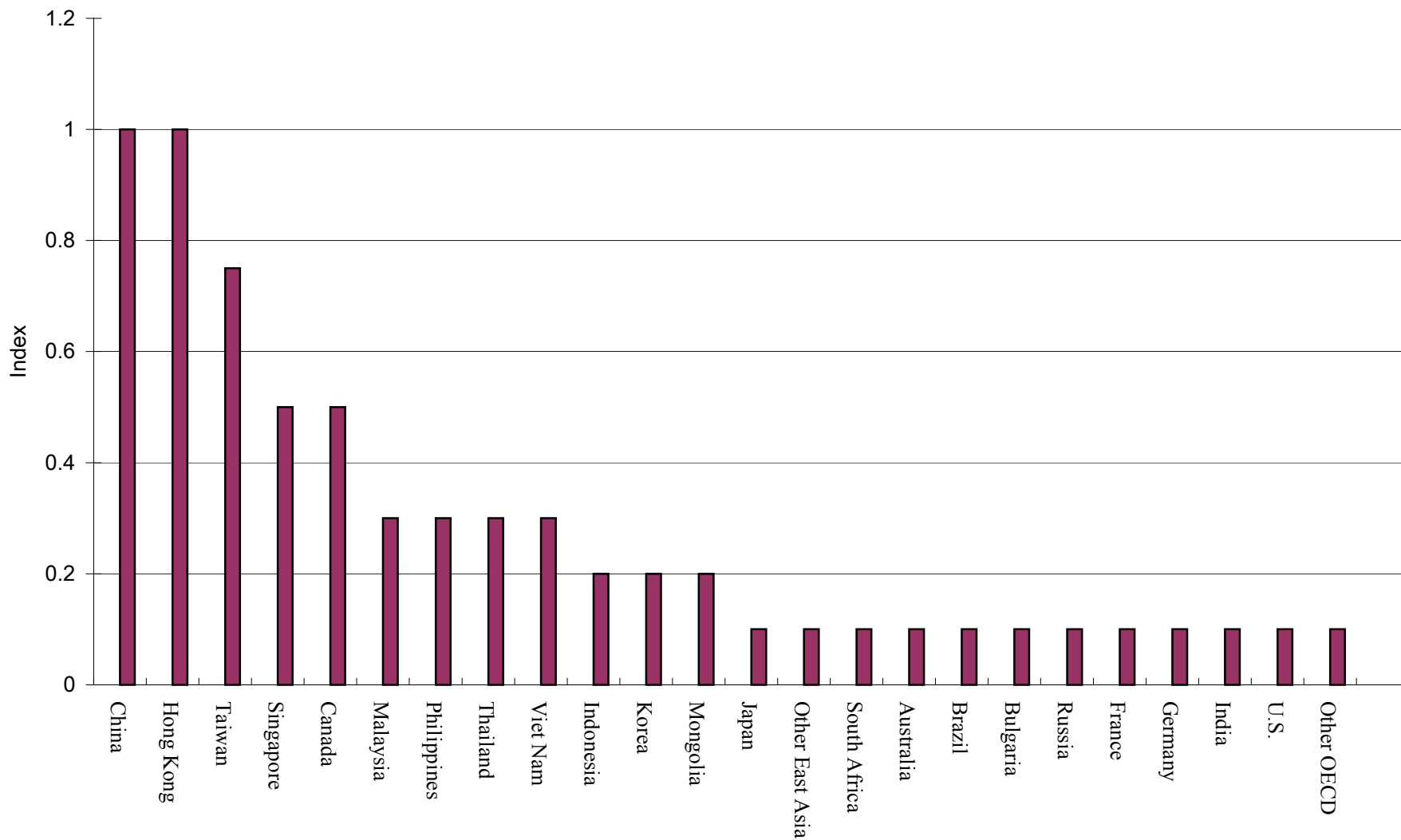
Figure 2. Global Exposure to SARS

Figure 3. Sectoral Exposure to SARS:
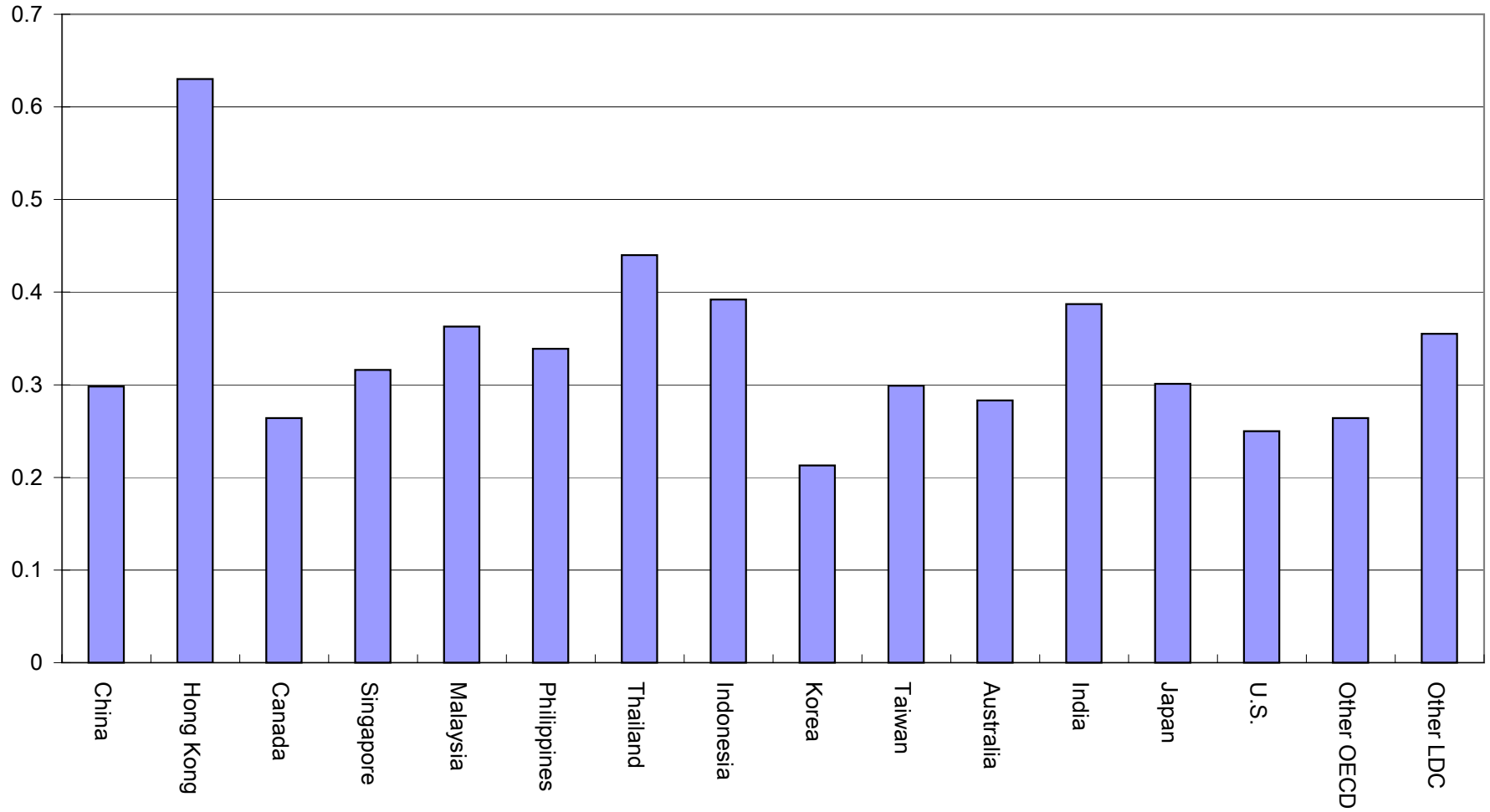Share of Retail Sales and Travel Industry in Service Sector
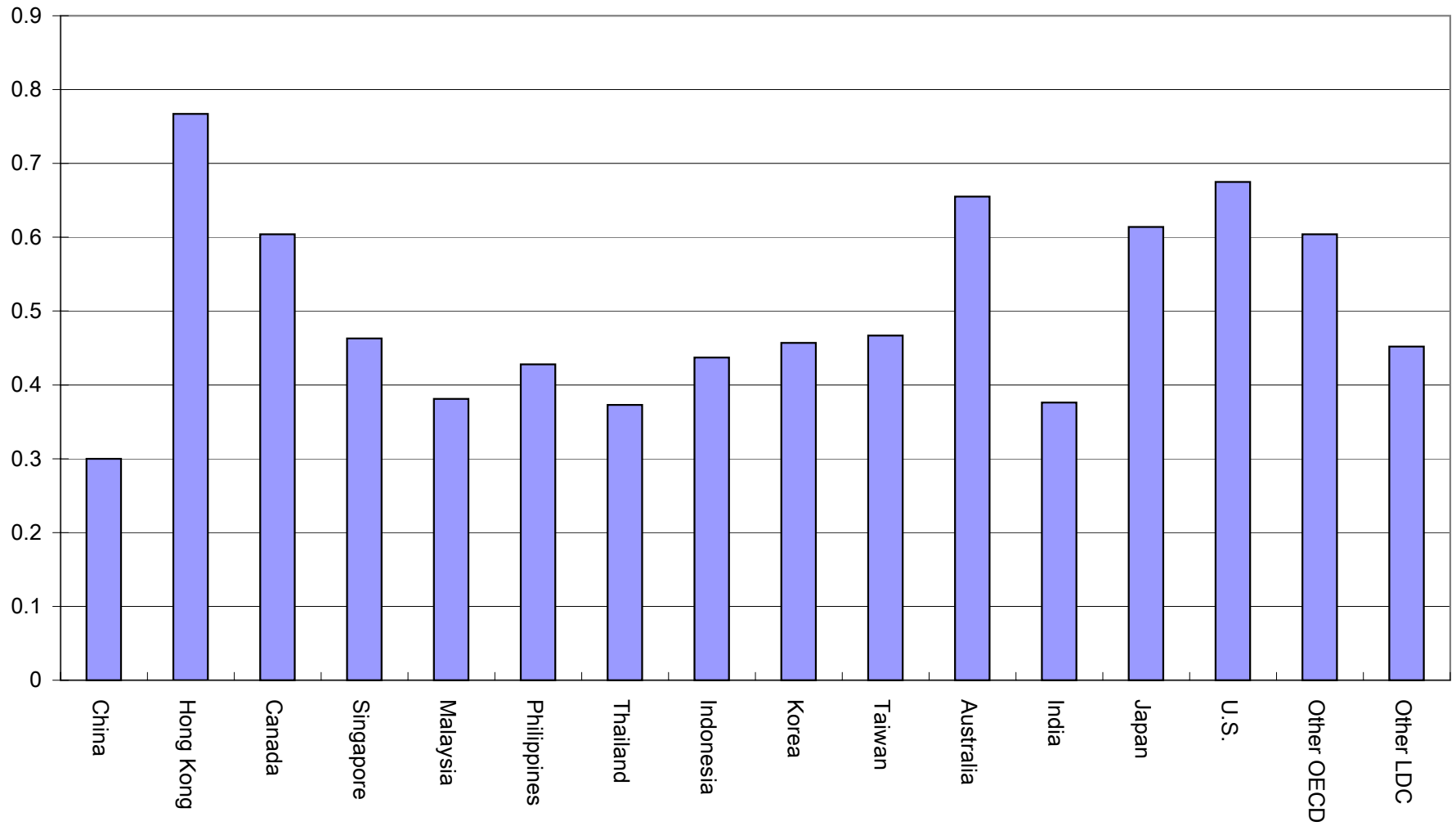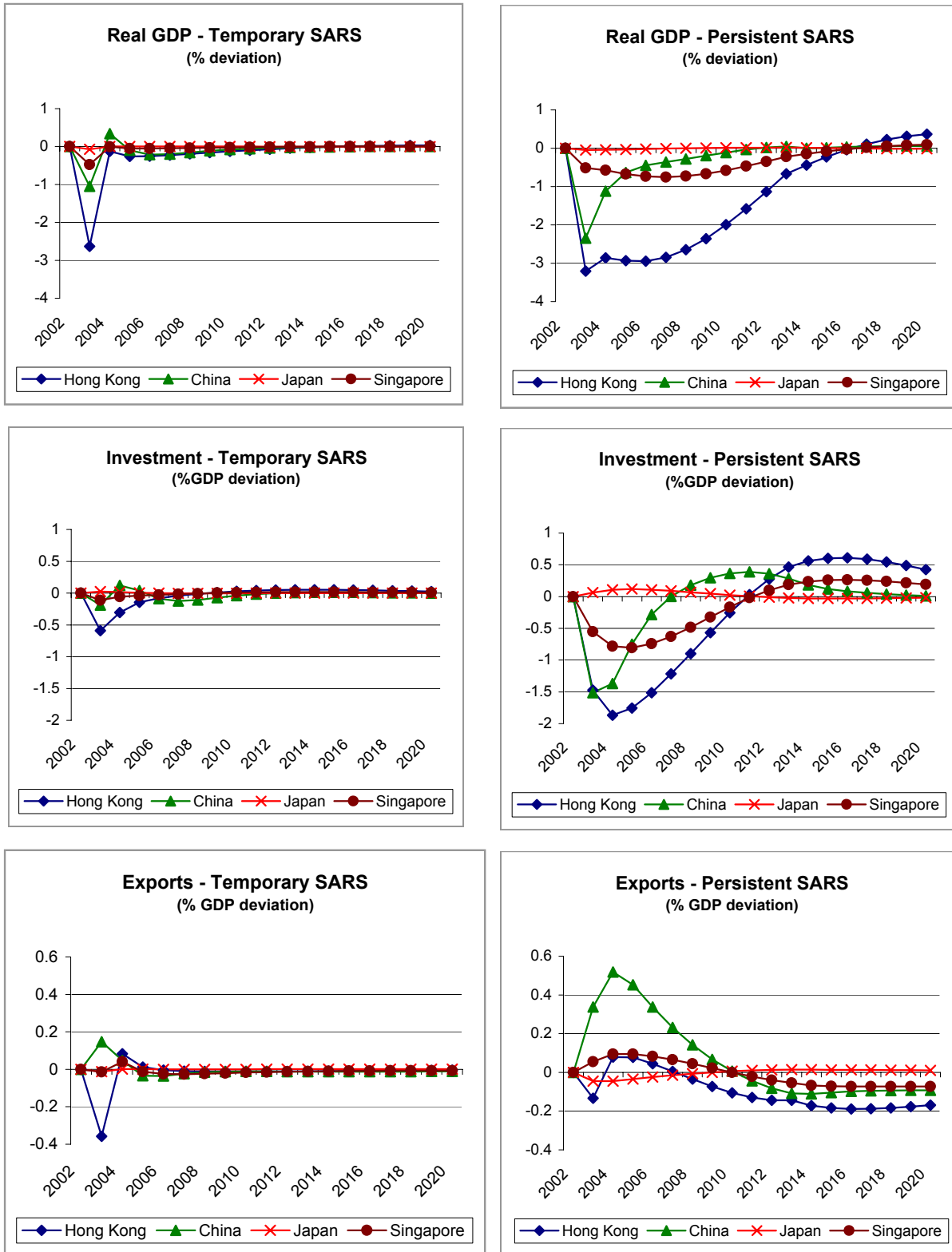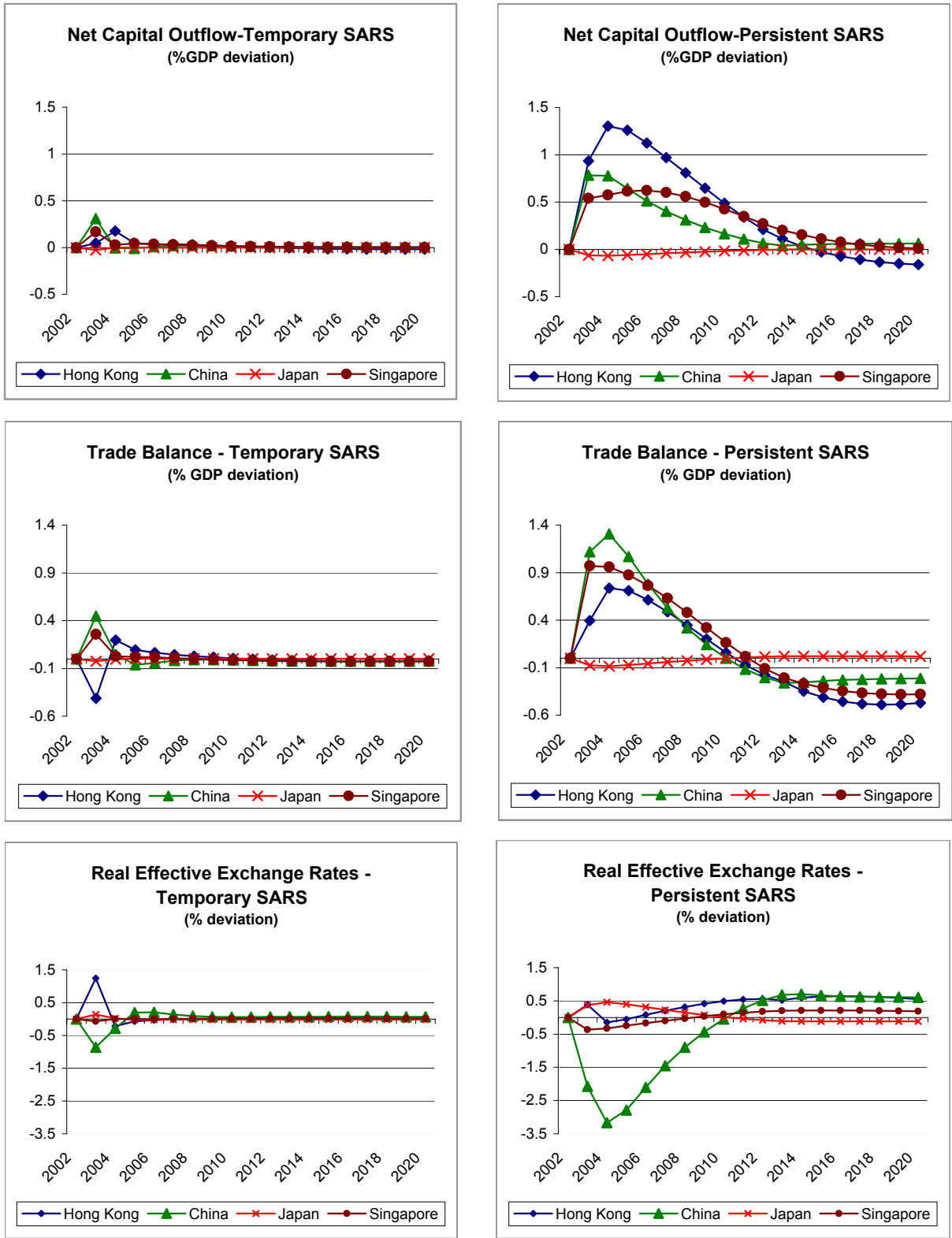
Figure 4. Share of Service Sector in Total Output

Figure 5 : Real Impacts of Temporary versus Persistent SARS shock

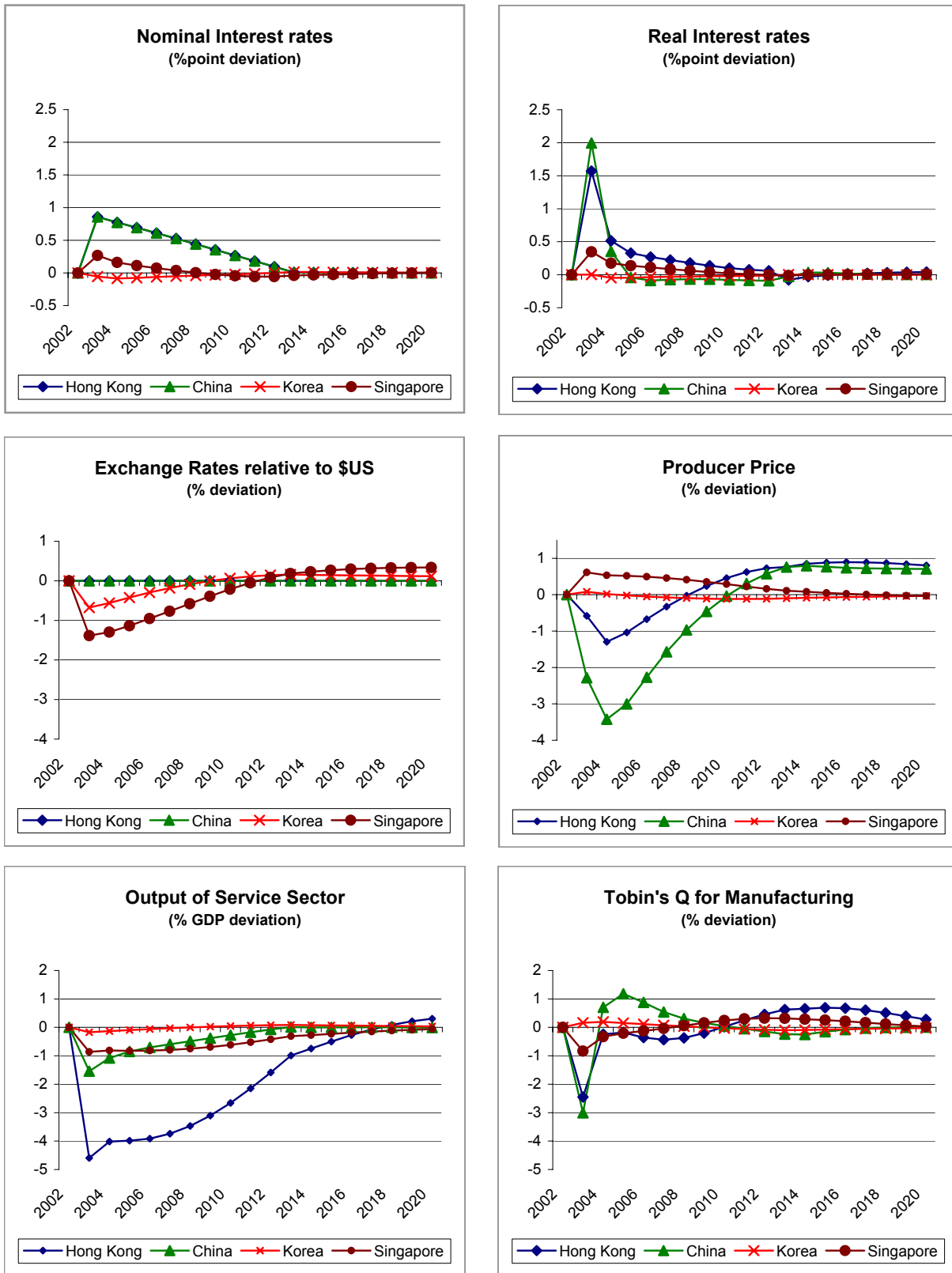**Real GDP - Temporary SARS**
(% deviation)

Real GDP - Persistent SARS
(% deviation)

Investment - Temporary SARS
(%GDP deviation)

Investment - Persistent SARS
(%GDP deviation)

Exports - Temporary SARS
(% GDP deviation)

Exports - Persistent SARS
(% GDP deviation)

Source:APG3 model version 50N

Figure 6: Trade and Captial Flow Impacts of Temporary versus Persistent SARS shock

Net Capital Outflow-Temporary SARS
(%GDP deviation)

Net Capital Outflow-Persistent SARS
(%GDP deviation)

Trade Balance - Temporary SARS
(% GDP deviation)

Trade Balance - Persistent SARS
(% GDP deviation)

**Real Effective Exchange Rates -
Temporary SARS**
(% deviation)

**Real Effective Exchange Rates -
Persistent SARS**
(% deviation)

Source: APG3 model version 50N

Figure 7: Financial and Sectoral Impacts of a Persistent SARS Shock

Source: APG3 model version 50N