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ANALYSIS

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Global Macroeconomic Consequences of Pandemic Influenza

Executive summary

This paper explores the implications of a pandemic influenza outbreak on the global economy through a range of scenarios (mild, moderate, severe and ultra) that span the historical experience of influenza pandemics of the twentieth century. An influenza pandemic would be expected to lead to: a fall in the labour force to different degrees in different countries due to a rise in mortality and illness; an increase in the cost of doing business; a shift in consumer preferences away from exposed sectors; and a re-evaluation of country risk as investors observe the responses of governments. The paper finds that even a mild pandemic has significant consequences for global economic output. The mild scenario is estimated to cost the world 1.4 million lives and close to 0.8% of GDP (approximately $US330 billion) in lost economic output. As the scale of the pandemic increases, so do the economic costs. A massive global economic slowdown occurs in the "ultra" scenario with over 142.2 million people killed and a GDP loss of $US4.4 trillion. The composition of the slowdown differs sharply across countries with a major shift of global capital from the affected economies to the less affected safe haven economies of North America and Europe.

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GLOBAL MACROECONOMIC CONSEQUENCES OF PANDEMIC INFLUENZA

INTRODUCTION[1]

An increasing number of human deaths from the rapidly spreading H5N1 avian influenza have raised the debate on whether avian flu could be the next influenza pandemic to afflict humans. There is much speculation regarding the likelihood of this event occurring and the potential impacts on global economic activity. There are enormous uncertainties involved with whether this might happen, when it might happen, and where it might happen first. This paper considers the possible global economic consequences of an influenza pandemic under four possible scenarios. These are a "mild" scenario in which the pandemic is similar to the 1968-69 Hong Kong Flu; a "moderate" scenario which is similar to the Asian flu of 1957; a "severe" scenario which is similar to the Spanish flu of 1918-1919; and an "ultra" scenario which is worse than the Spanish Flu.

The paper is structured as follows. Section 2 gives an overview of influenza pandemics to put the current analysis in perspective. Section 3 gives an overview of the literature on the macroeconomic costs of disease and puts the methodological approach of the current paper in the context of that expanding literature. Section 4 summarizes the global economic model that forms the basis of the quantitative analysis in the study, with a focus on where shocks are introduced in the model in order to simulate the various scenarios. The model[2] contains twenty countries/regions (USA, Japan, United Kingdom, Europe, Canada, Australia, New Zealand, Korea, China, India, Indonesia, Thailand, Taiwan, Hong Kong, Philippines, Singapore, Malaysia, Eastern Europe and the former Soviet Union, OPEC and other developing economies) with six sectors of production in each economy (Energy, Mining, Agriculture, Durable Manufacturing, Non-Durable Manufacturing, Services). The model captures both trade and financial market linkages between and within economies. The construction of shocks is outlined in Section 5. The approach follows the methodology developed by Lee and McKibbin (2003) for analysing the economic costs of SARS. Much of the benchmarking draws on that study with adaptation to influenza through the construction of a series of indexes for modifying the underlying influenza shocks across the twenty countries used in the study. Section 6 contains the results for the four scenarios as well as sensitivity analysis exploring the role of risk shocks and changes in consumer preferences. A summary and conclusion is contained in Section 7.

INFLUENZA PANDEMICS

Influenza pandemics - or epidemics that involve all people, *pan demos* - can be traced back with some degree of scientific accuracy for the past three hundred years (Beveridge (1991), Potter (2001), Killingray and Phillips (2003), Barry (2004), Kilbourne (2004)). Until the early 1930s, no history of infection could have been confirmed virologically and only clinical signs of the disease and the nature of outbreaks would be used to identify influenza. Historical records suggest that since 1590, there were 10 probable and three possible influenza pandemics, with the oldest records possibly attributed to influenza going to the 5th century BC (Potter (2001)). Typically, influenza pandemics started with a sudden onset in one geographic area and spread throughout the world causing millions of cases and a large number of deaths. Most of the experts agree that China/Russia/Asia were the most likely point of origin for all ten pandemics of the past three centuries (Shortridge and Stuart-Harris (1982), Potter (2001)).

Influenza is not the deadliest of all infectious diseases judged on the case fatality rate (0.1%-2% case fatality rate for influenza compares to 20-25% for smallpox and almost 100% for rabies), but the very high attack rate is what distinguishes influenza pandemics (Kilbourne (2004))[3].

Influenza A type virus proves to be the most important, the most prevalent and the least stable of the known human influenza viruses (Kilbourne (2006)). Its genome consists of eight single-stranded RNA segments. The viral particle has two major surface glycoproteins: hemagglutinin (HA) and neuraminidase (NA). A combination of these two surface proteins is formed out of 16 HA and 9 NA. These determine the major subtypes of the virus (HxNx) (Kilbourne (2006)). The special feature of the influenza virus is its continuous antigenic change and the availability of an animal reservoir which makes it next to impossible to eradicate the disease. In mutation of RNA viruses one distinguishes an antigenic drift or antigenic shift. Antigenic drift occurs when there is an amino acid replacement in HA or NA glycoproteins. Influenza A viral genes re-assort easily with other influenza A viruses of the same or different subtypes. When a human and animal virus exchange genes, an antigenic shift happens and a new pandemic influenza A strain may result (Scholtissek (1994)).

Influenza A sup-types based on H1, H2 and H3 hemagglutinin were involved in the known human influenza pandemics in the 20th century (H1N1 Spanish influenza 1918-19, H2N2 Asian influenza 1957-58 and H3N2 Hong Kong influenza pandemic of 1968-69) (Potter (2001), Palese (2004)). The Spanish influenza 1918-1919 exhibited the W-shaped mortality pattern with the increased death rate in the 15-25 age group and a peak in the 25-35 age group (Palese (2004)). All three influenza pandemics of the 20th century were characterised by a shift in the age distribution of deaths, with younger populations having an elevated mortality risk compared to seasonal influenza and accounting for an increased fraction of all influenza-related deaths (Simonsen, Olsen et al. (2005)).

Natural reservoirs of influenza A are humans and water fowl. Pigs can be infected by both human and avian strains providing a mixing bowl for the influenza A virus re-assortment. The reason for Asia being identified as a likely source of a future pandemic strain is the high density of human population and traditional animal husbandry practices including close cohabitation with pigs and water fowl. Asia is on the close watch as the most probable origin of the next influenza pandemic. Current H5Nx zoonosis in wild birds and domestic poultry involves twenty countries/ administrative areas in Southeast, East and Central Asia, and in Eastern Europe[4]. As of 9 December 2005, there were 137 confirmed human cases of avian influenza H5N1 in five East Asian countries[5] resulting in 70 deaths (a case fatality rate of 51%). Human to human transmission of H5N1 has not beet established to date.

Earlier seroepidemiological studies of rural population in China suggest that there was a previous exposure of humans to avian influenza viruses, with a reported 2-7% seroprevalence levels for H5, and 15-38% seroprevalence for H7, H10 and H11 (Shortridge (1992)). Palese (2004)) refers to the work of Profeta and Palladino (1986) to make a conjecture that the avian influenza viruses could have been infecting humans for decades, and improved data collection and reporting have brought these cases to the light, making the present emphasis on the imminent pandemic outbreak less justified. Pre-existing immunity to NA from the earlier circulating strain in Europe and Asia was hypothesised to have caused a delayed pattern of mortality from Hong Kong influenza in these regions, compared to North America (Viboud, Grais et al. (2005)).

The highly pathogenic avian influenza (H5N1) virus has been identified as one of the likely candidates for a mutation that may result in a new pandemic strain (Ruef (2004), Monto (2005)). Shortridge, Peiris et al. (2003) examine the H5N1 zoonosis in Hong Kong in 1997, 2001 and 2002 to conclude that "it is increasingly clear that pandemic is not only a zoonosis but also a non-eradicable zoonosis". Along with H5N1, the authors identify H9N2 and H6N1 as having a pandemic potential.

Over almost a century of influenza research, various theories of influenza were developed, tested and rejected. It is now generally accepted in the literature that seeking the pattern for pandemics is unrewarding (Potter (2001)), but we still see cycles in the theoretical literature on influenza and influenza preparedness, due to the grave effects of the Spanish influenza 1918-19 pandemic. Historically, the interval between pandemics since 1889 is 10-40 years, and with the latest confirmed pandemic of 1968, it is 37 years since the last pandemic and many argue that another pandemic is overdue.

The 1976 Swine flu episode, vaccination of 43 million population and ensuing side effects appeared to be a misfired attempt to prevent a pandemic. There was an 1994 surge in the influenza literature warning about the imminent pandemic and preparing for it (Dubois (1994), Hannoun (1994), Monto, Iacuzio et al. (1997), etc). Since 1997, a new flurry of activity now focuses on the avian influenza H5N1. For a new pandemic to ignite, the new (yet non-existent) strain has to acquire the capacity to transmit from human to human.

In inter-pandemic years, influenza epidemics are seasonally present usually in winter months characterized by cold weather and over-crowding in temperate climates (November through April in northern hemisphere, May through September in southern hemisphere). In humid tropical climates influenza outbreaks can occur any time; some of the countries report a biannual pattern of epidemics occurring in both spring and autumn, between the temperate climate epidemic seasons (Simonsen (1999)). If the pandemic strain emerges, its spread can be rapid given the current intensity of international travel (Grais, Ellis et al. (2003)). Border control measures such as quarantine or travel bans prove to be capable of postponing the arrival of infection somewhat, but not preventing it from entering the country.

Immunity to influenza is obtained through previous exposure to the virus or through vaccination. There is supporting evidence for some degree of protection from the previous exposure to earlier strains sharing some of the

HA or NA genes coding – so-called heterosubtypic immunity (Epstein (2006)). The major difficulty with influenza vaccines development is the need to hit the constantly moving target as the virus mutates very rapidly. Influenza vaccine manufacturing capacity is concentrated in nine developed countries[6]. They produce 95% of the world's influenza vaccine and account for 12% of the world population. While the vaccine is distributed internationally during the normal influenza season, there are going to be obvious distributional issues involved in making the domestically manufactured vaccine available to non-residents in the case of an influenza pandemic.

The public health response to influenza is different in pandemic years from that in the standard inter-pandemic situation. In particular, in a pandemic the population at high risk from influenza complications expands, potentially doubling or trebling. These includes the health care workers themselves who experience an attack rate as high as 59% during the outbreaks (Salgado, Farr et al. (2002)) . Protecting medical staff by administering them antiviral regimen becomes a priority recognized in all national pandemic preparedness plans.

Epidemiologists always remind us to expect the unexpected with influenza. The emergence of the influenza pandemic is as unpredictable as that of the extreme meteorological events or earthquakes. Due to the chaotic nature of the processes involved the most that is possible is to give an early warning that the disaster is imminent. Since 1970, many countries have invested scientific resources into development of the national influenza preparedness plans and into building a global influenza surveillance and monitoring system. The early warning systems include a network of laboratories capable of identifying the reference strain of the epidemic. The research capacity of developing countries is being strengthened to address the problem at a source. This is especially important given that the most likely epicentre of future pandemic is in one of the developing countries of East Asia.

Resources invested in preparing for the pandemic are the outcomes of decisions under uncertainty. Like other national disaster planning activities related to bioterrorism, nuclear and natural disaster, they are based on the assumption of a small probability of a catastrophic outcome (such as a pandemic with the virulence and attack rate of Spanish Influenza of 1918-19). Challenges surrounding pandemic preparedness planning include strengthening the surge capacity of the health system, building up antivirals stockpiles (taking into account constraints on the global supply, intellectual property rights issues, management of low inter-pandemic demand for antivirals and a possible loss of investment into stockpile with expiry date if there is no pandemic), and production of influenza vaccines. Efficacy of vaccines is confirmed when a sub-strain is correctly identified, but there is only limited protection through heterosubtypical immunity. There are technical constraints to the vaccine manufacturing at a scale required during a pandemic. Current manufacturing technology crucially depends on embryonated chicken eggs. Their supply may be limited during the pandemic and, if the pandemic is caused by a highly pathogenic avian influenza virus, the technology has to be modified to handle this. Alternative technologies such as reverse genetics and cell technology are proprietary and the Intellectual Property (IP) issues have to be addressed. A regulatory issue may also arise with vaccine manufacturers unwilling to rapidly launch the production of vaccine in times of pandemic unless granted liability immunity against the possible negative health effects of the vaccine. Standard licensing procedures are too time-consuming to allow for a rapid response: for example, during the 1976 swine influenza in the USA it took 2 months to develop vaccine while regulatory control and approval measures took another 5 months (Ghendon (1994)) – and negative side-effects of the vaccination campaign were not prevented either.

Macroeconomic costs of disease

Health is an input as well as an outcome of economic development. As an input, health capital in the classic Grossman (1972) definition is one of the forms of human capital determining the person's labour market proposition and efficiency in the labour market. On the micro level, health production function has medical care and time among its inputs. The health capital model extends the earlier models of optimal quantity of investment in human capitals such as Becker (1967) and Ben-Porath (1967). It has become the working model of the health economics literature that has grown tremendously since the pioneering Grossman's article (see Grossman (2000) for the review).

As an outcome of economic development, population health (measured by life expectancy, infant and child mortality, maternal mortality, etc) was shown to be positively related to economic welfare and growth. The positive correlation between health and economic growth was established in Pritchett and Summers (1996), Bloom and Sachs (1998), Bhargava and et al. (2001), Cuddington, Hancock et al. (1994), Cuddington and Hancock (1994), Robalino, Voetberg et al. (2002), Robalino, Jenkins et al. (2002), and analysed in detail in WHO Commission on Macroeconomics and Health (2001) and Haacker (2004). Following the Lucas (1988) framework, an endogenous growth model incorporating health is developed in van Zon and Muysken (2001).

How do infectious diseases influence economic activities and economic growth? Direct and indirect economic costs of illness are often the subject of the health economics studies on the burden of disease. The conventional approach explores the mortality and morbidity implications and estimates the loss of future income due to early death and chronic (or temporary) disability. Losses of time and income by carers and direct expenditure on medical care and supporting services are added to obtain the estimate of the economic costs associated with the disease.

It is becoming increasingly evident that this conventional approach is inappropriate for infectious diseases of epidemic proportions, highly transmissible and for which there is no vaccine. Examples include HIV/AIDS, SARS and influenza pandemics. The impact mechanisms of these three diseases, while different, provide a useful insight into wider economic consequences of their spread.

In its 20 years of existence, the HIV/AIDS pandemic has claimed 20 million lives and has

40 million sufferers worldwide[7]. It has emerged as a very real threat to the economic development of Africa, but other regions such as East Asia, Eastern Europe and Latin America are also experiencing its impact. HIV infection has a long latent (asymptomatic) period, affects mostly young people and has a long term demographic effect through decreased fertility and healthy life expectancy. The incentives to invest in own and children's education and health for those who may become sick are greatly diminished, especially so in the societies with high infant/child mortality and high fertility. Increased consumption of health care has a negative impact on investment in the economy[8].

The HIV/AIDS virus affects households, businesses and governments - through changed labour supply decision, efficiency of labour and household incomes; increased business costs and forgone investment in staff training by firms; and increased public expenditure on health care and support of disabled and children orphaned by AIDS, by the public sector. The effects of AIDS are long-term but there are clear prevention measures that minimise the risks of acquiring HIV, and there are documented successes in implementing prevention and education programs, both in the developed and in the developing world. Treatment is also available, with modern HAART therapies extending the life expectancy and improving the quality of life of HIV patients by many years if not decades.

Influenza virus is by far more contagious than the HIV virus, and the onset of epidemic is sudden and unexpected. The fear of the Spanish influenza 1918-19, the "deadliest plague in history", with its extreme severity and gravity of clinical symptoms, is still present in the research and general community (Barry (2004)).

The fear factor has been influential in the world's response to SARS – a new coronavirus not previously detected in humans (Shannon and Willoughby (2004), Peiris, Guan et al. (2004)). The initial animal-to-human interspecies transmission through the "wet markets" in Southeast Asia has been identified as the most plausible cause of the emergence of SARS. The SARS virus is characterised by lower transmission rates than influenza (a basic reproductive rate[9] of 2.2-3.7 for SARS compared to 5-25 for influenza)[10]. The overall case fatality rate of ~15% is much higher than that of influenza (Peiris, Guan et al. (2004)). The fear of unknown deadly virus is similar in its psychological effects to the reaction to bio- and other terrorism threat and causes high level of stress, often with the longer-term consequences (Hyams, Murphy et al. (2002)). A large number of people would feel at risk at the onset of a pandemic, even if their actual risk assessment were favourable.

Risk assessment

Individual assessment of the risks of death depends on the probability of death, years of life lost and the subjective discounting factor. Viscusi, Hakes et al. (1997) rank pneumonia and influenza as the third leading cause of probability of death (following cardiovascular disease and cancer) and the fourth leading in expected life year lost (with accidents as the third). Sunstein (1997) discusses the evidence that an individual's willingness to pay to avoid death increases for causes perceived as "bad deaths" – especially dreaded, uncontrollable, involuntary deaths and deaths associated with high externalities and producing distributional inequity. Based on this literature, it is not unreasonable to assume that individual perception of the risks associated with the new influenza pandemic virus similar to a Spanish influenza in its virulence and the severity of clinical symptoms can be very high, especially during the early stage of the pandemic when no vaccine is available and antivirals are in short supply. This is exactly the reaction revealed in two surveys conducted in Taiwan during the SARS outbreak in 2003 (Liu, Hammitt et al. (2003)), with the novelty, salience and public concern about SARS contributing to the higher than expected willingness to pay to prevent the risk of infection.

Shortage of vaccines and antivirals is another issue. Schoch-Spana, Fitzgerald et al. (2005) discuss the behavioural response in inter-pandemic 2004-05 in the United States when there was an acute shortage of vaccine and health authorities were faced with how to allocate the unexpectedly scarce resource through prioritising. The lesson from this experience is the effect of media reports and prior experiences on people's perception of their vulnerability during the shortage "crisis" and their rational response by rushing to get the vaccine (what was reported in the media as manifestation of a "scarcity mentality" and panic). Complex decisions were made that included scientific, legal, social and ethical dimensions.

Analysing the effects of SARS on stock markets of the countries mentioned in the first WHO global alert on SARS in March 2003, Nippani and Washer (2004) find that SARS had a negative impact on average daily return of the stock market indexes in China and Vietnam but not in Hong Kong, Singapore, Canada, Indonesia or Thailand. China's market was negatively affected for a short (10-day) period, while Vietnam underperformed both in a short- and a longer (3 month) term panel.

Application of macroeconomic models

Macroeconomic effects of infectious diseases were estimated using the growth model and the cross-sectional approach (for HIV/AIDS: Haacker (2002a), Haacker (2002b), Over (2002), Cuddington (1993b), Cuddington (1993a), Cuddington, Hancock et al. (1994), Cuddington and Hancock (1994), Freire (2004) etc.) The computable general equilibrium (CGE) macroeconomic models were applied in Arndt and Lewis (2001), Bell, Devarajan et al. (2004) to study the impact of AIDS. Smith, Yaho et al. (2005) apply a static single-country closed economy 10-sector CGE model of the UK to study the macroeconomic effects of antimicrobial resistance.

Epidemics have significant effects on economies through large reductions in consumption of various goods and services, increase in business operating costs, and re-evaluation of country risks reflected in increased risk premiums. Shocks to other economies are transmitted according to the degree of the countries' exposure, or susceptibility, to the disease. Lessons from the SARS epidemic in 2003 demonstrate that despite a relatively small number of cases and deaths, the global costs are significant and not limited to the directly affected countries (Lee and McKibbin (2003)). Other studies of SARS include Chou, Kuo et al.

(2004) for Taiwan, Hai, Zhao et al. (2004) for China and Sui and Wong (2004) for Hong Kong.

Macroeconomic costs of influenza

Kilbourne (2004) argues that "The principal impact of influenza is not mortality but morbidity – which is enormous – leading to absenteeism, school closing, declining production, and crowded hospital emergency rooms". This is the short term impact and it depends on the nature of the influenza outbreak. Schoenbaum (1987) is an example of an early analysis of the economic impact of influenza. Meltzer, Cox et al. (1999) examine the likely economic effects of the influenza pandemic in the US and evaluate several vaccine-based interventions. The mean number of clinically ill is estimated at 18-42 million (at a gross attack rate of 15-35%). The mean number requiring hospitalisation is 314-734 thousand (15-35% attack rate), and the corresponding number of deaths is 89 – 207 thousand. Estimated mean total economic impact for the US economy is $73.1- $166.5 billion. In contrast to Kilbourne (2004), 83% of the total economic loss attributed to mortality rather than morbidity but this figure includes the long term impact on foregone earnings from death which raises the mortality costs.

Bloom, Wit et al. (2005) use the Oxford economic forecasting model to estimate the potential economic impact of a pandemic resulting from the mutation of avian influenza strain. They assume a mild pandemic with a 20% attack rate and 0.5 percent case fatality rate; a consumption shock of 3% through social distancing and a labour effect (morbidity) . Scenarios include two quarters of demand contraction only in Asia (combined effect 2.6% Asian GDP or US$113.2 bil); a longer-term shock with longer outbreak and larger shock to consumption and export yields a loss of 6.5% of GDP (US$282.7 billion). Global GDP is reduced by 0.6%, global trade of goods and services contracts by $2.5 trillion (14%). Open economies are more vulnerable to international shocks. Economies that are large exporters of services suffer the most.

Another recent study by the US Congressional Budget Office (2005) examined two scenarios for the United States. A mild scenario with an attack rate of 20% and a case fatality rate of 0.1% and a more severe scenario with an attack rate of 30% and a case fatality rate of 2.5%. The CBO (2005) study finds a GDP contraction for the United States of 1.5% for the mild scenario and 5% of GDP for the severe scenario.

SUMMARY OF THE MODEL

The model used in this study is the Asia Pacific G-Cubed (APG-Cubed) model. The APG-Cubed model consists of 20 countries with 6 sectors of production and consumption as outlined in Box 1. For this study the model has been extended to include a separate country model for the United Kingdom. A more detailed summary of the model is contained in Appendix A. In particular, the equations where shocks enter are specified in detail.

Each sector produces a single good which is an imperfect substitute in the consumption bundle of every consumer in all countries. Thus there are 120 goods produced in 120 sectors using inputs of capital, labour energy and materials, sourced locally and internationally. Each firm in each sector in each country is assumed to maximize its stock market value subject to a production technology and subject to quadratic adjustment costs in physical capital accumulation.

Households supply labour, they save, and they consume goods and services. Within each region household behaviour is modelled by a representative agent with an intertemporal utility function, a function of consumption over all periods and over all goods. The household maximizes this utility function subject to the constraint that the present value of consumption be equal to the sum of human wealth and initial financial assets.

Labour is assumed to be perfectly mobile among sectors within each region but immobile between regions. Thus, nominal wages will be equal across sectors within each region, but will generally not be equal between regions. In the long run, labour supply is completely inelastic and is determined by the exogenous rate of population growth. Long run wages adjust to move each region to full employment. In the short run, however, nominal wages are assumed to adjust slowly according to an overlapping contracts model where wages are set based on current and expected inflation and on labour demand relative to labour supply. Wages are set one period ahead, and depend on current wages; current and expected inflation; and the ratio of current employment to full employment. The stickiness of nominal wages can lead to short-run unemployment if unexpected shocks cause the real wage to be too high to clear the labour market. At the same time, employment can temporarily exceed its long run level if unexpected events cause the real wage to be below its long run equilibrium.

Each region's real government spending on goods and services is assumed to be exogenous. It is assumed to be allocated among goods and services in fixed proportions, which we set to 2002 values. Total government outlays include purchases of goods and services plus interest payments on government debt, investment tax credits and transfers to households. Government revenue comes from sales taxes, corporate and personal income taxes, and from sales of new government bonds. The government budget constraint is that the present value of spending is constrained by the current value of government debt and the present value of future tax collections. It is assumed that agents will not hold government bonds unless they expect the bonds to be paid off eventually.

The implications of the fiscal assumptions are that a government running a budget deficit today must run an appropriate budget surplus at some point in the future. Otherwise, the government would be unable to pay interest on the debt and agents would not be willing to hold it.

The regions in the model are linked by flows of goods and assets. Flows of goods are determined by the import demands described above. These demands can be summarized in a set of bilateral trade matrices which give the flows of each good between exporting and importing countries.

Trade imbalances are financed by flows of assets between countries. Each region with a current account deficit will have a matching

Box 1: The G-Cubed (Asia Pacific) Model version 63A

Countries:
United States
Japan
United Kingdom
Canada
Australia
New Zealand
Europe
Indonesia
Malaysia
Philippines
Singapore
Thailand
China
India
Taiwan
Korea
Hong Kong
Other Non Oil Developing countries
Eastern Europe and Former Soviet Union
OPEC

Sectors:
Energy
Mining
Agriculture
Durable Manufacturing
Non-Durable Manufacturing
Services

capital account surplus, and vice versa.[11] We assume asset markets are perfectly integrated across regions.[12] With free mobility of capital, expected returns on loans denominated in the currencies of the various regions must be equalized period to period according to a set of interest arbitrage relations.

Capital flows may take the form of portfolio investment or direct investment but we assume these are perfectly substitutable *ex ante*, adjusting to the expected rates of return across economies and across sectors. Within each economy, the expected returns to each type of asset are equated by arbitrage, taking into account the costs of adjusting physical capital stock and allowing for exogenous risk premiums. However, because physical capital is costly to adjust, any inflow of financial capital that is invested in physical capital will also be costly to shift once it is in place. This means that unexpected events can cause windfall gains and losses to owners of physical capital and *ex post* returns can vary substantially across countries and sectors. For example, if a shock lowers profits in a particular industry, the physical capital stock in the sector will initially be unchanged but its financial value will drop immediately.

Money enters the model via a constraint that money is required to undertake all transactions[13]. This results in a money demand function in which the demand for real money balances is a function of the value of aggregate output and short-term nominal interest rates.

The supply of money is determined by the balance sheet of the central bank and is endogenous given the reaction functions of central banks in each country who set short term nominal interest rates.

Central banks in the model follow a variety of different policy rules but they are encompassed by a modified Henderson McKibbin Taylor Rule as outlined in Appendix A. Central banks set interest rates in period t based on the interest rate in period t-1, the gap between actual and desired inflation and the gap between actual and desired growth rate of real output. Central banks in some countries also place a weight on changes in the exchange rate relative to the $US. These countries include Indonesia, Malaysia, Philippines, Thailand, China, India, Korea, Russia and former Soviet countries, and OPEC economies. Hong Kong and the other developing countries (LDC) block peg to the $US.

This policy reaction function is important for the results of the pandemic especially for countries that experience the more severe mortality shocks.

Creating the Shocks

The logic behind the scaling of shocks is outlined in diagram 1. Note that because the model is an annual model all shocks are adjusted to be at an annual frequency. The assumptions in the epidemiological scenario drive the various scenarios. These shocks are scaled and adjusted by various factors for each country. Factors such as the exposure of individual service industries within the aggregate services sector are taken into account. Also the shocks to country risk premiums are adjusted by indexes such as: the extent of financial exposure and reliance on foreign capital funding the current account balance; the quality of government; and the quality of the health system. Further details are given below.

As indicated in Diagram 1 the shocks defining each scenario are:

- shocks to labour force (mortality and morbidity);
- additional supply shocks (increase in costs by sector);
- demand shocks (by sector);
- risk premium shocks

Transmission of the shocks is through the direct epidemic channels and through global economic linkages of trade flow adjustment and capital flow reallocation.

a) Epidemic shocks

The epidemiological shocks have been estimated using a variety of indicators for likely epidemiological severity. The approach is very simple and abstracts from age-specific case fatality rates by risk groups for each country because we do not have such detailed data for each country globally.

Four scenarios are created using the United States are the benchmark for each scenario. The four scenarios are :

Mild - similar to Hong Kong flu 1968-69,
Moderate - similar to Asian flu 1957,
Severe - similar to Spanish flu 1918-19, and
Ultra - similar to Spanish flu 1918-19 but without the anomalously high elderly survival rates.

We use two indicators to build up the mortality shocks. The first is an index of geographical susceptibility to an influenza pandemic. The second is an index of health policy

i. Index of geography

The index of geography consists of two components reflecting (a) the ease with which the influenza virus can enter the country through air travel, and (b) the capacity to spread within the country once introduced.

The first, “international” component of the geography index is based on Grais, Ellis et al (2003) who modelled the temporal progression of a Hong Kong-type influenza pandemic using the 2000 air transportation data. The international component of the index measures the number of days from the onset of the pandemic in Hong Kong until the epidemic peak day in the capital (reference) city of the country (region) in the model. The international component is further augmented depending on the location of the country/region in the Southern, Northern hemisphere, or in the Equatorial region, with weights 0.54, 1.8 and 2.7 representing the ratio of cumulative cases in a projected 2000 relative to the 1968 pandemic (Grais, Ellis et al (2003)).The “domestic” component of the geography index is a measure of population density in the country/ region. The higher the density and the frequency of contacts, the faster is the rate of spread of the epidemic within the country. The domestic component is a simple average of rural population density and a share of urban population in the country/ region, scaled to be between 0 and 1.

The index of geography is a simple average of the international and domestic components for a country, relative to the US value. It is shown in Figure 1.

ii. Index of health policy

An index of health policy is used as a measure of the response to influenza pandemic by the health services sector. It is constructed as a weighted average of the resources allocated to health care, and influenza-specific policies and measures described below. Given the degree of imprecision in the latter and the speed of change, we allocate most of the weight to the resource component of the index (75% versus 25% on policy).

The health resources index is based on per capita total expenditure on health in international dollars, adjusted for the index of overall health system attainment (reflecting access to and efficiency of health system) converted to antiviral treatment doses-equivalent per capita[14].

The health resources index for each country is shown in Figure 2. The lower the value of the index the better health policy is in a country or region. Perhaps surprisingly the United States performs very well in this index whereas a range of developing countries perform poorly. The United States stands out because we are measuring the quantity of health expenditure and not adjusting for quality of services delivered.

These two indexes are multiplied together to get an index of mortality rate[15] intensity relative to the United States. This relative impact is applied to each country to build up a world scenario and to get a distribution across countries. The four scenarios for the United States are Mild scenario, 20.2 thousand (mortality rate 0.007%); Moderate scenario 202 thousand (mortality rate 0.07%); Severe scenario 1 million deaths (mortality rate 0.35%); and Ultra scenario 2 million deaths (mortality rate 0.7%). This translates into an aggregate world scenario defined in terms of total world deaths as set out in Table 1: the Mild scenario 1.421 million (0.022% mortality); Moderate Scenario 14.216 million (0.22% mortality); Severe Scenario 71.08 million (1.1% mortality); and Ultra scenario 142.16 million (2.21% mortality).

Figure 3 contains the mortality rates for each country under the four scenarios. It is clear from Figure 3 that there is a dramatic difference in mortality rates between the mild and moderate scenarios and the severe and ultra scenarios. Also the largest shocks occur in the East Asian economies of Indonesia and the Philippines. In the ultra scenario over 5% of the population of these countries are assumed to die. The smallest shocks occur in the United States, Europe and Canada.

There are substantial asymmetries in the mortality shocks across countries. Although scaled in various ways these underlying asymmetries together with the underlying economic structures of economies and the inter-linkages through global trade and capital markets will be the key driver of the results outlined below.

b) Impact on labour force

The shock to the labour force through mortality and morbidity is based on the country (region)-specific index. To calculate the morbidity rate (or days of work lost through sickness), it is assumed that the attack rate among the labour force in each economy is

30%. An employee is sick for 10 working days on average (or dies within that period, with number of deaths determined by death rates in the general population. Losses due to absenteeism (sick workers), assuming a 5-day working week, are calculated as 10/(52*5)*.3=1.15% of the labour force.

The second component of the sickness index is due to absenteeism of workers to take care of sick family members. For simplicity, it is assumed that only female workers take time off to take care of their sick (or quarantined) children. The carer component is a number of females in labour force times average number of children adjusted for the age of females (assume 30% females do not have children of school age), as a proportion of labour force. The same "absenteeism loss" and attack rate are applied for carers (note that the attack rate for children is likely to be higher and can vary by scenario).

The "Index_sickness" variable shown in Figure 4 is a sum of the two components above. It is the same for all four scenarios. Thus in the mild scenario the sickness effect tends to dominate the shock on the labour force in the first year but it has no long run consequences whereas the mortality shocks lead to a permanent loss of labour. Under the severe and ultra scenarios the mortality shocks are much larger for developing countries at least.

The direct impacts on the labour force are the mortality shocks in Figure 3. The secondary effects on the labour force in each country are the shocks due to absenteeism as shown in Figure 4. These shocks are significant. The morbidity shocks shown in Figure 4 are assumed to hit in 2006 and then half in 2007 and are gone by 2008.

c) Sector Exposure (production)

The model contains an aggregate services sector. Country-specific shocks will differ based on the structure of the domestic economy, especially on the share of services in GDP, and on the share of the most affected services sub-sectors in total services. Using the GTAP database[16], we calculated the share of trade, air transport and recreational and other services (sectors 47, 50 and 55) in total services, and multiplied this by the share of services in GDP to obtain the share of exposed services sectors in a country's GDP. This enables us to capture the impacts of sector composition at a greater level of disaggregation than possible in the aggregate model sectors.

The service sector exposure index is shown in Figure 5. This figure shows the major differences in the structure of service industries in each economy. Hong Kong has the highest share of "exposed" sub-sectors in the services sector (high human contact sectors) at over 35% of services. These sectors are likely to be most affected. China has the smallest share of service industries "exposed" at 1.6%[17]. These sector exposure indexes are used to weight the mortality shocks as they impact on costs and demand for service sector output.

d) Risk Premium calculations

The initial risk premium shock will be applied to countries/regions in the model using a scale factor called "Index_risk". This index is a simple average of three components – an index of the quality of government response, a health policy index and an index of financial risks. The higher values of the index correspond to the higher risk premium relative to the United States (the index is scaled between 0 and 1).

i. Index of governance

An extensive finance literature suggests that investors' uncertainty over important factors impacting the economy results in excess volatility of stock returns. Political uncertainty is one of those factors (Bittlingmayer (1998)). To measure country-specific political risks, we used the indicators of the quality of governance constructed in Kaufmann, Kraay et al. (2004). These indexes are based on a statistical compilation of perceptions of the quality of governance of a large number of survey respondents in industrial and developing countries, as well as non-governmental organizations, commercial risk rating agencies, and think-tanks during 1996, 1998, 2000 and 2002. We use the 2002 value and construct a simple average of three components – government effectiveness, regulatory quality and control of corruption. Indexes were transformed to range from 0 (the highest effectiveness) to 1 (the lowest effectiveness).

Governments with higher effectiveness equipped with high quality regulatory framework and free from corruption are expected to provide a more and effective response to the pandemic threat, minimising disruptions to the economy and reducing risk premium associated with the country.

The index is shown in Figure 6. Countries such as Indonesia, China, India and Philippines perform poorly in this index. In contrast Singapore performs well.

ii. Index of health policy

The index of health policy has been discussed above. It also feeds into the country risk shocks.

iii. Index of financial risk

The index of financial risk is the current account balance to GDP ratio in 2002. The rationale for this measure rests on several propositions. Firstly, global shocks are transmitted through financial markets. Countries with well-developed financial markets have more highly correlated growth rates across sectors (Fisman and Love (2004b)). With a global shock such as pandemic influenza ocurring almost at the same time across countries, international markets respond to this systemic risk in a correlated movement, reducing the gains from international diversification and penalizing investors with highly leveraged position (Das and Uppal (2004)). Stock market reaction to the global innovation also depends on the underlying business cycle: stock prices overreact to bad news in good times (and under-react to good news in bad times), reflecting investors' risk aversion and their willingness to hedge against higher uncertainty (Veronesi (1999)). With well developed financial markets, the US serves as a benchmark for the effect of the shock on the growth rates (Fisman and Love (2004a)). The difference from the United States in terms of reliance on foreign financing would be responsible in part for a country-specific response to the global shock (Beckers, Connor et al. (1998) provide empirical evidence for the importance of country factors in the model of worldwide equity returns, with global market/industry factors explaining 25% of the typical equity return variance, and country factors explaining an additional 14%). As a result, higher exposure to foreign capital (higher leverage) compared to the US benchmark, increases a country's riskiness and impacts the volatility of stock returns. Some of this effect is captured - albeit imperfectly - in the proposed index of financial risks.

The combined risk weights (which are ultimately combined with the relative epidemiological shocks to measure the change in risk premia) are shown in Figure 7. This figure shows that a pandemic will cause relatively more panic in Eastern Europe and the former Soviet Union, China, India, Indonesia, the Philippines and other developing countries. Singapore performs well in this index largely as a result of the quality of the health system, the quality of government and the lack of reliance on foreign capital. This will be important in the large differences between Singapore and for example Malaysia and the Philippines in the results despite the same mortality shocks. The actual risk shocks are discussed further below.

e) **Shocks to costs of production**

The shocks to costs of doing business are assumed to vary across sectors and countries and across scenarios. The approach used to determine the scale of the shocks is to benchmark the cost shocks for the moderate scenario to those used for the SARS study by Lee and McKibbin (2003). These shocks are then scaled in the services sector by the service sector exposure index. The different costs shocks across scenarios are scaled by the mortality shocks. Between the mild and moderate scenarios we use the mortality shocks. However between the moderate and severe scenarios we use a linear scaling. We then use the mortality shocks between the severe and ultra scenarios. This is done because the scale of the mortality shocks is so large that the cost shocks appeared far too large relative to the moderate scenario.

Figure 8 through 11 show the shocks for each sector for each country with each figure being for one scenario. The East Asian economies have the largest cost shocks in the first five sectors reflecting the mortality shocks. The shocks to the service industry vary across countries because they are adjusted by the service sector exposure index. This difference shows in the case of China where the service sector shock is reasonably small relative to the other countries.

Figure 9 shows the "moderate" scenario. It is the mild scenario scaled by the mortality shocks for the moderate scenario.

Figure 10 shows the "severe" scenario. It is clear that between the moderate and severe scenarios there is a large change in the relative mortality shocks with East Asian economies proportionately more affected that the United States or Europe. The base cost shocks are linear between the moderate and severe scenarios however these are then scaled by the mortality shocks which are very large and exponential between the two scenarios.

Figure 11 contains the cost shocks for the ultra scenario. These are the same raw shocks as for the severe scenario, scaled by the mortality changes. The shocks are large for most countries as you would expect when a significant proportion of the population are assumed to die from human to human contact.

f) Shocks to demand

The model generates endogenous shifts in spending patterns as a result of the changes in incomes, wealth and relative prices caused by the various shocks imposed. In a pandemic it is likely that individual preferences for some activities will change independently of these economic variables. We model this behaviour by imposing shocks on the demand for various products. These are exogenous shifts in preferences which change relative spending on goods and services and well as the overall level of spending. It is assumed that a fall in spending on a particular good or services results in a fall in overall spending. The money not spent on consumption is not lost but it is saved and spent in future periods. We benchmark the change in spending in 2006 for the moderate scenario approximately to the spending shifts assumed in Lee and McKibbin (2003) for the SARS observations in Hong Kong and Singapore. We then scale the mild, severe and ultra scenarios to this shock using the mortality shocks adjusted as we did for the cost shocks. Some sensitivity to this assumption is explored in the section on sensitivity. The services demand shocks are scaled by the index of service sector sensitivity as it is for the cost shocks. It assumed that there is no shift in preferences for energy and mining. The shift is confined to agriculture, manufacturing and services.

Figure 12 shows the results for the mild scenario. The exogenous shift in demand is relatively modest with the demand for services in Hong Kong falling the most at 0.3%. The pattern of demand changes is very similar to the pattern of cost increases.

Figure 13 contains the results for the moderate scenario. The shocks are as in the mild scenario but scaled for the mortality rate differences.

Figure 14 contains the shocks for the severe scenario. The underlying demand shocks do not rise between the moderate and severe scenarios as quickly as the mortality rates change. The demand shifts in East Asian economies are becoming large with a 7.5% fall in services demand in Hong Kong.

Figure 15 shows the demand shocks for the ultra scenario. These are the shocks from the severe scenario scaled by the changes in mortality rates between the two scenarios.

g) Shocks to Risk

The risk premium weights in Figure 7 are combined with the mortality shocks to produce a risk premium shock for all countries. It is then expressed as relative to the United States (the numeraire country for financial flows). The shocks to the risk premium for each country (relative to the United States which is therefore shown as zero) in each scenario are shown in Figure 16. This indicator of the degree of financial panic shows that the countries most prone to panic are those in East Asia and other developing countries. The risk shocks for the mild and moderate scenarios might seem small. For the severe scenario, some countries such as the Philippines have risk premium change of close to 8 percentage points in 2006.

The sensitivity of the results to assumption about changes in risk premium are tested in the following section where we explore the impact of the size of these risk premium changes as well as the assumption about more sustained versus temporary changes.

RESULTS

a. Core Scenarios

Results for each scenario are presented in Tables 1 through 16. Sensitivity analysis is presented in subsection b) below and is contained in Tables 17 through 22. The dynamics are considered in Figures 17 and 18 for one scenario discussed below to illustrate a common pattern in the time dimension of the results.

The economic adjustment to the pandemic in the global economy reflects aggregate effects as well as relative effects because countries are impacted differently. As labour supply contracts because of mortality and morbidity shocks, the marginal product of capital will fall in all countries but more in those countries experiencing a larger shock. Global growth will slow as output falls. But the differential nature of the shock implies that financial capital will flow from the developing countries to the United States and Europe. Japan experiences a larger mortality shock than North America and Europe as well as having much larger reliance on trade and investment in countries of each East Asia that are most affected by the shock and thus is less of a safe haven than the other major economies.

All results are expressed as relative to the baseline. Figures 17 and 18 show the dynamics of adjustment over time for six of the countries. Figure 17 shows results for GDP as percent deviation from what otherwise would have been experienced along the "no-pandemic" baseline projection. It is clear that most of the shock occurs in 2006, with further losses in 2007. This time profile is largely driven by assumption. Much of the level effects of the pandemic are washed through the global economy by 2008 although the permanent loss in labour force is still noticeable in countries like Malaysia at 0.4% per year lower labour force after 2008. Because results are expressed as percent deviation from what otherwise would have been the case in baseline, the changes should not be interpreted as absolute declines but declines along a growing baseline. The growth rate changes are quite different as shown in Figure 18. In Figure 18, the growth rate in the Philippines in 2006 is almost 7% below baseline. With a GDP growth of 4.7% generated in the baseline, this implies that in 2006, GDP growth in the Philippines would be a contraction of 2.3%. In 2007, despite the pandemic still impacting on the economy, the growth rate would recover to 4% above the 2007 baseline growth rate even though the level of GDP is still below what it would have been in 2007.

Since most of the action for all countries occurs in 2006 (as shown in Figures 17 and 18), the results for the remainder of this report focus on the 2006 outcomes.

Table 3 presents the change in real GDP in 2006 as a result of the pandemic for the mild scenario, decomposing the total change in GDP into the percentage changes caused by each of the main shocks. This gives a clearer indication of the relative importance of each shock, A similar breakdown of the GDP results for each other scenario is given in Tables 4 to 6. For the mild scenario, clearly the labour force shock is the largest driver of the GDP contraction for most countries. Next most important is the increase in costs of production. The fall in GDP is significant - ranging from 0.6% for the United States to 1.54% for the Philippines. The contribution of risk shocks and demand shifts are small relative to the supply side shocks for the mild scenario. This partly reflects the assumption that the monetary authorities are responding to the shocks and can manage demand changes far more easily that supply shocks. It also reflects the relative magnitude of the shocks. It is possible that financial panic might be very large and we have underestimated the contribution from this. Sensitivity of the results to this assumption in terms of the size of the risk shock and the persistence are considered below.

Table 4 decomposes the GDP outcome for the moderate scenario. The dominant cause of the larger GDP decline is the rising importance of cost increases. Increased financial panic also starts to matter for the Philippines and Hong Kong. GDP losses are more substantial in the moderate scenario with Hong Kong losing 9.3% of GDP and the Philippines losing 7.3% of GDP in 2006 (relative to what would have been experienced). The sharp GDP loss in Hong Kong is caused by a combination of a larger set of shocks but also because of the substantial monetary tightening required to maintain the peg to the $US. As shown below the $US is the strongest currency in the face of the shocks under each scenario.

Table 5 contains results for the severe scenario. In this scenario the world is substantially affected by the pandemic. In parts of Asia, GDP contracts by up to 26% relative to baseline which is a major economic shock. The contraction in the most affected economies relative to the United States and Europe partly reflects the much larger shocks in these economies as well as the large reallocation of global capital away from affected economies towards the less affected economies in North America and Europe. The costs shocks are also playing a much larger role on the GDP losses in the severe scenario. Markets begin to close down as the shocks intensify. The demand substitution effects are large by themselves (up to 3.1% for Hong Kong) but small relative to the losses caused by costs increases and loss of working hours. The risk shock also begins to be more significant for countries like the Philippines but again small relative to the underlying supply shocks.

Table 6 shows the decomposition of results for GDP in the ultra scenario. The model had problems solving a shock of this magnitude. In some countries such as Hong Kong, the economy shrinks by more than 53%. This is clearly a major economic catastrophe. The large scale collapse of Asia causes global trade flows to dry up and capital to flow to safe havens in North America and Europe.

This decomposition of the GDP losses from a global pandemic show that even for the mild scenario, the loss of labour and an increased cost of doing business have the largest negative impact. As the pandemic worsens through each scenario, rising production costs lead to the largest GDP losses. The panic component captured by rising risk premiums appears to have much less effect on GDP than the fundamentals driven from supply shocks.

So far the focus has been on the GDP effects of each scenario and the relative contribution of the shocks. A wider group of economic outcomes is considered in Tables 7 through 15. Table 7 shows the GDP losses across each country for each scenario. As the pandemic scenario worsens GDP losses rise. The losses rise much more quickly for Asian and developing countries partly because that is what is built into the mortality assumption (see Figure 3). The second major issue is that because the shocks in developing countries are larger there is a reallocation of global capital and thus the output fall in developing countries reflects a fall in labour input as well as a fall in capital utilization. In addition the wealth and income effects are larger in the more impacted economies and the contraction of demand therefore much larger than in the European and North American economies. Thus the substitution captured by the model accentuates even further the asymmetric adjustment to the asymmetric shocks.

Japan is an interesting intermediate case since it experiences a larger shock that other industrialized economies but a smaller shock that the rest of East Asia. Japan is also much more integrated with the collapsing East Asian economies and takes a further shock through declining trade flows.

The loss of labour input through deaths and sickness reduces output in all countries and is expected to raise inflation in the short run to the extent that output falls by more than demand falls through income and wealth contraction. Because the shock is expected to be temporary, the temporary loss in income is expected to be smoothed by households and consumption remains relatively strong. The rise in the cost of doing business also acts to push up prices. The shift in demand away from affected sectors tends to lower the relative price of those products and the imposed fall in aggregate spending also tends to lower prices. These different factors act together to raise inflation in most economies. The standout exception is Hong Kong but there is also mild deflation in the Philippines, Malaysia and New Zealand. The deflationary outcome reflects both the nature of the shocks in relation to each other within these countries as well as the monetary policy reaction in different countries. Hong Kong experiences a large shock and is very exposed in services. The real exchange rate needs to depreciate most relative to the United States, yet the fixed exchange rate regime means that the adjustment is forced into falling domestic prices. This is similar to the experience of Hong Kong after the Asian economic crisis of 1997/98. The Philippines experiences the largest mortality shock and largest loss of hours due to sickness given the structure of its working population. Although it is not very exposed in the production of services (Figure 5), the Philippines is very reliant on exports of exposed services thus as economies contract, the demand for service exports falls and previously exported services are forced back to compete in the domestic economy driving down prices. The third determinant of the results for the Philippines is due to the weight given to the exchange rate in Philippine monetary policy which forces a relatively tight monetary policy in order to prevent the exchange rate from depreciating too quickly. Although real interest rates appear to rise less than for other East Asian economies (Table 11) the output shocks are much larger in the Philippines and therefore the exchange rate smoothing accentuates the deflationary impulse.

The fall in labour supply reduces the marginal product of capital in all countries which drives down returns on capital. The decline in the return on capital also manifests in a fall in equity prices as investors substitute into bonds pushing up bond prices. The magnitude of this effect varies across countries but in most countries the nominal interest rate falls. This is not true in Hong Kong and the developing country block who by pegging to the $US are forced to raise nominal interest rates in order to prevent a nominal depreciation. This tightening of monetary policy increases the output losses from the pandemic but lowers the inflation consequences. A similar tendency occurs for those countries in Asia that have exchange rate smoothing in addition to inflation and output in their monetary policy reactions (Indonesia, Malaysia, Philippines, Thailand, China, Korea). Interestingly real interest rates tend to rise since they are determined by expected inflation. After the initial surge in prices in 2006, both because of monetary responses and because the shock reverses in subsequent years inflation is expected to fall in future years pushing real interest rates higher in 2006.

The short run interest rate (Table 10) is determined by monetary policy in these economies whereas the long term bond rate (Table 9) is determined by changes in real interest rates associated with the marginal product of capital as well as change in expected longer term inflation. Technically the long bond rate is also the geometric average of expected future short rates. Much of the bond market action is at the short end in the results in Tables 9 and 10. This is because the shock is known to be temporary and central banks are more activist in the short run. Inflation in the medium term is credibly tied down by the monetary policy reaction function and the longer real interest rate follows the marginal product of capital back towards its equilibrium level over time.

The exchange rates in Table 13 are expressed as $US per unit of each currency. A fall in the exchange rate is a depreciation of the currency of the country indicated relative to the $US. The US dollar rises against all currencies except those who are pegging tightly to it (Hong Kong and the LDC bloc). It also appreciates less than it otherwise would against countries that have the exchange rate in their monetary reaction functions. This pattern is not quite so clear from the table because the underlying shocks differ so much across countries.

Table 14 shows the change in current accounts as a percent of baseline GDP. This also reflects the extent of financial capital reallocation globally since a move towards current account deficit (a negative in the table) is a capital inflow.

Table 15 shows the change in equity prices for the non–durable manufacturing sector in each scenario. In the mild scenario equity prices fall between 0.18 percent and 1.1 percent. As the scenarios worsen, there is a larger fall in equity prices in the more affected economies whereas in the safe haven economies such as North America and Europe equity prices fall by less. This reflects the capital inflow into these economies which end up being invested across assets including equity. This only reflects the fundamentals determined by the model which includes knowledge that after the first year the shocks disappear and real activity recovers except for the permanent loss of labour. It may be that markets over-react and force down prices sharply initially but then recover over the year or it may be that the equity risk premium rises sharply and there is a rout of equity markets. In this case the bond price outcomes would be higher still and real interest rates would be driven down. The key point from these results is that the money flowing around globally must go somewhere and because the shocks are temporary and known to be so, the long term outlook for equities is not undermined very much except for the 2006 expectations.

b. Sensitivity Analysis

The various scenarios in the previous section give some idea of sensitivities of the results to alternative assumptions. In this section six further sensitivities are explored more closely. These are the sensitivities to the scale of "financial panic" at the country level as modelled through the change in the country risk premium. The second is the extent to which the risk premium are more sustained rather than known to be fading out over three years. The third is related to the size of the exogenous shift in consumer preferences (or spending patterns). The fourth is the sensitivity to the secondary cost shocks in addition to the contraction in labour supply. The fifth is the sensitivity of the results to assumptions about the attack rate of the influenza pandemic. The sixth sensitivity is related to changes in fiscal spending that might accompany a pandemic outbreak. In the core simulations there is no additional fiscal response[18].

Each of the above assumptions is explored in relation to the moderate scenario since this is probably the most likely outcome. The one exception is for the sensitivity to attack rate which we explored in the mild scenario since this was the only scenario where the morbidity assumptions (which are based on the attack rate) are most affected by the attack rate assumption. To a first approximation the sensitivities can be re-interpreted for the other scenarios by scaling the results of the sensitivities for the moderate scenario relative to the mortality rates of the other scenarios.

The results for GDP, inflation, the 10 year bond rate, the short interest rate and the exchange rate under the moderate scenario and a modification to that scenario (as indicated) for all countries are contained in Table 17 through 22.

Table 17 contains the results for the moderate scenario when it is assumed that the country risk shock is a factor of ten larger for each country (relative to the United States). This implies that countries that are subject to a major mortality shock lose even more capital to less impacted economies through pure financial panic. Remember that capital will also be reallocated because of changes in underlying fundamentals determined by the model. This is clear in Table 17 where the GDP loss for the US and Europe are lower as the risk premium rises everywhere. Inflation is lower in the US because the capital inflow (flight to quality) appreciates the US Dollar and reduces imported prices lowering domestic inflation. Countries that are losing capital and facing exchange rate depreciation and that have exchange rate changes in their monetary reaction functions (Asian economies except Japan and Taiwan) attempt to reduce the capital outflow by raising short term interest rates. This is noticeable for Indonesia, Malaysia, Philippines and Korea. For countries that are safe havens such as the US and Europe, interest rates fall further as interest rates are driven down by capital inflows. In countries that fix their exchange rate to the United States such as Hong Kong and the developing country block, this effect is even larger with a 10 fold rise in the response of short term interest rates to prevent a depreciation of the exchange rate. The consequences for GDP of these fixed exchange rate systems are significant.

Table 18 looks further at the country risk shocks and instead of phasing out the risk premiums by half in 2007 and having it disappear by 2008, the higher country risk premium gradually decays at a rate of 10% per year. This makes a bigger difference for the most affected economies such as the Philippines where the GDP loss increases from 7.3 percent in 2006 to 9 percent. The more sustained the risk premium the sharper the rise in interest rates, the weaker the exchange rate and the more deflationary the shock.

Table 19 contains the result when the exogenous demand switch is assumed to be a factor of 5 times larger than the moderate scenario but everything else in that scenario remains the same. For all countries the larger fall in demand reduces GDP in the short run even more. The most interesting result is that the shock switches from being inflationary in most countries to being deflationary. This is not surprising because as demand contracts the rise in prices caused by higher input costs is attenuated. The policy reaction of central banks is to cut interest rates further as a result. This is also reflected in a larger fall in 10 year bond rates in all countries. The currency depreciations relative to the $US are also larger as a result of the decline in demand and the monetary response.

Table 20 removes the additional cost shocks for the moderate scenario. As expected this reduces the GDP losses but makes the shocks more deflationary since costs rise by less than in the moderate scenario. Short interest rates fall by more in safe haven economies and by less in the more impacted economies. The long term bond rates fall by less than under the moderate scenario. The less severe supply contraction leads to smaller exchange rate fluctuations.

Table 21 contains the results for the mild scenario with a higher attack rate of 35% rather than 30%. This leads to a rise in the number of sick but is assumed not to impact on the mortality rate. The results are not affected significantly by this assumption in the mild scenario and will be even less so for the other scenarios.

Table 22 explores the impacts of a fiscal response modelled as a rise in government spending. It is unclear what fiscal changes would occur under a pandemic scenario. To get some idea of sensitivities, the change in government spending in each country is scaled by the mortality rate and is shown in the second column of Table 22. The average change in government spending is 1.5% of GDP with the United States at the low end of 0.21% of GDP and East Asian economies at 1.5% of GDP. The main effects of temporarily higher government spending are to reduce the GDP loss in the most affected economies, raise inflation in these economies and raise short term interest rates in response to the change in the relative responses of GDP and inflation. The fiscal response could be a critical determinant of the impact of the pandemic on bond markets.

Summary and Conclusion

This report analyses four scenarios surrounding an influenza pandemic. Many of the assumptions built into the scenarios are necessarily arbitrary because in practice it is not possible to know in detail how the pandemic will evolve if it does occur, or how individuals and markets will respond. Much of the calibration of shocks draws on research and experience from the 2003 SARS outbreak as studied in Lee and McKibbin (2003) and uses that methodology to attempt to capture the possible outcomes and sensitivity of outcomes to various assumptions.

There are a number of conclusions. The first is that even a mild pandemic has significant consequence for global economic output. The mild scenario is estimated to cost the world 1.4 million lives and the global economy close to 0.8% of GDP (approximately $US330 billion in lost economic output). As the scale of the pandemic increases, so do the economic costs. A massive global economic slowdown occurs in the "ultra" scenario with over 142.2 million people killed and some economies, particularly in the developing world shrinking by over 50% in 2006. The loss to global GDP is $US4.4 trillion or 12.6%. The composition of the slowdown differs sharply across countries with a major shift of global capital from the affected economies to the less affected safe haven economies of North America and Europe. The size of changes is sensitive to the underlying assumptions. Some robust results emerge. One result is that equity markets fall and bond markets rally although to differing degrees in different countries. The equity price reactions appear reasonably small but that is partly because the economic outcomes in 2006 are bad but recover quickly in future years. In addition the fall in interest rates also supports equity prices. The second result is that a key part of the story is the monetary policy responses. Those countries that tend to focus on preventing exchange rate changes are coincidentally those countries that experience the largest epidemiological shocks. The focus on preventing a depreciating exchange rate leads to monetary tightness which exacerbates the costs of the pandemic. This is particularly true of Hong Kong which receives the largest shocks and has the most rigid exchange rate regime.

Whether inflation rises or falls depends on whether demand or supply shocks dominate. The main supply shocks are the fall in labour supply and the rise in the cost of doing business. The major demand shocks are due to shifts in preferences and induced changes in spending due to income and wealth losses. If the supply shocks are larger then inflation tends to rise. Because consumers see beyond the pandemic year and attempt to smooth consumption, the endogenous demand contractions tend to be smaller than the supply contractions. This can be reversed with large enough imposed exogenous shifts in consumption spending. The more costs rise the more there is likely to be an inflationary rise. The inflationary outcome is also affected by the response of monetary policies since central banks are responding to declining output as well as any changes in inflation. Some central banks are also assumed to respond to exchange rate fluctuations. If inflation is rising while GDP is falling then this presents a policy dilemma; whereas if inflation is falling while output is falling then there can be a greater relaxation of monetary policy to address both falling output and inflation. This sensitivity is important for bond markets.

Some measure of the plausibility of the results in this report can be gained by comparing the various scenarios with the historical experience on the major influenza pandemics. Table 23 contains results for GDP during the 1918-19 Spanish influenza and the 1957-58 Asian influenza. To get an accurate measure of the GDP loss due to influenza would require a detailed model such as used in this paper or a substantial econometric exercise to disentangle various factors, because there are more things happening in the historical data than just the influenza pandemic. In particular, during the 1918-19 Spanish Flu the world was emerging from World War I. A very rough measure of what would have happened can be gauged by using average GDP growth over the 5 years before the influenza pandemic, as the growth baseline. Making that very crude assumption suggests that the deviation in GDP from trend ranges from a gain of 2.4% to a loss of 16.9% for the Spanish Flu. The deviation in GDP from trend during the Asian Influenza of 1958-59 ranges from a gain of 0.4% to a loss of 3.5% of GDP.

In summary there are many unknowns in modelling pandemic influenza scenarios. There are very few observations in history to draw on and there is a great deal of uncertainty about how individuals and markets will respond when faced with a pandemic. The assumptions in the model are clear and the implications follow from these assumptions. Despite the manifest uncertainty, this report has attempted to draw out some economic insights and quantify potential economic consequences of four plausible epidemiological scenarios. If an influenza pandemic emerges this report suggests the economic consequences are potentially very large and disparate across countries. As in most crises, developing countries are far more negatively affected than the large economies of North America and Europe. The extent of potential human and economic losses across the scenarios considered suggests that large investment of resources should be dedicated to preventing an outbreak of pandemic influenza.

NOTES

[1] This report was partly funded through the NHMRC Health Services Research Program, Project ID No. 316951 (ACERH). The authors are grateful to Adrian Sleigh, Niels Becker and Katie Glass for their assistance with identifying the sources of epidemiological data. Helpful comments from Mark Thirlwell, Andy Stoeckel and Joanne Bottcher are appreciated. Remaining errors are our own.

[2] The model used is the Asia Pacific G-Cubed model version 63A. Documentation can be found at WWW.GCUBED.COM

[3] Estimated clinical attack rates for the previous pandemics are 42-55% for 1957 Asian influenza, 41-57% for 1968 Hong Kong influenza, see Simonsen, L. (1999). "The global impact of influenza on morbidity and mortality." *Vaccine* 17 Suppl 1: S3-10. Attack rates varied internationally and reached up to 70-80% in at risk populations such as immunologically naïve populations, school children and hospital staff.

[4] Cambodia, PR of China, Croatia, Hong Kong (SARPRC), Indonesia, Japan, Kazakhstan, Korea (Rep. of), Laos, Malaysia (Peninsular), Mongolia, Philippines, Romania, Russia, Taipei China, Thailand, Turkey, Ukraine, and Vietnam; reported by OIE 9 as of 11 December 2005, http://www.oie.int/downld/AVIAN%20INFLUENZA/A_AI-Asia.htm

[5] Cambodia, China, Indonesia, Thailand and Vietnam; reported by WHO http://www.who.int/csr/disease/avian_influenza/country/cases_table_2005_12_09/en/index.html

[6] Australia, Canada, France, Germany, Italy, Japan, Netherlands, United Kindom and United States, Fedson, D. (2005). Pandemic influenza vaccines: obstacles and opportunities, in *The threat of pandemic influenza: Are we ready? Workshop Summary*, S. L. Knobler, A. Mack, A. Mahmoud and S. M. Lemon (eds). Washington, D.C., The National Academies Press.: 184

[7] http://www.unaids.org/NetTools/Misc/DocInfo.aspx?LANG=en&href=http://GVA-DOC-OWL/WEBcontent/Documents/pub/Media/Speeches02/SP_Piot_EPI05_21Nov05_en.pdf

[8] *ibid*

[9] Defined as the average number of secondary infections generated by a single case, R_0.

[10] Peiris, J. S., Y. Guan and K. Y. Yuen (2004). "Severe acute respiratory syndrome." *Nat Med* 10(12 Suppl): S88-97.

[11] Global net flows of private capital are constrained to be zero at all times – the total of all funds borrowed exactly equals the total funds lent. As a theoretical matter this may seem obvious, but it is often violated in international financial data.

[12] The mobility of international capital is a subject of considerable debate; see Gordon, R. H. and A. L. Bovenberg (1996). "Why Is Capital So Immobile Internationally? Possible Explanations and Implications for Capital Income Taxation." *American Economic Review* 86(5): 1057-75. or Feldstein, M. and C. Horioka (1980). "Domestic Saving and International Capital Flows." *Economic Journal* 90(358): 314-29.

[13] Unlike other components of the model we simply assume this rather than deriving it from optimizing behaviour. Money demand can be derived from optimization under various assumptions: money gives direct utility; it is a factor of production; or it must be used to conduct transactions. The distinctions are unimportant for our purposes.

[14] Assuming the constant price of a AV dose of US$20 in constant 2000 dollars

[15] Influenza-related deaths as percent of population

[16] https://www.gtap.agecon.purdue.edu/databases/default.asp

[17] Recent official revisions to Chinese GDP have raised the service sector value added by around 50%. These new data are not incorporated in this study and may change the results for China significantly.

[18] We also tested the sensitivity of the results for China to the assumption about the exchange rate regime and monetary reaction function but found very little difference because the Chinese exchange rate in the scenarios changes very little relative to the $US and those results are not reported

Appendix A: Overview of the G-Cubed Model and Shocks

The model used in this study is the Asia Pacific G-Cubed (APG-Cubed) model. The APG-Cubed model consists of 20 countries with 6 sectors of production and consumption as outlined in Box 1. For this study the model has been extended to include a separate country model for the United Kingdom.

Each sector produces a single good which is an imperfect substitute in the consumption bundle of every consumer in all countries.

Firms

The model assumes that each of the six sectors can be represented by a price-taking firm which chooses variable inputs and its level of investment in order to maximize its stock market value. Each firm's production technology is represented by a constant elasticity of substitution (CES) function.

(1)
$$Q_i = A_i^o \left(\sum_{j=k,l,e,m} \left(\delta_{ij}^o\right)^{1/\sigma_i^o} x_{ij}^{(\sigma_i^o - 1)/\sigma_i^o} \right)^{\sigma_i^o/(\sigma_i^o - 1)}$$

where Q_i is the output of industry i, x_{ij} is industry i's use of input j (in this case capital, labour, energy and materials),. and A_i^o, δ_{ij}^o, and σ_i^o are parameters. A_i^o reflects the level of technology, σ_i^o is the elasticity of substitution, and the δ_{ij}^o parameters reflect the weights of different inputs in production;

Solving a full intertemporal optimization problem yields a set of input demand functions. Assuming adjustment costs in capital formation also yields a model of investment based on Tobin's Q theory. The input demand functions can be substituted back into the production function to generate price equations where output prices depend on input costs as well as the capital output ratio.

(2)
$$P_i = \left((1/A_i^o) \sum_{j=k,l,e,m} \left(\delta_{ij}^o\right) \; P_{ij}^{(1-\sigma_i^o)} \right)^{1/(1-\sigma_i^o)}$$

Total factor productivity (A_i^o in equations 1 and 2) is the variable that is reduced to capture an increase in costs of production.

The goods and services purchased by firms are, in turn, aggregates of imported and domestic commodities which are taken to be imperfect substitutes. We assume that all agents in the economy have identical preferences over foreign and domestic varieties of each commodity. We represent these preferences by defining composite commodities that are produced from imported and domestic goods. Each of these commodities is a CES function of inputs domestic output and an aggregate of goods imported from all of the country's trading partners

Households

Households have three distinct activities in the model: they supply labour, they save, and they consume goods and services. Within each region household behavior is modeled by a representative agent with an intertemporal utility function a function of consumption over all periods and over all goods . The household maximizes this utility function subject to the constraint that the present value of consumption be equal to the sum of human wealth and initial financial assets.

Human wealth is defined as the expected present value of the future stream of after-tax labour income plus transfers Solving the maximization problem gives the familiar result that aggregate consumption spending is equal to a constant proportion of private wealth, where private wealth is defined as financial wealth plus human wealth.

The demand equations by households for capital, labour, energy and materials can be shown to be:

(3) $$p_i x_i^c = \delta_i^c C \left(\frac{p^c}{p_i} \right)^{\sigma_c^o - 1}, i \in \{k, l, e, m\}$$

where C is total expenditure derived from intertemporal utility maximization, x_i^c is household demand for good i, σ_c^o is the top-tier elasticity of substitution between goods and services and the δ_i^c are the input-specific parameters of the utility function. Within the materials basket of goods and services a further nesting is located.

(4) $$p_j x_j^c = (\beta_j + \delta_m^c) x_m^c \left(\frac{p^i}{p_j} \right)^{\sigma_{ci}^o - 1}, \; j \in \{2,3,4,5,6\}$$

The term β is the exogenous shifter for demand for good j. The constraint is imposed that $\sum \beta_j = 1$. In addition to the exogenous shifts in demand shares we also reduce aggregate consumption but the sum of the changes in the levels of consumption of each good and service.

Labour Markets

We assume that labour is perfectly mobile among sectors within each region but is immobile between regions. Thus, wages will be equal across sectors within each region, but will generally not be equal between regions. In the long run, labour supply is completely inelastic and is determined by the exogenous rate of population growth. Long run wages adjust to move each region to full employment. In the short run, however, nominal wages are assumed to adjust slowly according to an overlapping contracts model where wages are set based on current and expected inflation and on labour demand relative to labour supply. Wages one period ahead, depend on current wages; the current, lagged and expected values of the consumer price level; and the ratio of current employment to full employment. The stickiness of nominal wages can lead to short-run unemployment if unexpected shocks cause the real wage to be too high to clear the labour market. At the same time, employment can temporarily exceed its long run level if unexpected events cause the real wage to be below its long run equilibrium.

The Government

Each region's real government spending on goods and services is assumed to be exogenous. It is assumed to be allocated among goods and services in fixed proportions, which we set to 2002 values. Total government outlays include purchases of goods and services plus interest payments on government debt, investment tax credits and transfers to households. Government revenue comes from sales taxes, corporate and personal income taxes, and from sales of new government bonds. The government budget constraint in that the present value of spending in constrained by the current value of government debt and the present value of future tax collections. It is assumed that agents will not hold government bonds unless they expect the bonds to be paid off eventually.

The implications of the fiscal assumptions is that a government running a budget deficit today must run an appropriate budget surplus as some point in the future. Otherwise, the government would be unable to pay interest on the debt and agents would not be willing to hold it.

Financial Markets and the Balance of Payments

The regions in the model are linked by flows of goods and assets. Flows of goods are determined by the import demands described above. These demands can be summarized in a set of bilateral trade matrices which give the flows of each good between exporting and importing countries.

Trade imbalances are financed by flows of assets between countries. Each region with a current account deficit will have a matching capital account surplus, and vice versa.[1] We assume asset markets are perfectly integrated across regions.[2] With free mobility of capital, expected returns on loans denominated in the currencies of the various regions must be equalized period to period according to a set of interest arbitrage relations of the following form:

(5) $$i_k + \mu_k = i_j + \mu_j + \frac{\dot{E}_k^j}{E_k^j}$$

where i_k and i_j are the interest rates in countries *k* and *j*, μ_k and μ_j are exogenous risk premiums demanded by investors (calibrated in the baseline to make the model condition hold exactly with actual data), and E_k^j is the exchange rate between the currencies of the two countries. The risk premium shocks discussed below are the shocks μ_k and μ_j where these are netted out and country j is taken as the United States.

Capital flows may take the form of portfolio investment or direct investment but we assume these are perfectly substitutable *ex ante*, adjusting to the expected rates of return across economies and across sectors. Within each economy, the expected returns to each type of asset are equated by arbitrage, taking into account the costs of adjusting physical capital stock and allowing for exogenous risk premiums. However, because physical capital is costly to adjust, any inflow of financial capital that is invested in physical capital will also be costly to shift once it is in place. This means that unexpected events can cause windfall gains and losses to owners of physical capital and *ex post* returns can vary substantially across countries and sectors. For example, if a shock lowers profits in a particular industry, the physical capital stock in the sector will initially be unchanged but its financial value will drop immediately.

Money Demand

Money enters the model via a constraint that money is required to undertake all transactions[3]. This results in a money demand function in which the demand for real money balances is a function of the value of aggregate output and short-term nominal interest rates.

The supply of money is determined by the balance sheet of the central bank and is endogenous given the reaction functions of central banks in each country who set short term nominal interest rates.

Central Bank Reaction Functions

Central Banks in the model follow a variety of different policy rules but they are encompassed by a modified Henderson McKibbin Taylor Rule[4].

(6) $$i_t = i_{t-1} + \alpha(\Pi_t - \overline{\Pi}_t) + \beta([y_t - y_{t-1}] - [\overline{y_t - y_{t-1}}]) - \gamma([e_t - e_{t-1}] - [\overline{e_t - e_{t-1}}])$$

In equation (6) i_t is the short term policy interest rate in period t and i_{t-1} is the policy interest rate in the previous period; Π_t is actual inflation in period t; $[y_t\text{-}y_{t-1}]$ is the change in the log of output (or output growth) in period t and $[e_t\text{-}e_{t-2}]$ is the change in the log of the nominal exchange rate relative to the $US in period t. Corresponding variables with a bar overhead indicate desired values of these target variable.

Countries that follow a conventional HMT rule with no weight on the exchange rate are assumed to have weights of α=0.5, β=0.5 and γ=0. These include United States, Europe, United Kingdom, Japan, Australia, New Zealand, Canada, Taiwan and Singapore.

Countries that follow some exchange rate policy are assumed to have α=0.5, β=0.5 and γ=0.5. These countries include Indonesia, Malaysia, Philippines, Thailand, China, India, Korea, Russia and former Soviet countries, and OPEC economies.

Countries that follow an exchange rate peg are assumed to have α=0, β=0 and γ=1000000. These countries include Hong Kong and the other developing countries (LDC) block.

This policy reaction function is important for the results of the pandemic especially for countries that experience the more severe mortality shocks.

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[1] Global net flows of private capital are constrained to be zero at all times – the total of all funds borrowed exactly equals the total funds lent. As a theoretical matter this may seem obvious, but it is often violated in international financial data.

[2] The mobility of international capital is a subject of considerable debate; see Gordon, R. H. and A. L. Bovenberg (1996). "Why Is Capital So Immobile Internationally? Possible Explanations and Implications for Capital Income Taxation." *American Economic Review* **86**(5): 1057-75. or Feldstein, M. and C. Horioka (1980). "Domestic Saving and International Capital Flows." *Economic Journal* **90**(358): 314-29.

[3] Unlike other components of the model we simply assume this rather than deriving it from optimizing behavior. Money demand can be derived from optimization under various assumptions: money gives direct utility; it is a factor of production; or it must be used to conduct transactions. The distinctions are unimportant for our purposes.

[4] See Henderson and McKibbin (1993) and Taylor (1993)

Appendix B: Data Sources

Estimates/Sources for the initial epidemiological assumptions

Epidemiological assumptions: case fatality rate, % cases			
Year/category	Lower	Medium	Upper
US modelling estimate			
Standard risk#			
0-19	0.001	0.002	0.013
20-64	0.003	0.004	0.009
65+	0.028	0.042	0.054
High risk			
0-19	0.013	0.022	0.765
20-64	0.010		0.572
65+	0.276		0.563
Historical estimates			
Overall			
1918/19*	0.2-0.5	2.5	4
1957/58**	0.04		0.27
1968/69***	0.01	0.013	0.07
G-Cubed model assumptions			
Mild 0.02333			
Moderate 0.2333			
Severe 1.1667			
Ultra 2.3333			

Meltzer (2005)
* Patterson and Kyle (1991), Wilton (1993), Sanford (1969)
** Simonsen, Clarke et al (1998), Beveridge (1991)
*** Barker and Mullooly (1980)

Epidemiological assumptions: influenza attack rates, %			
Year/category	Lower	Medium	Upper
US modelling estimate[#]	15		35
Historical estimates			
1918/19			
USA, overall [(i)]	10		40
USA, subpopulations			
school/nursing home [(ii)]			50
hospital staff [(iii)]			78
1957/58			
USA, overall [(iv)]	15		40
USA, subpopulations			
school/nursing home [(v)]			69
hospital staff [(vi)]			63
Percent subclinical cases [(vi)]		28	
1968/69			
Hong Kong [(vii)]	10		30
G-Cubed model assumptions			
Mild 30%			
Moderate 30%			
Severe 30%			
Ultra 30%			

\# Meltzer (2005)
(i) Reid and Taubenberger (1999), Cox and Fukuda (1998)
(ii) Cox and Fukuda (1998)
(iii) Figura (1998)
(iv) Beveridge (1991)
(v) Sanford (1969)
(vi) Blumenfeld, Kilbourne et al. (1959)
(vii) Sanford (1969)

Variables/ Sources Used to Construct the Index of Geography

Days from onset on Hong Kong to epidemic peak, Grais, Ellis and Glass 2003

Urban population (% of total) (WDI)

Population density, rural (people per sq km) (WDI)

Variables used to construct the labour force index/ Sources:

Fertility rate, total (births per woman), World Development Indicators (WDI), World Bank, http://devdata.worldbank.org/dataonline/NewCountries.htm

Labour force, total (WDI)

Labour force, female (% of total labour force) (WDI)

Variables/ Sources Used to Construct the Sectoral Exposure Index

Share of exposed sectors in services (GTAP v 6.0)

Services as per cent of GDP, (GTAP and WDI)

Variables/Sources Used to construct the Risk Index

Current account balance (% of GDP)

The indicator is calculated as a ratio to GDP in U.S. dollars.

Source: WDI, based on International Monetary Fund, Balance of Payments database.

Variables/Sources Used to construct the index of Governance

Governance Indicator Dataset , Research Project by Daniel Kaufmann, Aart Kraay and Massimo Mastruzzi, as described in "Governance Matters III: Governance Indicators for 1996-2002".

http://siteresources.worldbank.org/DEC/Resources/govmatters3.pdf

Dataset:
http://siteresources.worldbank.org/DEC/Resources/KKGovernanceIndicators2002.xls

Variables/Sources Used to construct the Risk Premium index

Per capita total expenditure on health in international dollars, WHO WHOSIS

Overall health system attainment (World Health Report 2000) is a composite measure of achievement in the level of health (weight 25%), the distribution of health (25%), the level of responsiveness (12.5%), the distribution of responsiveness (12.5%) and fairness of financial contribution (25%). The composite is constructed on a scale from 0 to 100, the maximum value.

Source: "The World Health Report 2000 - Health systems: improving performance", http://www.who.int/whr/2000/en/index.html

The *health policy index* is a simple average of the following four variables:

- % population covered by an existing or pre-ordered stockpile of Tamiflu, August 2005, Source: Lokuge (2005)
- Manufacturing capacity to produce antivirals, Source: Lokuge (2005)
- National Influenza Centres and Laboratories – members of the WHO Influenza Surveillance Network / Global Influenza Programme, Source: WHO http://www.who.int/csr/disease/influenza/centres/en/index.htmlAccessed 22 Nov 2005

National Influenza Preparedness Plans publicly available. Source: WHO http://www.who.int/csr/disease/influenza/nationalpandemic/en/index.html

Diagram 1: Structure of Shocks for a given Country i

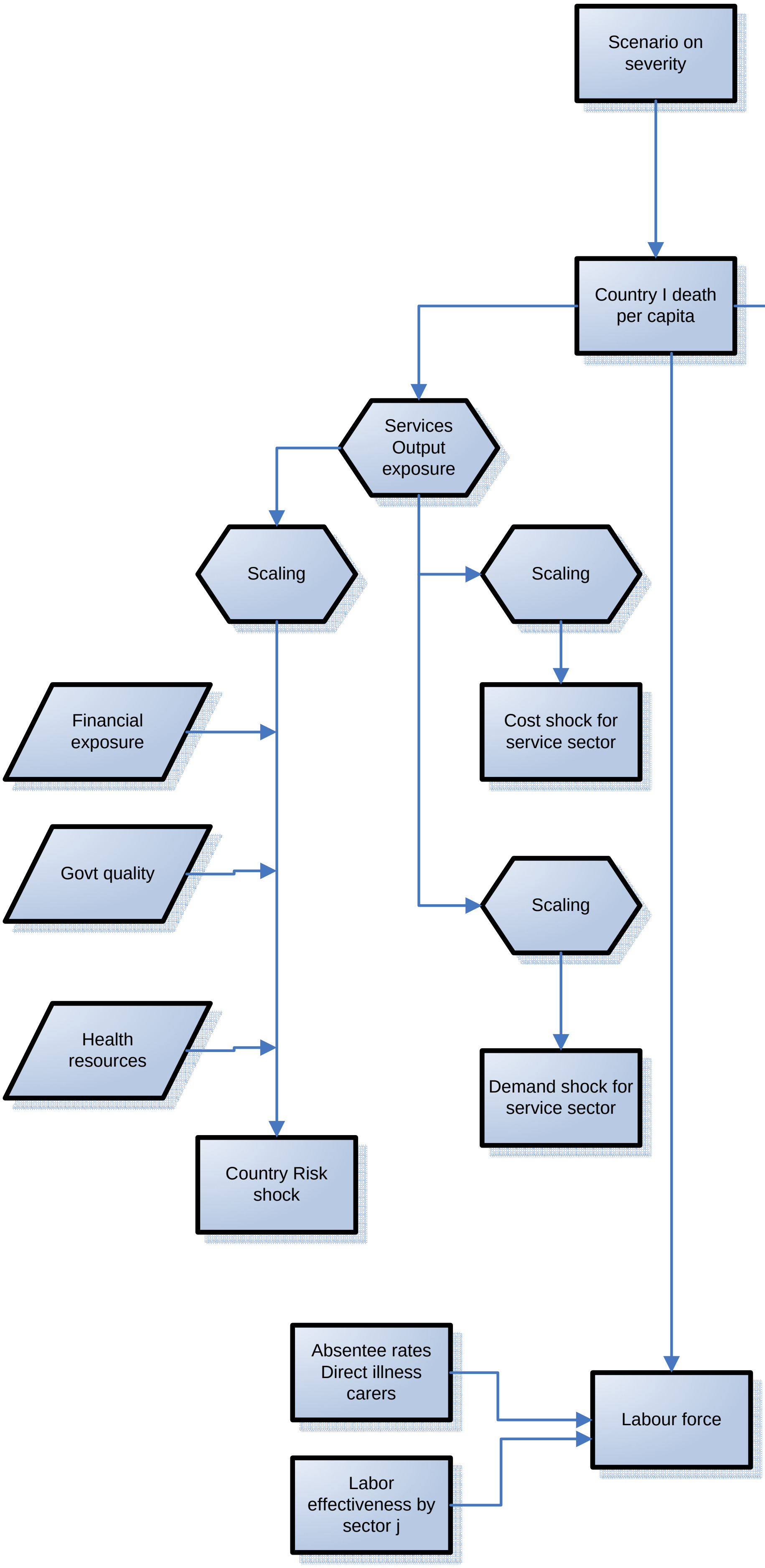
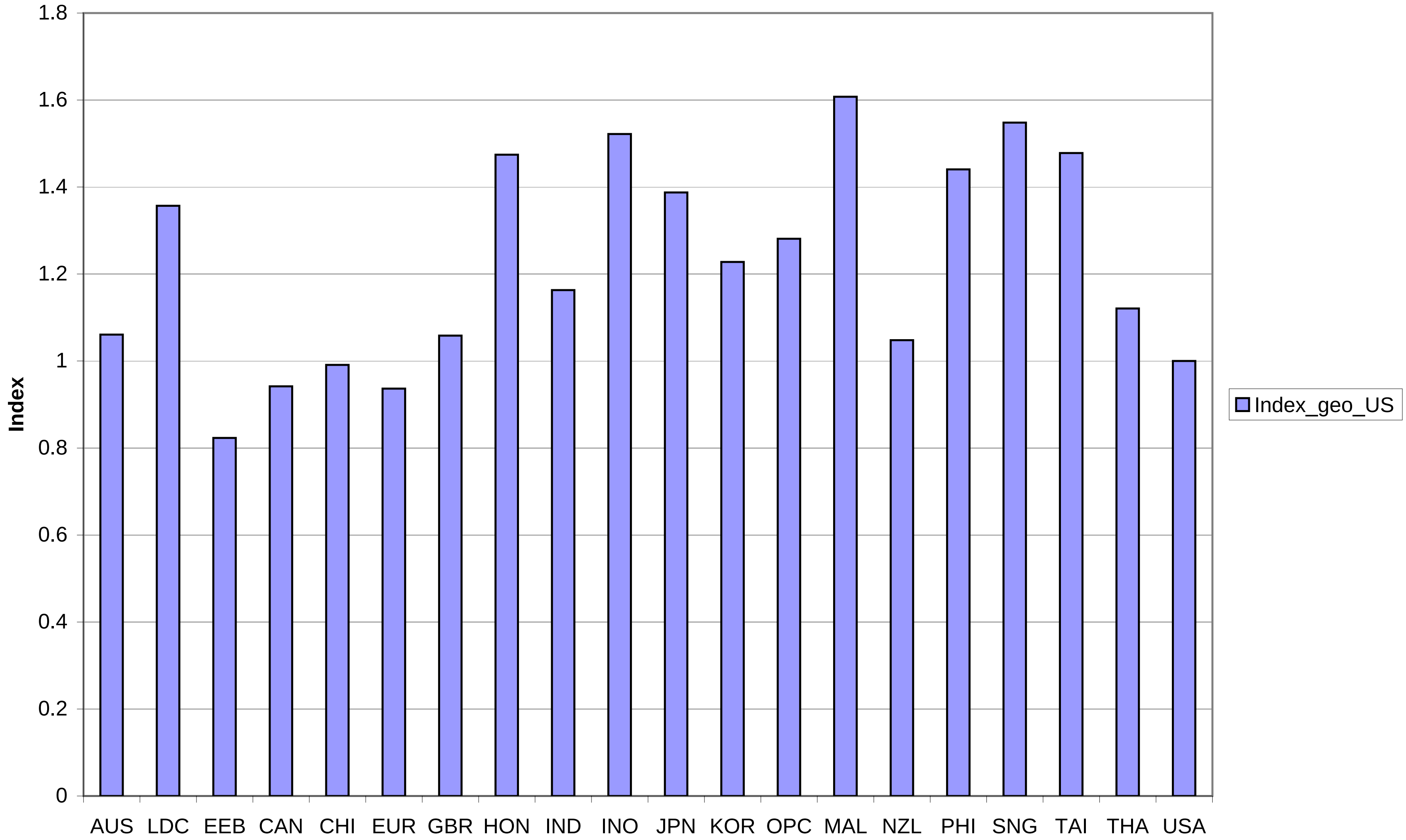


Figure 1: Geography Indicator



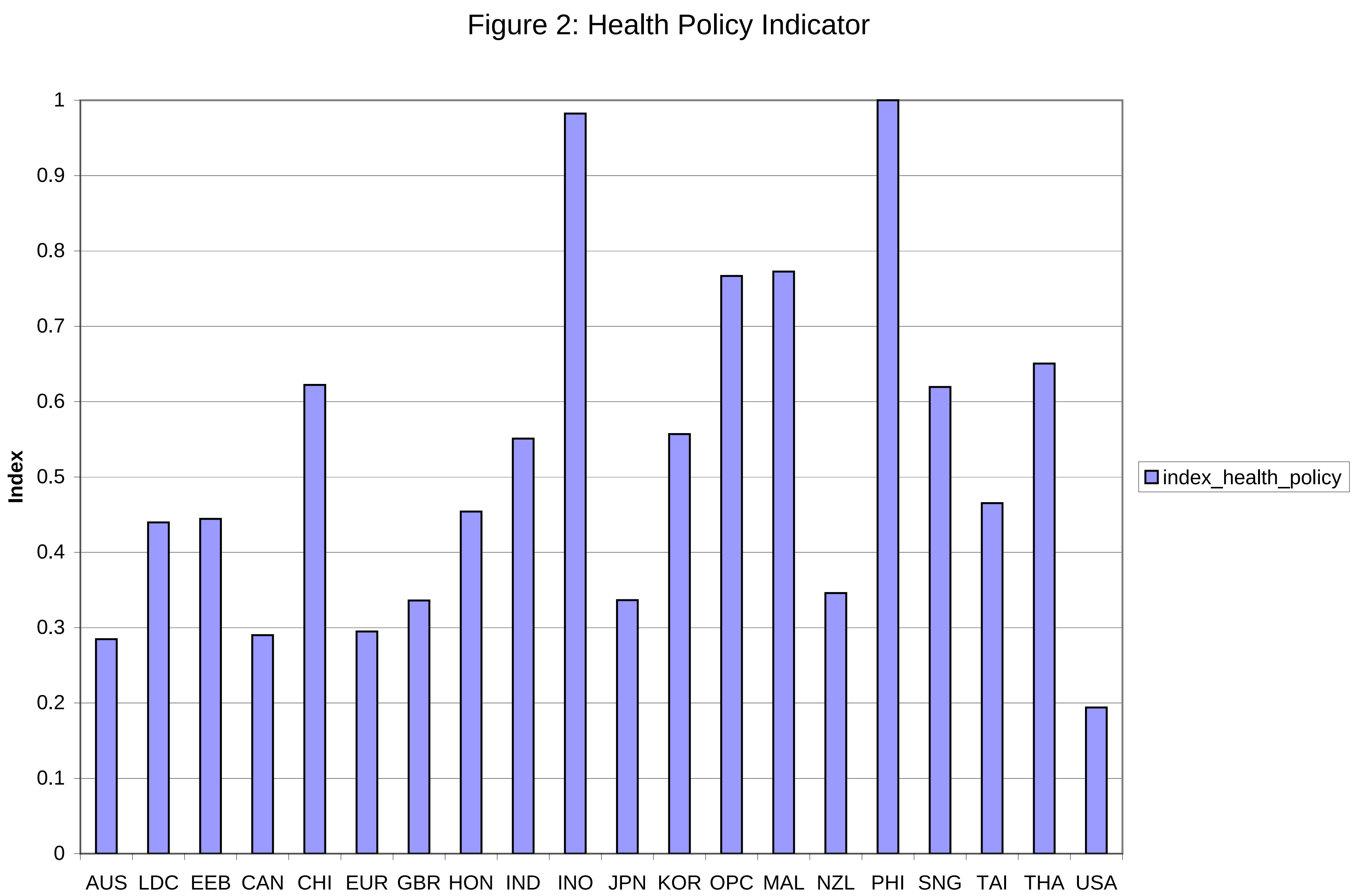


Figure 2: Health Policy Indicator
Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
AUS
LDC
EEB
CAN
CHI
EUR
GBR
HON
IND
INO
JPN
KOR
OPC
MAL
NZL
PHI
SNG
TAI
THA
USA
index_health_policy

Figure 3: Mortality Rate Under each scenario

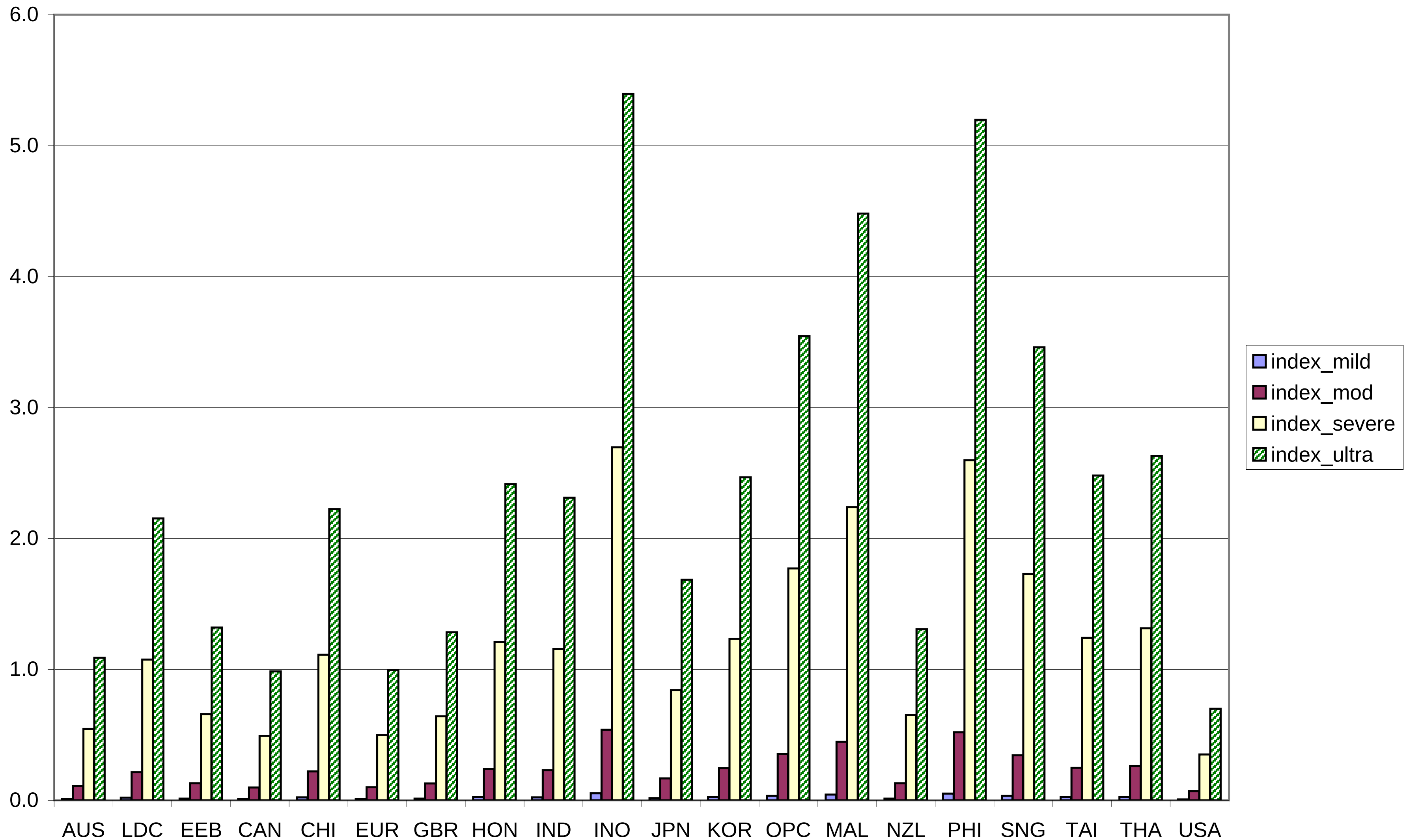


Figure 4: Additional labor force shock due to Absenteeism

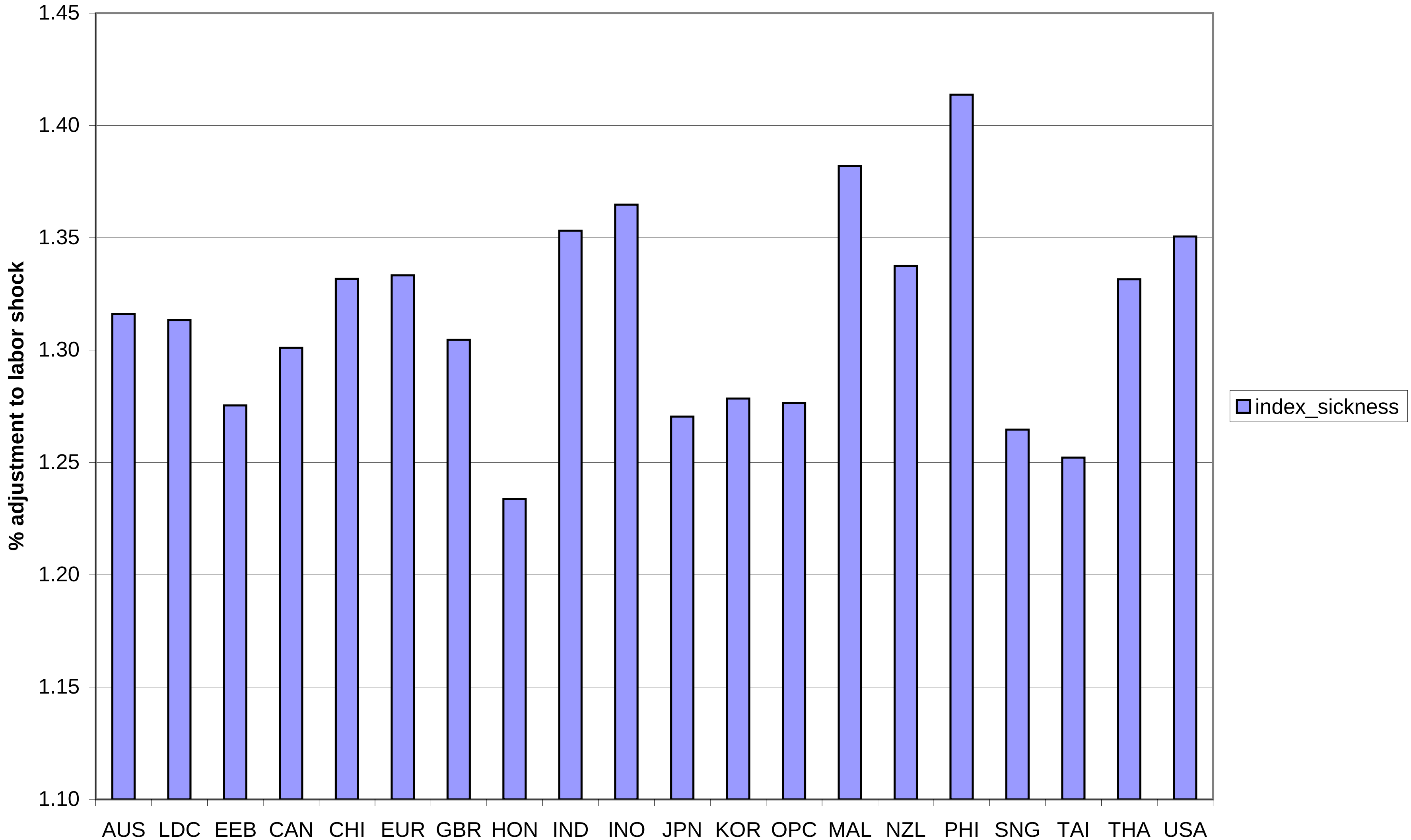


Figure 5: Service Sector Exposure in Production

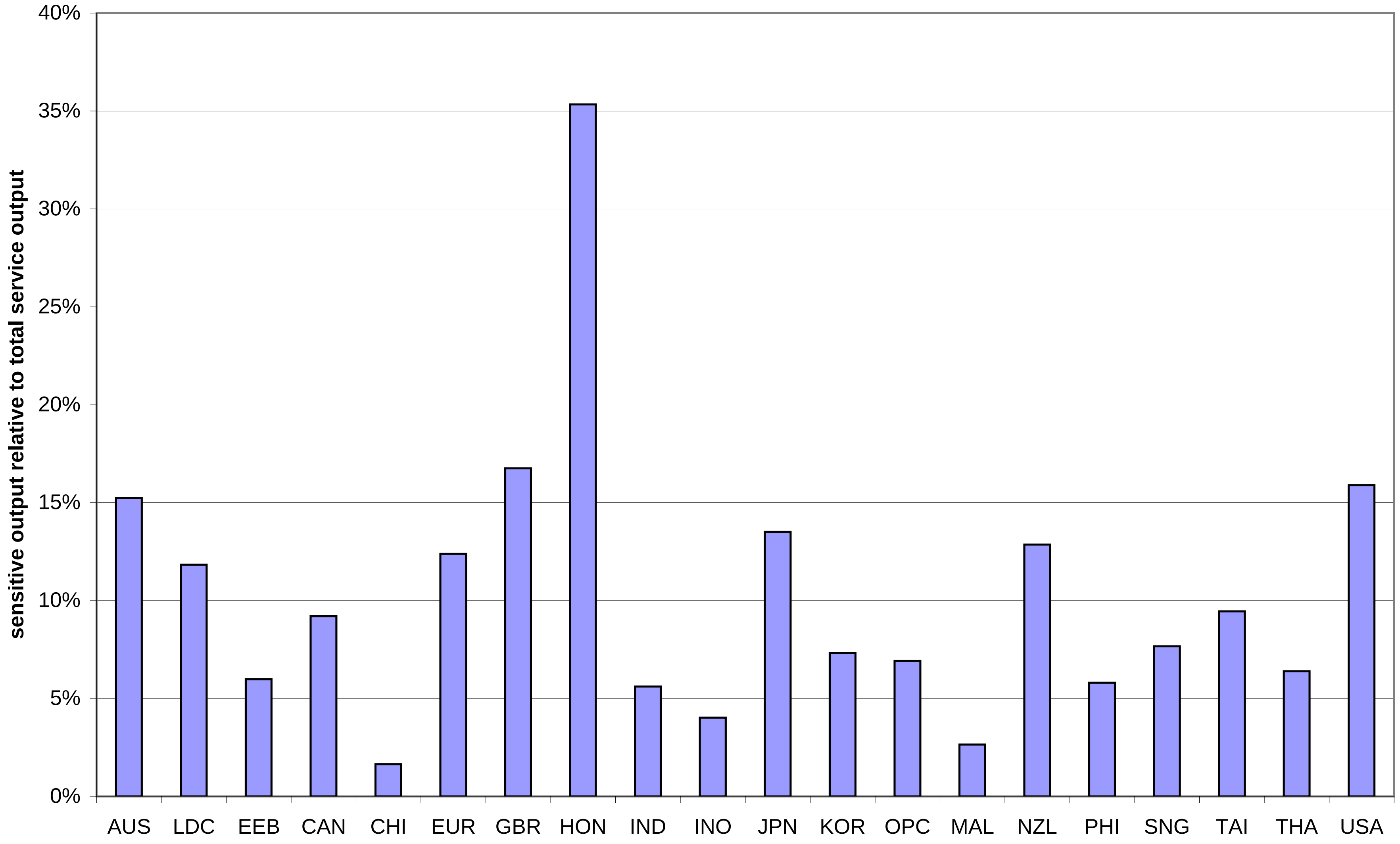


Figure 6: Governance Indicator

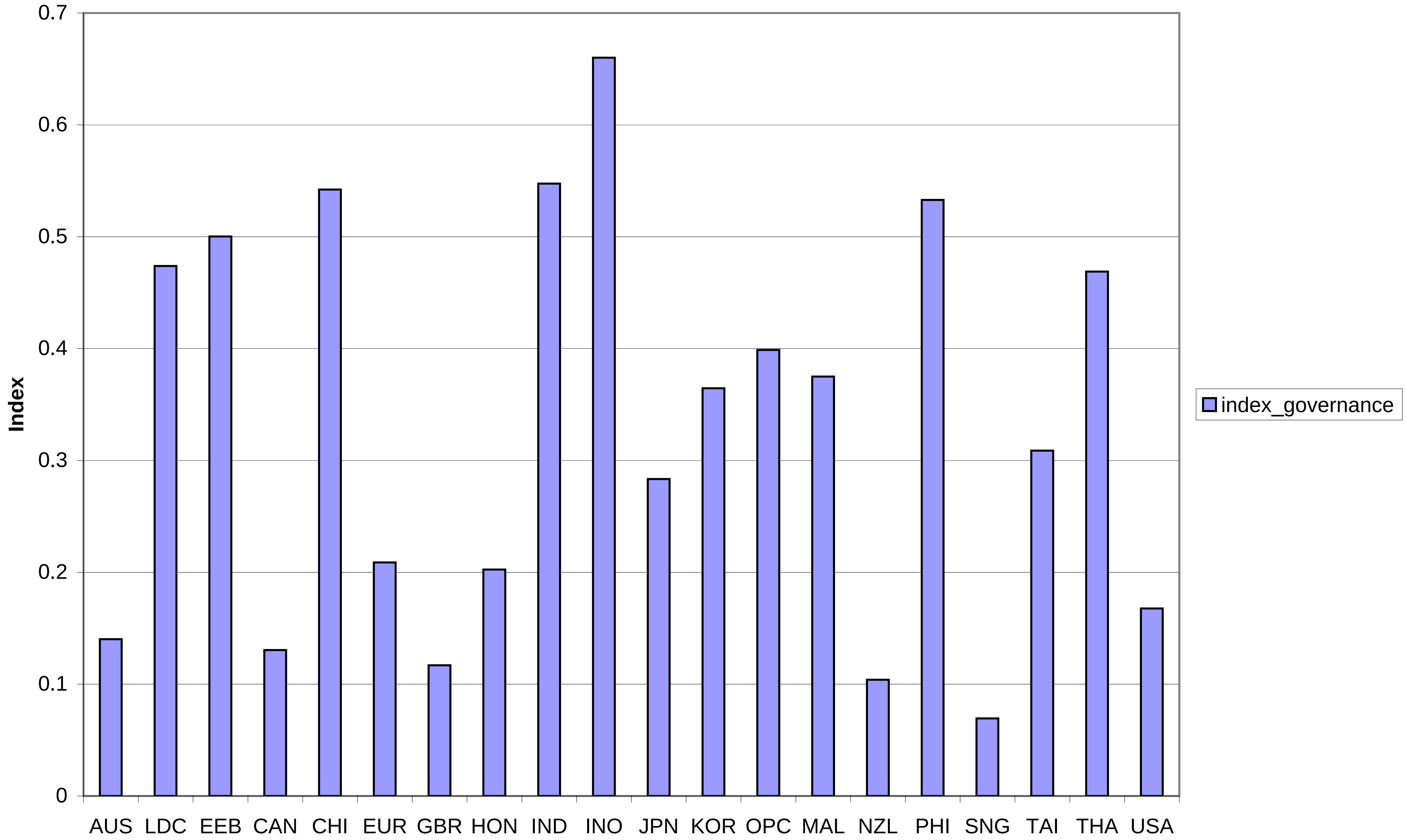


Figure 7: Country Risk Premia weighting relativity to US

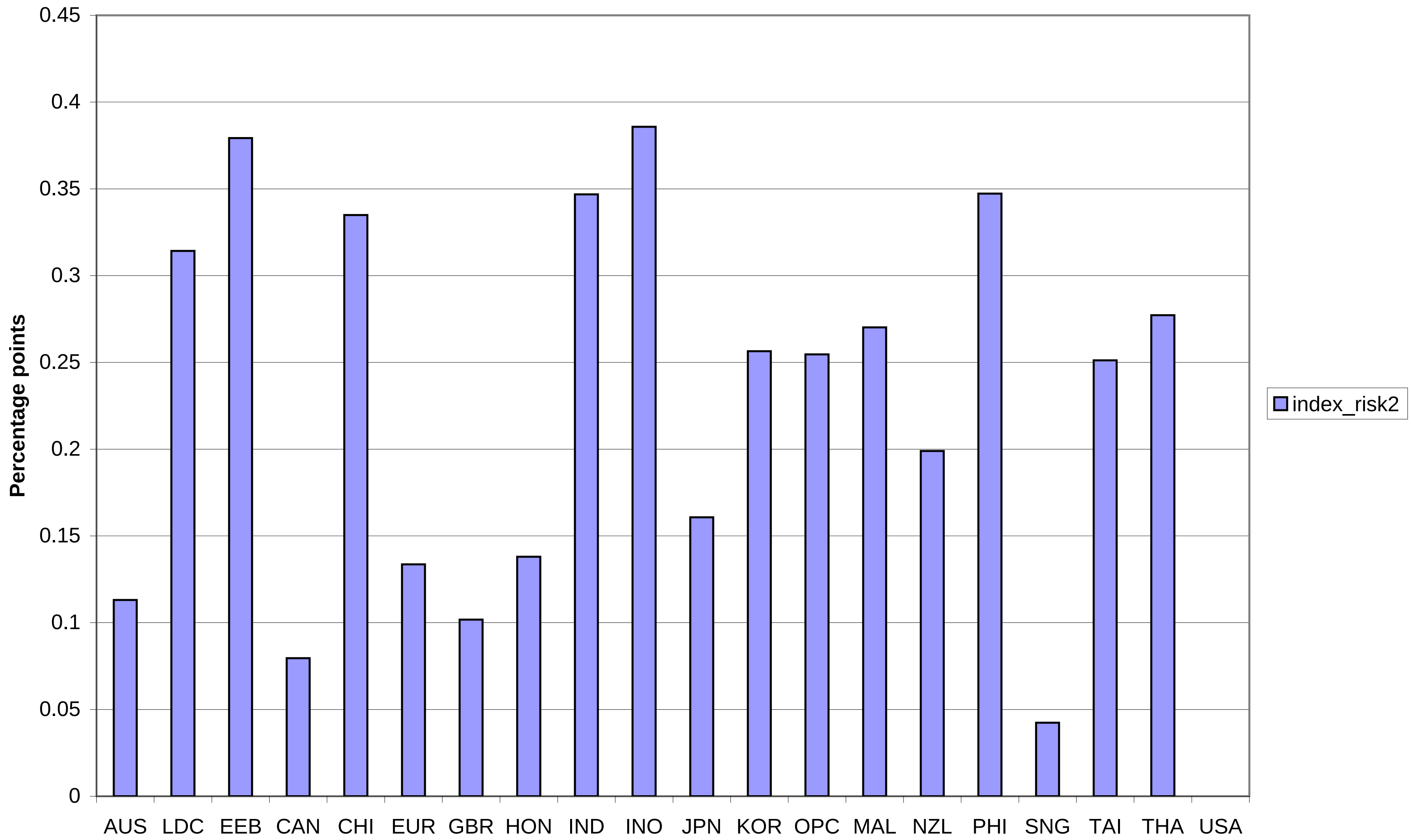


Figure 8: Cost shocks - Mild Scenario

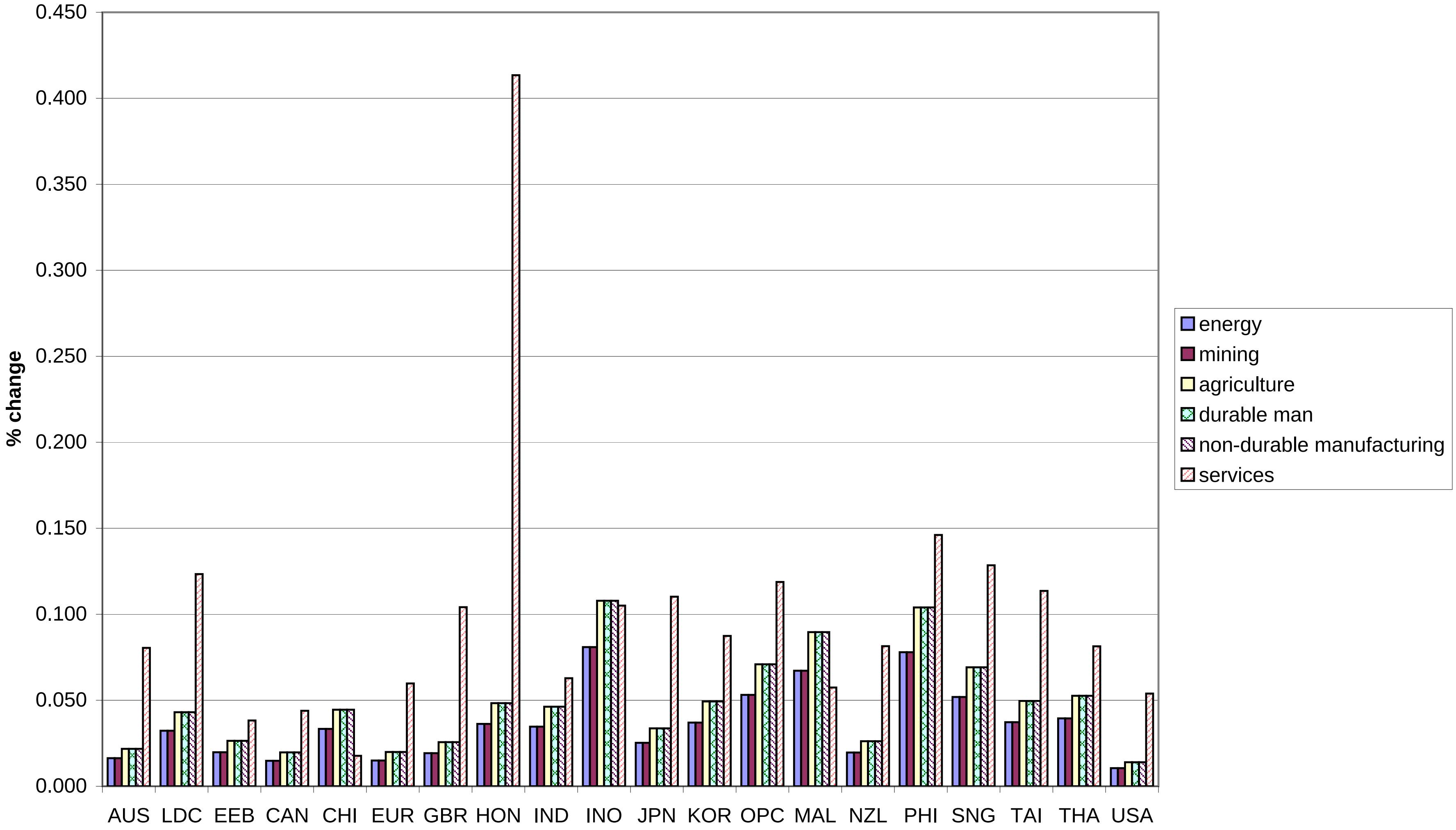


Figure 9: Cost shocks - Moderate Scenario

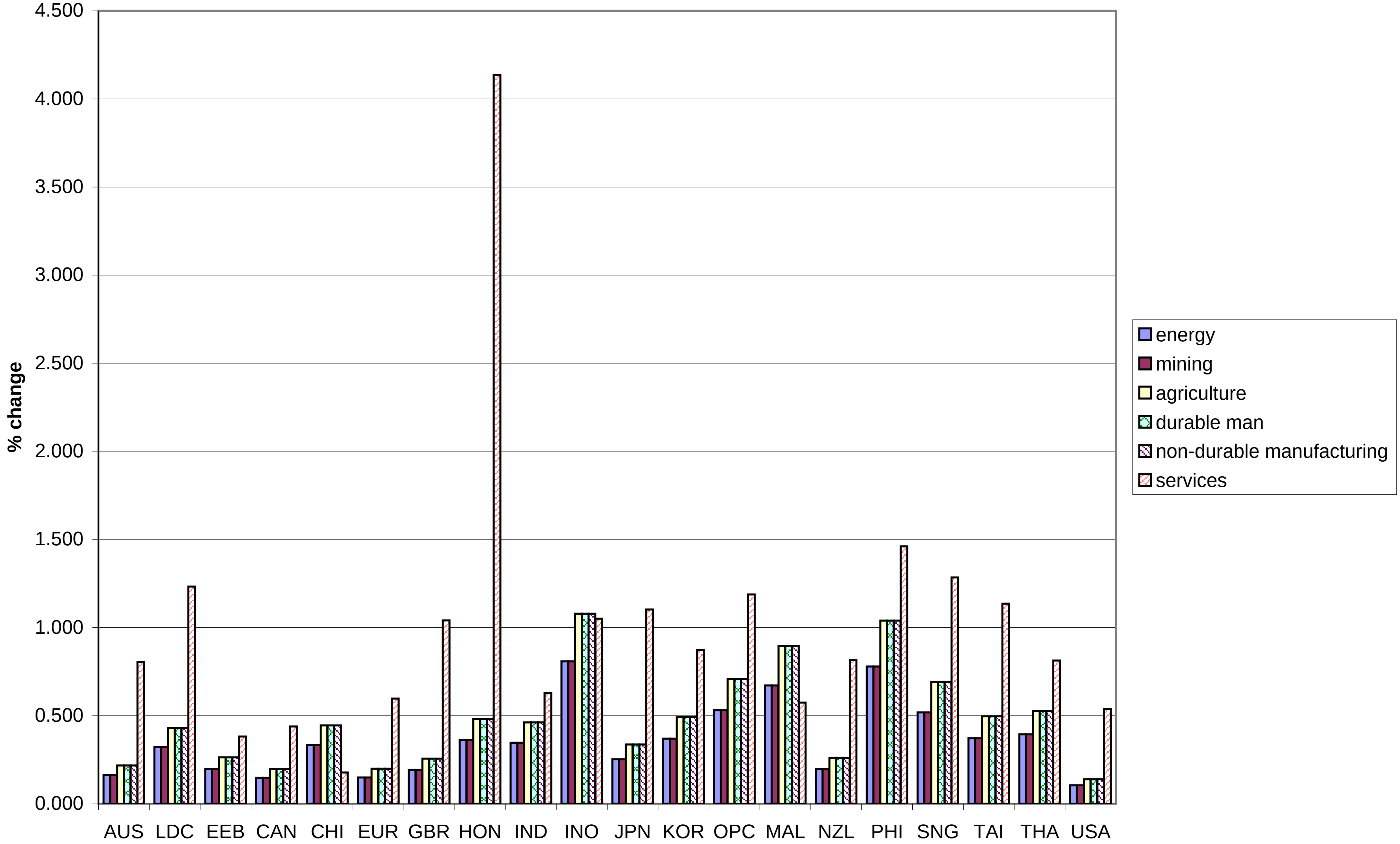
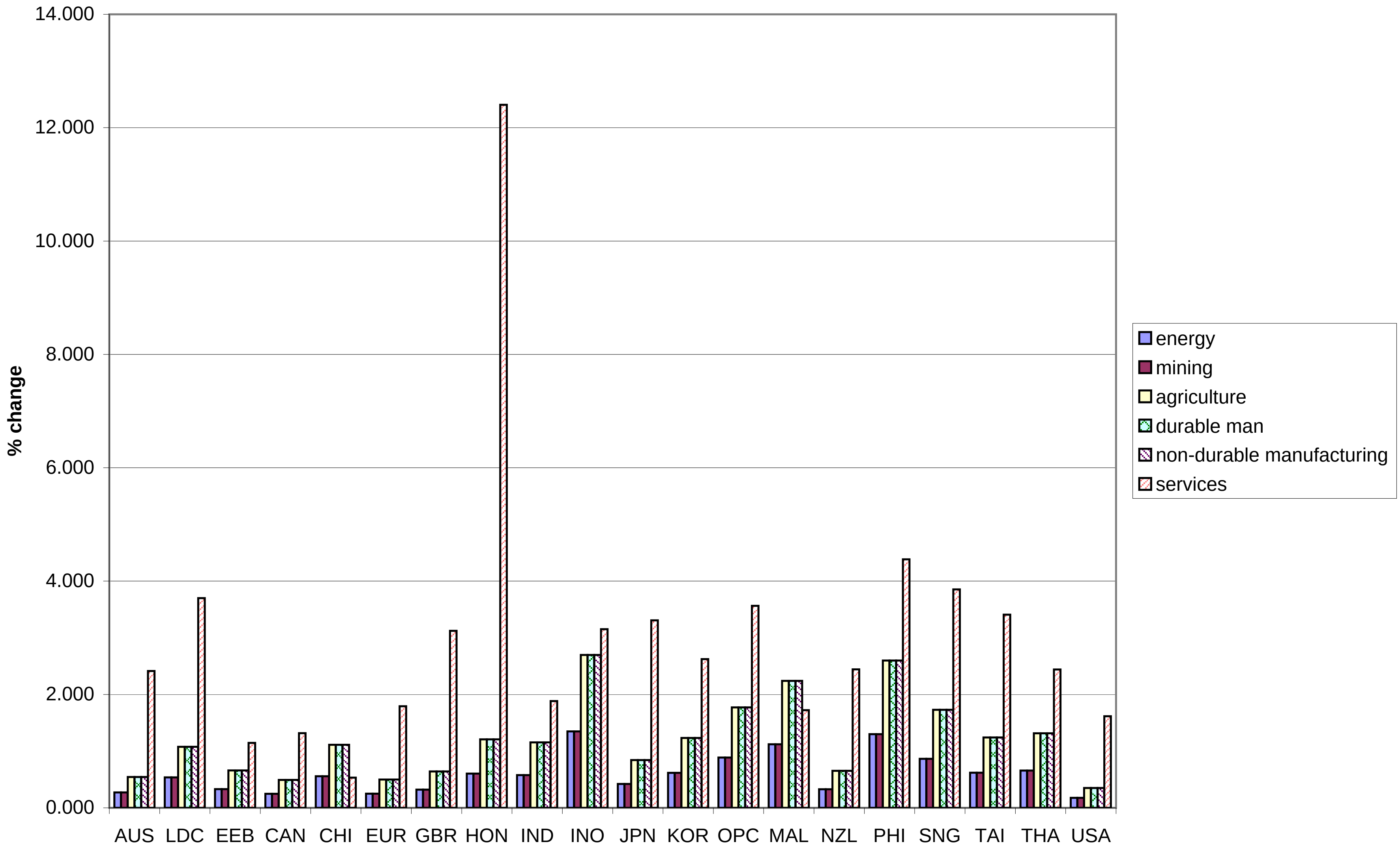


Figure 10: Cost shocks - Severe Scenario



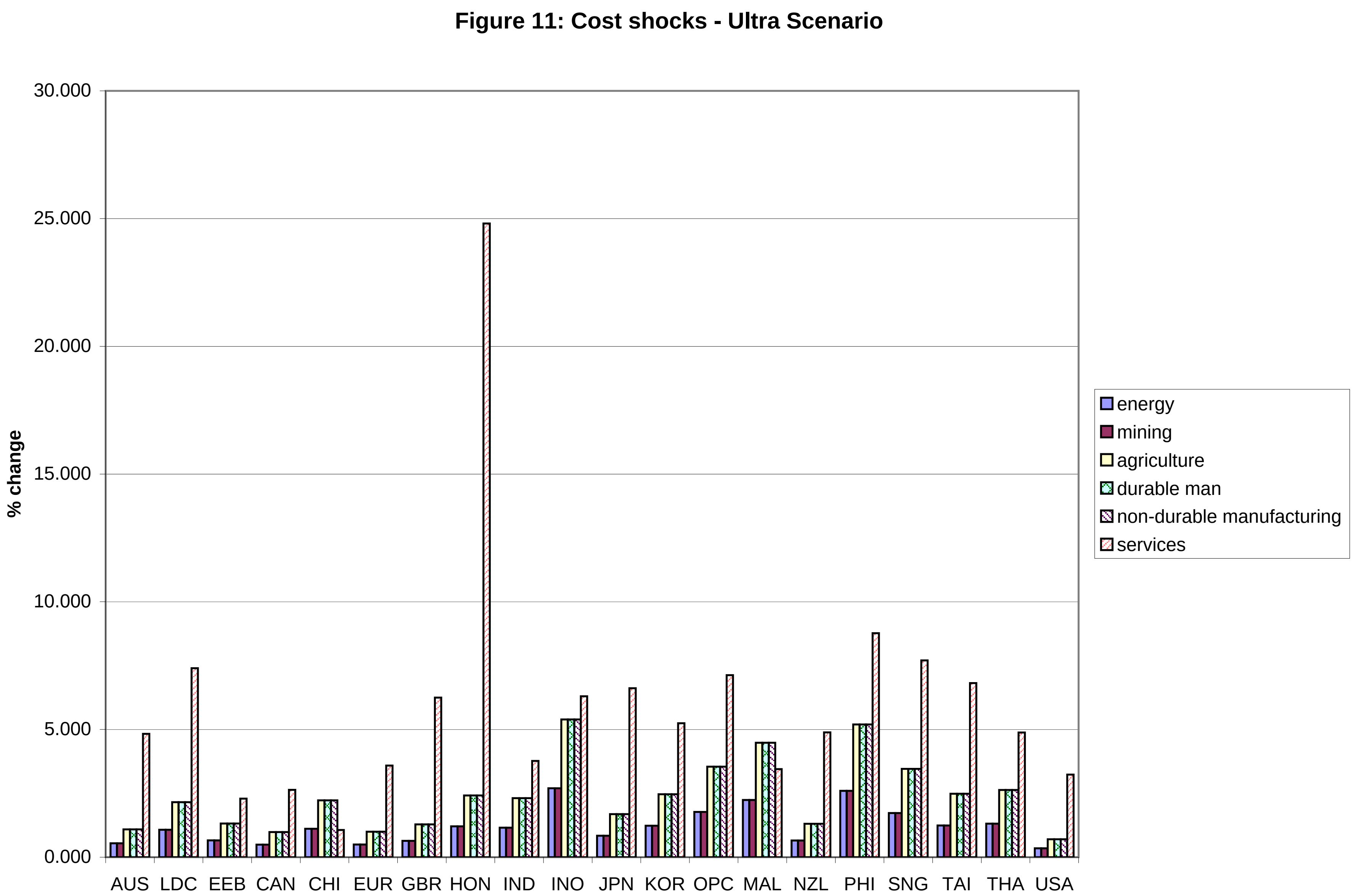


Figure 11: Cost shocks - Ultra Scenario
30.000
25.000
20.000
15.000
10.000
5.000
0.000
% change
AUS LDC EEB CAN CHI EUR GBR HON IND INO JPN KOR OPC MAL NZL PHI SNG TAI THA USA
energy
mining
agriculture
durable man
non-durable manufacturing
services

Figure 12: Demand shocks - Mild Scenario

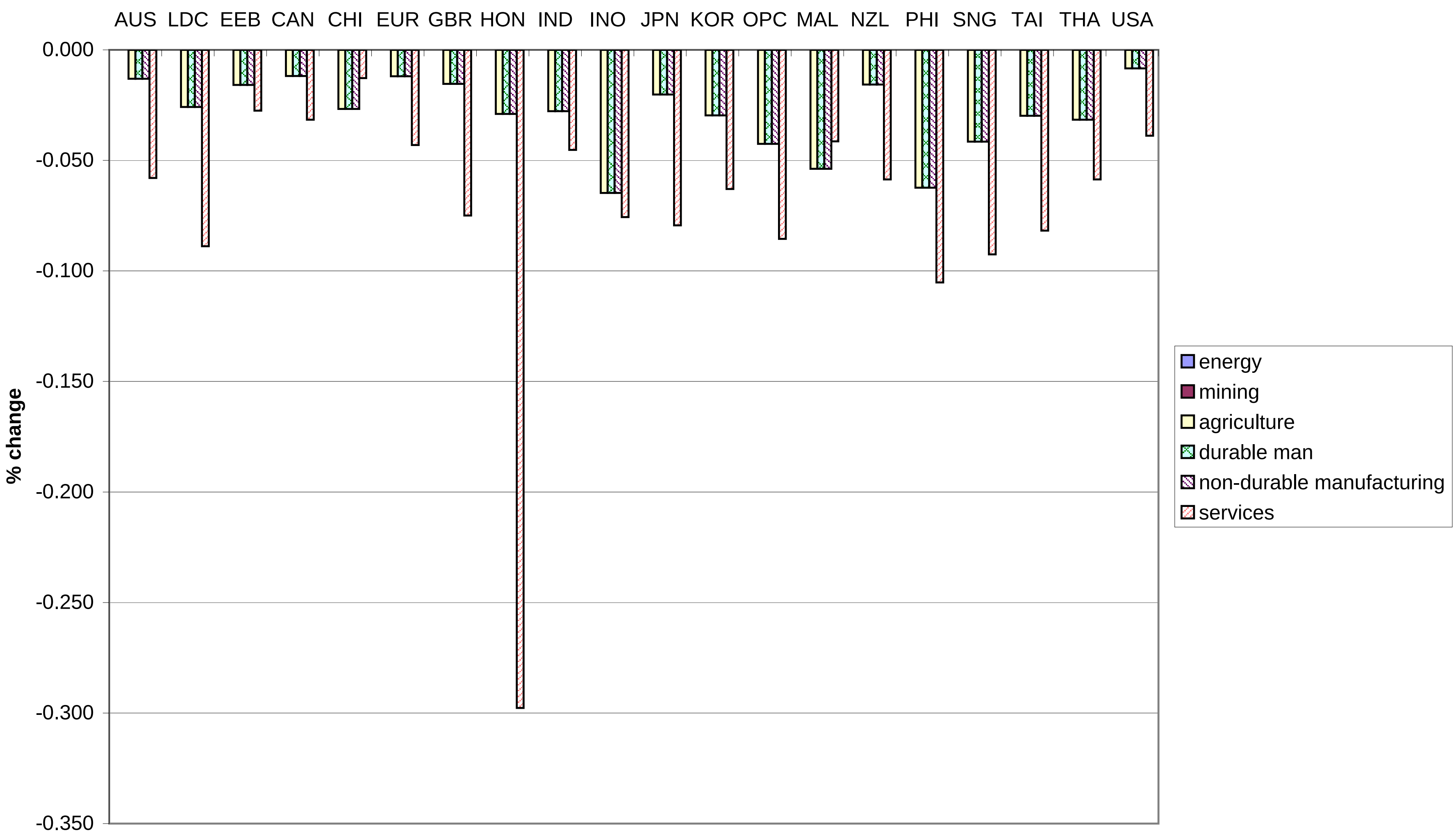


Figure 13: Demand shocks - Moderate Scenario

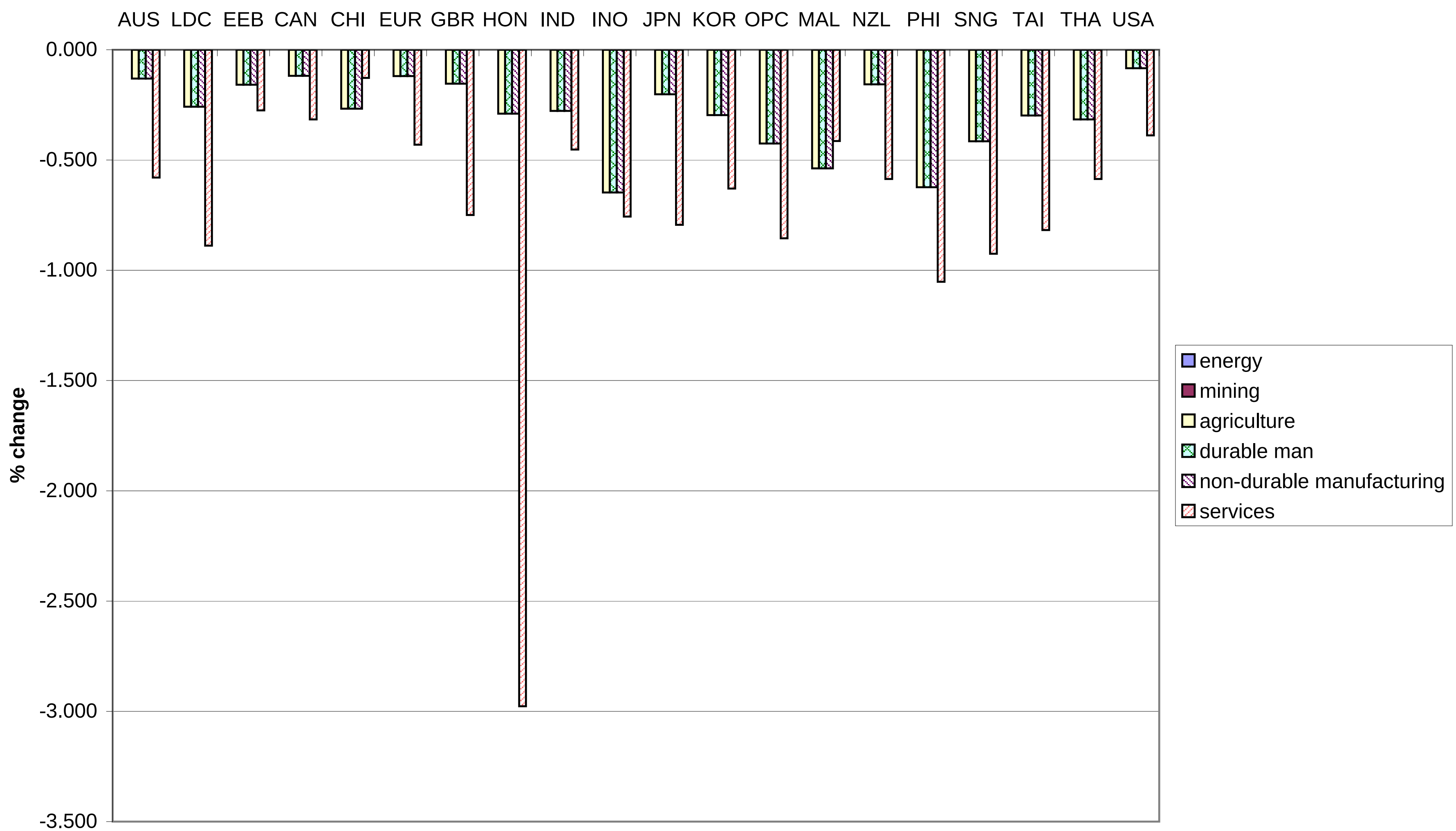


Figure 14 Demand shocks - Severe Scenario

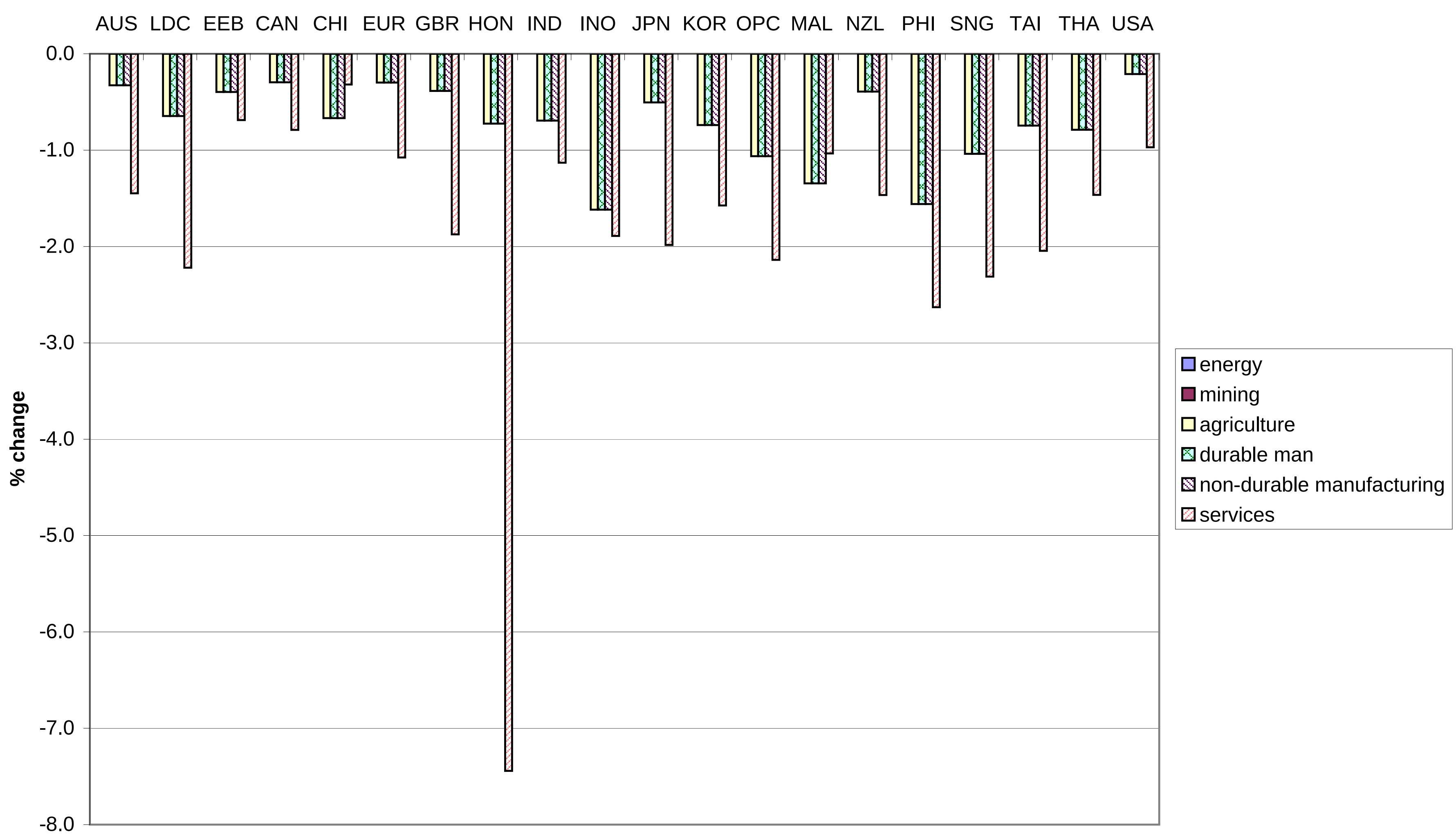


Figure 15 Demand shocks - Ultra Scenario

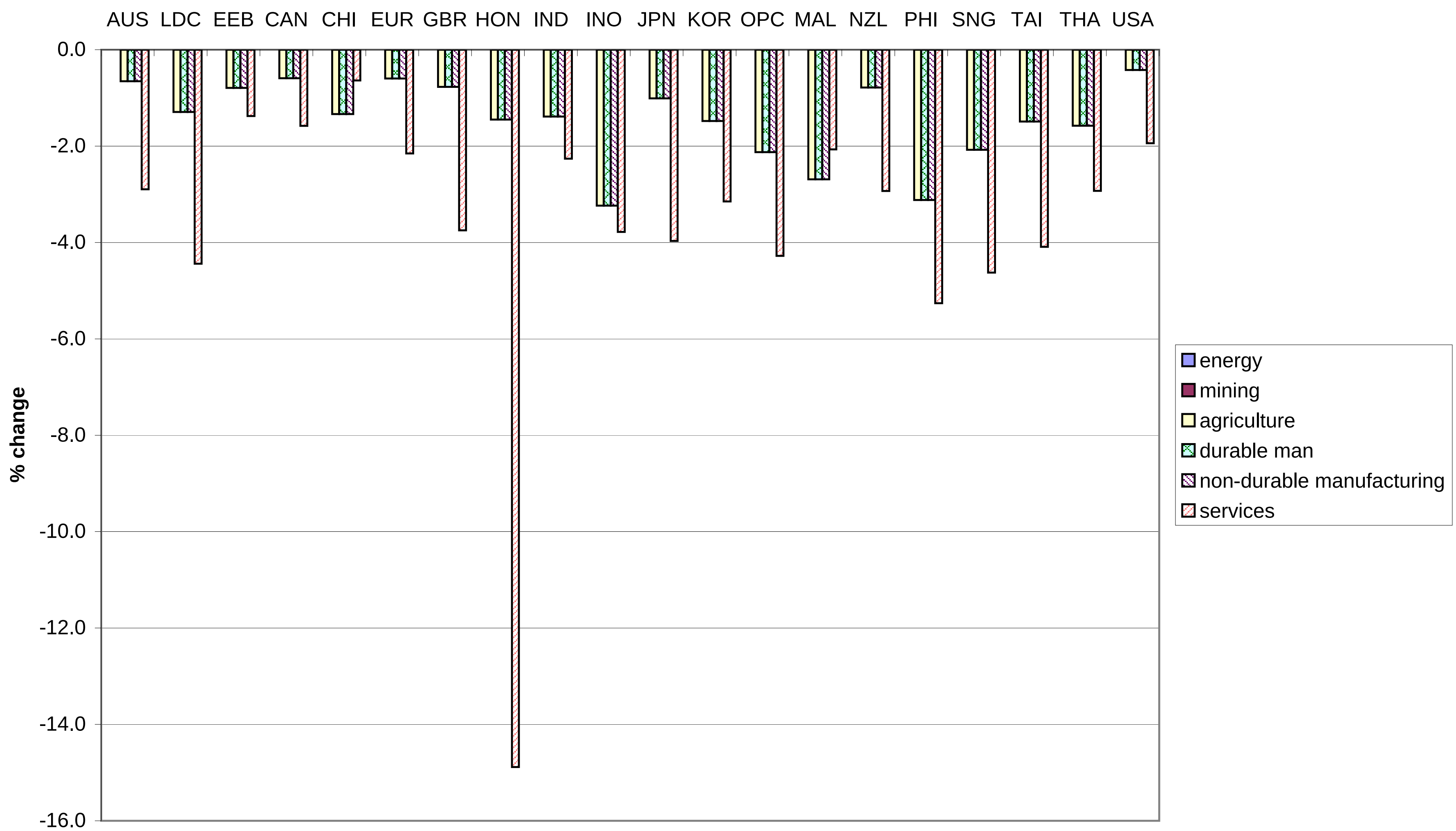


Figure 16: Risk Premia adjusted by Scenario

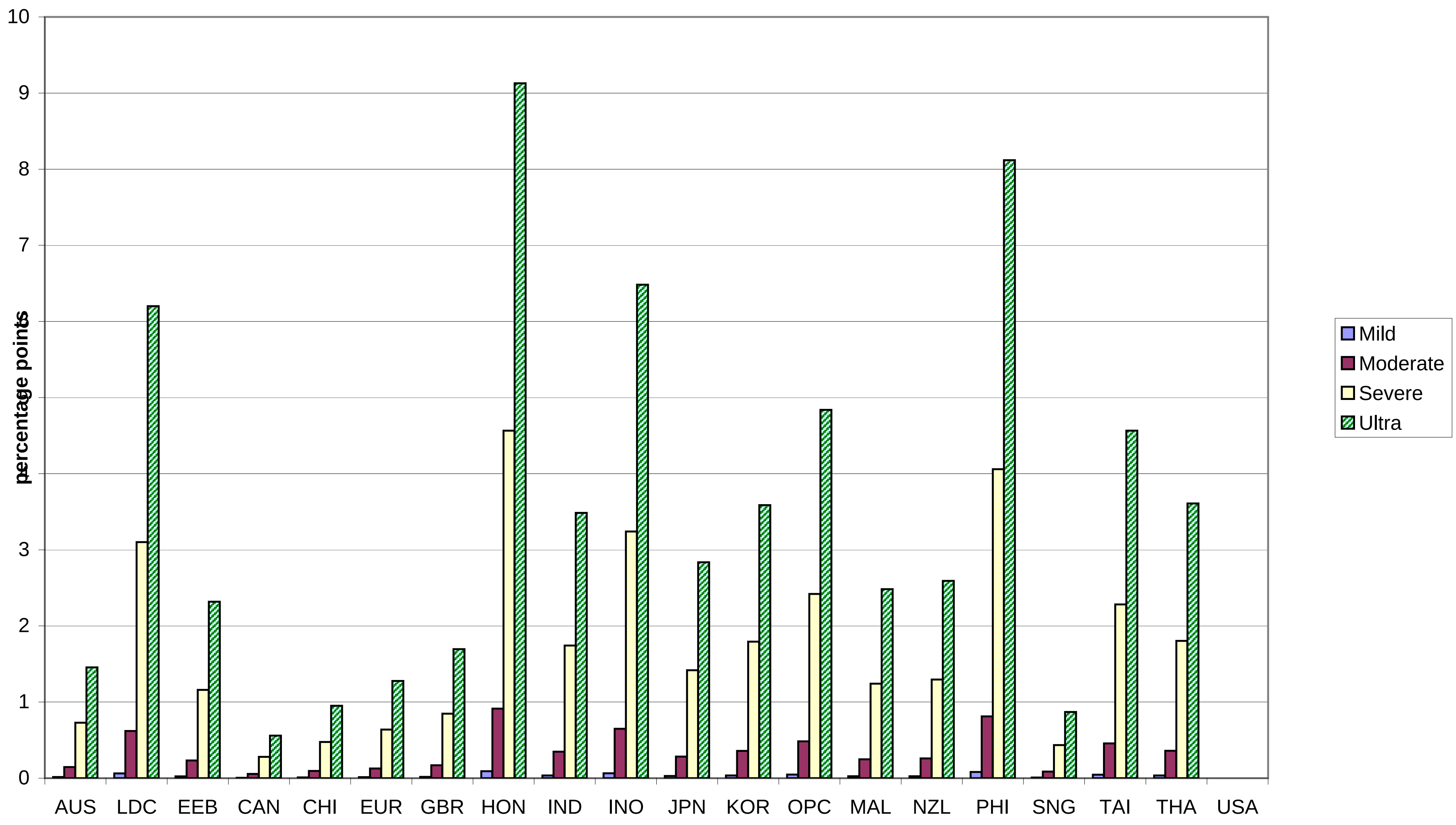


Figure 17: Change in GDP in the Moderate Scenario

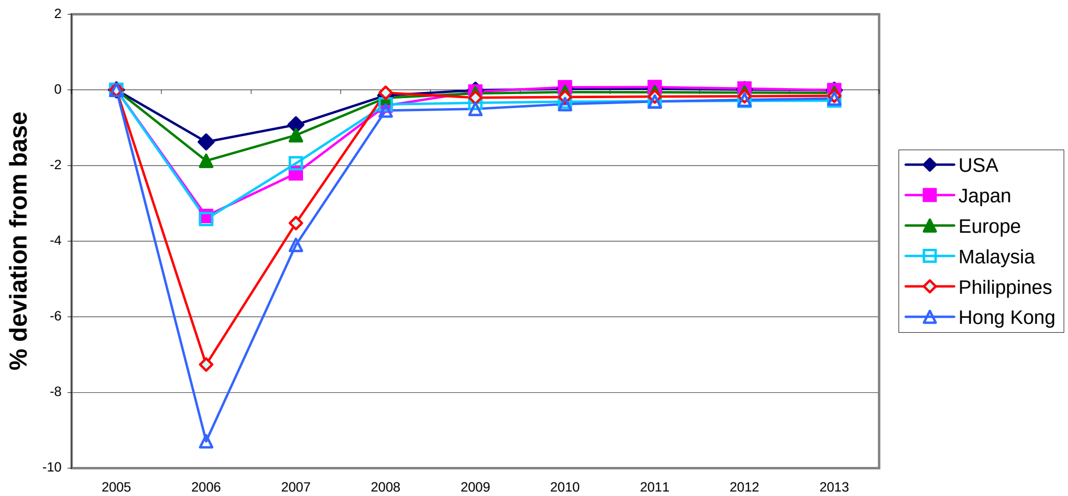


Figure 18:Change in GDP Growth in the Moderate Scenario

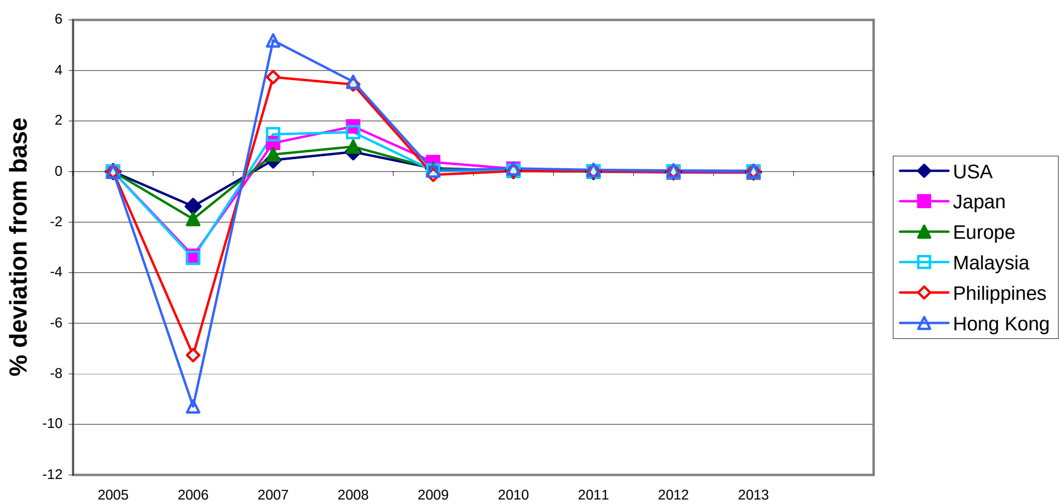


Table 1: Deaths in each region in 2006 (Thousands)

	Mild		Moderate		Severe		Ultra	
	number	%population	number	%population	number	%population	number	%population
USA	20.2	0.007	201.9	0.07	1009.3	0.35	2018.6	0.70
Japan	21.5	0.017	214.6	0.17	1073.1	0.84	2146.2	1.68
UK	7.6	0.013	76.0	0.13	380.0	0.64	759.9	1.28
Europe	56.5	0.010	565.5	0.10	2827.4	0.50	5654.9	1.00
Canada	3.1	0.010	30.9	0.10	154.5	0.49	309.1	0.99
Australia	2.1	0.011	21.4	0.11	107.1	0.54	214.2	1.09
New Zealand	0.5	0.013	5.2	0.13	25.8	0.65	51.5	1.31
Indonesia	114.3	0.054	1142.5	0.54	5712.6	2.70	11425.1	5.39
Malaysia	10.9	0.045	108.9	0.45	544.5	2.24	1089.1	4.48
Philippines	41.5	0.052	415.5	0.52	2077.5	2.60	4155.0	5.20
Singapore	1.4	0.035	14.4	0.35	72.0	1.73	144.1	3.46
Thailand	16.2	0.026	162.1	0.26	810.3	1.32	1620.5	2.63
China	284.9	0.022	2848.6	0.22	14242.8	1.11	28485.6	2.22
India	242.4	0.023	2423.6	0.23	12118.1	1.16	24236.1	2.31
Taiwan	5.6	0.025	55.9	0.25	279.4	1.24	558.8	2.48
Korea	11.8	0.025	117.5	0.25	587.6	1.23	1175.2	2.47
Hong Kong	1.6	0.024	16.4	0.24	82.0	1.21	163.9	2.42
LDCs	330.9	0.022	3308.6	0.22	16543.1	1.08	33086.2	2.15
EEFSU	67.1	0.013	670.7	0.13	3353.7	0.66	6707.3	1.32
OPEC	181.6	0.035	1816.3	0.35	9081.5	1.77	18163.1	3.54
Total	1421.6	0.022	14216.5	0.22	71082.3	1.10	142164.5	2.21

Source: Authors Calculations

Table 2: Benchmark Cost and Demand Shocks

	Mild	Moderate	Severe	Ultra
Costs				
energy	1.5	1.5	0.5	0.5
mining	1.5	1.5	0.5	0.5
agriculture	2.0	2.0	1.0	1.0
durable manufacturing	2.0	2.0	1.0	1.0
non-durable manufacturing	2.0	2.0	1.0	1.0
services	5.0	5.0	3.0	3.0
Demand				
energy	0.0	0.0	0.0	0.0
mining	0.0	0.0	0.0	0.0
agriculture	1.2	1.2	0.6	0.6
durable manufacturing	1.2	1.2	0.6	0.6
non-durable manufacturing	1.2	1.2	0.6	0.6
services	3.6	3.6	1.8	1.8

Table 3: GDP Decomposition by Shock for Mild Scenario

	Total	Labor Force	Costs	Demand	Risk
USA	-0.58	-0.50	-0.07	-0.01	0.00
Japan	-1.00	-0.77	-0.23	-0.01	0.00
UK	-0.72	-0.56	-0.14	-0.02	0.00
Europe	-0.72	-0.60	-0.12	0.00	0.00
Canada	-0.69	-0.61	-0.07	0.00	0.00
Australia	-0.80	-0.64	-0.15	-0.01	0.00
New Zealand	-1.38	-1.13	-0.26	0.00	0.00
Indonesia	-0.88	-0.60	-0.24	-0.01	-0.02
Malaysia	-0.78	-0.52	-0.26	0.00	0.00
Philippines	-1.54	-0.98	-0.49	-0.02	-0.05
Singapore	-0.86	-0.52	-0.34	0.00	0.00
Thailand	-0.45	-0.27	-0.17	0.00	-0.01
China	-0.70	-0.56	-0.13	0.00	0.00
India	-0.63	-0.49	-0.13	0.00	-0.01
Taiwan	-0.76	-0.56	-0.20	-0.01	0.00
Korea	-0.85	-0.61	-0.22	0.00	-0.01
Hong Kong	-1.20	-0.45	-0.72	0.00	-0.03
LDCs	-0.59	-0.41	-0.14	-0.01	-0.02
EEFSU	-0.56	-0.48	-0.07	0.00	0.00
OPEC	-0.68	-0.48	-0.18	-0.01	-0.01

Source: APG-Cubed model version 63A

Table 4: GDP Decomposition by Shock for Moderate Scenario

	Total	Labor Force	Costs	Demand	Risk
USA	-1.38	-0.52	-0.70	-0.16	0.01
Japan	-3.34	-0.85	-2.26	-0.22	-0.01
UK	-2.38	-0.60	-1.43	-0.35	-0.01
Europe	-1.88	-0.64	-1.19	-0.05	0.00
Canada	-1.50	-0.65	-0.73	-0.12	-0.01
Australia	-2.35	-0.68	-1.52	-0.15	0.00
New Zealand	-3.95	-1.21	-2.59	-0.13	-0.02
Indonesia	-3.59	-0.79	-2.45	-0.20	-0.17
Malaysia	-3.42	-0.63	-2.61	-0.13	-0.04
Philippines	-7.26	-1.25	-4.94	-0.55	-0.52
Singapore	-4.38	-0.62	-3.40	-0.39	0.03
Thailand	-2.10	-0.32	-1.68	-0.05	-0.05
China	-2.15	-0.64	-1.33	-0.19	0.01
India	-2.06	-0.55	-1.30	-0.14	-0.06
Taiwan	-2.86	-0.63	-1.97	-0.24	-0.01
Korea	-3.15	-0.70	-2.19	-0.18	-0.08
Hong Kong	-9.29	-0.54	-7.16	-1.24	-0.34
LDCs	-2.37	-0.45	-1.43	-0.28	-0.20
EEFSU	-1.35	-0.51	-0.75	-0.06	-0.03
OPEC	-2.77	-0.57	-1.78	-0.30	-0.12

Source: APG-Cubed model version 63A

Table 5: GDP Decomposition by Shock for Severe Scenario

	Total	Labor Force	Costs	Demand	Risk
USA	-3.00	-0.62	-2.03	-0.40	0.05
Japan	-8.26	-1.20	-6.47	-0.56	-0.04
UK	-5.83	-0.78	-4.15	-0.87	-0.03
Europe	-4.31	-0.82	-3.39	-0.13	0.02
Canada	-3.14	-0.78	-2.03	-0.30	-0.03
Australia	-5.58	-0.86	-4.36	-0.39	0.02
New Zealand	-9.39	-1.59	-7.39	-0.32	-0.08
Indonesia	-9.22	-1.59	-6.31	-0.49	-0.83
Malaysia	-8.40	-1.16	-6.70	-0.33	-0.22
Philippines	-19.27	-2.44	-12.86	-1.39	-2.59
Singapore	-11.06	-1.03	-9.21	-0.97	0.14
Thailand	-5.28	-0.52	-4.37	-0.13	-0.26
China	-4.76	-0.98	-3.34	-0.48	0.03
India	-4.90	-0.84	-3.40	-0.36	-0.30
Taiwan	-7.14	-0.98	-5.50	-0.59	-0.07
Korea	-7.82	-1.08	-5.86	-0.45	-0.42
Hong Kong	-26.85	-0.91	-21.11	-3.11	-1.71
LDCs	-6.30	-0.63	-3.96	-0.71	-1.00
EEFSU	-2.90	-0.66	-1.94	-0.16	-0.14
OPEC	-7.03	-0.96	-4.73	-0.74	-0.60

Source: APG-Cubed model version 63A

Table 6: GDP Decomposition by Shock for Ultra Scenario

	Total	Labor Force	Costs	Demand	Risk
USA	-5.50	-0.74	-4.06	-0.80	0.11
Japan	-15.77	-1.63	-12.95	-1.11	-0.07
UK	-11.11	-1.01	-8.30	-1.75	-0.05
Europe	-8.03	-1.04	-6.79	-0.25	0.05
Canada	-5.68	-0.96	-4.06	-0.61	-0.06
Australia	-10.58	-1.09	-8.75	-0.78	0.05
New Zealand	-17.68	-2.06	-14.79	-0.65	-0.17
Indonesia	-17.97	-2.60	-12.70	-1.01	-1.66
Malaysia	-16.35	-1.81	-13.44	-0.66	-0.44
Philippines	-37.79	-3.94	-25.87	-2.81	-5.17
Singapore	-21.65	-1.54	-18.45	-1.95	0.28
Thailand	-10.31	-0.78	-8.75	-0.26	-0.53
China	-9.06	-1.41	-6.74	-0.98	0.07
India	-9.34	-1.20	-6.81	-0.73	-0.60
Taiwan	-13.76	-1.42	-11.01	-1.18	-0.15
Korea	-15.06	-1.57	-11.76	-0.91	-0.83
Hong Kong	-53.51	-1.39	-42.43	-6.26	-3.43
LDCs	-12.24	-0.85	-7.95	-1.43	-2.01
EEFSU	-5.37	-0.85	-3.91	-0.33	-0.28
OPEC	-13.65	-1.46	-9.50	-1.50	-1.20

Source: APG-Cubed model version 63A

Table 7: 2006 percentage GDP loss by region

	Mild	Moderate	Severe	Ultra
USA	-0.6	-1.4	-3.0	-5.5
Japan	-1.0	-3.3	-8.3	-15.8
UK	-0.7	-2.4	-5.8	-11.1
Europe	-0.7	-1.9	-4.3	-8.0
Canada	-0.7	-1.5	-3.1	-5.7
Australia	-0.8	-2.4	-5.6	-10.6
New Zealand	-1.4	-4.0	-9.4	-17.7
Indonesia	-0.9	-3.6	-9.2	-18.0
Malaysia	-0.8	-3.4	-8.4	-16.3
Philippines	-1.5	-7.3	-19.3	-37.8
Singapore	-0.9	-4.4	-11.1	-21.7
Thailand	-0.4	-2.1	-5.3	-10.3
China	-0.7	-2.1	-4.8	-9.1
India	-0.6	-2.1	-4.9	-9.3
Taiwan	-0.8	-2.9	-7.1	-13.8
Korea	-0.8	-3.2	-7.8	-15.1
Hong Kong	-1.2	-9.3	-26.8	-53.5
LDCs	-0.6	-2.4	-6.3	-12.2
EEFSU	-0.6	-1.4	-2.9	-5.4
OPEC	-0.7	-2.8	-7.0	-13.6

Source: APG-Cubed model version 63A

Table 8: Inflation rate change in percentage points in 2006

	Mild	Moderate	Severe	Ultra
USA	0.58	0.77	1.37	2.22
Japan	0.61	1.32	3.20	5.90
UK	0.61	1.07	2.51	4.50
Europe	0.46	0.77	1.62	2.83
Canada	0.54	0.70	1.18	1.86
Australia	0.46	0.83	1.83	3.28
New Zealand	0.10	-0.03	0.04	-0.01
Indonesia	0.30	0.51	1.04	1.78
Malaysia	0.12	-0.23	-0.84	-1.80
Philippines	0.04	-0.73	-2.17	-4.45
Singapore	0.36	0.40	0.89	1.49
Thailand	0.20	0.27	0.40	0.64
China	0.51	0.79	1.34	2.23
India	0.35	0.50	0.82	1.33
Taiwan	0.43	0.84	2.41	4.47
Korea	0.44	0.85	1.84	3.33
Hong Kong	0.04	-3.84	-11.27	-22.83
LDCs	0.41	0.33	-0.33	-1.05
EEFSU	0.48	0.74	1.28	2.14
OPEC	0.43	0.85	1.98	3.61

Source: APG-Cubed model version 63A

Table 9: 10 Year Bond rate change in basis points in 2006

	Mild	Moderate	Severe	Ultra
USA	-1	-4	-8	-16
Japan	-2	-5	-10	-19
UK	-1	-7	-14	-27
Europe	-1	-4	-7	-14
Canada	-2	-5	-10	-18
Australia	-2	-5	-12	-22
New Zealand	-5	-14	-31	-58
Indonesia	-2	-7	-6	-11
Malaysia	-3	-12	-23	-43
Philippines	-5	-18	-36	-70
Singapore	-4	-18	-44	-85
Thailand	-1	-4	-4	-7
China	-1	-6	-11	-22
India	-1	-5	-5	-10
Taiwan	-3	-10	-20	-37
Korea	-2	-5	-5	-8
Hong Kong	0	10	59	118
LDCs	0	5	38	76
EEFSU	-1	-2	-1	-1
OPEC	-1	-4	-2	-3

Source: APG-Cubed model version 63A

Table 10: Short interest rate change in basis points in 2006

	Mild	Moderate	Severe	Ultra
USA	1	-18	-50	-101
Japan	0	-18	-38	-78
UK	-2	-35	-83	-165
Europe	-1	-16	-37	-74
Canada	-2	-18	-47	-93
Australia	-2	-24	-59	-117
New Zealand	-27	-85	-190	-358
Indonesia	-5	-32	-12	-23
Malaysia	-7	-54	-109	-215
Philippines	-19	-103	-180	-352
Singapore	-11	-99	-246	-489
Thailand	-1	-17	-10	-21
China	-1	-25	-57	-116
India	-2	-19	-16	-30
Taiwan	-7	-47	-91	-177
Korea	0	-14	-1	-2
Hong Kong	10	73	407	812
LDCs	7	44	260	519
EEFSU	1	-6	4	7
OPEC	0	-16	10	19

Source: APG-Cubed model version 63A

Table 11: Short real interest rate change in basis points in 2006

	Mild	Moderate	Severe	Ultra
USA	20	26	38	59
Japan	25	61	146	273
UK	19	37	85	156
Europe	21	36	71	125
Canada	26	38	59	95
Australia	25	45	94	169
New Zealand	8	0	5	3
Indonesia	25	67	199	379
Malaysia	28	67	158	297
Philippines	19	35	149	284
Singapore	28	66	130	239
Thailand	18	45	124	235
China	29	60	107	192
India	24	51	124	230
Taiwan	25	56	160	302
Korea	28	76	197	373
Hong Kong	58	307	1044	2074
LDCs	30	94	318	616
EEFSU	22	42	89	160
OPEC	26	75	214	413

Source: APG-Cubed model version 63A

Table 12 Long real interest rate change in basis points in 2006

	Mild	Moderate	Severe	Ultra
USA	6	7	11	16
Japan	6	13	30	55
UK	7	11	24	43
Europe	4	7	14	23
Canada	5	7	10	15
Australia	5	8	16	28
New Zealand	0	-2	-5	-10
Indonesia	3	9	25	47
Malaysia	2	6	15	28
Philippines	1	0	5	9
Singapore	3	9	17	32
Thailand	2	4	11	20
China	5	9	15	25
India	3	6	14	25
Taiwan	4	8	23	43
Korea	4	11	26	49
Hong Kong	7	41	140	268
LDCs	5	13	41	77
EEFSU	5	8	15	26
OPEC	5	12	31	59

Source: APG-Cubed model version 63A

Table 13: Nominal exchange rate ($US per currency) %change in 2006

	Mild	Moderate	Severe	Ultra
USA	0.00	0.00	0.00	0.00
Japan	-0.08	-0.52	-2.28	-4.53
UK	-0.03	-0.47	-1.74	-3.49
Europe	-0.06	-0.22	-1.00	-1.96
Canada	-0.14	-0.22	-0.64	-1.14
Australia	-0.09	-0.38	-1.44	-2.82
New Zealand	-0.46	-1.39	-4.37	-8.39
Indonesia	-0.22	-1.33	-4.92	-9.80
Malaysia	-0.24	-1.18	-3.60	-7.08
Philippines	-0.46	-2.60	-8.78	-17.39
Singapore	-0.32	-1.61	-4.47	-8.77
Thailand	-0.05	-0.55	-2.29	-4.59
China	-0.06	-0.34	-1.10	-2.20
India	-0.10	-0.60	-2.34	-4.65
Taiwan	-0.28	-1.33	-4.77	-9.39
Korea	-0.10	-0.62	-2.38	-4.71
Hong Kong	0.00	0.00	0.00	0.00
LDCs	0.00	0.00	0.00	0.00
EEFSU	-0.01	-0.15	-0.90	-1.82
OPEC	-0.09	-0.79	-3.09	-6.19

Source: APG-Cubed model version 63A

$US per local currency - negative is a depreciation of the local currency

Table 14: Current Account Change (%gdp) in 2006

	Mild	Moderate	Severe	Ultra
USA	0.00	-0.04	-0.20	-0.40
Japan	0.01	0.02	0.07	0.12
UK	0.01	0.02	-0.02	-0.05
Europe	-0.01	-0.07	-0.24	-0.47
Canada	-0.08	-0.17	-0.47	-0.86
Australia	-0.03	-0.13	-0.39	-0.75
New Zealand	0.32	0.77	1.96	3.67
Indonesia	0.00	0.20	0.95	1.95
Malaysia	0.02	0.09	0.41	0.80
Philippines	0.40	2.08	6.60	13.00
Singapore	0.14	0.49	0.74	1.36
Thailand	0.09	0.27	0.96	1.84
China	-0.01	-0.08	-0.27	-0.54
India	-0.01	0.01	0.11	0.24
Taiwan	0.01	0.17	0.68	1.37
Korea	0.00	0.01	0.18	0.34
Hong Kong	-0.20	0.04	0.49	1.17
LDCs	-0.01	0.12	0.57	1.16
EEFSU	0.03	0.06	0.15	0.28
OPEC	0.02	0.05	0.42	0.83

Source: APG-Cubed model version 63A

Table 15:Equity Price (Manufacturing) change in percent in 2006

	Mild	Moderate	Severe	Ultra
USA	-0.48	-0.52	-0.51	-0.56
Japan	-0.49	-1.01	-2.34	-4.28
UK	-0.43	-0.58	-1.03	-1.69
Europe	-0.43	-0.62	-1.11	-1.83
Canada	-0.43	-0.52	-0.64	-0.90
Australia	-0.33	-0.50	-0.89	-1.51
New Zealand	-0.18	-0.17	-0.49	-0.85
Indonesia	-0.32	-0.93	-3.07	-6.02
Malaysia	-0.54	-1.36	-3.43	-6.47
Philippines	-0.39	-1.39	-5.03	-9.83
Singapore	-0.49	-0.91	-1.56	-2.74
Thailand	-0.35	-1.04	-2.95	-5.66
China	-0.52	-1.04	-1.85	-3.34
India	-0.32	-0.74	-1.89	-3.55
Taiwan	-0.43	-1.04	-3.08	-5.84
Korea	-0.51	-1.32	-3.44	-6.53
Hong Kong	-1.07	-4.38	-15.29	-30.34
LDCs	-0.38	-1.07	-3.55	-6.85
EEFSU	-0.53	-0.88	-1.77	-3.10
OPEC	-0.47	-1.22	-3.57	-6.85

Source: APG-Cubed model version 63A

Table 16:Export change in percent in 2006

	Mild	Moderate	Severe	Ultra
USA	-0.99	-1.97	-5.19	-9.50
Japan	-1.04	-2.57	-5.64	-10.45
UK	-1.04	-1.98	-4.70	-8.51
Europe	-0.63	-1.48	-3.58	-6.64
Canada	-0.74	-1.21	-2.47	-4.25
Australia	-0.69	-1.92	-4.92	-9.26
New Zealand	-0.42	-1.06	-3.03	-5.74
Indonesia	-0.28	-0.77	0.09	0.46
Malaysia	-0.33	-1.41	-3.23	-6.28
Philippines	-0.18	-1.17	-5.13	-10.17
Singapore	-0.70	-2.67	-6.87	-13.33
Thailand	-0.01	-0.31	-0.17	-0.36
China	-0.35	-1.04	-2.58	-4.93
India	-0.15	-0.44	-0.42	-0.71
Taiwan	-0.42	-0.87	-1.36	-2.37
Korea	-0.51	-1.58	-3.40	-6.44
Hong Kong	-0.58	-3.27	-9.75	-19.52
LDCs	-0.41	-0.95	-1.56	-2.80
EEFSU	-0.57	-1.23	-2.38	-4.26
OPEC	-0.45	-1.49	-2.92	-5.55

Source: APG-Cubed model version 63A

Table 17: Sensitivity of Moderate scenario to 10*risk shock

	GDP		Inflation		10 year Bond		short rate		exchange rate	
	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative
USA	-1.4	-1.3	0.8	0.4	-4	-6	-18	-43	0	0
Japan	-3.3	-3.4	1.3	1.5	-5	-5	-18	-9	-0.5	-3.9
UK	-2.4	-2.4	1.1	1.0	-7	-8	-35	-42	-0.5	-2.5
Europe	-1.9	-1.8	0.8	0.6	-4	-6	-16	-30	-0.2	-1.8
Canada	-1.5	-1.5	0.7	0.3	-5	-8	-18	-46	-0.2	-0.9
Australia	-2.4	-2.3	0.8	0.6	-5	-7	-24	-38	-0.4	-2.2
New Zealand	-4.0	-4.1	0.0	0.1	-14	-14	-85	-81	-1.4	-4.5
Indonesia	-3.6	-5.1	0.5	-0.5	-7	21	-32	168	-1.3	-6.9
Malaysia	-3.4	-3.8	-0.2	-1.1	-12	-3	-54	4	-1.2	-3.4
Philippines	-7.3	-11.9	-0.7	-2.1	-18	8	-103	123	-2.6	-10.3
Singapore	-4.4	-4.1	0.4	-0.3	-18	-24	-99	-140	-1.6	-2.9
Thailand	-2.1	-2.6	0.3	-0.4	-4	11	-17	90	-0.6	-3.6
China	-2.1	-2.1	0.8	0.1	-6	-4	-25	-22	-0.3	-1.2
India	-2.1	-2.6	0.5	-0.3	-5	9	-19	74	-0.6	-3.6
Taiwan	-2.9	-3.0	0.8	1.8	-10	-4	-47	16	-1.3	-6.4
Korea	-3.2	-3.9	0.8	0.3	-5	10	-14	91	-0.6	-3.7
Hong Kong	-9.3	-12.4	-3.8	-12.3	10	130	73	870	0.0	0.0
LDCs	-2.4	-4.2	0.3	-3.7	5	86	44	577	0.0	0.0
EEFSU	-1.4	-1.6	0.7	0.3	-2	6	-6	54	-0.2	-2.1
OPEC	-2.8	-3.8	0.9	0.7	-4	18	-16	149	-0.8	-4.7

Source: APG-Cubed model version 63A

Table 18: Sensitivity of Moderate scenario to more sustained risk shock

	GDP		Inflation		10 year Bond		short rate		exchange rate	
	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative
USA	-1.4	-1.3	0.8	0.7	-4	-6	-18	-43	0	0
Japan	-3.3	-3.4	1.3	1.4	-5	-5	-18	-9	-0.5	-1.8
UK	-2.4	-2.4	1.1	1.1	-7	-8	-35	-42	-0.5	-1.2
Europe	-1.9	-1.8	0.8	0.7	-4	-6	-16	-30	-0.2	-0.8
Canada	-1.5	-1.5	0.7	0.6	-5	-8	-18	-46	-0.2	-0.5
Australia	-2.4	-2.3	0.8	0.8	-5	-7	-24	-38	-0.4	-1.1
New Zealand	-4.0	-4.0	0.0	0.0	-14	-14	-85	-81	-1.4	-2.6
Indonesia	-3.6	-4.3	0.5	-0.3	-7	21	-32	168	-1.3	-2.7
Malaysia	-3.4	-3.6	-0.2	-0.7	-12	-3	-54	4	-1.2	-1.8
Philippines	-7.3	-9.0	-0.7	-1.6	-18	8	-103	123	-2.6	-4.7
Singapore	-4.4	-4.3	0.4	0.3	-18	-24	-99	-140	-1.6	-2.3
Thailand	-2.1	-2.3	0.3	-0.2	-4	11	-17	90	-0.6	-1.3
China	-2.1	-2.2	0.8	0.5	-6	-4	-25	-22	-0.3	-0.6
India	-2.1	-2.4	0.5	0.0	-5	9	-19	74	-0.6	-1.4
Taiwan	-2.9	-3.0	0.8	1.1	-10	-4	-47	16	-1.3	-3.0
Korea	-3.2	-3.5	0.8	0.4	-5	10	-14	91	-0.6	-1.4
Hong Kong	-9.3	-10.0	-3.8	-5.9	10	130	73	870	0.0	0.0
LDCs	-2.4	-3.0	0.3	-1.2	5	86	44	577	0.0	0.0
EEFSU	-1.4	-1.5	0.7	0.4	-2	6	-6	54	-0.2	-0.7
OPEC	-2.8	-3.2	0.9	0.4	-4	18	-16	149	-0.8	-1.7

Source: APG-Cubed model version 63A

Table 19: Sensitivity of Moderate scenario to 5 times larger demand switch

	GDP		Inflation		10 year Bond		short rate		exchange rate	
	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative
USA	-1.4	-2.0	0.8	-0.9	-4	-16	-18	-29	0	0
Japan	-3.3	-4.2	1.3	-0.5	-5	-15	-18	-14	-0.5	-1.5
UK	-2.4	-3.8	1.1	-1.6	-7	-30	-35	-38	-0.5	-1.4
Europe	-1.9	-2.1	0.8	-0.9	-4	-12	-16	-22	-0.2	-1.2
Canada	-1.5	-2.0	0.7	-0.6	-5	-11	-18	-31	-0.2	-0.5
Australia	-2.4	-3.0	0.8	-0.9	-5	-15	-24	-30	-0.4	-1.0
New Zealand	-4.0	-4.5	0.0	-1.6	-14	-20	-85	-84	-1.4	-1.8
Indonesia	-3.6	-4.4	0.5	-1.7	-7	-21	-32	57	-1.3	-3.9
Malaysia	-3.4	-3.9	-0.2	-2.4	-12	-22	-54	-28	-1.2	-2.3
Philippines	-7.3	-9.5	-0.7	-3.8	-18	-34	-103	-3	-2.6	-4.6
Singapore	-4.4	-5.9	0.4	-3.1	-18	-38	-99	-117	-1.6	-3.2
Thailand	-2.1	-2.3	0.3	-1.2	-4	-14	-17	31	-0.6	-3.0
China	-2.1	-2.9	0.8	-1.1	-6	-18	-25	-24	-0.3	-0.9
India	-2.1	-2.6	0.5	-1.1	-5	-16	-19	22	-0.6	-1.7
Taiwan	-2.9	-3.8	0.8	-1.9	-10	-24	-47	-19	-1.3	-2.9
Korea	-3.2	-3.9	0.8	-1.2	-5	-16	-14	33	-0.6	-2.7
Hong Kong	-9.3	-14.3	-3.8	-21.0	10	-2	73	427	0.0	-0.6
LDCs	-2.4	-3.5	0.3	-2.8	5	-6	44	281	0.0	0.0
EEFSU	-1.4	-1.6	0.7	-0.4	-2	-11	-6	21	-0.2	-0.9
OPEC	-2.8	-4.0	0.9	-1.7	-4	-21	-16	57	-0.8	-1.9

Source: APG-Cubed model version 63A

Table 20: Moderate Scenario with no additional cost shocks

	GDP		Inflation		10 year Bond		short rate		exchange rate	
	moderate	**alternative**	**moderate**	**alternative**	**moderate**	**alternative**	**moderate**	**alternative**	**moderate**	**alternative**
USA	-1.4	-0.7	0.8	0.1	-4	-4	-18	-25	0	0
Japan	-3.3	-1.1	1.3	0.1	-5	-3	-18	-21	-0.5	-0.4
UK	-2.4	-1.0	1.1	-0.1	-7	-7	-35	-44	-0.5	-0.5
Europe	-1.9	-0.7	0.8	0.0	-4	-3	-16	-20	-0.2	-0.2
Canada	-1.5	-0.8	0.7	0.2	-5	-4	-18	-21	-0.2	-0.1
Australia	-2.4	-0.8	0.8	0.0	-5	-4	-24	-25	-0.4	-0.2
New Zealand	-4.0	-1.4	0.0	-0.2	-14	-7	-85	-40	-1.4	-0.7
Indonesia	-3.6	-1.1	0.5	-0.3	-7	-2	-32	-11	-1.3	-0.8
Malaysia	-3.4	-0.8	-0.2	-0.5	-12	-4	-54	-23	-1.2	-0.4
Philippines	-7.3	-2.3	-0.7	-0.8	-18	-5	-103	-26	-2.6	-1.3
Singapore	-4.4	-1.0	0.4	-0.6	-18	-8	-99	-52	-1.6	-0.6
Thailand	-2.1	-0.4	0.3	-0.3	-4	-1	-17	-9	-0.6	-0.3
China	-2.1	-0.8	0.8	0.0	-6	-4	-25	-26	-0.3	-0.2
India	-2.1	-0.8	0.5	-0.1	-5	-2	-19	-15	-0.6	-0.4
Taiwan	-2.9	-0.9	0.8	-0.1	-10	-5	-47	-28	-1.3	-0.8
Korea	-3.2	-1.0	0.8	-0.1	-5	-2	-14	-14	-0.6	-0.4
Hong Kong	-9.3	-2.1	-3.8	-5.2	10	10	73	66	0.0	0.0
LDCs	-2.4	-0.9	0.3	-0.8	5	6	44	37	0.0	0.0
EEFSU	-1.4	-0.6	0.7	0.1	-2	-2	-6	-11	-0.2	-0.1
OPEC	-2.8	-1.0	0.9	-0.2	-4	-2	-16	-13	-0.8	-0.6

Source: APG-Cubed model version 63A

Table 21: Mild Scenario with 35% rather than 30% attack rate

	GDP		Inflation		10 year Bond		short rate		exchange rate	
	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative
USA	-0.6	-0.7	0.6	0.7	-1	-1	1	1	0	0
Japan	-1.0	-1.1	0.6	0.7	-2	-2	0	1	-0.1	-0.1
UK	-0.7	-0.8	0.6	0.7	-1	-1	-2	-2	0.0	0.0
Europe	-0.7	-0.8	0.5	0.5	-1	-2	-1	-1	-0.1	-0.1
Canada	-0.7	-0.8	0.5	0.6	-2	-3	-2	-2	-0.1	-0.2
Australia	-0.8	-0.9	0.5	0.5	-2	-2	-2	-2	-0.1	-0.1
New Zealand	-1.4	-1.6	0.1	0.1	-5	-6	-27	-31	-0.5	-0.5
Indonesia	-0.9	-1.0	0.3	0.3	-2	-2	-5	-6	-0.2	-0.2
Malaysia	-0.8	-0.9	0.1	0.1	-3	-3	-7	-7	-0.2	-0.3
Philippines	-1.5	-1.7	0.0	0.1	-5	-5	-19	-21	-0.5	-0.5
Singapore	-0.9	-1.0	0.4	0.4	-4	-5	-11	-12	-0.3	-0.4
Thailand	-0.4	-0.5	0.2	0.2	-1	-1	-1	-1	0.0	0.0
China	-0.7	-0.8	0.5	0.6	-1	-2	-1	-1	-0.1	-0.1
India	-0.6	-0.7	0.3	0.4	-1	-2	-2	-2	-0.1	-0.1
Taiwan	-0.8	-0.9	0.4	0.5	-3	-3	-7	-8	-0.3	-0.3
Korea	-0.8	-0.9	0.4	0.5	-2	-2	0	0	-0.1	-0.1
Hong Kong	-1.2	-1.3	0.0	0.0	0	0	10	10	0.0	0.0
LDCs	-0.6	-0.7	0.4	0.5	0	0	7	7	0.0	0.0
EEFSU	-0.6	-0.6	0.5	0.5	-1	-1	1	1	0.0	0.0
OPEC	-0.7	-0.8	0.4	0.5	-1	-1	0	0	-0.1	-0.1

Source: APG-Cubed model version 63A

Table 22: Moderate Scenario with Fiscal response 1.5% of GDP (on average) scaled by mortality rate

	spending	GDP		Inflation		10 year Bond		short rate		exchange rate	
	%GDP	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative	moderate	alternative
USA	0.21	-1.4	-1.3	0.8	1.0	-4	-2	-18	0	0	0
Japan	0.51	-3.3	-3.3	1.3	1.6	-5	-3	-18	5	-0.5	-0.5
UK	0.38	-2.4	-2.3	1.1	1.4	-7	-3	-35	-7	-0.5	-0.3
Europe	0.30	-1.9	-1.9	0.8	1.1	-4	-2	-16	4	-0.2	-0.2
Canada	0.30	-1.5	-1.4	0.7	1.0	-5	-3	-18	4	-0.2	-0.2
Australia	0.33	-2.4	-2.4	0.8	1.1	-5	-3	-24	-3	-0.4	-0.4
New Zealand	0.39	-4.0	-3.8	0.0	0.3	-14	-12	-85	-59	-1.4	-1.4
Indonesia	1.62	-3.6	-3.4	0.5	1.5	-7	-1	-32	20	-1.3	-1.0
Malaysia	1.34	-3.4	-3.3	-0.2	0.4	-12	-8	-54	-21	-1.2	-1.1
Philippines	1.56	-7.3	-6.8	-0.7	0.1	-18	-14	-103	-53	-2.6	-2.4
Singapore	1.04	-4.4	-4.3	0.4	0.9	-18	-15	-99	-63	-1.6	-1.5
Thailand	0.79	-2.1	-2.2	0.3	0.8	-4	-1	-17	9	-0.6	-0.4
China	0.67	-2.1	-2.0	0.8	1.3	-6	-2	-25	5	-0.3	-0.2
India	0.69	-2.1	-2.0	0.5	1.1	-5	-1	-19	12	-0.6	-0.5
Taiwan	0.74	-2.9	-2.8	0.8	1.3	-10	-7	-47	-13	-1.3	-1.2
Korea	0.74	-3.2	-3.1	0.8	1.3	-5	-2	-14	13	-0.6	-0.5
Hong Kong	0.72	-9.3	-9.1	-3.8	-3.2	10	12	73	91	0.0	0.0
LDCs	0.65	-2.4	-2.2	0.3	1.1	5	7	44	62	0.0	0.0
EEFSU	0.40	-1.4	-1.3	0.7	1.1	-2	0	-6	16	-0.2	-0.1
OPEC	1.06	-2.8	-2.4	0.9	1.6	-4	1	-16	24	-0.8	-0.5

Source: APG-Cubed model version 63A

Table 23: GDP Consequences of Historical Influenza Pandemics

Spanish Influenza 1918-1919

GDP Growth rate, %		**1908-1913**	**1914**	**1914-1918**	**1919**	**1919 GDP (loss), %**
		Average	Annual	Average	Annual	Annual
AUS	Australia	5.16	-7.70	0.89	-1.84	-2.73
CAN	Canada	8.69	-6.70	3.54	-11.14	-14.68
GBR	Great Britain	2.88	1.00	3.02	-13.89	-16.91
JPN	Japan	2.52	-3.00	5.56	7.94	2.38
USA	United States	5.48	-7.70	6.09	-5.22	-11.32

Asian Influenza 1957-58

GDP Growth rate, %		**1953-57**	**1958**	**1958 GDP (loss), %**
		Average	Annual	Annual
AUS	Australia	4.38	4.80	0.43
CAN	Canada	5.28	1.79	-3.49
GBR	Great Britain	3.06	-0.21	-3.27
JPN	Japan	8.43	5.83	-2.60
USA	United States	2.62	-0.49	-3.12

Source: Maddison (1995) Table B-10a pg 148-51 and own calculations

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