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ASSESSING THE IMPACT OF PANDEMIC FLU

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C O N T E N T S

P R O C E E D I N G S

MS. GRAHAM: Good morning. Welcome to our event on Assessing the Impact of Avian Flu. I am Carol Graham. I co-direct the Center on Social and Economic Dynamics here at Brookings, and I am also on the faculty at the University of Maryland.

Prior to introducing our speakers, I thought I would say just a few words about our Brookings Center and how our approach to social science problems is reflected in these presentations, but also it can be applied to many different other kinds of similarly challenging social science and policy challenges.

At the Center we place a particular focus on the social norms that govern behavior and the way in which social interactions can determine very large differences in aggregate outcomes. So we address a range of policy questions, from inequality, to spontaneous outbreaks of civil violence, and to the spread of epidemics and infectious diseases, the topic of today's forum. In our view though, understanding the social interactions that underlie these phenomenon are absolutely critical to understanding the aggregate outcomes, and if you consider that most models of disease transmission do not really account for social interactions and yet how people interact with each other makes a major difference to the rate and pattern of disease spread, I hope you will see today that our models are uniquely well suited to addressing these questions.

Then just a quick word about Brookings which I think will be

again reflected in these presentations. One of the things that distinguishes Brookings from other think tanks is our capacity to do in-depth longer-term research, and while certainly at times we do focus on short-term problems and tell people what to think about particular policy problems, I think what distinguishes us is our ability to frame policy debates and, in other words, not to tell people what to do about a particular policy problem, but how to think about a deeper range of policy problems. And I think you will see in these presentations that they are as much about how to think about the pandemic flu challenge as to what to think about a particular outbreak. One presentation from Josh Epstein will do so from the epidemiological side, and the other by Warwick McKibbin will do so from the economics perspective.

Just a word about our two speakers, and then I will turn it over to them. Josh Epstein on my immediate right is a Senior Fellow in Economic Studies at The Brookings Institution, a member of our Center on Social and Economic Dynamics, and a member of the external faculty at the Santa Fe Institute. He holds a Ph.D. in political science from MIT and is a member of the New York Academy of Sciences. He is also most importantly in my view the mastermind behind all of our computational models. His latest book, "Generative Social Science: Studies in Agent-Based Computational Modeling" is forthcoming from Princeton University Press and, indeed, he is a pioneer in developing this method. As you will see, it has very, very powerful implications. He is going to talk about global pandemic flu simulation and mitigation.

Our second speaker on my far right, Warwick McKibbin, is Professor of International Economics at the Research School of Pacific and Asian Studies in Australia, and Director of the Center for Applied Macroeconomic Analysis and Adjunct Professor at the Australian Center for Economic Research in Health at the Australian National University. He is also a Professorial Fellow at the Lowy Institute for International Policy Studies, a Nonresident Senior Fellow here at Brookings, and President of McKibbin Software Group. He is a member of the board of the Reserve Bank of Australia, and a member of the Australian Prime Minister's Science, Engineering and Innovation Council.

Professor McKibbin is internationally renowned for his contributions to global economic modeling. He has been a consultant for many international agencies and a range of governments on issues of macroeconomic policy, international trade and finance, greenhouse policy issues, global demographic change, and the economic costs of infectious diseases, the topic that he will cover today. His presentation today will be on the macroeconomic consequences of pandemic influenza. With that, I will turn it over to Josh.

MR. EPSTEIN: Thank you, Carol, and thank you all for being here. As Carol said, I want to talk about the epidemiological side, and then Warwick will talk about the economic side.

I should acknowledge my colleagues and funders before beginning. This work is done in collaboration at the colleagues at the Research Triangle Institute whose names are here, and it is funded by the National Institutes

of Health MIDAS Project. MIDAS is Models of Infectious Disease Agent Study which is part of the National Institute of General Medical Sciences.

I thought I would start by just talking a tiny bit about pandemic flu proper. You have all heard a lot about this over the last year or so. This is the so-called bird flu or avian flu. It is also known as H5N1. The salient feature of this particular pathogen is that it is highly lethal in humans but at the moment is not transmissible from human to human. You can only get it from a bird. Of the 150 or confirmed cases in humans, roughly half have died, or a little more than half. What epidemiologists or what doctors would call the case fatality rate is uncertain, of course, the number who die divided by the number who got it, because we do not really know the number who got it. We are talking about 300 million people scattered around Thailand, Vietnam, Cambodia, and Indonesia, where the surveillance system is not terrific and so we do not actually know the number of cases with high accuracy. But it is not a good bug to catch, and many of the people who have caught it certainly have died of it, but as I say, no confirmed human-to-human transmission. So it is highly lethal with no human-to-human transmission.

By contrast, the normal influenza A annual flu that we get is really the reverse. It is highly transmissible, but low lethality. I say low advisedly because almost 40,000 people in the U.S. die of regular old flu every year, so it is not low lethality, but compared to avian, it is not nearly as lethal, but it is more transmissible.

So what are people worrying about? We are worried about an appearance of a human-to-human strain of this bird flu, and there are a number of evolutionary mechanisms that might bring about that emergence. One of them is the so-called recombination scenario, and here you might imagine someone infected with both the H5N1 avian flu and a typical influenza A, so both of those are circulating in this person, and a recombination or reassortment event occurs in which a new strain is formed by a combination of those co-circulating bugs. The problem would be that the new bug, the reassortment, could be highly contagious from human to human like normal flu, but highly lethal like avian flu. It could have the worst attributes of both, we would have no natural immunity, there would be little if any strain-specific vaccine, limited supply of antiviral drugs of uncertain effectiveness, and voila, you have a global pandemic.

We have had these before. The famous one was the 1918 Spanish flu, also a bird flu, with something like 50 million deaths worldwide, three-quarters of a million or so in the U.S., and from an economic standpoint that we will hear more about, the attack rate was concentrated in the economically most productive sector of the society, the age group 20 to 40, unlike normal flu which is mostly U-shaped, infants and elderly. That was 1918. Modern transportation and higher population densities would exacerbate the spread under modern conditions. So the question is, how do you make a reasonable projection? As Carol was saying, how do you think about this, get your brain around it, make sense of it and prepare for it to the extent possible?

What we have been doing at NIH is build computational simulation models on a very large scale. We have produced two models of Thailand published in "Nature" and "Science", two models of the U.S. published in "Proceedings of the Academy of Sciences" and "Nature." Those are both activities of Neil Ferguson and Ira Longini. I direct development of a global epidemic model at NIH that I will show you in a minute. Our missions, as it were, are to project the global spread of these diseases, development containment strategies, and offer real-time decision support in crises.

But the question is really, why should you believe any of these models? What makes them credible? One answer to that is that we try to make them credible by using what data exists and calibrating the models to known outbreaks of influenza. We can try to at least get the social contact dynamics right, and in some cases we know how the bug acted in human hosts and so we can reconstruct these epidemics on computers and say this is how the 1968 global flu really did unfold on the 1968 population transportation system, and that is what we are going to do. So we are going to say let's reconstruct the 1968 flu, then leaving the 1968 bug, let's update the transportation and population to modern levels and then with modern levels captured let's make the best CDC/WHO best biomedical estimate we can about what a human-to-human variant would look like and plot that into this contact dynamic and make some sort of ballpark estimate of how things might unfold under a huge array of uncertainties, but nonetheless, we think it is a valuable exercise. So step one is

reconstruct the real one, and then we will update it and try to make an estimate of the modern one.

This was a Hong Kong originating bug, a few million deaths, fewer than would have happened without a preceding pandemic that gave people some immunity. I do not want belabor this one because there is lots to say about it, but this is the idea. We build a global model. This one in 1968, there wasn't nearly the level of transportation there is today. It starts in Hong Kong. We will color your city blue if it is all healthy, pink the minute there is an introduction, red the minute it is above some prevalence threshold, and this is how that bug actually unfolded. We get the sequence of cities correct; we get the size distribution of citywide outbreaks correct. It is a computational reconstruction of an historical event, and we have done this before.

You can query the system for what is going on in each city, so in Singapore susceptibles exposed, infected, removed, so forth, and in our publications, of course, there is more detail about these. It did not unfold explosively as you can see, and I think what you will notice immediately about the modern version, and I am going to skip the exercise of the 1968 bug and modern transportation and move directly to modern and modern.

The computer system we have developed puts out a geographical spread over time, and I will show this running, so at the outset you would look at something like this. It is all air travel, there is no ground transportation, so it starts from Hong Kong, looks like this, then later it looks like this.

We can query the software for the situation in any particular city in real simulation time, and we can give global plots of the wave of epidemic as it goes across the globe, and I will show you all this. Of course, what I will show is a particular realization of this model. These are so-called stochastic simulation models that differ from run to run just like the real word differs from day to day. You do not bump into exactly the same people every day; you do not take exactly the same bus home. There are differences, and they are random, but they can matter a great deal. So when you report results, you report statistical results based on lots and lots of run. You build up a robust statistical portrait rather than present one eye candy realization, but I am going to present the eye candy realization so you can get some impression of how these things work. I will show the Hong Kong start, and then I will show a London start, and then I will talk about more systematic findings.

Here is a start on Hong Kong in July. You can see the dates progressing in the upper right of the screen. This is unfolding very quickly as you can see. This was on five continents in 24 hours. Things happen very quickly under modern transportation, obviously much faster than the evolution for 1968. Again, we can look at what happens in each city and we can see the wave of epidemic across the planet. This you will notice is spread out quite a lot. When I run the London start you will see that it looks quite a bit different than that because London is much more connected to the developed world, it radiates in a different way, and I think you will agree that not only the geometry but the

temporal evolution is also very different. It is very clustered in a way that the other was spread out.

I will say that I do not know how you could start thinking about this without building a model of it. I like to say everybody is a modeler, everybody in this room is a modeler, the difference is we try to write the model out explicitly rather than using the implicit model in our heads, and I do not see how you can begin to think about this type of problem, the dynamics, on this scale without modeling them, and sort of scratching your beard and trusting your gut is hopelessly inadequate.

With worldwide cases, again, I really want to emphasize that this is not a prediction. It is an estimate of a range of plausible outcomes under a range of assumptions none of which are remotely certain or trustworthy. We just do not have this bug, when we have it we will not know how it behaves in human hosts, we do not know how it would respond to antiviral drugs, we will not have a vaccine, and we do not know how people will behave. They may all go to the basement and protect themselves; they may all run around like maniacs and spread the thing. There is just a huge amount we do not know, but it is a starting point for thinking about it, and there are so-called base case runs in which there is no intervention, no adaptation, people are just in this contact dynamic. But it does depend heavily on a parameter that epidemiologists call the R naught, the R0 of the bug, and the idea of the R0 is kind of like an interest rate. If I take a container full of susceptible people moving around in a nice mixed way, this room, for

example, and I drop a single infected person into that pool, how many people will that person give the bug to? How many immediate secondary cases will there be? If that number is less than 1, the thing fizzles. If it is more than 1, it spreads. If it is 3, it spreads very fast. If it is 6, it is really wild. 1918 was in the range we are talking about. It was between 1.5 and 2. Again, if you believe this is an influenza-like illness, a bird flu that might be genetically related to 1918, and Taubenberger's work is very interesting here, people in our field are using this range of estimate. Everybody agrees that it might be wrong, but we are going to go with a sort of midline R Naught and show what the implications are. These are in millions on the left. Again, with no intervention, no adaptation, and again, it is an urban model. I am not talking about rural cases or even ground transportation, just global air.

We have taken different time slices of it for different times and places. You can release it in Hong Kong in January and Hong Kong in July, London in January and London in July, Sydney in January, Sydney in July, any city in the software, any of the 155 of the cities. Then we ask how everybody is doing at 6 months, 12 months, and when the thing is over. As I said before, you never run a single run; you build up a distribution, so we report the mean and the standard deviation over a hundred runs under every one of the assumptions. The standard deviation is high in some cases and not so high in others. You could compute the so-called confidence intervals at any level of significance and so forth. But the basic idea is you are ending up in this ballpark, the 400 million

cases kind of ballpark. That is not a prediction.

What are interesting policy avenues at this global level? The one that I would like to talk about is the imposition of travel restrictions on the global transportation system, and we have the model of all this air activity, so what happens if you suspend air transport, for example? The idea would be to delay the global propagation of the bug, buy time, and in the time you buy, do intelligent things like develop a vaccine and distribute it, give people good recommendations about social distancing, close schools, take measures that are likely to improve the situation.

When you say delay the propagation, you have to decide what you mean by that. One thing you might mean by it is, looking now the U.S., the first passage time to the U.S. would be if it emerges in Hong Kong, how long does it take for it to get to the U.S.? When is the first U.S. case? That is one measure, and you gain a couple of weeks by restricting travel at 90 percent. That is to say, the minute we detect 1,000 cases in any country of the world, you can do this sequentially or all at once, but if you suspend 90 percent of air travel all at once, that is what we are looking at. You can also suspend it country by country so that every time a particular country exceeds the threshold, their traffic gets clamped down. We have done it both ways. It actually does not make much difference, so that we are just going to do the simple one where everything stops, and you buy a couple of weeks of time. That is interesting. You could do a lot with a couple of weeks.

More interesting perhaps is the effect on the peak incidence which is shifted out by months. So the first passage time is when does it emerge in the United States, that is a couple of weeks, when is the peak in the United States, that is months, so you might be able to do a lot. If in the time you have you do develop a vaccine and vaccine at some rate, again, a percent a day and assume that the vaccine is effective, you depress cases a lot. This is the yellow curve. And if you do both travel restrictions and vaccine, you take a big bite out of the epidemic. Cumulative results look like this, you reduce incidence from 100 million to 30 million, and it is a big difference. Notice that I am not saying anything about fatalities and will refuse to if pressed.

So the U.S. results are very good. Global results are also good. The no intervention level, as I said, is in the 400 million infection range, and with these interventions, travel restrictions, vaccination combination, you cut it very substantially, and that is this light blue curve. Those are for the July start.

The January start behaves a little differently, but the basic results are the same. It is actually more impressive suppression of the epidemic if it starts in January for reasons I will come to in a minute.

This is a very interesting result for the January start. The blue curve is no intervention, the purple curve is the result with 90-percent travel restrictions, and for the U.S., it is actually higher with travel restrictions than without. We get more cases with travel restrictions than without in the U.S. for the January start. Why in the world would that happen? We were very confused

by that for quite a while and we thought of a number of possibilities, one of which was by imposing travel restrictions you are bottling everyone up in the United States and you are getting better, more thorough mixing for that reason, and the epidemic is bigger because of the better mixing. That does not fly. Not enough people fly. There were not enough new cases. It just does not work.

What is really happening is a seasonal effect. The flu has very dramatic seasonal oscillations, and the big oscillations happen in February, March, April, or February and March, the dead of winter in this hemisphere, and by imposing restrictions we move the United States from the low season into the high season. Imposing these restrictions delays the introduction, and depending on where you are, it can delay instruction from the low season to the high one. So we actually found that in some cases, imposing restrictions pushes you into the higher season and you get a bigger epidemic. Nonetheless, if you use the time afforded, you still get very dramatic suppression of the epidemic, so it is worth running the risk of pushing it into the high season if in the time afforded you impose these other interventions. So you really do still suppress the epidemic. We found that interesting and it is one of the nice arguments for planetary scale modeling. Models at a subplanetary scale would never notice any connection between your policies and global seasonal dynamics, and they turn out to be very interestingly related.

I will wrap up by saying that combined measures of restrictions, vaccines have very substantial potential benefits. To the economist, we want to

know how the benefit is related to the cost. It is not just that it is beneficial, if it is beneficial and it costs you everything then you still do not do it. Cost here is a whole field, but a very crude estimate would be to the U.S. economy suppose you just zap all passenger fares, international fights, because we don't care about cargo moving around, we just care about contagious humans, so it is movement of bodies that you are worrying about. So let's imagine that you just cancel that, no movement of bodies by air. That is about $19 billion a year to the U.S. economy, a couple percent of total goods, and a sixth of a percent of U.S. GNP. That is not a general equilibrium treatment; it is just a ballpark claim that it is a dinky whack to the economy and might be a very big benefit to public health. So we are thinking, and again, this is my opinion, it is not a policy of the NIH, it is a study conducted by Brookings, but we are finding that global travel restrictions can be a very powerful adjunct to pharmaceutical and other mitigation strategies, and from a methodological standpoint, that planetary scale modeling is really rather central to the formulation and analysis of global public- health policies. With that I will turn this over to Warwick.

(Applause.)

MR. McKIBBIN: Thanks very much for coming, and thank you very much for the introduction, Carol. Also, Josh has given you a wonderful introduction into the epidemiological background, and I will pick up what he started with and I will talk more about the economics.

I should mention that this paper was available outside and it is a

joint paper with a colleague, a former Ph.D. student of mine, Alexander Sidorenko who is currently at the National Center for Epidemiology and Population Health in Australia, and this work was a funded by a research grant from the Australian National Health and Medical Research Council. The opinions in the paper are the authors' and have nothing to do with the funding institution or the Brookings Institution.

The paper is quite long and rather technical. I will not go through the entire paper today, but I will just give you a quick introduction to what is in the paper. There is a section on the background of influenza pandemics which Josh has already covered. There is a section on the macroeconomic cost of disease, and I think it is important to put the very large numbers that we get from pandemic influenza in the context of the enormous numbers you get from malaria, from AIDS, and from all these other diseases which are really diseases of the developing world but still quite large relative to the results that we are getting for a global pandemic.

There is also quite a large introduction into the model which we are using which I will not go into detail today. The paper also discusses how do you model pandemics, which is very difficult as Josh has mentioned. Then there are core results from the scenarios that we examined and a lot of sensitivity analysis. As Josh said, the next pandemic could be the H5N1 avian influenza, and it is interesting to try and take what we know about that influenza and the historical experience from previous pandemics and try and understand what might

happen.

There are a few other studies on the consequences of pandemics. The Asia Development Bank recently did a study which focused on Asia, and the Congressional Budget Office did a very good study which focused on the U.S., but there are very few people who are willing or silly enough to do a study at the global level, and that is what we are trying to do.

You might argue that the uncertainty is enormous, which it is, but we do have historical experience to draw on as Josh did in his presentation. This gives us a good initial condition to start with, and then we try and modify the historical experience for what we observe in the world today.

We came up with four possible scenarios. There have probably been between 15 and 20 pandemics since the 16th century at the global level, and there have been three major pandemics in the 20th century. The reason we explore four scenarios is because with the 1918-1919 Spanish flu, the estimates cover such a wide range that we decided to pick a high and a low from that experience. The four scenarios are the mild scenario which is the 1968 Hong Kong flu that Josh talked about, a moderate scenario which was the 1957 Asian flu, and then a severe scenario which is at the lower end of the estimates of the Spanish flu, and then an ultra scenario which are the higher estimates of the 1918-1919 Spanish flu.

The approach that we follow is very different to Josh. We follow an approach that Jong-Wha Lee and I developed for the World Health

Organization on how you model the impacts of SARS. The official estimate of $40 billion for the cost of SARS to the global economy was actually the estimate that we developed in our paper. What we do is we take the experience from the SARS outbreak and we take the pandemic experience historically and we translate the pandemic scenarios into a series of economic shocks and put them into an economic model, and the model is the Asia-Pacific G-Cubed multicountry/multisector model.

This is quite different to Josh. Josh focused on individual cities, we are focusing on entire countries, and there are 20 countries in this model, and quite a large focus on the Asia-Pacific region which is quite important from an economic point of view.

Interestingly, rather than just have a single part of the economy, it really does matter what the structure of the economy is, and we break the economy down into six sectors, energy, mining, agriculture, two types of manufacturing and services, and it turns out the structure of the economy matters a lot for the way in which the economic costs evolve.

I will not go into much detail, but for any economists or modelers in the audience, I just want to stress that this model is not an equilibrium model. It is a long-run equilibrium model, but in the short run there are a lot of rigidities and imperfections. We have adjustment costs in capital accumulation, we have financial capital moving around the globe subject to risk country by country, we have labor markets which allow unemployment to emerge because of stickiness in

the labor market institutions. In addition we have a wide range of financial markets. This is very important because when people panic as Josh mentioned, it changes rates of return and expected rates of return and this causes a reallocation of global capital as we saw during the Asian currency crisis. These capital flows can be orders of magnitude bigger than the actual pandemic itself because people panic, pull their money out of countries who are going through series economic disruptions, and that in itself is a very large disruption to the global economy.

We also have individuals who react both in an optimizing way in the sense that they know the model, they know what is coming, but there are also rule of thumb individuals who are partly looking backwards, so they do not instantaneously respond to the pandemic.

How do we model a pandemic? In an economic model, it really is a function of what sort of shocks are we talking about, and one big shock is the reduction in the labor force. People die. If people die, they are not working. Therefore, economic activity is reduced. But also people get sick and people also stay home to look after partners or children who are sick. So for the mild scenarios, the illness is actually a bigger source of lost employment in the short run in many economies than the mortality itself. And we try and capture this effect by looking at the labor market structures in each of the economies we focus on, what is the proportion of the women in the labor force, what is the dependency ratio of children. We assume that women are more likely to stay at home to look after children than men, et cetera, so there are a lot of assumptions

involved, but we try and capture the distinct characteristics of different countries.

But apart from the labor force shock and, in fact, in the minor scenarios, it is actually the human response rather than the labor changes that drive the economic changes. There is a big increase in business cost for some sectors. If you are in a sector where there is a lot of human-to-human interaction, then the cost of doing business goes up enormously. We saw that during the SARS pandemic where hotels in China were 95 percent empty at some point. That is a very large increase in business cost.

In addition to the cost side, there can be a large change in the way people spend their money and we try and model this by pushing consumers away from spending in infected sectors toward either saving that money or spending on other goods. In addition to the demand and the supply impacts, country risk can be a very important issue. If you lose confidence in Indonesia because you are not sure how they are responding and the economic costs are mounting and you pull your money from Indonesia, that has a very large impact potentially on the Indonesian economy, but a positive impact on the country where it likely to be heading which is likely to be the U.S. or Europe in these scenarios.

So how do we build this scenarios ? The critical assumptions are we need an epidemiological framework, and when we started doing this research we did not have Josh's numbers. We numbers by Metzler, Cox, and Fukuda for the U.S. which is a widely quoted study, and out of that study we got the attack right and the case mortality right for our pandemic influenza today. Then we

scaled those numbers for individual countries by focusing on a series of indicators we had developed for these countries to convert it into the country characteristics that are important. We constructed our own crude epidemiological model, but it turns out we get some very similar to Josh which is encouraging.

I will not spend much time here, but what really matters is a geography indicator we developed and, again, it comes down to air travel, how easy is it to enter and exit a country, what is the capacity within a country for the disease to spread internally. The sort of data we used is air transport data as Josh has used, whether the country is located in the Northern or Southern Hemisphere because of the seasonality of the influenza pandemic, what the population density is in a country, because the more densely populated a country the more easily the disease can spread, and what is the share of urban population to total population. A lot of people in high-rise buildings in Hong Kong are more likely to be infected than a lot of Australians on one square kilometer each, they are not really breathing on each other very often. These indicators are important.

We also developed what we call a health policy indicator, which are the resources available in a country to respond to the disease. One measure is per capita health spending. It is a bit problematic for a country like the U.S. because you spend a lot on health, but we do not adjust for quality. So the U.S. looks a lot better than a country like Japan, but we really probably need to take into account the quality of the health spending. Other indicators include the antiviral doses that are available, on the assumption that they will have some

impact, and they may or may not.

Equally important to the way the disease will spread is how the governments respond, and we saw that with the SARS outbreak. Those countries that refuse to acknowledge, who did not let this information become public, their outcomes at the end were much worse than those countries that were much more open and transparent. We developed this government quality indicator which looks at the effectiveness of government, the regulatory quality of the economy, and the sort of corruption indexes which are available.

We also look at the index of financial risk, and it turns out that the U.S. does not do very well on this index because one of the inputs is how open are you to reliance on foreign capital, how likely is it that foreigners will pull their money out of your economy, and with the sort of current account deficits to GDP we now have in the U.S., the U.S. does look a little bit more vulnerable than it used to.

Finally, we have to worry about what is the composition of the service industries, and unfortunately we do not have a lot of detail on the service sector in the model so we have to dig deeper to create relative shocks that capture the composition of the service industries in economies.

What are the epidemiological assumptions? In the survey in the paper, the attack rates that you find in the literature for the 1918-1919 flu were 10 to 40 percent, for the 1957-1958 flu, 15 to 40 percent, for the Hong Kong flu, 10 to 30 percent, and the estimates in the Metzler study are 14 to 35 percent. What

we use in the model is 30 percent. We are assuming 30 percent across each scenario, so we are assuming that the attack rate does not change given the severity. What changes is the case fatality rate. Again, .2 to 4 percent for the U.S. for the 1918-1919 pandemic, down 2.01 to .07 for the Hong Kong flu. You can see what is driving the pandemic severity is actually the fatality rate, not the infection rate.

I will quickly go through a couple of the indicators that we developed just to show you. This shows you, given a certain U.S. pandemic mortality and fatality rate how we adjust the rates in different countries based on indicators. For example, here is the index of geography where the U.S. on the far right has an index of 1, and you can see that Malaysia, for example, has an index of 1.6. That is a lot worse. That is 60 percent worse than the U.S. There are a variety of reasons why that is the case, but you can see a lot of countries actually have a worse geography indicator.

Interestingly, Eastern Europe and the former Soviet Union which is the EEB on the chart actually has a lower geography indicator. That has to do with density of populations, and I do not want to get into the individual countries, but this just shows you some of the spread in the geography indicator. The health policy index actually spreads even further. Here the U.S. has an index of .2, the Philippines is 1. So the Philippines are 5 times worse in terms of being able to deal with this from a health policy point of view. Thus whatever the shock was in the U.S., you can see that the health policy indicator is going to drive the shock

quite dramatically in countries like the Philippines, Indonesia, Malaysia, Thailand, and China.

Putting all those together, and there are a lot of indexes I have not talked about and there is a lot of arbitrariness in some of the ways we calculate these, this figure shows the sorts of mortality rates that we get under the four scenarios. The figure has each country along the bottom axis. The blue bar is the mild scenario, the red bar is moderate, the yellow bar is severe, and the green is ultra. To get the context right here, we have a mortality rate in Indonesia where 5-1/2 percent of the population dies as a result of the ultra scenario. That is taking what we saw in 1918-1919, scaling it to the structure of the word today and these are the sorts of mortality rates that come out. For the U.S. we see that it is about .7 percent in the ultrascenario.

Those mortality shocks then feed into labor force shocks, and here is the labor force shock not due to death because that is proportional to the mortality rate, this is due to absenteeism. You can see that for the U.S. the index is up around 1.35, so there is likely to be a lot more absenteeism in the U.S. than in Thailand as a reflection of the labor market in the U.S., et cetera.

A very important aspect of these shocks is what part of the service economy is highly exposed, and this gives you an indication. We looked here at total service industries, and then we looked at travel, tourism, hospitality, restaurants, et cetera. For example, in Hong Kong which is the highest bar, 35 percent of Hong Kong's services are highly exposed. So again, if you think that

the service industry is going to get hit, it is going to get hit much worse in Hong Kong than in the U.S. just because of the structure of the service industries in the economies.

You will probably enjoy this, because in terms of the quality of government, Australia does better than the U.S., which is a completely impartial calculation.

(Laughter.)

MR. McKIBBIN: But you will see that in countries like Indonesia where we have an index of .65, that is 4 times worse that for the U.S.

What we do then is we take these shocks to the population and to the labor force and we covert them into cost shocks, and this figure give and indication of the relative shocks. I will not go into detail, there is a lot of information here, but just take Hong Kong. You can see that in Hong Kong there are six sectors in the economy. Energy and mining tend to get hit less in terms of the cost to business, agriculture and manufacturing tends to get hit a little bit more, but services gets hammered. For the service industry in Hong Kong in the ultra scenario there is about a 4.2 percent increase in cost. You might think that is a big number or a small number, and I think it is a relatively small number, so we have tried to be conservative here.

The demand shocks are shown next. This is how people switch their demand away from different sectors, again you can see that the demand for services drops by more, obviously, because one is much more exposed to catching

the disease in the service industries.

What are the results? These are the results of the numbers of deaths, and these are in thousands. You can see from left to right the U.S. in the ultra scenario has about 2.5 million people dying, and you can see that clearly overwhelmingly in terms of aggregate numbers, it is Indonesia, China, India, and oil-producing countries in terms of aggregates get overwhelmingly hurt by this disease. But the large number of deaths in these countries is a reflection of the scale of the population in these economies, and if you look at it scaled to the proportion of population, you can see that there is a much more evenly spread death rate. However you still have the developing countries of Indonesia, Malaysia, the Philippines, Singapore, Thailand, et cetera, getting quite a severe shock as a proportion of their population, in Asia, between 2-1/2 percent and 5 percent of the population die in the most extreme scenario, a lot less in the other scenarios. These are just the death rates.

What happens to the economy? Given time constraints I cannot go through every result because we look at a lot of things, this table shows you the percent of GDP loss in the first year of the pandemic. The way to read this is the U.S. is the first country. The mild scenario reduces GDP by .6 percent. That means that if the economy was growing at 3 percent, it would now grow at 2.4 percent. That is not an absolute decline; it is a decline relative to where the economy has been, so it is really the conseqeuence of the shock.

As you move to the right, the scenario becomes more severe and

the economic consequences become more severe. You can see that in the ultra scenario that the U.S. economy contracts by about 5.5 percent of GDP which is technically a recession in the United States.

What about in the rest of Asia? In the rest of Asia, this really becomes a very severe shock. Take the Philippines for example, in the mild scenario they lose 1.5 percent of GDP which is not a recession, but as you move from left to right, you see that in the ultrascenario the economy contracts by nearly 38 percent. There are two things going on here. One is that the shock is becoming more severe because the developing countries are getting hit much worse as the pandemic gets bigger. But secondly, there is a very large relocation of resources away from these crisis countries to the safe countries, and that is to countries like the U.S. and the U.K. and Europe. There are a lot of very similar reactions to the 1997-1998 crisis in Asia where people just pulled their money out because these economies are collapsing, you see that the economic costs actually become quite dramatic as you move to the ultrascenario.

It is interesting, though that was the first year's shock, -- the pandemic occurs in the first year and it can be quite devastating. This next figure shows you what happens over time, and I think the dynamics are quite interesting. These results are for a subgroup of countries for the moderate scenario. This is the pandemic impact relative to base, so this is relative to a growing world economy, and you can see that the U.S. contracts by 1.4 percent which is what it did in the previous graph, but the economy recovers within a couple of years.

You can see that for the countries that get very badly hit, it takes a bit longer to recover, and you can see that the countries that have lost a lot of their work force never get back to the same level of GDP because they have lost a lot of workers, but the long-run effects are actually reasonably small compared to the short-run effects.

One of the focuses of the paper is what are the optimal macropolicy responses, not so much the epidemiological responses, but how do policy makers respond. You can see that Hong Kong really gets hammered for two reasons. One is it gets quite a big shock. But secondly, it is pegging its exchange rate to the U.S. dollar so it contracts monetary policy like it did in the SARS epidemic and it doubles the impact of the negative shock so that the macroeconomic context of the disease turns out in the short-run to be a very important issue, and that is one of the focuses.

The reason we are interested in how policy makers respond is because some of us are policy makers and we have to respond. An interesting question is how should the Fed respond to a shock like this. It is an interesting shock, because from the supply side, costs have risen which means that economic activity will fall, but inflation will rise. From the demand side, falling demand means economic activity will fall, but in inflation will fall. The question of whether you are facing a loss of output or an increase in inflation is a very big problem for the monetary authorities, which is why there is a lot of sensitivity analysis in the model.

Just to show you very quickly one of the sensitivities, here we look at a base scenario which has the purple lines as the GDP losses by country, the pink line are the alternative GDP losses if we increase the severity of the demand shock. The sensitivity here is that the demand shock is a lot worse in the base scenario of what happens. You can see that in the base scenario, inflation actually rises in the U.S. and output falls. But if the demand shock is actually a lot bigger, so the fall in demand is even bigger, then in fact output falls by even more and inflation actually falls. So the Fed here could respond by loosening monetary policy and not worry about the inflation target. It might seem esoteric to an audience on health, but to central bankers, this is the key question, is it going to be inflationary or deflationary.

And it is the same sort of story on the cost side. If the cost shock is a lot less severe, you can see that the GDP losses are a lot less and the inflation consequences are a lot less, so it turns out that the results are very sensitive to these assumptions.

Let me just summarize at this point. What are the size of these shocks? Even a mild pandemic which we have modeled here as the 1968 pandemic takes about .8 percent of GDP out of the world economy which is about $330 billion. A repeat of the 1918-1919 Spanish flu of the worst scenario can take about $4.4 trillion out of the world economy, a nontrivial amount of money. It depends on what you compare it to, I guess. If you compare it to the cost of the Iraq war, then it may not be so trivial.

A key point is the impacts are larger on developing countries because they get hit with larger shocks and the macroeconomic adjustment in global capital markets gives them a double-whammy. So people move their funding from the high risk countries to the low-risk countries which turn out to be interestingly the U.S. and Europe. I should have mentioned that one of the interesting results in this table is Japan who you would think would look like the U.S., actually does not look like the U.S. Japan looks like the U.S. at the beginning; as Asia collapses, Japan gets sucked down with it because it is trade structure is so reliant on sectoral flows in Asia that the economic drag is so great that Japan actually does become a serious problem. You can see that in the ultrascenario, nearly 16 percent of GDP is wiped out of the economy. That is an important point if you are a Japanese policy maker. So this point about developing countries is not just the developing countries that get hit, if you are highly integrated into the developing region you also suffer.

A minor point about the financial market responses, equity markets fall as you would expect, but they do not fall as much as financial analysis would suggest. Someone might think a 50 percent fall in the Dow would be plausible. We get a much smaller number because people look through the pandemic and see that the economy is going to recover next year, so the equity markets effects are surprisingly small in this model and the bond markets rally. That inflation may rise or fall depends on the relative size of the cost shocks versus the demand switches, and as I mentioned before, monetary responses matter. If you are

pegging your exchange rate and you get hit by the shock, then you are shooting yourself in the head at the same time.

Finally in conclusion, predicting the impacts of pandemic information is very difficult, but the range of estimates we have tried to calculate in this paper suggest that the costs are likely to be either large or very large, and probably largest in the resources being spent to prevent this occurring at source.

(Applause.)

MS. GRAHAM: Thank you very much for two really wonderful presentations. We now have about half an hour for questions. I suggest there are microphones right there, so you can probably take the answer from there, and when you have a question, if you could identify yourself, please.

I am going to take advantage of the power of the chair and ask each of the presenters a starting question. Josh, you mentioned behavior and how do people respond to these edicts to not travel or stay home or get vaccinated, do they hide in the basement or do they run around and spread the disease. I was wondering what your base case assumed about compliance and how you might be thinking about incorporating behavior in the future.

For Warwick, I had two related questions. I was surprised that the health policy indicator was better for the U.S. than for Europe, unless I read the chart wrong, which could have been, sitting where I was sitting. Then the other question was about the variance in absenteeism and the structure of labor markets, I was again surprised that the U.S. had higher absenteeism and I was wondering if

that reflected a more formal labor sector structure than informal or what underlay that.

MR. EPSTEIN: The base case scenario is a very good question, a very important question. The base case scenarios assume compliance, but I think this is a huge problem and it involves for some communities just trust. There is a fabulous study by Roz Lasker of the New York Academy of Sciences where she did very thorough surveys of New York and Washington. The question people were asked was this: If there were a confirmed release of small pox in your community and the government said go to a vaccination site and get a shot immediately, would you go? Smallpox is a well-known disease. We have a vaccine and the vaccine is perfectly effective. There are risks of side effects, but it is easy to find out if you are at risk for any of them. Half of the people in the survey responded, no, I would not go. That's where all the sick people are. I would want to get to my family. And of the minority respondents, the black respondents, in Washington and New York, it was more like two-thirds will not go, and part of the reason is that this is going to be some investigational drug, it is going to be a Tuskegee event, and another group will get the good drug and we just do not trust that the government is going to allocate equitably, and in the wake of Katrina and other things, that is a completely understandable fear.

Here is a case in which you really will have an investigational drug and I think it is quite likely that large groups in the United States will decline a vaccine. We couldn't even get the health care providers to take a small pox shot,

and these are doctors, nurses, people who know all about it. So I think the presumption that there will be a high level of compliance on the pharmaceutical side is very dubious, and it might be equally dubious in the nonpharmaceutical interventions, stay home, with, no, I can going to load up my family and get the heck out of here, and people who do that may spread the thing to whole new areas. So the behavioral side is very important and very uncertain.

MS. GRAHAM: Thanks, Josh.

MR. McKIBBIN: On the health policy indicator, the share of health spending on GDP is the key part of that, and the U.S. does very well in terms of absolute dollars as a share of GDP. That is why I mentioned that the quality probably needs to be taken into account.

Secondly, in measures like the availability of the antiviral responses, the U.S. has pretty good capacity as far as I understand the data, so there are a bunch of indicators which drive the U.S. number down quite a lot.

On the labor market responses, people staying at home because of illness or looking after children is a function of the structure of the U.S. labor market with a lot more women working perhaps than in the Australian labor market. There are a variety of factors in there, but that is the most likely.

MS. GRAHAM: So you would have more in and more out, basically.

MR. McKIBBIN: I should mention, and I did not mention in the presentation, that this model is a very course model in the sense that it is an

annual model, so Josh was taking about days, and I am putting all of the epidemic effect in 1 year, so it is a very coarse model from a timing point of view. You might ask why doesn't everybody just stay at home? If there is a pandemic outbreak, everyone will just stay at home won't they? The answer is not over a year they won't, and they did not during the SARS outbreak because they cannot afford to in most places. So they might stay for a week or 2 weeks and we built that into our estimates, but when you annualize the effect, it is actually nowhere near as big as you might expect.

MS. GRAHAM: Thank you. Are there any questions? If you could just identify yourself.

QUESTION: (Off mike) — USA Daily. My question to Dr. McKibbin, did you take into account cultural differences between countries that you studied? What I mean by cultural differences is the way people perceive the threat and react to those threats, because the consequences of pandemic influenza is pretty much related to how people react to these threats; you can compare, for example, the USA and Philippines.

MR. McKIBBIN: No, we did not because we did not have any way of calculating those sorts of effects except by doing sensitivity analysis on the scale of the cost shocks and the demand shocks. For example, if you had your own information on cultural differences, and normally the Japanese ask me that question, we respond very differently to face masks than the Americans, so why wouldn't our result be totally different? Maybe it would, so you can take our

sensitivity analysis and modify the shock to uncover your own estimates if you wish. It is all in the paper.

But it is a difficult issue to deal with, and maybe we are out by a factor of 100 in some of the assumptions we are making. We are very explicit in what they are, and you may not agree with them, but that is the best we can do give the size of the issue we are dealing with.

MS. KLECHNER: My name is Meg Klechner (phonetic), and I am from the IMF in the public health area. This question is for Dr. Epstein. In your assumptions regarding the restriction of travel, you added in the vaccination potential. Was that based on our availability and capabilities to produce the volume of vaccines? I know Dr. Fauci often comments that the —

(End Side A. Begin Side B.)

MS. KLECHNER: (In progress) —perspective is what your limitation is right now because we do not have the potential to produce enough vaccines, and I wondered if you could comment a little about your assumptions related to the vaccination portion.

MR. EPSTEIN: That is a very good question. We were just running a tenth of a percent per day, until we have the specimen, it is very hard to design any vaccine. As Warwick said, we have a large stockpile of antiviral drugs and we do not know whether they are effective or not. I would again send you to the papers in "Nature" and "Science." They try to make an estimate based on the viral load, viral titers observed in patients, and they make estimates of what a

moderately well-matched vaccine might do about transmissibility and about fatality per case.

There are two issues. One is, do you save the patient or not. As a completely separate issue, do you prevent that person from transmitting to other people, and I think a lot of people are placing their bets on the latter mechanism, that the avoidance of transmission is what you are hoping for. We do not really know how a vaccine will work in actual hosts. That was a very good question and a huge uncertainty running what we thought was a conservative number.

QUESTION: (Off mike) — from the Department of State. Thank you both of your presentations today.

Just a quick question to Dr. Epstein, and forgive me, I was pretty far back and it was hard to read some or in fact most of the numbers. I was curious, in examining the benefit of restricting air travel, I was unclear in your assumption if you assumed that there was no human travel across borders, that the only human travel was via air, or was it just the air travel alone and you allowed for other human travel, for example, people who cannot fly to the U.S. go to Vancouver and take a bus.

MR. EPSTEIN: Very good question. This is a work in progress. The ground transportation is under development. The model I showed is purely by air, so it understates the amount of actual flow, and the example you suggest is very real. People might fly to alternative places and people would cross borders on the ground rather than by air.

QUESTION: With no other travel?

MR. EPSTEIN: It does not assume it. That is just not in the model. The only flow that I am reporting is by air. So as I say, the model needs to be improved there. That is a defect. That is an important omission certainly in the E.U. and probably in our hemisphere. These are big giant models, it is a huge amount of work to get the air part right, and we will get the ground part right as we go.

MS. GRAHAM: Presumably there is better data for the air part.

MR. EPSTEIN: Yes. And ships are another thing, of course.

MR. McKIBBIN: The fact that you were able to replicate the 1968 without that additional information suggests that it may not be such a big deal, like they are offsetting errors.

MR. EPSTEIN: There may be offsetting errors. That is true. Spoken like a true economist. Thank you.

MS. GRAHAM: I have a whole room full of questions. I will try and just be geographically fair as I select here. There is a lady right there.

MS. HECHT: My name is Joy Hecht. I consult on environment in Third World development projects. My question is for both of you, but mostly for Dr. McKibbin. You are talking about economic shocks that result from movements of capital and pulling their money out because they are scared. I am wondering whether you are thinking at all about convincing people not to be afraid of that risk and therefore not move their capital, or actually not allowing

movements of capital. It is interesting that we assume that can stop people from moving, but I am guessing there is an implicit assumption that we cannot stop people from moving their money even if we can stop them from moving their money even if we can stop them from moving themselves. So I am wondering how you think about that approach to minimizing the economic risk.

MR. McKIBBIN: We could in principle prevent capital from moving because we have the actual risk premia calculated from the data which shows you how easy it is to prevent capital from moving.

The reality is I just do not imagine that policy makers could respond fast enough in real time to this problem. We know during the Asia crisis that there was only one country that actually was able to close capital markets and that was Malaysia, and it turned out that that probably hurt the economy in the medium term because after the shock has passed through, people had lost confidence in putting money in Malaysia. So there is this dilemma because this shock does go away over a few years just like the Asian crisis and it is the short-term response that may actually cause long-term costs for the economy.

Most of the results are from the death rates and from the domestic changes in behavior, and the capital flows on top of that. So it is not as if we are ignoring the real problems in the economy, it is just to point out that, yes, the capital markets do make things worse in the short-term but may help in the long-term.

MS. ANDRES: I am Katherine Andres (phonetic). I am with the

Air Transport Association. We represent the major U.S. passenger and cargo carriers. Dr. Epstein, you described the result of travel restrictions as a dinky whack to the economy based on passenger ticket revenues.

MR. EPSTEIN: Right.

MS. ANDRES: I would suggest that that is a probably a wholly inadequate way of measuring the impact of a travel restriction even extending to cargo the fact that a significant portion of air cargo is shipped in the bellies of passenger aircraft which would not be flying if there were travel restrictions, not to mention the kind of massive layoffs and even liquidations of companies that we would expect to see based on what we saw post-9/11 when it was a matter of just a few days of travel restrictions, and presumably this would require a longer period of time. My question is for Professor McKibbin.

MR. EPSTEIN: I would like to answer that when you are done.

MS. ANDRES: I just wanted to add on to that that travel restrictions obviously would create significant impact to the air transportation sector, but we have also been looking at and trying to get our arms around the demand shock, as you put it, which we believe might precede any actual transmission of disease in this country, and in fact from what we have seen, might look very similar in the mild case as in a severe case because by the time that people will be begin to respond by deferring travel, it may not yet be known what we are really dealing with, whether it is a mild or severe pandemic. So if each of you could respond to that, I would be appreciative.

MR. EPSTEIN: I probably was not clear enough there. I am not talking about restricting domestic air travel at all. Domestic air travel is not part of this recommendation. This is purely international movement of human bodies by air. You could even ship the cargo, just do not do the passengers. In fact, the NIH projects of Ferguson and Longini for the U.S. models have concluded very loud and clear that it is not sensible to restrict air travel in the United States precisely because the ground transportation network is so dense and active that you do not actually cut the epidemic substantially by doing that. So if I was unclear, let me be really clear that all I am talking about when I talk about those passenger fares, it is purely international fights, and that is a dinky whack, I suspect it is a minor whack, even to the airlines, but it is a very dinky whack to GNP. But domestic flights could continue. Nobody is recommending that they be stopped.

MR. McKIBBIN: If I can add on, I think it is very difficult to measure the impacts because we saw from 9/11 and we saw from SARS that those shocks were very concentrated and a lot of airlines got into extreme difficulty because they were hammered on the demand side as well as on the cost side, and so you could imagine there would be an enormous amount of pressure on a given sector, and Josh's numbers may underestimate that because then that would feed through to all the linkages to the airline industry in the economy. In some countries it is much bigger than it is in the U.S. You can do these calculations and I do not think there would be a small number particularly for the airline

industry.

MR. EPSTEIN: But if you had to wipe out the airline industry to save tens of millions of people, tough, is my attitude.

(Laughter.)

MS. GRAHAM: I am going to try and fair geographically, so I will take the gentleman all the way in the very back.

MR. THURMAN: Thank you. I am Stefan Thurman (phonetic) also from the State Department. At the risk of some of you thinking that State is fixated on this question, let's go beyond travel restrictions and talk about closing the borders, meaning except for pipeline trade from Canada for oil that we just close all the borders. There is serious discussion going on in some policy circles in this town on closing the borders, but I also understand Australia and New Zealand have considered this option. Warwick, I think this is for you.

MR. McKIBBIN: We have not looked at the economic costs of doing that. I think it much easier for Australia to control the borders than it is for the U.S. to control the borders because we do it now much more effectively than the U.S. I guess my dilemma is where would I be? Will I be here or will be there? That matters a lot to the GDP of my household.

But I do not know the answer. Closing the borders could be quite severe. You do not need to close the borders for the trade in goods I wouldn't have thought, it is really the flow of people that matters.

MR. EPSTEIN: Right.

MR. McKIBBIN: But who knows. Policy makers do all sorts of interesting things.

MR. PERLMAN: Lew Perlman (phonetic). I am with the Homeland Security Policy Institute. Warwick McKibbin mentioned the problems of inflation and figuring out the effect on inflation and monetary policy. Obviously you have described the shrinkage in the total economy and presumably the work force also, but debt does not go away. Debt endures, so I assume the implication of this is that the debt burden tends to increase and that causes problems. Could you say something about that?

MR. McKIBBIN: That is right. If you have fewer people in the economy, the existing stock of debt relative to the new population is going to be a bigger number. And in addition, and I did not talk about it in my presentation, there is obviously going to be an increase in debt because you have to respond, and there is one analysis in the paper where we look at what happens if in fact you do respond with fiscal policy and that increases government debt.

But it is still important that you have to worry about the macroeconomic levers even while you are getting panic in the streets, and I think a lot of people ignore the fact that how the authorities respond especially with monetary policy in a small country can be devastating because they do not understand the nature of the shock. So it may seem a little superficial to worry about inflation when millions of people are dying, but actually the real world that policy makers will try and respond, and Hong Kong in my view really devastated

their economy for a decade by responding incorrectly to the SARS outbreak purely from their particular monetary stance.

MS. BERPOE: I am Meryl Berpoe (phonetic). I am with RAS Strategies (phonetic) and one of my clients is a major international energy company and we have been doing some business continuity planning for them based on the pandemic. I am a little bit surprised you have not addressed the economic impact as a result of energy issues. Of course, here in the U.S. we get a large amount of our fuel for energy from overseas, much of it from the Middle East, Asia, and Africa, there should be some impact there on being unable to ship the fuel to the United States. As a major company in a major city responsible for power generation, we are looking at if there is a 30 percent reduction in who can get in to work or a 70 percent reduction in who can get in to work at any given time, or if the Metro buses are down or the other transportation in a city is closed because of work outages, even if our people can get to the power plant to keep it running, you have difficulty getting the resources to run it or you have difficulties from other economic impacts.

So my question to you is have you really taken a look at how serious the infrastructure and ability to continue operating infrastructure would be for economic impact?

MR. McKIBBIN: In fact, we do have energy in our modeling framework and the energy shocks are taken into account. Obviously, they are very coarse because we are talking about the United States, we are talking about a

single energy sector which comprises natural gas, coal, oil, et cetera, so it is very rough, but we do take into account changes in the demand and supply of energy in the way that we formulate the problem.

The sorts of issues you are talking about really are the same kinds of issues that the financial community always asks me about. These things could happen in a week or 2 weeks or 5 weeks, but it is unlikely for a whole year that the energy system in a country will close down. It may happen, in which case we have completely underestimated the consequences. But the numbers we get are so big that to me we have underestimated a lot of stuff, and if you believe our numbers, you should be investing a lot in either preparedness for the outcome in the sorts of issues you are talking about, having a strategy for responding so that you do not get a major closure, or in preventing the disease in the first place by investing large resources into the public health systems of the countries where this thing is going to come from which is likely to be the Southeast Asia and Southern China. But I agree, you can do any scenario you like, and they get a lot scarier than the ones I put up. I am being very conservative.

MR. NESMITH: Dr. Epstein, I am Jeff Nesmith with the Cox Newspapers. I wanted to make sure going back to the travel restrictions graph, when you say it may push the U.S. part of it into the flu season, is that based in part on assumptions about when it all starts?

MR. EPSTEIN: Yes.

MR. NESMITH: In response to the person from the IMF, if we

delay it and that makes possible time to produce this vaccine, is that part of the overall effect that causes the pretty pink line at the bottom? That is the reason for that then?

MR. EPSTEIN: Yes to both questions. On the first one, the travel restrictions increase cases in the U.S. only for the January release. Again, what we are worrying about here is the first passage time to the U.S., that is, given that it is released somewhere, when is the first case in the U.S. on average over lots of runs. If it is released in July, the travel restrictions move the first passage time a few weeks so that if it is released in July, it is still going to arrive in the U.S. in the low summer flu season, in August or something like this. Whereas if it is released in late-December or early-January, then you are shoving it into February or March, something like this, where that is the high flu season.

In either case, however, you are buying enough time to do intelligent things, and even in the case of the January release, if you use the time afforded to develop and distribute vaccine and do social distancing and all the other intelligent things you could do, you still get a huge depression in the number of cases. But I think we need to work as Warwick said a lot harder than we are working on staging up to use the time afforded by travel restrictions.

MR. BROWN: Alan Brown from the Canadian Embassy. I have a question for Dr. Epstein. Given the model of SARS where there seemed to be an outbreak in Canada before the United States which originally originated in Asia, do you think that there is a similar probability that the pattern would be duplicated

in a pandemic flu?

The second part of the question would be if transcontinental flights were restricted, would there be any rationale for restricting inter-North American flights in this kind of pandemic scenario?

MR. EPSTEIN: Those are good questions. On the first one, I could find out quickly for you, but off the top of my head, I think more likely is that it goes from Asia to L.A. than it is that it goes from Asia to Canada to the U.S. So, no, I would not expect the SARS experience to be duplicated, although, as I say, it is a stochastic process and there are doubtless runs in which it is, and whether SARS was an outlier or not, we would have to discuss it.

The second question was? Please repeat that quickly.

MR. BROWN: If there were flight restrictions transcontinentally would it make sense to restrict flights within North America?

MR. EPSTEIN: Again, I do not know. I would have to look at it. It is a very good question. I am guessing no because the hemispheric effect is huge and once it is all over the United States it is going to be quickly in Canada. I do not know.

MR. SEGAL: Misha Segal (phonetic). I am a consultant. In the ultrascenario I am interested in how trade disruption flows through and its ultimate impact. And secondly, again in the ultrascenario and mitigation, how that flows through. In the model, the four components for GDP, how mitigation flows through and maybe how you would do that one again if you could.

MR. McKIBBIN: On the trade, I did not mention the trade impacts, but they are in the paper. My recollection of the ultrascenario is that you get a very large contraction of international trade, bigger proportionally than the contraction in GDP in most countries, probably a 35 to 40 percent contraction in trade just because of the way the model fits together, people changing their demand and costs are increasing. We do not specifically target trade in the way we do the scenarios, but that is what comes out.

I am not sure what you mean about the mitigation issue because we do not have any policy responses.

MR. SEGAL: The health policy index seems to me like at least a way of trying to target mitigation, that some countries would respond better than others based on their index, and also possibly the governance index might be another way of trying to get at that. Or maybe I am wrong about that.

MR. McKIBBIN: The question is why don't we run a scenario where the health policy is the same everywhere and then do an alternative scenario where the health policies are according to our index and look at the difference. We do not do that because we are trying to construct a range of scenarios constrained by the four main ones we are talking about, but you could do what you are suggesting.

The health policy effect is only in the construction of the shock. It is not actually in the response to the shock, but you could do that way. It would be interesting to see what difference it makes. I guess the geography indicator

would be similar to Josh's experiment of preventing air travel, so we could do the same thing with your geography indicator where we are looking for policy responses, but we do not do that in the report.

It is already 100 pages long and it could easily be 500 pages long. In fact, the number of people who ask me after I present it can you do this for my sector or my country, where is Botswana for the World Bank, for example, you are constrained. These are very simplistic representations of the world even though they are very complicated tools, both of them very differently complicated. But, yes, we can dig down in these various directions, and that is the beauty of having a modeling frame work is it gives you that capacity to ask the next question in a sensible way.

MS. GRAHAM: Speaking of questions, we have time for a last one.

MR. NERIN: I am Steve Nerin (phonetic). I am with IBM and I am working on the MIDAS project also. I have a question not for my compatriot but for the other doctor up there, two questions that are outside of the model proper you have, but they are economic in nature. Have you looked at the effect on individual sectors longer-term, for example, people might start substituting things for travel longer-term? And the second economic question is, is there a good place to look at the relative fragility of supply chains by country or region and how long we have to breathe if we are holding our breath during an epidemic.

MR. McKIBBIN: That are very good questions. We try and

capture the sectoral impacts because we only have six sectors in the economies, so each economy has six sectors and that means there are 6 times 20 sectors in the world because U.S. agriculture is not quite the same as Australian agriculture, so we do try and capture that. You could in principle dig down. We could answer the airline question by pulling airlines out of the service industry and modeling that, so we do try and take that into account.

On the linkages, that is a really critical part of the story in Asia because with the Japanese economy, we have the data that is tracking which sector is supplying which sector across borders, and so at a very course level we can capture these linkages, but in practice you would probably want to dig deeper than six sectors, and we would love to. At the moment the deepest we have gone is that we have built a model for India which has 21 sectors, so we can actually dig down, but we have to contract the number of countries,. In this other model we have India, the U.S. and the rest of the world. It could be that disaggregation matters a lot. I am sure that the airline industry, for example, is going to be quite unique compared to most of the other services. So in principle we can do it, but we have not done it in this report.

MS. GRAHAM: I am sorry to cut it off, but we really have reached our time. I would like to thank both of our presenters for absolutely wonderful insights into a very complicated and frightening problem.

(Applause.)

(END OF RECORDED SEGMENT.)

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