SESSIONAL MEETING DISCUSSION

"Dependencies between risks" by Patrick Kelliher

[Institute and Faculty of Actuaries, Sessional Webinar, Monday 7 March 2022]

This discussion relates to the paper Kelliher et al. (2020) which was presented at the IFoA sessional event held on Monday 7 March 2022.

The Moderator (Mr P. D. G. Tompkins, F.I.A.): Welcome to this sessional meeting of the Institute and Faculty of Actuaries (IFoA). I am Peter Tompkins. I am a member of the IFoA Council. This is a sessional meeting which is intended to give the opportunity both for Patrick (Kelliher) to present and discuss his paper on "Dependencies between risks," and for people to make contributions to the paper. This can include a discussion about elements of the paper. It does not have to be in the form of questions to be answered by Patrick (Kelliher), but if you want to comment on a particular aspect of the paper, please feel free to do that.

You can let me know if there are aspects you want to discuss so I can determine when best to call you when the time comes for discussion.

So, without further ado, let me introduce Patrick Kelliher. Patrick (Kelliher) is a Fellow of the IFoA with more than 30 years of experience, predominantly in the life insurance field and specialises in risk management. First, he was doing that with Scottish Widows and later as head of market risk and asset liability management for Aegon UK before starting up his own business, Crystal Risk Consulting, 10 years ago. He is a Chartered Enterprise Risk Actuary and a member of several of our profession's risk management working parties and has produced papers and articles on a variety of risk topics, including risk classification, operational risk, liquidity risk, and the differences between banking and life insurance risks.

Mr P. O. J. Kelliher, F.I.A.: Thank you Peter (Tompkins) and good morning, everybody. I am from a life insurance background. My focus was on Solvency II and meeting the internal model requirements of Solvency II regulations, and in particular, the need to identity the key variables driving dependencies and also the lack of diversification you might see under extreme scenarios.

My research is split into two parts. The first one concerns the dependency between market and credit risks. We often have enough data to calculate correlations empirically. The key point I would like to stress about this paper is that empirical correlations are only a starting point. There are many issues with empirical correlations. They provide evidence of the dependency between risks, but they say little about why that dependency exists. I think they are intrinsically backward looking, so they might miss changes in interactions between risks. Also, they sometimes have a problem where risks are normally uncorrelated but may be correlated in stressed conditions. Sometimes, if you are not careful, the empirical correlation measures can simply average out the two states and end up with an unsatisfactory representation of each of them.

There are a lot of issues with empirical correlations and for that reason we need an expert judgement overlay to find a suitable answer. This is the key thrust of my paper. In terms of expert overlay, I contend that it comprises three components:

(1) the analysis of historic periods of stress.
(2) academic research into systemic risk and dependencies between risks.

(3) investigation of forward-looking scenarios and trying to understand how risks may interact in the future.

I have gone into great details about periods of market stress in the paper. I would like to highlight a few periods. The first one is 1973–74. This is topical because the crash that occurred in this period was triggered by a war, in this case the Yom Kippur war of October 1973, which was followed by an oil embargo of the west and rises of over 400% in the price of oil. As you can imagine, this led to a sharp spike in inflation and bond yields and led to severe equity market falls in most markets. The one thing I would highlight about this is that the UK suffered a lot more than other markets because there were idiosyncratic events beyond the oil shock. The UK had a secondary banking crisis and there was industrial unrest which led to a 3-day working week. Because of these idiosyncratic factors, UK equities fell a lot further than US equities.

There was also a different, weaker monetary policy framework, so there was a much sharper spike in inflation and bond yields than in Germany. The interesting thing about this period of stress is that even in global downturns, there can still be idiosyncratic factors affecting different countries.

Another period of stress is the dot.com bust, which was again exacerbated by a geopolitical event on 9/11 as well as the high-profile failures of Enron and WorldComm. What was observed in this period was a protracted fall in equities. Over a period of 2 to 3 years, we saw a decline in equities, rising bonds spreads and an increase in defaults. The interesting thing about this period was the increase in commercial property values over the period. It highlights how property returns may diverge from equity returns. Economic growth was also robust over the period so we cannot always say that equity falls are associated with recessions.

However, one case where we did have that relationship was in the Global Financial Crisis of 2007–09. The initial cause was the mispricing of US sub-prime risks which was exacerbated by stressed asset sales, a credit crunch in bank funding markets, and a major counterparty default by Lehman Brothers.

What was observed were large falls in equities and property prices, sharp spikes in bond spreads, increase in defaults and credit rating downgrades. Option prices spikes were also observed, particularly after the Lehman default. Then there was what I term the "flight to quality" effect, where the pound fell against the US dollar, due to the US dollar being viewed as a safe-haven currency. That flight to quality also helped push down risk free rates as did rate cuts and Quantitative Easing (QE) by central banks trying to bolster markets.

The result of it all was that the distress in markets got passed to the real economy and saw a spike in unemployment, reaching 8% at the start of 2010.

The last period of stress is related to COVID-19 in Q1 2020. What we saw in the first quarter, when COVID-19 came to the fore, was very sharp falls in equities, rises in bond spreads and rises in implied option volatilities. We also saw the flight to quality effect because there was a large fall in the pound relative to the US dollar. That flight to quality, combined with QE, helped drive down risk free rates. The central bank interventions at the end of March 2020 were relatively decisive as the markets observed a sharp rebound shortly after the interventions. We saw a 60% rise in the MSCI World Index. Highlighting the idiosyncratic effects again, the rise in UK markets was far less than the US markets. Also, although credit spreads came back to their 2019 levels, defaults continued rising over the year, highlighting the lag effects where defaults can be rising even when spreads are narrowing.

The second leg of expert judgement involves consideration of academic and other papers. There are two papers I would like to highlight. The first is "Systemic Risk in Financial Services" by Besar et al. (2009), which was presented at an IFoA sessional meeting in 2009. I recommend this paper because there is a very detailed analysis of historic banking and other market crises. It identifies several key mechanisms by which shocks are transmitted across the financial system. One network for transmission is the short-term interbank markets. We saw that

a seizure of those interbank markets during the Global Financial Crisis led to a credit crunch which led to the financial market shock transmitting to the wider economy.

Another network for transmission is common exposure to assets and derivative markets. Some funds were forced into selling their assets at distressed prices, and that impacted on other holders of those assets. You might not have been a forced seller, but the fact that somebody out there was distressed and having a "fire sale," was affecting the mark to market value of your portfolio.

The third vector of transmission shocks is counterparty exposures, particularly the losses on over-the-counter exposures that were observed after the Lehman's default and which exacerbated the whole shock.

The second paper I would highlight is "Systemic Risk in Insurance" by the Geneva Association Systemic Risk Working Group in 2010 (Geneva, 2010). Similarly, to other papers produced shortly after the Global Financial Crisis, it was making the point to regulators that insurers are different from banks and need to be treated differently. It is a very thorough paper with a number of good insights into sources of systemic risks. For instance, insurers are exposed to banks in terms of the bonds and shares of banks that they hold. There is also a potential mismatch resulting from callable bonds. This is where a bank, in stressed conditions, may exercise their right not to redeem certain subordinated debt which can cause Asset Liability Matching (ALM) issues for insurers.

The paper also highlights a few examples of automated programme trading stock losses, which can exacerbate and amplify market falls. The paper also discussed securities lending, both from the point of view of insurers being exposed to banks who secure this, but also the risks that may arise in terms of investment of collateral. Reinsurer counterparty default is a key source of systemic risk for insurers. But the paper did note that generally reinsurers are well capitalised. They quoted the statistic that reinsurers' aggregate capital was two and half times what they would need to cover the catastrophic loss from a combination of a 1918–19 flu pandemic and Hurricane Katrina. Thus, reinsurance counterparty default is a systemic but very low probability risk.

Finally, there is an issue with mass lapses. What you could see in a stressed condition is policyholders lapsing policies en masse. If an insurer is not careful, it could find itself being a distressed seller in such conditions.

I would recommend a few other papers. The Financial Stability Reports (FSRs) are always recommended reading. I would particularly highlight two papers:

(1) The Bank of England's FSRs, and in particular the August 2020 report, which had a very detailed analysis of how markets ground to a halt in Q1 2020 (Bank of England, 2020).
(2) The International Monetary Fund (IMF)'s FSRs, and in particular their November 2019 report, which was very prescient because it highlighted a lot of issues, for instance with corporate bond funds and dollar funding, which then crystallised a few months later during the COVID-19 pandemic (IMF, 2019).

Other papers are the World Economic Forum (WEF) Global Risk Reports, which provides a long-term bigger picture view of risks, while reinsurers and others produce emerging risk reports, which are also useful for potential interactions between different risks.

This leads me onto forward-looking scenarios. We have regulatory scenarios, such as those defined by the Prudential Regulatory Authority (PRA) and the European Insurance and Occupational Pensions Authority (EIOPA). In terms of the former, it includes a climate change scenario, which I think is useful because it captures interactions that are not present in data.

The Bank of England also produces banks stress tests, which again are insightful. One scenario I have been very fascinated by in recent papers is one where you have a global downturn coupled with a loss of confidence in "UK Plc" which leads to a good old-fashioned run on the pound with rising inflation, rising base rates and spikes in bond yields. The scenario causes a spike in bond yields, and at the same time falling equities, which differs from the situation during the global financial crisis where we saw falling equities and falling risk free rates.

Lastly, Own Risk and Solvency Assessment (ORSA) scenarios are important as they might feature some unique interactions between risks for your own firm.

To sum up on the market and credit risk interactions, we can group assets into "risk on" and "risk off" assets. "Risk on" assets include equities, corporate and other risky bonds such as lower rated sovereign bonds and property. For these assets, in stress conditions, we are likely to see a re-pricing of risk with investors looking for a higher premium for holding risky assets which will depress values. This could be exacerbated by distressed sales of risky assets as people flee to quality and sell risky assets for safer assets. As such, we will likely see equities and corporate bond spreads being highly correlated in stressed conditions. There may be a lag between falls in equities and rise in bonds spreads, and that, in turn, feeding into corporate bond defaults and downgrades. Property, as we have seen before in the "dot.com" scenario, can diverge from equity trends. This is reflected in lower correlation. There is also a lag effect in that the peak fall in property may arise 6 to 9 months after the peak fall in equities. That is something to bear in mind in modelling.

In terms of "risk off" assets, these will be things such as the US dollar and other safe-haven currencies like the Swiss Franc. It will include highly rated sovereign bonds such as US T-bonds, and it would also include equity and other options. In stressed conditions, a flight to quality is likely to see an increased demand for these assets and push up their prices. We have also seen that the flight to quality along with monetary stimulus has pushed down risk free rates, suggesting there is a positive correlation between falling equity markets and falling rates.

However, there is another dynamic where inflation or unexpected monetary tightening leads to a spike in bond yields, and that could be the trigger for an equity market crash. So, we have two different states. One is where equity markets fall and then a cumulative flight to quality leads to falling rates. Another one is where a spike in risk fee rates leads to falling equity markets. This is an area where a lot of careful judgement will be needed.

The second part of the paper includes insurance, persistency, expense and operational risk. The issue here, unlike market and credit spreads, is that we do not have a lot of data and cannot typically calculate the empirical correlations. This places a heavier reliance on expert judgement.

There are a few other nuances that complicate matters. A lot of the relationships are asymmetric. For instance, markets will not cause pandemics, but pandemics, like COVID-19, can have an impact on markets. There is a need to adjust for that one-way nature when modelling dependencies.

Another issue is timescale. I was focused on the 12 months timescale that underpins Solvency II, but many interactions might take place over decades. For instance, climate change will have an impact on mortality rates as well as catastrophe losses over a period of 10–20 years.

For life insurance risks, another complication is that we need to consider not just the interactions in mortality rates over the coming year but also the impact on longer-term assumptions. The example I would use here is economic conditions and their correlation with income protection claims where there might an impact on short-term claims over the year but the impact on long-term assumptions may be negligible. This is something you are going to need to factor into in your diversification modelling.

In terms of general insurance risks, another complication is the dependencies between risks and claim costs, where there could be different interactions between future claim costs and the costs of settling past claims. These interactions may also differ between lines of business, for example, motor claims may have a different interaction between liability and the repair cost element of claims and other risks.

Lastly, non-market risk is very idiosyncratic. Considering the impact of recessions on lapses, it may have a more significant impact on a mass-market term assurance portfolio than a portfolio of high-net-worth client bonds.

I have identified three key drivers of relationships between non-market risks. The first driver is economic conditions, including recessions. The second is pandemics and other catastrophes. The third is reputation damage.

In terms of economic conditions, we can see a link between market falls and economic conditions like recessions, which have an impact on unemployment and lapses. It is important not to overstate the link between market falls and lapses. First, there is significant lag between markets falling and unemployment rising. If we look at the global financial crisis, unemployment in the UK peaked at the start of 2010 when markets were rebounding quite strongly. The other thing to note is that lapses can also be driven by other non-economic factors, like tax changes.

Recessions and economic conditions could have a positive impact on expense inflation, but that is assuming you do not have stagflation. Recessions could lead to falling sales and higher lapses, and that could then lead to higher unit costs. So, recessions could have an adverse impact on expense levels.

In terms of mortality and morbidity, there are some good papers about linking economic conditions and mortality rates. One link that seems to come through is the impact of austerity measures, particularly those taken in the aftermath of the global financial crisis, which were shown to lead to higher deaths and mortality and morbidity rates. I am, however, sceptical that they will have a significant effect on long-term assumptions.

Finally, in terms of general insurance, what we see in the UK is when there is a recession you often see an increase in fraud attempts. This could transmit into higher claim costs, to the extent that your controls do not pick up on these fraud attempts. There could also be positive impacts. For example, depressed economic conditions could temper rebuild cost inflation.

In terms of pandemics, COVID-19 gave a classic example of how such extreme events could lead to sharp falls in markets and economic contraction as well as credit losses. Regarding reinsurance counterparty risk, the interesting thing is that most reinsurers retained their rating during COVID-19. They were able to sail through it relatively unscathed.

The impacts on long-term mortality and morbidity rates are still uncertain. There is likely to be an adverse impact on mortality and morbidity rates because of things such as delayed diagnosis of conditions and long COVID.

In terms of general insurance, as expected, the road deaths fell in the UK during lockdown. Interestingly, in America, road deaths increased.

In terms of operational risk, first all, pandemics are business continuity events. They will have costs in terms of enabling staff to work from home. The other thing to note about the COVID-19 pandemic is that cyber criminals were quick off the mark to exploit the dislocation, and that led to a large increase in fraud attempts and cyberattacks. Again, this highlights the asymmetric nature of these relationships. This is very much a one-way dependency.

Catastrophes do not seem to be associated with very sharp market falls and economic impacts seem to be muted. There is a very weak level of correlation, except perhaps at the tail. In terms of counterparty risk, 9/11 and Hurricane Katrina did not lead to defaults of reinsurers. As I said, most reinsurers are quite well capitalised, but it did lead to downgrades and that could have an impact on Own Funds.

Catastrophes can also have an impact on individual bonds and sectors. For example, Pacific Gas and Electric defaulted due to the 2019 Californian wildfires.

In terms of mortality and morbidity, I have not been able to identify any immediate longer-term impacts of catastrophes, but we could suppose that if we look over a 20- to 30-year period, climate change could be a driver of changes in mortality rates and in catastrophe losses.

For general insurance, the surge in claims will likely have an adverse impact on rebuild and repair costs, which will affect non-catastrophe claims. For operational risk, catastrophes can be a business continuity event if you are in an affected area. If you are a general insurer, you could see higher process volumes that could lead to higher process errors. It could also expose errors in your reinsurance treaties.

The third area of dependency is reputation damage. This could come from operational failures like mis-selling, or it could come from a reduction in financial strength due to credit losses, which leads to a loss of consumer confidence. It could also be caused by misguided communications by senior managers or malicious remarks on social media.

Reputation damage can lead to higher lapses and lower sales and could feed through to portfolio contraction, loss of economies of scale and higher unit costs. In this way we could say reputation is a link between operational loss events, like mis-selling and lapse and expense risks.

The Operational Risk Working Party produced, at the start of 2020, a paper that contains a lot more detail on the topic of operational risk dependencies with other risks. Some of the other interactions could be related to operational losses being conditional on other risks. If we look investment bond mis-selling, that might only arise if markets fall.

Insurance claims experience may effectively reflect operational risk, like non-disclosure or underwriting processing errors, to the extent that they are not picked up by controls. Your claim experience, and your insurance risk model built on that claim experience, may have an implicit operational risk allowance in them. There could be a potential double counting there, which is something to bear in mind.

The final comment on operational risk drivers would be regarding business models. I see these as a common driver of operational and other losses. An example would be the aggressive bank growth models that were adopted in the run-up to the global financial crisis. Another example is that, in the UK, PPI mis-selling, as well as short cuts in mortgage underwriting led to substantial credit losses down the line. One thing of which to be aware is that there is often a substantial lag between market and credit losses, and operational losses crystallising.

Moderator: Thank you very much Patrick (Kelliher). There is a lot of further analysis in Patrick's paper. Thank you for stressing the types of risks in the way you did.

I will now open the meeting to the floor.

Audience member: Is it a view that the lack of understanding of dependencies between risks might mean that there is double counting, or over reserving or higher levels of prudence than are necessary? Or do you think there is scope for overall levels of reserve to be refined in a way that will improve the management of solvency positions of insurers?

Mr Kelliher: I think it depends. In certain areas, what I have seen is that there is a very strong reliance on data driven correlations without understanding what is driving these very high correlations. In some instances, they probably understated the level of loss that could be expected. What I am trying to do is to make sure that actuaries have resources, and knowledge of areas to consider, so they can better justify the correlation assumptions. I do not necessarily believe that reserves are systematically understated or overstated. In some cases, I have seen empirical correlations being understated, for instance when you look at extreme tail events. I am trying to provide a platform for actuaries who at some point may wish to put together a rationale for correlations when they are dealing with the regulator. So, they can make statements like "My correlation assumption is this, and therefore I believe this. This is what I believe is driving the dependencies." The aim is to give actuaries the ammunition they need to justify their correlations.

Moderator: Having thought through all the links and causes and potential scenarios for interaction between two different risks, what advice do you give on how to settle upon, and justify, a reasonable input and output modelled correlation, for example in building internal models?

Mr Kelliher: This is all going to come down to expert judgement in a lot of cases. There is no getting away from that. We cannot just blindly rely on empirical correlations. What is needed is a robust expert judgement process. The need is to get the right people involved and the right level of analysis performed. It is not just a process of "This is what the data says, this is the answer." You need the proper expert judgement process to arrive at that assumption. Then that assumption should be tested independently by validation. When I validate, the first thing I would consider is the robustness of the expert judgement process. Is it data driven, or has it a considered the underlying drivers, as required by the Solvency II rules? I would use other tools as well and look

at the meaning of the correlation assumption. What I often tend to do is take the correlation assumption and look at the conditional expectation. For instance, given for a 1 in 200 equity fall, what does the correlation assumption mean for the average property return modelled? I would look and say, "Does that make sense compared to what we have seen before. Does that make sense compared to some of the scenarios that we have out there."

Moderator: Any thoughts from somebody grappling with Solvency II modelling? Or indeed just experienced in having looked at wide ranges of potentially correlated or dependent types of risk.

Mr C. M. Smerald, F.I.A.: The paper is very timely, looking at structural causes of things rather than looking at events as statistical anomalies that can be analysed. There is a lot that actuaries miss because they are not being curious enough about why things are as they are. I found the paper useful as a repository of information. I am doing work, as many are, on COVID inflation impacts. Your information on actual versus implied inflation is useful because when you deal with inflation you need to think about discounting as well as the effect on losses. I have done structural modelling in the past, where you identify correlations between economic variables and what occurs in insurance losses. It is a difficult subject and it is hard to know where to get started. It is an area in which we need more research. The striking thing is the quality of our modelling. In the traditional economic capital model, you set variability parameters on how much different variables vary according to a standard deviation measure. You use correlation matrices and then run it a thousand times. You get the answer, and it gives you your 99.5th percentile. I think you are trying to fight against using that approach as a silver bullet. I am struck by the idea that there are states in which certain rules apply. You talked about the flight to quality. I will call that a state, where people are behaving a certain way because we are under flight to quality conditions. It is important, perhaps, to bring another step to capital modelling that is not currently there. We should consider what scenario we are under. What is normal now, and what rules would apply if something extreme happens? The "now" we are living in is not the same as some of the pasts. There is quite a lot of work there to identify what is important to baseline. Additionally, we are in a particularly fragile world right now. We have war and COVID coming in and shaking us up. This is something that relates to my own research. How do you bring futurist ideas into actuarial work? What states are reasonably close to where we are so that we might be operating in the rules relevant to those states? We might run the capital model using of best guess of the current world state. What shocks and dependencies might exist in this state? But we also might think, "What is around the corner? What else might happen that could give us a completely different answer?" Our capital models should be linked to scenario analysis in a more disciplined, structured way. Your paper and the references are a helpful step towards that objective.

Mr Kelliher: Using different states is a problem that I have encountered and I must admit I am not sure about the best solution. For a lot of UK insurers, two of the biggest market risks would be interest rates and equities. The correlation between those will be key. But what we have seen recently is that we have had this state where equities fall, and the central bank prints money to support markets, which drives down risk fee rates. Thus, you have had a positive correlation between falling markets and falling rates.

However, if you go back to the 1980s and 1990s, we had a different dynamic. You had rising bond and gilt yields and falling markets. Are we returning to that state? One of the drivers for the situation in the 1980s and 1990s was a lot of boom and busts, which was one reason you had spikes in inflation. This led to the spikes in bond yields, which led to higher interest rates, and then to recessions and falling markets. In some ways, we have broken that cycle with UK central bank independence in 1992 but that could be undermined in the future. This is a very difficult area and I am not sure I have the answers but there are two very different states for the way interest rates can interact with equities. We are at a very fragile moment where it could go either way.

Mr G. R. J. Mitchell, F.I.A.: One of the things that struck me on reading your paper was how the correlations between, for example, inflation and bond yields, depend on the actions of

policymakers such as central banks. On a couple of occasions, you mention an apparent shift in correlations since the Bank of England's independence. In the short term, if you are modelling risks over a 12-month period, it may be reasonable to suppose that current policy persists. But over a longer period, if you are looking at risk emerging to ultimate, then it is reasonable to suppose that in some circumstances policy could change and therefore, do you have to look back further into history for the wider range of scenarios that may pertain?

Mr Kelliher: This is very topical question. I think if we looked at correlations going back to 1997, we will probably see a paradigm that is still reflected in recent interactions. It is driven by something that is called the Greenspan Put where every time equity markets fell, the central bank cut rates and injected money into the system. For a 12-month period, it is not unreasonable that we could assume that paradigm continues. But longer term, could we see some other type of shock happening? Are we currently experiencing such a shock? The current situation is probably the biggest stress test the independent central bank has had. Effectively, we have had de facto central bank independence in the UK since 1992. Historically, it has been a period of quite benign inflationary pressures. You have had the rise of China, and that has pushed down costs globally. You had some issues during the global financial crisis, but this seems to be the first big inflationary test of the Bank of England. I must admit, I am not certain whether the UK will prevail. Will we stick with low inflation or will we find ourselves in a higher interest rate, higher inflation paradigm which we cannot really break? This is where getting the facts and having a discussion and seeing the impact on our internal model results would be useful. Will we suddenly find ourselves in a lot of economic trouble? I think that is why it is important to have scenario analysis on top of your core results, just to understand what ways things could go.

Mr H. Walpole, F.I.A.: I was struck by what Chris (Smerald) was saying in terms of looking more at states. If you were to fuse that idea with the 1-year time horizon in our Solvency II approach, perhaps it marks the end of a through the cycle view, in terms of how we set these correlations.

Mr Kelliher: In terms of setting correlations through the cycle I think we should probably look over a certain period reflecting the relationship between rates and equity. We should probably just look back to 1997 or maybe even just look back to 2009, since we had QE. You could say that such a through the cycle view reflects the current paradigm. We will come back to this whole question. Are we currently at an inflection point? I do not have a good feel for it. I feel that we are in uncharted territory right now. In terms of recent experience, if you go back to the 1980s and 1990s, you can see different kind of interactions arising. I think it is a possibility that we are reverting to that historic state. It is something we need to consider. It is important to be aware of that there are two very definite and different states. Currently it looks as if we are somewhere in this dead zone between what is known from the last 10–15 years and a state that existed maybe back in the 1980s.

Moderator: As is inevitable with something like this. Patrick (Kelliher), you are raising as many questions as answers. You are revealing a lot of uncertainty with plenty more to explore.

Ms L. Sayed: How could an economic condition affect a morbidity and mortality rate? Is it a direct way? I think maybe it depends on governmental decisions or spending on the health sector? But I am not sure if it is significant? Should I consider modelling the mortality rate?

Moderator: There was a focused discussion during the pandemic about the damage it caused to GDP and the link that might have to health outcomes. There is good data that suggests that poorer societies can experience worse health because of their inability to invest in their health systems. It may be a very long run correlation in terms of time. If you are wealthier, you can afford to spend more on developing health systems and controlling morbidity and mortality.

Mr Kelliher: I started from a preconception about a link between wealth and health so that richer people have generally better health outcomes. I felt that with recession, people are poorer and surely that is going to lead to higher mortality. There has been some work on the linkages. Unexpectedly, the Great Depression of 1929–32 did not have a huge adverse impact on mortality

except for suicides. I found that very surprising. But I have seen a few papers looking at the more recent impact of the Eurozone sovereign debt crisis, which flowed from the global financial crisis. There are studies, particularly in Greece, suggesting that the austerity measures chosen and imposed did lead to a significant increase in cancer deaths. That is a possible link. The key thing is not so much economic conditions, but the choices government makes in terms of cutting health spending. If pandemics lead to economic contraction, there is also likely to be an impact on longer-term mortality.

Moderator: We are currently in an unusual situation, in terms of correlations, because of what is happening internationally. Is anybody grappling with particular model building issues that they want to discuss at the moment? Patrick (Kelliher) is there anything else about which you would like to particularly hear peoples' thoughts? Do you plan to take this further or encourage others to take to do further work to take it forward?

Mr Kelliher: In terms of further work, Chris (Smerald) made some interesting points about state modelling. I think investigating that further is a possibility. There are people who have expertise about modelling different states, who can take this forward. What I am hoping, though, is that this work gives enough people the ammunition to take things forward. I see this as a starting point for actuaries engaging with these issues. They can take the paper and some useful resources and gradually do their own research and improve the expert judgement around the correlation assumptions.

Mr Smerald: There are some questions that I was thinking about as I was reading the paper. What is a good place to get started? There are many things to worry about. Which correlations make the most sense? What are the basics that everyone should be considering in their own model? Are correlation matrices good enough? Should elements become more structural? I wonder if, through writing this paper, your view has changed in terms of the best approach to modelling itself, in terms of correlation matrices versus structural relationships?

Mr Kelliher: In terms of modelling, what I am used to is copula-based aggregation simulation. One of the problems is perversely due to the fact that it is more sophisticated than standard variance/covariance matrix multiplication. For example, we can consider interest rate dynamics which we discussed earlier. In the old style, unsophisticated approach, if you have an interest rate exposure, it would be up and down, and you have a certain correlation of that with equities. You could allow for different states with the variance/covariance matrix, but with a copula it is just one direction. So, with a copula, your simulations are either sharp falls in rates and sharp falls in equities, or the opposite way around. It is just one direction. There may need to be more sophisticated models built on that, to reflect the fact that copula cannot deal with a multi-state relationship between rates and equities. I am not an expert in structural modelling, but I can see it as a growth area in terms of modelling, trying to build up more complex structures of what drives rates and how they feed back into each other. That could be a very promising area for analysis and research.

Mr S. R. Reeves, F.I.A.: My question is about how we go about capturing asymmetric correlations because, as we were just discussing, one of the problems with copulas is it is quite difficult to do one-way correlations. Do you have any thoughts on how you can capture asymmetric correlations?

Mr Kelliher: A very common approach is simply to divide the correlation in half. That is something I have seen in practice. I think the question is whether this is correct? Looking from a life insurance perspective, one of the key risks is pandemics, and I sometimes wonder whether you could get away with not adjusting for asymmetry between pandemics and market risk. If you do not adjust for this, then in a 1 in 200 pandemic the expected market fall is quite significant. The problem with that is when you have your 1 in 200 market fall, you are also going to have an element of excess mortality, and you have to consider whether that is reasonable. I think it depends on your judgement of what is appropriate. So, sometimes, it could be that you do not bother for pandemics.

Operational risk is another area where you have a lot of asymmetry. It is a lot trickier. You need to look at the conditional losses that emerge and your simulations. I have a spreadsheet to do this. I have my percentiles, and given a certain correlation, I consider what is the percentile of the loss distribution I would see in risk B, given the 1 in 200 in risk A? I then consider whether that is reasonable. For example, if we take a 1 in 200 market fall, are we seeing operation losses in line with what we would expect. So, that might be a way to consider the output and then perhaps adjust it.

Moderator: I have a comment about the term "expert judgement." The concept of expert judgement might imply some discretionary aspect, given the negative effect on capital levels or balance sheets from adverse scenarios, which is in contrast with the fact that Solvency II has a very prescriptive nature.

Mr Kelliher: There is always a risk with expert judgement that you could end up trying to game the results. Whenever you use expert judgement you should be prepared to justify it. You need to have good arguments because the regulators may say, "What are you doing here? Our correlation assumption is X, and you have reduced that down to Y." Alternatively, you have come up with this correlation assumption that is lower than what we have seen from your peers. However, even where we have the data, we need to overlay it with expert judgement. Where that reduces correlation dependencies, we need to have a robust process around that expert judgement, to show that we are not trying to just game it.

I have a very purist opinion, which most people will not share. Considering economic capital, if you are just gaming results to get a low capital figure, you are doing two things. You are lying to the regulator, but worse, you are lying to yourself in terms of how much capital you need to withstand events. That is one thing that struck me from the financial crisis. One of the drivers behind the sub-prime crisis in America was that you had very low expected levels of correlation between underlying portfolios. What happened then was suddenly you had a lot of correlations starting to emerge, and that you ended up making a lot of losses. To summarise, you need to have a robust process to satisfy the regulator, but also to satisfy yourself. It is not a game. If you reduce your capital below what is a realistic, then, at the end of the day, you are just taking a lot more risk for a lot thinner capital base.

Mr Kelliher (summarising the discussion): It has been a very good discussion with a lot of very good questions, which I am not sure that I was able to fully answer. There are many very difficult issues out there. We base our models on assumptions that a certain state exists. How do we allow for the fact it might transition to another state? It is a very difficult question. It is an area where expert judgement is required. While I do not have many of the answers, I do hope that the paper will be a platform to help. First, it might help with further research. There are many areas, in terms of structural models, on which we can build. I also hope it will help people struggling with the day-to-day job of trying to justify our various diversification assumptions to the regulator, and to ourselves. I hope it will give them at least a starter on certain areas that we should consider to make sure that they are reasonable and give them the ammunition they need to justify their assumptions in line with the actual underlying drivers.

Moderator: Thank you very much, Patrick (Kelliher), for all the work you have put into this paper, and for presenting to us today. Thank you for those who have contributed.

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