Discussion: Deterministic or Stochastic

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A question we need to ask is when to use a deterministic model and when do you really need a stochastic model?

Now, some modelers out there would say, if in doubt, build a stochastic model. The argument as always would be, the computer can handle it. Maybe the computer can handle it, but the point I've been stressing all along is, we've got to be able to handle it as well. And if you think about the difficulty we had in presenting results on the stochastic model, you'll begin to realize that there's a lot to be said for having a deterministic model. It's much easier to do your sensitivity analysis on a deterministic model. There's one answer, and all you've got to see is how that one answer changes as you change your parameter values.

On a stochastic model, if you present your results as a histogram, well, each time you do your sensitivity analysis, you've got to have a whole new histogram. So there's a cost. There's a trade-off between realism in the sense that very often the real world is stochastic and the grasp or understanding one has of the model results. And I want to make the point that realism is often overrated. What one needs is to decide whether the stochastic model is absolutely necessary for producing the kind of results that one needs to present to people. And it's only going to be absolutely necessary when you want to present your result as a probability or when the variance is important.

Now, clearly with roc flu it was essential to be able to tell the caliph what the probability was that the population might drop below a certain threshold. So there's absolutely no argument that he needed a stochastic model. But let's go back a step. Think back to the model we had before we knew about roc flu. And remember how we handled silver bullets? We had an argument as to whether the number of effective silver bullets would be constant from one century to the next. And, of course, in the real world it wouldn't be. Maybe in one century 10 rocs would be killed by silver bullets and in another century, 15 rocs might be killed by silver bullets.

A more realistic way to handle this would be to use a random number generator to decide how many rocs are going to be killed by silver bullets in each century. So, for example, if you decided the number was between 10 and 20, you would generate a random number, and you would choose 10 if the random number was 0, 20 if the random number was 1, and a number in between if the random number was in between. That would be much more realistic. Would it help you to understand the effect of silver bullets? My argument is no, it would make it harder for you to understand the effect of silver bullets. By building a spreadsheet where you keep the number of silver bullets constant, you can see straightaway what happens if the number of silver bullets is 10, what happens if it's 20, what happens if it's 0. You have more control over your understanding of the model.

People who argue to put realism in models are very often the same people who if they were designing experiments in the field would want to control variables in the field. So they wouldn't want to leave something like silver bullets flying around loosely in a field experiment. They would want to control that. And it is precisely the same thing one is doing in modeling. Your computer model is just a laboratory for a thought experiment, and what you are designing is an experiment in the same way as you do it in the laboratory or field.

I want to make this point in a slightly different way. If you look at this diagram, I'm going to argue that this represents a model. It's a very simple model. And every model one has – has certain things you can and can't say about the real world from the model. They are very few things you can say about the real world in this model. You can say both the man and the lady are standing. You can say the lady's to the right of the man. That's about the limits of what you can say. Now, suppose I add some detail to this model. This is equivalent, in a sense, to making it stochastic. Suppose I do something like this. Have I gained in what my model can do? Well, I still can't say much more than the man is to the left of the lady and the lady's to the right of the man and they're both standing. And only if the question of whether the man was wearing a hat or not, or whether he was smoking a pipe or not, were essential to the management decision to be made would this be a more useful model than the first. It's more realistic, but my argument is that realism actually distracts from the rest of the model.

So my rule for when to build a stochastic model is only when it's absolutely necessary, and then only to make those parts of the model that are absolutely necessary to be stochastic and control the rest to improve your understanding of what's going on.

This is not generally an accepted view of things. I recently worked on a model which was looking at a fur seal population off the coast of New Zealand, and pup survival in that population was greatly affected by whether or not there was an El Niño event. And so to understand the interaction between the by catch of fur seals in a fishery and climactic effects, one built a model in which one modeled both the by catch and pup survival as a function of El Niño.

The way we developed the model is we put El Niño in on a regular basis. It was equivalent in our flu model to saying there will be a flu epidemic every third year or every fourth century or every fifth century. That way we really got to understand the interaction between the two effects, the climactic effect and the by catch effect.

When the paper was sent out for review, the reviewers came back and said, this is ridiculous. El Niño is a stochastic event. So you should put it into the model as a stochastic simulation. And they turned the paper down.

They were wrong. Adding stochasticity made the model more realistic, but it made it much harder to separate out the interactions between El Niño events and the by catch. Sometimes it's not always that obvious, however, when a model should have a stochastic component.

Many years ago I was working on a lion population model in South Africa, and we were simulating lions on an individual basis with a lot of social behavior, and that social behavior included what are called takeovers. You would perhaps have two or three pride lions in control of a pride, and you might have four or five younger nomadic lions wandering around looking for a pride to breed with. And we modeled whether or not they had a fight, and if they did have a fight, who won the fight. And the reason this was important in the model was because when young lions take over from older lions, they kill their cubs so that they can breed with the females as quickly as possible. So this was an important part of the population dynamics.

When we ran the model, some information that we had that we hadn't built into the model was that on average a pride would have - a group of males would have tenure with a pride for about two to three years before they were ousted. When we ran our model, we discovered that the pride males were in control for eight or nine years. So clearly something was wrong with the model.

We did a sensitivity analysis. We fiddled with the parameters. We couldn't get that number down. And then we realized something - we had modeled the sexing of lion cubs as a deterministic process. So, for example, if a litter of 10 cubs, or total number of 10 cubs were born in a particular year, we said five of them were male and five of them were female. If we made that stochastic, then occasionally all 10 cubs would turn out to be male. Or occasionally you would have eight or nine cubs turning out to be male. Those occasions produced strong coalitions of young males, and those strong coalitions of young males were able more readily to displace older males in control of prides.

So by merely changing one little component of the model from deterministic to stochastic we saved the model and got realistic results. These are the things one has to learn by trial and error.

So we've ended up with three types of models in our different versions of the roc story. We started off with a deterministic model. We then developed a model with environmental stochasticity, and now you've seen a model with demographic stochasticity.

Remember our heuristic - was never build a stochastic model unless there is a real need to.

When environmental stochasticity is important, one needs to put that into the model. When demographic stochasticity is important, one needs to put that into the model. So again, what we are thinking about here is not the idea that one has a single all-purpose model, but that - depending what is important and depending on one's objectives - one chooses a model that fits the problem.

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