Stephen S Poloz: Models and the art and science of making monetary policy

Remarks by Mr Stephen S Poloz, Governor of the Bank of Canada, at the University of Alberta School of Business, Edmonton, Alberta, 31 January 2017.

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Introduction

The Alberta School of Business sits a couple of hundred metres east of the Centennial Centre for Interdisciplinary Science, which houses a number of telescopes. When you look at a star through a telescope, you see it not as it exists today, but as it existed years in the past, when its light started heading toward Earth. In that sense, a telescope is something like a time machine.

If only those telescopes could do the reverse and see into the future! Economic forecasting and policy making would be a snap. But since we do not have a machine that lets us see the future, we have to make do with the next best thing: the economic model.

Models have become indispensable to the conduct of monetary policy. This is because central banks typically use monetary policy to target a variable, such as inflation, in the future. Policy actions take time to affect targets. For example, it takes up to two years for a change in interest rates to have its full effect on inflation. This means that there is little point reacting to the latest movement in inflation. Rather, central bankers need tools that can forecast where inflation is likely to be two years from now and tell them how to adjust policy today so inflation will hit the target.

Of course, economic models are not crystal balls. They generally explain what happens in the economy on average—they always make errors, but the errors are expected to offset each other over time. The fact that models can deliver only an approximation of the truth means that conducting monetary policy is not a mechanical exercise. It is a complex blend of art and science—in effect, it is an exercise in risk management.

Sooner or later, something extraordinary happens to the economy that a model cannot explain, pushing it persistently off track. A forecaster can rationalize a string of prediction errors for a while and adjust his or her judgment around the outlook accordingly, but eventually the time comes to rebuild the model.

The global financial crisis of 2007–09 is one such event: a significant outlier in economic history. Models have struggled to explain the forces that led to the crisis and the behaviour that followed. This experience is now guiding the work of model builders. And in the Bank's most recent medium-term plan, we identified as a core priority the need to reinvent central banking, in part by refreshing and upgrading the tools we use.

The cycle of modelling-forecasting-remodelling is as old as empirical economics. It is how we make progress. Today, I want to review the history of models at the Bank of Canada, illustrating how each new generation of models has built on the successes of the previous generation and adapted to the changing needs of policy-makers. I will describe how economic theory and computer technology have enabled this evolutionary process and speculate on what we can expect in the next generation of economic models.

Evolution and progress

A key issue in building economic models is the trade-off that exists between forecasting ability and theoretical rigour. Forecasting models focus primarily on capturing empirical regularities. They work well when the economy and the shocks that it faces do not change much over time. In contrast, theoretical models built for policy analysis are based on a specific interpretation of how the economy functions. Their specifications may hold true on average, but not for every data point. So models with a strong theoretical base tend to underperform empirical models in normal times. However, they can be very useful in explaining behaviour when large shocks cause data-based models to break down.

The two types of models have tended to be complementary, but that has never stopped economists from pursuing the holy grail of a single model that combines strong theoretical foundations with good empirical performance. Over time, advances in computing capability have made it possible to build more realistic behavioural assumptions into models, improving this trade-off. However, the history of model development at the Bank of Canada reflects both this quest for synthesis as well as the evolving needs of policy-makers. Each new model has drawn on the strengths of its predecessors while addressing their shortcomings. And throughout this history, advances in both economic theory and computer technology have played an important enabling role.

The Bank began modelling in the 1960s, when staff and visiting academics built RDX—which stood for the Research Department Experimental model. The development of the mainframe computer was essential to this work, but not every institution had one. One academic involved in those early efforts at the Bank, John Helliwell of the University of British Columbia, tells of sending boxes of punch cards by bus to a computing centre at the Université de Montréal and of inputting data by modem to a computer in Utah.

Early models used by most central banks were based on Keynesian theory, with the demand side of the economy driving growth. However, the inflationary experience of the late 1960s showed the importance of modelling the supply side, which led to the successor model, RDX2. But after the oil price shock of 1973–74, the Bank wanted to use its model to examine alternative policies. The Bank actually began targeting the money supply as a means of reducing inflation and anchoring inflation expectations in 1975, but RDX2 did not have the ability to compare alternative policy paths.

This led to the development of RDXF, with “F” denoting “forecasting.” This version of RDX2 was more amenable to policy analysis. Acquisition of an in-house mainframe computer greatly facilitated this work. This is the model that was being used for quarterly projections when I arrived at the Bank in 1981.

I can vividly recall my initial disappointment with RDXF. I was fresh out of graduate school, where the natural rate hypothesis and rational expectations were *de rigueur*. The natural rate hypothesis holds that there is no permanent trade-off between inflation and unemployment. Rather, the economy settles at full employment in the long run, and inflation reflects the impact of monetary policy actions and people’s rational expectations. Rational expectations were seen as key to anchoring both models and economies as well as critical for properly analyzing alternative policy paths.

The gaps between RDXF and the thinking of the day became even more real when the Bank dropped its monetary targets and began searching for a replacement policy anchor. We believed that RDXF would be vulnerable to the Lucas critique. The Lucas critique held that empirical models based on data generated under a given policy regime and expectations-formation process would prove unstable and forecast poorly when the policy regime shifted.

By the late 1980s, the Bank was converging on targeting inflation directly as the central goal of monetary policy. This meant policy making would put much more focus on the future. We needed a model that would allow the Bank to make detailed projections—not just over the next couple of quarters, but for at least two years into the future—to reflect the lag between interest rate changes and their ultimate effect on inflation.

This thinking led to the development of SAM, the Small Annual Model. SAM incorporated the natural rate hypothesis and also defined a steady state to which the model would converge after being hit with a shock. However, the flip side of these theoretical strengths was that SAM was unsuitable for short-term projections. So SAM was used to complement RDXF.

The longer-term plan was to use SAM as a prototype to build a quarterly model with the same key properties to replace RDXF. Thus, QPM—for Quarterly Projection Model—was built. It incorporated forward-looking consumers and companies with rational expectations and a coherent steady state. Its short-run dynamics fit the data well enough to be used for projections. It also embraced all of the stock-flow dynamics necessary to analyze the significance of rising government debt, a prominent issue in the early 1990s.

QPM represented a big leap in sophistication, and the desktop computers we had at the time were not up to the task. As the Chief of the Research Department, I had to make a special request of then-Governor Gordon Thiessen for money to buy more powerful computers just to run the experimental model—a process that nevertheless lasted all night.

QPM served the Bank well for more than a decade. Its main shortcoming was that it could not deal with shocks to Canada's terms of trade—essentially, fluctuations in the prices of key commodities, such as oil—and these would become larger and more frequent. So adding a commodity sector to QPM moved to the top of our project list.

At the same time, the economics literature was shifting to a new class of models: DSGE, for dynamic stochastic general equilibrium. DSGE models capture the idea that economic behaviours—such as decisions about household consumption and business investment—are perfectly informed, forward-looking and always optimal. These models also predict how an economy can evolve over time as expectations change. Furthermore, stochastic shocks are built into the model at the household and firm level, dealing completely with the Lucas critique. The model's solution describes an economy that has reached a state of general equilibrium, with individual decisions aggregated into economy-wide prices and production quantities.

So the Bank decided to make the major investment to build ToTEM—the Terms-of-Trade Economic Model. ToTEM kept all the functionality of QPM, while adding the commodity sector and using the DSGE paradigm. Again, this work proved to be too much for the standard workstations that staff had on their desks, despite their increased power. Calibrating ToTEM required an extremely complex series of mathematical problems that took up enormous amounts of computing power. The solution during the prototype stage was to buy some top-end gaming computers to crunch the numbers on nights and weekends when the heat and noise would not make people's offices unbearable.

ToTEM continues to work extremely well for both projection and policy analysis. Of course, ToTEM's foundations represented a shift toward the theoretical side of the trade-off between forecasting ability and theoretical rigour. So Bank staff built a new model designed to complement ToTEM and guard against different types of forecast risks. This is the Large Empirical and Semi-structural model, known as LENS. It operates under a different paradigm than ToTEM does, is based more on what the data show and has only a loose set of theoretical constraints. LENS acts as a cross-check for ToTEM, and staff use the two models together to develop their projection and to facilitate a dialogue around policy options. In this way, the Bank is thus managing the trade-off by using two complementary models simultaneously, much as we did with RDXF and SAM. But ToTEM and LENS are much closer in performance than RDXF and SAM were, reflecting the improvements in the trade-off that I mentioned earlier.

Our approach proved to be extremely valuable in late 2014, when Canada was faced with a collapse in the price of oil. In contrast to standard Keynesian models, ToTEM anticipated how serious the oil price shock would be, how the effects would endure and how the economy would adjust to lower oil prices. Our confidence in this analysis led the Bank to lower its policy rate twice in 2015, long before the negative effects of the oil price shock began to be widely felt. This put a cushion under the economy and made for a faster adjustment.

A big outlier: the global financial crisis

Together, ToTEM and LENS represent a powerful, modern approach to economic modelling at a central bank. Nevertheless, they provide little insight into the forces that produced the global financial crisis or the behaviour that has come afterward. This is true for all major models previously used by central banks.

The period since the crisis has raised related questions that these models are not well-equipped to answer. For example, how will the prolonged period of low interest rates affect risk-taking behaviour? How are business confidence and geopolitical uncertainty affecting business decisions? How do global value chains affect the way monetary policy is transmitted?

To be clear, ToTEM and LENS have continued to do a good job, despite their shortcomings. And to complement them, we have developed a number of "satellite models" to deal with specific issues. For example, the Bank has built a model called MP2—the Macroprudential and Monetary Policy Model—to study the impact of financial shocks and macroprudential policies on the economy. Other models look at the ways inefficiencies in financial markets can lead to financial imbalances. There have also been ambitious efforts to model exports, at a very granular level, in light of extensive destruction of export capacity over the past decade.

This multi-model strategy has allowed us to successfully mitigate the limitations of the current generation of models and appropriately manage the risks facing monetary policy. But the next generation of models at central banks will need to address these issues directly.

The next generation of models

While no one can say with any certainty what the next generation of central bank models will look like, we can expect them to stand on the shoulders of models like QPM, ToTEM and LENS.

One lesson we have learned over the years is that a single model is unlikely to satisfy all our needs. This is a consequence of the fact that models are, by construction, an abstraction from reality. Striking the right balance between theory and data fit is more an exercise in judgment than an empirical one, and those judgments are best formed by drawing upon complementary models.

Another lesson is that central banks have traditionally stuck with their models until well after their "best before date." This is no doubt because greater realism in models means greater complexity, more computing power and big investments in research and people. Guarding against keeping a model too long may mean continuously investing in new approaches, even when there are no obvious shortcomings in existing models.

Indeed, often it is the unforeseen advances in modelling paradigms—enabled by improved computer technology—that drive modelling progress. Today, the DSGE paradigm appears to have a long future, but no one was dreaming of this approach when we were building QPM only 25 years ago.

To illustrate, an alternative approach worth exploring may be agent-based models. Unlike the DSGE approach, agent-based models assume that the economy consists of individuals who repeatedly interact with each other and adapt their behaviour based on what they learn from those experiences. Macroeconomic behaviour emerges naturally. Such models have their own limitations, but in a world of big data, where the advertisements you see online can be derived from what you type into your search engine, agent-based models could be a valuable tool.

The next generation of models is also likely to take a more nuanced approach to rational expectations. In reality, people seem to behave in a way that falls somewhere between full rational expectations and simple rules of thumb. Hence the promising concept of "bounded rationality."

Another potentially desirable attribute of future models is to allow for more forms of heterogeneity. We know, for instance, that different companies make different decisions about when to enter and exit markets and how to invest. We know that people with different income and wealth levels respond differently to interest rate movements, and these responses can change depending on the person's stage of life. Many financial transactions occur because people have varied risk tolerances. However, most current models assume uniformity among companies and individuals.

And at a minimum, the next generation of models must capture the links between the financial system and the real economy. They should explain how the financial system can be a source of shocks and how those shocks can be propagated. They need to capture the possibility of nonlinearities that cause small shocks to have outsized economic effects. They should be able to show how debt that builds up in a specific sector can affect the entire economy. And we need models that capture risks and vulnerabilities within the financial system and can show how these interact with monetary and macroprudential policies.

This is not an exhaustive list, but it illustrates the point. Bank staff have been given a licence to innovate on these issues because we know model evolution takes time, and we should invest continuously in it.

Models and uncertainty

Before I conclude, I want to return to an issue I raised at the beginning—the role of uncertainty in policy making.

It is tempting to think that we can use today's sophisticated models to give us a precise numerical forecast for inflation two years from now as well as the exact policy response needed today to keep inflation precisely on target. In earlier speeches, I have likened this to an exercise in engineering.

In fact, economists do exactly that with their models, but they express their predictions in probabilistic terms. They point to the many margins of error that exist around all the variables in their model, and all the assumptions they must make, and admit that their ultimate calculation contains all of these sources of error by construction.

This creates uncertainty around both the model's inflation forecast and its recommended policy path. At the Bank, we think of this inherent uncertainty as creating a "zone" within which our interest rate setting has a reasonable probability of bringing inflation back to target over a reasonable time frame.

So uncertainty exists even when models are performing well. But there are additional uncertainties, including those related to model-disrupting structural changes, such as those that were triggered by the global financial crisis. These additional uncertainties may introduce a bias in the model's projections, making it more likely that its suggested interest-rate path will lead to missed targets.

And, of course, there is uncertainty generated by the risks to our inflation forecast. We begin our interest rate deliberations with the policy path recommended by our models, but we are always mindful of the uncertainties, including the range of risks that might cause us to undershoot or overshoot our target. All of these sources of uncertainty define the zone in which we can be reasonably assured that policy is on track. Factors that increase uncertainty—such as geopolitical risks—can widen this zone temporarily. Conversely, resolution of uncertainties can narrow it.

This is the essence of the Bank's risk-management approach to monetary policy. Interpreting, weighing and managing those risks approaches art, but the art is built on the science of our models.

Allow me to make three related points. First, the starting point matters to a monetary policy decision. If inflation is on target and is projected to be on target in two years, then various risks can be interpreted and managed in an even-handed manner. But our current situation serves as a counter example. While we project that inflation will be sustainably at target around the middle of next year, we are well aware that the lingering aftermath of the crisis has left the Canadian economy with persistent excess capacity, and inflation has been in the lower half of our target range for some time.

Second, the uncertainty in economic models makes it ill-advised to reduce the conduct of monetary policy to a simple mechanical rule. The fact that there are so many sources of uncertainty, some of which cannot be quantified, makes the risk-management exercise highly judgmental. A corollary is that we need to explain our underlying reasoning very carefully to ensure that it is well understood. To this end, the Bank has taken a number of measures to increase its level of policy transparency in recent years.

Third, uncertainty does not equal indecision. It is true that the notion of a zone generated by uncertainty can create a degree of tolerance for small shocks. At the same time, a large shock—or, perhaps, an accumulation of smaller shocks—can tilt the balance of risks to projected inflation and prompt policy action.

In early 2015, for example, ToTEM was showing how the oil price shock would play out and the downside risk to projected inflation became unacceptably large. The shock pushed us out of the zone in which the existing interest rate setting provided reasonable assurance of hitting our inflation target within a reasonable time frame. Accordingly, we reduced interest rates to bring projected inflation back into line with our target.

Conclusion

It is time for me to conclude.

The Bank has been pursuing inflation targets for 25 years, and the average rate of inflation has been extremely close to target over that period. This alone suggests that our models have done their job reasonably well.

And while our current models continue to perform well, recent experience is pointing to some shortcomings that we need to address. Given how long it can take to develop a new model, investing in the next generation of models is one of the Bank's top priorities, and I want it to be a top priority for the economics profession as well. Better tools will mean a more stable and predictable rate of inflation, and an even better environment for economic decision making.

It is an exciting time for economics and monetary policy. I can hardly wait to see what comes next. But economists have a tendency to get overly excited about their own issues, so let me leave you with an analogy to help you keep this in perspective.

Today's macroeconomic models are as different from those of the 1970s as the latest *Star Wars* film, *Rogue One*, is from the first of the original trilogy, *A New Hope*, released in 1977. No matter which film you prefer, it is clear that the tools and the technology available to the director have evolved dramatically. The state of the art today is light years ahead of what was state of the art 40 years ago. But ultimately, storytelling remains what is important. That has not changed.

Our economic models will continue to evolve, becoming better and more sophisticated tools. But it will always be up to central bankers to use these tools, as well as their judgment, to conduct monetary policy, achieve their targets and offer a compelling narrative that everyone can understand.

I would like to thank Rhys Mendes and Oleksiy Kryvtsov for their help in preparing this speech.