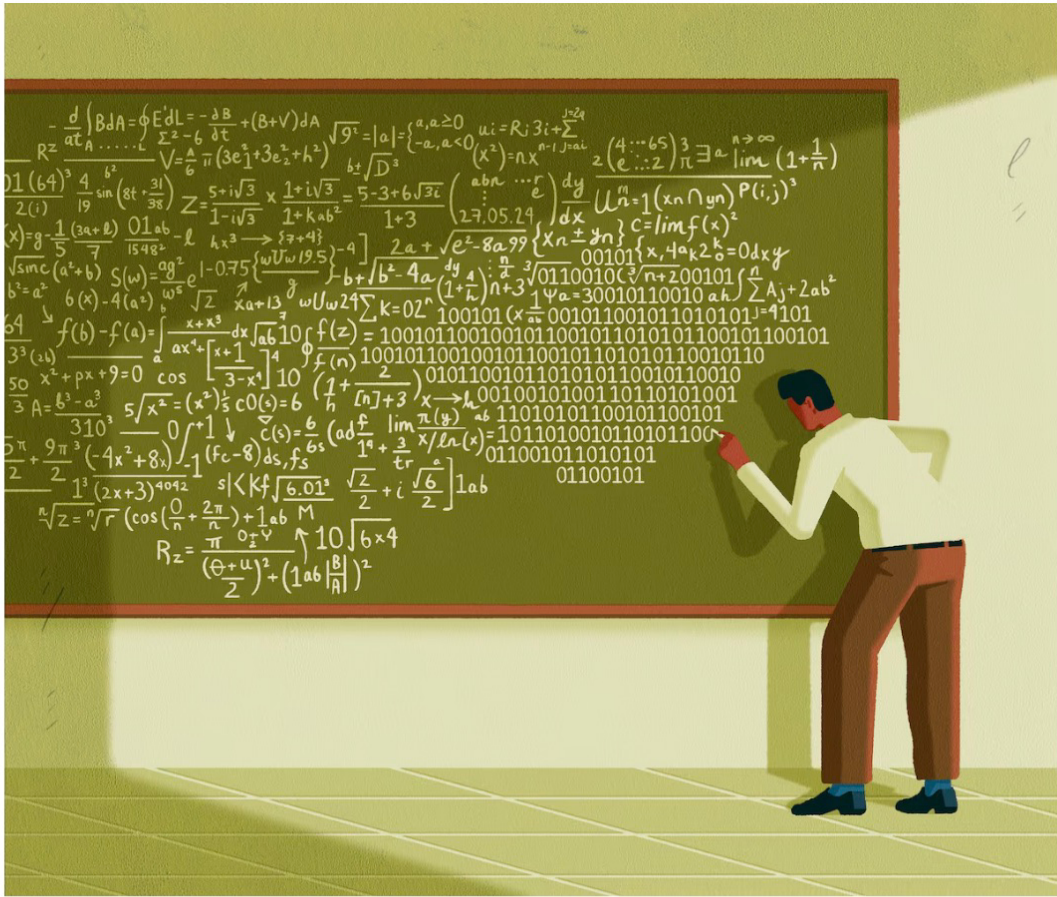# The Bank of Canada retools its economic forecasting for a future that does not look like the past

In what will be the largest revamp in nearly two decades, the central bank intends to replace its two main macroeconomic models with a new core model for forecasting and analysis

MARK RENDELL ›
PUBLISHED JANUARY 19, 2024
UPDATED YESTERDAY

A macroeconomic model is a representation of the economy made up of equations and computer code. Central bankers use them to produce quarterly forecasts for inflation and economic growth, and to test potential monetary policy choices.

ILLUSTRATION BY PETE RYAN

In the summer of 2021, inside the Bank of Canada's headquarters in Ottawa, about a dozen economists were feeding reams of data into their mathematical

mock-ups of the world – hundreds of equations and thousands of lines of computer code designed to simulate the conditions of the economy.

There was reason for optimism: The COVID-19 virus's third wave had receded, pandemic restrictions were easing and businesses were reopening.

Yes, inflation had been running at more than 3 per cent, the upper end of the central bank's control band, since the spring. But this, it seemed, was owing to factors that did not require an immediate monetary policy response. Inflation would return to the bank's 2-per-cent target the following year. The mathematical models said so.

In went the barrage of employment statistics, gross domestic product figures, energy prices and consumer spending data. Out came projections suggesting that slack in the economy would dampen inflationary pressures once global supply chains normalized and oil prices levelled off.

It was a reassuring outlook – one that bolstered Governor Tiff Macklem's promise to keep interest rates near zero until the economy was well into a recovery.

We know, in retrospect, that these forecasts were wrong. By the time the bank began its historic campaign of interest rate increases in March, 2022, the annual rate of inflation was running above 5 per cent. It would hit a four-decade high of 8.1 per cent that June, after Russia's invasion of Ukraine pushed up global commodity prices.

The surge in inflation in recent years has challenged central bankers to a degree not seen since the high inflation of the 1970s and early 1980s. And as with that earlier period, the experience has called into question the models central bankers rely on to understand the economy and figure out how to keep inflation under control.

No economic model, no matter how sophisticated, could have predicted a global health emergency, the speed of vaccine development or the outbreak of a major European war.

But models can do a better or worse job identifying key economic forces and providing a rough road map for where inflation is headed. And through much of 2021 and early 2022, the economic models used by central bankers and most private-sector forecasters came up short.

"Obviously, if oil prices go up really fast and food prices go up, the models can explain that part: You feed in higher oil prices, you're going to get higher inflation in Canada," Mr. Macklem said in a recent interview with The Globe and Mail. "But there were some parts of the model that didn't [work]; it was hard to explain how rapidly inflation went up."

No economic model, no matter how sophisticated, could have predicted a global health emergency, the speed of vaccine development or the outbreak of a major European war.
ILLUSTRATION BY PETE RYAN

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Over the past year, a team of about 20 Bank of Canada economists, aided by other staff researchers, have been working on a major overhaul of the bank's workhorse macroeconomic models.

These are representations of the whole Canadian economy that the bank's research team uses to produce quarterly forecasts for inflation and economic growth, and to test potential monetary policy choices.

Because interest-rate changes take up to two years to percolate through the economy and impact inflation, central bankers need to have a sense of where the economy will be in the future, and of how their own actions could affect that path. Model forecasts form the starting point for the governing council's discussions about where to set interest rates, which happen eight times a year.

In what will be the largest revamp in nearly two decades, the bank intends to replace its two main macroeconomic models – the Terms-of-Trade Economic Model (ToTEM) and Large Empirical and Semi-structural Model (LENS) – with a new core model for forecasting and analysis.

It also plans to build a suite of additional models it calls satellites, which will act as a check on the main model's assumptions, and a set of specialty models

designed to address specific issues, such as financial stability risk or the economic impact of climate change.

If all goes to plan, these models will go live in mid-2025.

The overhaul isn't simply a response to recent forecasting errors, bank officials say. Computer technology improves, economic theory advances and all models have a best-before date. Even before the pandemic, the bank was re-examining its models in light of forecasting errors made during the 2008 financial crisis.

Central banks have underpredicted inflationary pressures
Year-over-year inflation projection errors for 2022 Q1 for three central banks, quarterly data (percentage points)

● Bank of England ● European Central Bank ● Bank of Canada
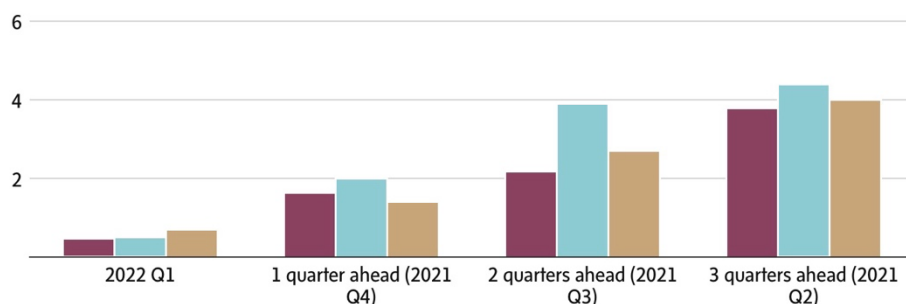
Note: The horizontal axis refers to the quarters when the forecasts were made for 2022Q1 inflation. Projection errors are the difference between the actual observed value and the projection value.
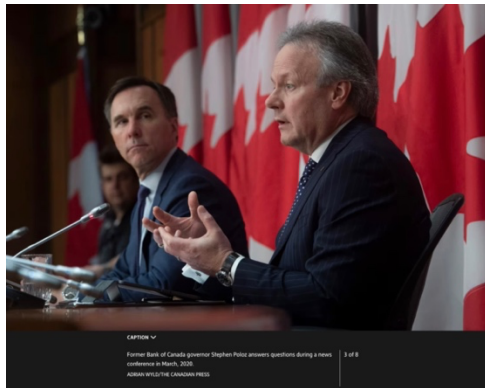THE GLOBE AND MAIL, SOURCE: BANK OF CANADA

But the past few years have highlighted plenty of pitfalls in the current generation of models. ToTEM and LENS both seem to have unrealistic assumptions about how people form beliefs about inflation and how companies set prices.

They also have only a rudimentary understanding the supply side of the economy. That was a major impediment during the pandemic, when supply shocks – such as factory closings, transportation bottlenecks and labour shortages due to illness – became the most important drivers of inflation.

"I certainly hope and expect that the next few years are much less volatile than the last few years," Mr. Macklem said. "Nevertheless, I think we are headed to a world where there are more supply shocks and where there could be more breaks and shifts [on the supply side of the economy]. And so we are going to have to be more alive to those lessons."

Some private-sector and academic economists think newer, more realistic models will improve the central bank's ability to identify and respond to shocks. Others see it as more of the same, with the bank relying on the same theoretical framework as before, with some minor tweaks around the edges.

CAPTION ⌄

Former Bank of Canada governor Stephen Poloz answers questions during a news conference in March, 2020.
ADRIAN WYLD/THE CANADIAN PRESS

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Former governor Stephen Poloz, who led the bank from 2013 to mid-2020, said the emphasis on multiple satellite models is an important development in an increasingly complex world, where forecasting is becoming tougher and any model can send erroneous signals.

"The central banker's job may get harder, but I think at the same time they're going to get better at it," he said.

Still, better models won't change the nature of central banking, Mr. Poloz said. All models are built on assumptions, and even the most detailed ones can't capture how the world actually works. Monetary policy decision-making always comes down to judgment.

"You're using the model as a framework to make sure you don't do something dumb," Mr. Poloz said. "It's all about risk management, not an engineering exercise."

The story of macroeconomic model building goes back to the 1930s, when Dutch economist Jan Tinbergen tried to figure out whether the Netherlands should take its currency off the gold standard to stimulate the country's flagging economy.

He created 24 interlocking equations that showed the impact of a lower exchange rate on output, unemployment and other variables. The model led him to suggest devaluation – a path the Dutch government subsequently followed, although it's not clear how much of a role he played in the decision.

This spurred a whole field of research, with economists developing representations of the economy that could be used to test different policies and help with forecasting. This was mostly a mathematical exercise: Picture pages of algebra equations underpinned by theories about the structure of the economy. But there were some more eccentric efforts, including a hydraulic model of the British economy, built by New Zealand economist Bill Phillips in 1949, which illustrated the movement of money throughout the economy with coloured liquid flowing through a series of tanks and pipes.

From the get-go, macroeconomic models had significant limitations, which they've never really escaped. By their nature, models simplify reality; they prioritize some economic variables over others and leave many things out altogether. And as much as they can help explain historical data, they can't actually predict the future.

What they can do is help economists think about things in a consistent manner and pick up dynamics they might otherwise have missed, said David Andolfatto, an economics professor at the University of Miami and a former research director at the St. Louis branch of the U.S. Federal Reserve.

"Because these models are so rich, they embed the feedback effects that would escape you and me just using our brains," Prof. Andolfatto said. "So they help the policy maker identify, 'Woah, this looked like a good idea on the surface, but we didn't take into account the force that's identified in the model.'"
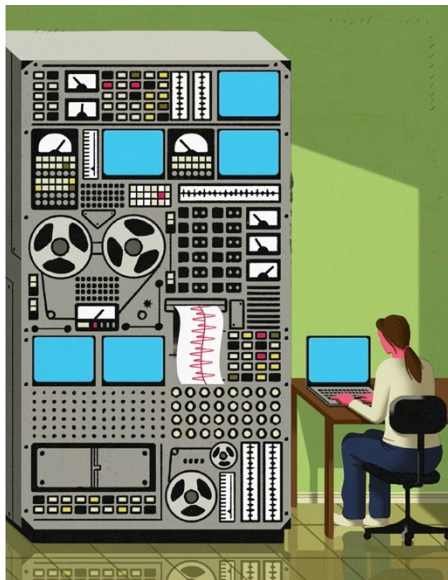
By their nature, models simplify reality; they prioritize some economic variables over others and leave many things out altogether. And as much as they can help explain historical data, they can't actually predict the future.
ILLUSTRATION BY PETE RYAN

The Bank of Canada got into the model-building game in the 1960s, and has since gone through three generations. Early efforts were based on the ideas of British economist John Maynard Keynes and relied on mainframe computers. To run the web of equations, the bank had to send punch cards by bus to a computing centre at the Université de Montréal and transmit data by modem to a computer in Utah.

These models ran into trouble as inflation surged in the 1970s. The models assumed there was a stable trade-off between unemployment and inflation, given the connection between tight labour markets and wage growth. But this assumption meant the models couldn't explain the combination of high unemployment and high inflation, known as stagflation, that took hold after the oil price shocks that decade.

They also struggled with an influential argument known as the Lucas Critique, which emphasized the importance of expectations when it comes to forecasting. You can't predict the impact of an economic policy change based on historical data, the argument goes, because individuals and businesses will adjust their behaviour in anticipation of the change. If economic policy makers try to permanently boost inflation to lower unemployment, for example, businesses will begin expecting higher inflation and change their hiring decisions, undercutting the original intention of the policy.

Academics and central bankers went back to the drawing board, and through the 1980s and 1990s they built a new generation of models from the ground up, based on what economists call "microfoundations."

These look at big-picture variables such as inflation in terms of the behaviour of individual consumers and businesses. And they get around the Lucas Critique by assuming that individual agents have rational expectations – that is, they make decisions with a complete understanding of how the model economy works.

The bank's current workhorse models are based on these principles, although they differ from one another. ToTEM is what's known as a Dynamic Stochastic General Equilibrium (DSGE) model, which is built from a strong set of assumptions about the structure of the economy and typically does a better job analyzing the impact of potential policy changes. LENS, a semi-structural model, puts more weight on observed economic data, and is often better at forecasting.

Each subsequent generation of model was aided by improvements in computer technology. When the Bank of Canada introduced ToTEM in 2006 it had to jury-rig a computer system capable of processing the mass of equations without melting down.

"It was running on two gaming consoles hard-wired together with a great big fan blowing on them," Mr. Poloz said. "The guys would put in a job and go home for the night, and I come in the morning, it was done."

Today, ToTEM lives on laptops throughout the bank's headquarters in Ottawa and it takes about a minute to run through all of its equations.

Over the decades, central bank forecasters have tended to outperform their private-sector peers – possibly because they have access to better data, plus deeper insight into monetary policy discussions. But they have struggled to read the tea leaves at moments of economic change and crisis.

Ahead of the 2008 financial crisis, central bankers misread the housing boom, particularly in the United States. And they underestimated the risk that serpentine financial instruments, tied to mortgages, were spreading through the global banking system.

"They missed the boat on the financial stuff," said Stephen Williamson, an economics professor at the University of Western Ontario. "They didn't have that in their models."

In the wake of the crisis, central banks, including the Bank of Canada, added more detail about housing markets and household debt into their models, and developed alternative tools to help monitor financial stability risks. But they still haven't integrated the financial system into their models in a comprehensive way, Prof. Williamson said.

The next big challenge came in the spring of 2020, when much of the world went into COVID-19 lockdowns. GDP plunged and unemployment soared. Consumer spending swung from services to goods. Governments and central banks unleashed an unprecedented amount of stimulus to prevent the downturn from spiralling into a depression.

A mural in downtown Vancouver reads 'Stay Apart,' echoing public-health messaging during the early days of the COVID-19 pandemic in April, 2020.

DARRYL DYCK/THE CANADIAN PRESS

In April, 2020, the Bank of Canada opted not to publish a central forecast in its Monetary Policy Report (MPR), the bank's quarterly update about where it thinks the economy and inflation are headed. Instead, it presented upside and downside scenarios, heavily contingent on pandemic developments, while warning that any forecasts at that time were extremely dicey.

"Our models were not equipped for COVID," said Mr. Macklem, who became Governor in June, 2020. "There's no pandemic in the data, and models really reflect how things have behaved over history. We don't make it up."

Early in the pandemic, health factors such as virus mutations, lockdown measures and the pace of vaccine development played the leading role in determining the direction of the economy. As such, it's of little use to criticize forecasting errors from that period.
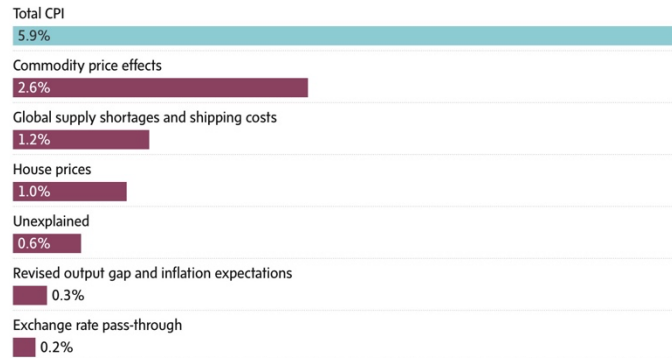
But the story was different in 2021 and 2022. As inflation picked up for the first time in decades, central bankers systematically underestimated the strength and persistence of price pressures. If you chart the quarterly forecasts published in the Bank of Canada's MPRs through this period, it looks like a mountain range, with the peaks getting higher and higher, quarter after quarter. Other central banks, including the Federal Reserve, European Central Bank and Bank of England, had similar difficulties – as did most private-sector forecasters.

Much of the surprising surge in inflation had to do with supply shocks that followed the easing of pandemic lockdowns. Oil prices spiked. There was a

shortage of semiconductors. Transportation networks jammed up, as seen in the backlog of container ships at U.S. and Chinese ports.

Sources of Bank of Canada inflation forecast errors
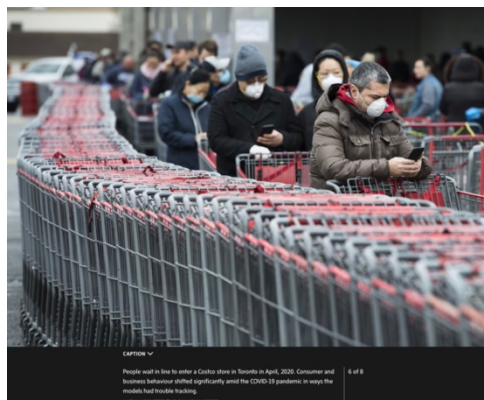Difference between actual CPI inflation in 2022 Q2 and the year-before forecast

Total CPI
5.9%

Commodity price effects
2.6%

Global supply shortages and shipping costs
1.2%

House prices
1.0%

Unexplained
0.6%

Revised output gap and inflation expectations
0.3%

Exchange rate pass-through
0.2%

[Analysis published by the Bank of Canada](#) in July, 2022, found that roughly two-thirds of the missed inflation – comparing actual inflation in Q2 2022 with the year-before projection – was due to some combination of "global factors," such as higher commodity prices, increased supply shortages and rising shipping costs.

These supply shocks not only pushed up prices in the short term, they muddied the water for central bank models.

LENS, in particular, puts a lot of weight on the "output gap" in the economy – the difference between what an economy is actually producing and what it could be producing, if it was firing on all cylinders without overheating. But in a period of extreme supply disruptions, normal estimates of the economy's potential became less meaningful. That meant there was less slack in the economy than the bank assumed.

CAPTION ˅
People wait in line to enter a Costco store in Toronto in April, 2020. Consumer and
business behaviour shifted significantly amid the COVID-19 pandemic in ways the
models had trouble tracking.
NATHAN DENETTE/THE CANADIAN PRESS

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Consumer and business behaviour also shifted significantly in ways the models had trouble tracking.

Unable to spend on travel, restaurants and the like, people poured money into electronics, home furniture and exercise equipment – most of which was produced in Asia and had to be shipped. Service prices stagnated, even dropped. Goods prices soared.

"That synchronization, if you will, across sectors broke down in important ways during COVID. And that had implications not just for thinking through activity, but also thinking through inflation," Bank of Canada deputy governor Sharon Kozicki said in an interview.

Companies also got more aggressive. ToTEM and LENS both assume that businesses change prices at regular intervals. It's a simplification of reality; but it was a reasonable assumption for the better part of 25 years. However, as inflation increased, businesses started passing costs along to customers more rapidly, raising their prices more frequently than the models assumed was possible.

René Lalonde, head of modelling and forecasting at Bank of Nova Scotia, and a former research director at the Bank of Canada, said his former colleagues "were not pragmatic enough" in adjusting their models to the changing circumstances. This was especially true for how they handled inflation expectations.

Because ToTEM and LENS are both based on a rational expectations framework, they downplay the possibility that inflation expectations can become unanchored. The virtual consumers and businesses inside the models basically trust the central bank to do its job and keep inflation at 2 per cent.

"No matter what happens, inflation [in the model] will always come back to the target eventually because there's a proportion of the expectation that is directly anchored on the target," Mr. Lalonde said. "But that's not what we saw recently over the last two years; short-term expectations became unanchored."

Some other economists argue the Bank of Canada paid too little attention to the money supply, which increased rapidly in 2020 as the federal government spent hundreds of billions of dollars on emergency relief measures, and the central bank purchased huge quantities of government bonds to suppress

interest rates. Others say it should have watched asset prices and the structure of government debt more closely.

For Prof. Andolfatto, the crucial mistake had to do with how central bank models interpret government spending. These tend to assume that large deficits will be offset by future surpluses and higher taxes, and that agents in the model understand this.

But again, the real world proved more complicated.

"These are very large deficits, and I don't see any future taxes," Prof. Andolfatto said. "If you're running big deficits, and there's no prospect of future tax increases, then something else has to give. And if you're at full employment, I mean, the thing that has to give is the price level. Prices have to go up."

Bank of Canada Governor Tiff Macklem takes part in a news conference in October, 2023. Work on the bank's fourth-generation models is still at an early stage, but it has published a blueprint revealing key aspects of the new system.
PATRICK DOYLE/REUTERS

Bank of Canada economists have spent the past year scribbling down new equations and thinking about the structure of the economy. At its core, an economic model is a jumble of math built on top of theories about the way the world works: How people form beliefs about the future; how companies set prices; how commodity shocks affect different sectors. That means building a new model involves going back to the basics.

Work on the bank's fourth-generation models is still at an early stage. But it has [published a blueprint](#) outlining the key ingredients of the new system.

The core workhorse model will be a DSGE model like ToTEM. But it will likely take what economists call a "bounded rationality" approach to inflation expectations instead of the current rational expectations framework. That can mean many different things; but, in effect, agents in the model won't look like

miniature economists who understand monetary policy perfectly and think inflation will almost always remain on target.
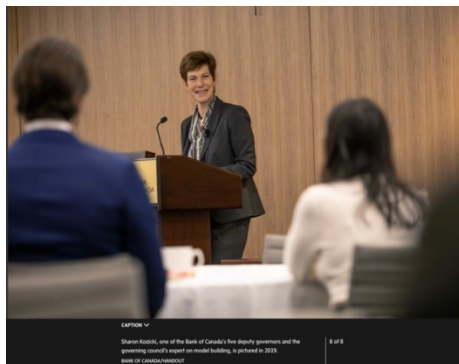
The model is expected to have a more detailed description of the supply side of the economy, including labour market dynamics and wage growth, as well a more modern view of how companies set prices that can account for them being more or less aggressive depending on the broader economic context.

"What we discovered is when the economy is in excess demand, and you get a supply shock, it's not linear; it's non-linear. You get more of an inflationary effect," Mr. Macklem said. "I think the other kind of lesson is that behaviour can really change when you get outside of the normal zone."

There's also an increased emphasis on what economists call "heterogeneity." Current models are built around a small number of representative agents: one household, one business and so on. But this fails to capture the fact that people spend, save and bargain for wages very differently depending on their wealth, location and other individual circumstances – and that these characteristics aren't static.

"It can make it difficult to figure out what's driving your results when you have so many things that differ across agents," said Luba Petersen, an economics professor at Simon Fraser University. But if the bank can figure out how to add diversity to its models, "it can start incorporating more realistic assumptions and tell more empirically consistent stories."

All of this is being built using data-rich methods, which will allow central bank economists to fine-tune their models using larger amounts of information, perhaps with the help of machine learning.

CAPTION ⌄

Sharon Kozicki, one of the Bank of Canada's five deputy governors and the governing council's expert on model building, is pictured in 2019.

BANK OF CANADA/HANDOUT

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For Ms. Kozicki, one of the bank's five deputy governors and the governing council's expert on model building, the most important change will be how the

bank approaches uncertainty and manages the risk that its models might be wrong.

In the fourth-generation system, there will be a range of satellite models, each that differ from the workhorse model on one key assumption – say about inflation-expectations formation or how the labour market functions. These will play devil's advocate against the core model.

The bank is also developing specialty models to understand what happens if the economy is pulled off a normal trajectory and into what the bank calls a "dark corner" – say by a war, pandemic or financial crash.

"It will put more rigour in our ability to do risk analysis, that's not just, 'Well, what if the demand shock is more persistent?' " Ms. Kozicki said.

The art of central banking isn't knowing what's going to happen next, according to Mr. Poloz. It's about looking at a range of possibilities and choosing a path for interest rates that "hedges against the worst possible outcomes."

This skill set will become increasingly important amid tectonic shifts in the global economy, including population aging, artificial intelligence and geopolitical turmoil, Mr. Poloz said. When these forces interact, "you're going to generate what looks like chaos in the data and therefore it's unforecastable, even by the best models."

In that world, it's important to run multiple models, each with different assumptions about how things work.

Ms. Kozicki said that she expects Bank of Canada economists in the future will spend less time tending the central workhorse model, and more time looking at the surrounding models and asking: What if?

What if there's another global pandemic? What if people lose faith in the bank's ability to control inflation? What if an asteroid knocks out the rail links in Western Canada?

"What-ifs are never a waste of time," Ms. Kozicki said. "Because even if the 'if' never, ever comes to pass, it's remarkable how much you can learn by thinking about it."