Methodology Used to Construct Fan Charts in the April 2009 *Monetary Policy Report*

The fan charts presented in the April 2009 Monetary Policy Report (MPR) are derived from a combination of (i) the staff projection errors for the current quarter and one quarter in the future,[1] and (ii) the forecast errors generated by ToTEM, the Bank of Canada's main projection model for the Canadian economy.[2] In both cases, the errors are calculated using quarterly data from 1995Q1 to 2008Q3. Therefore, the confidence intervals for the first two quarters in Charts A and B in Technical Box 2 in the April MPR are based on real-time staff projection errors, whereas the confidence intervals for the third quarter and beyond are based on extrapolations of the one-step-ahead ToTEM errors, adjusted for the lagged effects of the projection errors. Uncertainty associated with the outlook for Canada's main trading partners, which also influences the fan charts, is estimated using the forecast errors from a small forecasting model, calibrated to replicate the dynamics predicted by MUSE, the Bank's model of the U.S. economy.[3] The forecast errors from this model and from ToTEM are based on forecasts that use revised, rather than real-time, data.

Forecast errors (both model-based and from the staff projection) are assumed to have a zero-mean, multivariate normal distribution that is time invariant. Since both models used to construct the fan charts are linear (in logs), if we ignore the influence of the effective lower bound (ELB) on nominal interest rates (as discussed in the April MPR), the projection distributions for each period will also be multivariate normal with means equal to the base-case MPR projection. The level of uncertainty at a given projection horizon will also not vary from one projection to the next. Since the ELB introduces an asymmetry into the models, these distributions will no longer be symmetric when the Canadian economy, and/or the economies of our major trading partners, are close to the ELB. Specifically, the ELB will introduce a negative skew into the projected distributions for core and total CPI inflation since the target overnight interest rate can be raised if the economy turns out to be stronger than anticipated, but it cannot be lowered if the economy turns out to be weaker. This skew is mitigated by the assumption that the Bank will undertake unsterilized credit easing or quantitative easing if the economy is materially weaker than projected in the base case.

The fan charts are generated numerically through repeated stochastic simulations of ToTEM and the small rest-of-world model, both of which are so-called *forward-looking* models. Agents in the models (households, firms, governments, and the central bank) are assumed to have rational expectations, so their expectations of the future are consistent with the structure of the model being used, including the existence of the ELB and unconventional monetary policy measures. If the target overnight interest rate is expected to reach the ELB in the future, it will be reflected immediately in longer-term interest rates, and will therefore influence current-period economic behaviour.

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1 Bank staff typically rely more on sectoral experts and indicator models that can exploit higher-frequency data to project the first two quarters, and less on ToTEM, which is better suited to projecting the medium term. For a more detailed discussion of the policy advice process, see Tiff Macklem, "Information and Analysis for Monetary Policy: Coming to a Decision," *Bank of Canada Review* (Ottawa: Bank of Canada, Summer 2002): 11–18.

2 A detailed discussion of the Terms-of-Trade Economic Model (ToTEM) is provided in: Stephen Murchison and Andrew Rennison, "ToTEM: The Bank of Canada's New Quarterly Projection Model" (Technical Report No. 97, Ottawa: Bank of Canada, 2006); and Paul Fenton and Stephen Murchison, "ToTEM: The Bank of Canada's New Projection and Policy-Analysis Model," *Bank of Canada Review* (Ottawa: Bank of Canada, Autumn 2006): 5–18.

3 See Marc-André Gosselin and René Lalonde, "MUSE: The Bank of Canada's New Projection Model of the U.S. Economy" (Technical Report No. 96, Ottawa: Bank of Canada, 2005).