General Discussion

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Introduction

One result from a rather large literature on optimal monetary policy is that central bankers can obtain better outcomes on average if they have a good understanding of what determines economic behaviour and, importantly, inflation dynamics. For instance, after a shock, policy responses to bring inflation back to its target within a given horizon may depend on the persistence of inflation—more persistent inflation may require more aggressive policy.

The papers in this session set out to further develop our understanding of Canadian inflation dynamics by estimating expressions for inflation derived from structural models with optimizing agents. Both papers start from a theoretical, New Keynesian model that relates inflation to a measure of real marginal cost, but they take different approaches in dealing with complexities associated with real-world data. Overall, the papers present interesting results that educate the reader on inflation dynamics.

My comments can be grouped under five broad topics: (i) sources of inflation persistence; (ii) superneutrality in the New Keynesian Phillips curve; (iii) empirical regularities; (iv) empirical irregularities; and (v) the structural model and deep parameters. In the process of discussing these topics, I will highlight regularities apparent in the results of this session's papers that provide useful insight for policy-makers. As will become clear from my comments, however, a number of important questions remain for future research.

1 Sources of Inflation Persistence

In the New Keynesian Phillips curve (NKPC) of the papers in this session, inflation (π_t) depends on steady-state inflation (π_t^T), lagged and expected inflation gaps ($\hat{\pi}_t = \pi_t - \pi_t^T$), marginal cost ($y_t$), the mechanism by which expectations are formed/learning behaviour (E_t), and a Euler-equation residual (ε_t):

$$\hat{\pi} = \gamma_b \hat{\pi}_{t-1} + \gamma_f E_t \hat{\pi}_{t+1} + \lambda y_t + \varepsilon_t . \quad (1)$$

Inflation persistence may derive from any or all of these features. This section discusses the merits and motivation of each feature as a source of inflation persistence and comments on potential implications for monetary policy.

1.1 Steady-state inflation

From a technical point of view, steady-state inflation appears in the model as the rate of inflation around which the non-linear model is log-linearized. From a macroeconomic standpoint, however, steady-state inflation is typically linked to the actual or perceived inflation target. Kozicki and Tinsley (2003), Levin and Piger (2002), and both papers in this session—Amano and Murchison (henceforth AM), and Barkbu and Batini (henceforth BB)—argue that shifts in the actual or perceived inflation target contribute to inflation persistence. *This observation is important for monetary policy makers, because it implies that inflation persistence can be reduced by policy that provides a credible constant inflation target.*

1.2 Inflation gaps

Lags of inflation or inflation gaps have been added to models of inflation dynamics to help capture empirically estimated persistence in inflation. Indeed, most studies find that both lagged and expected inflation gaps are statistically significant in estimated NKPCs. Many theories have been developed to justify the inclusion of lagged inflation-gap terms, including indexation by non-optimizing firms (Christiano, Eichenbaum, and Evans 2005; Sbordone 2005); rule-of-thumb firms that set prices in a backward-looking way (Galí and Gertler 1999); models with staggered contracts (Taylor 1980; Fuhrer and Moore 1995); and frictions on price adjustment (Kozicki and Tinsley 1999, 2002, 2003). Such sources of inflation persistence are generally outside the influence of monetary policy, but are not necessarily time-invariant. To the extent that advances in information technology make it easier for firms to optimize, changes in inflation

dynamics are possible and something that policy-makers may want to monitor.

1.3 Marginal cost

The NKPC suggests that persistence in the driving variable, real marginal cost, will be magnified and reflected in inflation. A puzzle in Canadian data that is evident in both of this session's papers is that since 1991, estimates of aggregate real marginal cost have been considerably more persistent than inflation. An important question to address is how to reconcile apparent properties of real marginal cost with inflation. One possible explanation is that the NKPC is a poor model of inflation dynamics. Alternatively, real marginal cost may not be measured correctly. The relevant variable for the log-linearized NKPC is the deviation of real marginal cost from its steady state. Is the steady state of real marginal cost a constant? More generally, is real marginal cost a stationary variable or an integrated variable?

1.4 Expectations/Learning

A fourth potential factor influencing inflation dynamics is expectations formation and/or learning behaviour. Expectations formation has been modelled in a variety of ways in the macroeconomic literature, including assumptions that expectations are rational, formed in a model-consistent fashion, or based on some less restrictive mechanism. The latter includes, for example, models of adaptive expectations, as incorporated into an NKPC by Roberts (1997). In addition, the expectations-formation mechanism may depend on point of view, i.e., on which economic agent is forming the expectations.

AM provide two estimates of the inflation target that capture views of different economic agents. Their moving endpoints (MEP) measure provides an estimate of the market view of the inflation target, while their staff economic projection (SEP) measure might be taken as providing an estimate of the Bank of Canada view of the inflation target. The importance of viewpoint is highlighted by examining the differences between these measures. In particular, *the gap between the MEP and SEP estimates of the inflation target suggests that monetary policy was not fully credible prior to the institution of inflation targeting by the Bank of Canada*, and provides a historical justification for explicitly modelling learning behaviour.

Short-horizon learning is absent in the models of both AM and BB. This is a potential weakness of their analyses. Milani (2005) suggests that persistence in US inflation is mainly from the expectations-formation mechanism and learning. That said, Canadian inflation has recently been much less

persistent than US inflation, suggesting possibly that the benefits to modelling short-horizon learning may not be as large for understanding the dynamics of Canadian inflation.

1.5 Shocks

Economists appeal to stories of persistent shocks when all else fails to explain inflation peristence or when they are unwilling to consider some of the explanations offered above. Within a structural model, however, justification of persistent shocks is no less ad hoc than stories motivating inclusion of lagged inflation-gap terms.

2 Superneutrality in the NKPC

A longstanding question, or perhaps belief, in macroeconomics is superneutrality. Here, it translates into the question of whether or not the NKPC is vertical in the long run. In other words, does real marginal cost have a permanent effect on the level of inflation?

In the context of the NKPC, I believe the answer to this question is no. In my view, the NKPC embeds superneutrality by construction. However, incorrect empirical implementations may lead one to conclude that the NKPC does admit a permanent trade-off between inflation and real marginal cost.

Often, researchers empirically test superneutrality by examining whether the sum of coefficients on lags and leads of inflation equals one. In a model that includes explicit or implicit steady-state inflation, this simplistic approach is flawed. In particular, because the log-linearized NKPC is a model of the deviation of inflation from its steady state, if the steady state moves with market expectations of the target, as in Kozicki and Tinsley (2005), superneutrality does not require that the sum of coefficients on leads and lags of inflation equals one. More generally, *superneutrality requires that the sum of coefficients on steady-state inflation, leads of inflation, and lags of inflation equals one*. Consequently, excluding the coefficients on steady-state inflation and examining only the sum of coefficients on leads and lags of inflation isn't particularly informative.

In the case of non-stationary inflation, exclusion of a measure of steady-state inflation may predispose tests of superneutrality to not reject that the sum of coefficients on leads and lags of inflation equals one. I believe that if inflation is non-stationary, then steady-state inflation is also non-stationary and the two should be cointegrated. If steady-state inflation isn't explicitly included in empirical implementations of the NKPC specification, as in BB, then estimates of coefficients on the sum of coefficients on leads and lags of

inflation will be biased towards one in order to balance the integration properties of the left- and right-hand-side variables. Thus, having a sum of coefficients close to one doesn't provide evidence on superneutrality.

3 Empirical Regularities

Our understanding of the dynamics of Canadian inflation is increasing. Despite the use of a variety of empirical techniques and different measures of key macroeconomic variables, the two papers in this session and other recent studies of Canadian inflation agree on key properties of Canadian inflation.

First, over a relatively long history, inflation appears non-stationary. This suggests that steady-state Canadian inflation hasn't been constant. Consequently, explicitly accounting for time-varying steady-state inflation in NKPCs is important. This session's papers use different approaches in dealing with this source of non-stationarity. AM use a two-step estimation approach, where a time-varying steady-state inflation rate is estimated in a first step, and deviations of inflation from this steady state are used in the NKPC specification estimated in the second step. BB use a one-step estimation approach with techniques appropriate for non-stationary data.

A second regularity in empirical studies of Canadian inflation is that both forward- and backward-looking terms appear to be important. Furthermore, point estimates suggest that more weight is placed on forward-looking terms. The weight on forward-looking terms is about 0.7, with that on backward-looking terms close to 0.3.

4 Empirical Irregularities

Although general agreement on some properties of Canadian inflation is relatively widespread, empirical results in other dimensions are less consistent. These differences are related to the estimate of the coefficient on real marginal cost (or an alternative driving variable used in its place) and are sizable. Using data from 1980 through 2004, AM estimate the coefficient to be 0.008. These results are similar to those obtained by Guay, Luger, and Zhu (2003) and Nason and Smith (2005). Estimates obtained by BB were considerably larger, however, and equalled 0.165 for data from 1973 through 1990 and 0.415 for data from 1991 through 2003. The latter were close to results obtained by Kozicki and Tinsley (2003)—although they used a measure of the output gap rather than real marginal cost in their variants of the NKPC.

Differences in the measurement of real marginal cost might explain these drastic differences in empirical results. On one hand, because the BB measure of real marginal cost was on a considerably smaller scale than that of AM, the BB coefficient estimate should be expected to be larger than that of AM. On the other hand, although AM and BB used somewhat different measures of inflation and real marginal cost, the two sets of data were highly correlated. The correlation between the two inflation series was 0.76 and the correlation between the two measures of real marginal cost was 0.73.

Overall, combined with the previously mentioned puzzle of the relative persistence of real marginal cost and inflation, these results suggest that the measurement of real marginal cost has not yet been fully resolved.

5 The Structural Model and Deep Structural Parameters

Up to this point, my comments on economic dynamics in the NKPC apply to a model specification that is only partially structural—in the sense that, as noted by BB, a multitude of models leads to the same general form of the NKPC. While notable regularities have been obtained in estimating such "partially structural" specifications, important questions remain about the values of "deep structural parameters" and the underlying structural model.

Estimation of deep structural parameters is typically contingent on two types of assumptions. First, estimates are necessarily conditioned on a specific model. Second, lack of identification of parameters and/or insufficient information in available data (that would lead to very imprecise estimates) often leads researchers to calibrate a subset of the deep structural parameters.

Because estimates of deep structural parameters generally don't incorporate model uncertainty or imprecision associated with calibrated parameters, true standard errors of these estimates are generally larger than reported. For instance, AM report that the average duration between price changes is 2.6 quarters, with a 90 per cent confidence interval of 2 to 4 quarters. However, these estimates are conditional on several assumptions, including assumptions that the demand elasticity is 11 and that real rigidities stemming from the assumption of firm-specific capital make inflation more than 20 times less sensitive to movements in real marginal cost than a model that assumes a rental market for capital. If the demand elasticity were to be decreased to 5, 2.67, or 0, average duration would increase to 3.9, 6.3, and 10.6 quarters, respectively. The latter two durations lie well outside the 90 per cent confidence band reported by AM, even though a demand elasticity of 2.67 is within a range of plausible empirical estimates. Clearly, by not accounting for uncertainty in the calibrated deep parameters, true

confidence bands are probably considerably larger than those reported in AM.

I am concerned that modifications to the standard NKPC and calibrations are often chosen so that sensible estimates of one or more deep structural parameters are obtained. The starting point is a model of pricing decisions by optimizing firms that links inflation to real marginal cost. A complication encountered by AM and others is that when a basic version of the model is taken to the data, the coefficient on real marginal cost is tiny and the implied average duration between price reoptimizations is implausibly large. By adjusting the model to account for firm-specific capital and making a judicious choice of the demand-elasticity parameter, the lack of a relationship between real marginal cost and inflation can be used to estimate a plausible average duration, as in AM.

Perhaps it would be useful to take a step back and look more broadly at the issue and evidence. Does it make sense to use the lack of an empirical relationship between real marginal cost and inflation to estimate structural parameters of a model that asserts a relationship between real marginal cost and inflation? Given the different persistence properties of real marginal cost and inflation, the lack of an empirical relationship between them shouldn't be surprising. The model adjustments in AM may help generate a plausible average duration, but they don't reconcile the persistence puzzle. Consequently, before additional modifications are made to the basic NKPC, I recommend that more time be spent investigating the measurement of the deviation of real marginal cost from its steady state.

Conclusion

Empirical regularities in the papers of this session provide useful insight for policy-makers. In particular, prior to the introduction of inflation targeting, monetary policy in Canada appeared to have suffered from imperfect credibility. This lack of policy credibility and a possibly shifting implicit inflation target likely contributed to higher degrees of inflation persistence historically. However, empirical results also suggest that inflation persistence can be (and has been) reduced by monetary policy that provides a credible constant inflation target. Nevertheless, even over samples where the focus of policy was on a fixed constant and policy actions appear to have been credible, other sources of persistence remain.

I wish I could conclude by claiming that we finally have a good structural model of inflation dynamics, including good estimates of deep structural parameters. At this point, however, I believe that more investigation is needed into data-measurement issues—particularly the measurement of real

marginal cost and its steady state. While we are closer to understanding and explaining inflation dynamics, important questions remain.

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