Annex 1
IFT at the Czech National Bank

1.1 Background

The Czech National Bank (CNB) provides an outstanding example of the deployment of IFT. In the early 2000s the CNB invested considerable resources to set up a structured Forecasting and Policy Analysis System (FPAS), with a quarterly projection model (QPM).[1] QPM incorporates partly forward-looking expectations in the transmission mechanism, and provides a coherent medium-term perspective, as well as consistency for the projection. The introduction of the FPAS shifted the emphasis of CNB policy analysis from data collection and description, to information extraction, and more structured debate about risks and policy strategy. The ability of the FPAS to produce timely alternative scenarios was a major asset in this development. The FPAS also led to improved internal communication between policymakers and staff, and across staff divisions. Systematic documentation has made the production of the staff forecast more transparent, and has allowed for ex-post evaluations, and decompositions of changes to forecasts, which help improve the process. The CNB describes the role of the staff forecast very clearly: "The forecast is the key, but not the only, input to the Bank Board's decision-making." Despite this disclaimer, the CNB has been able to use the forecast to tell a logical and coherent story, in terms of the effect on inflation and output of its policy decisions.

The CNB started publishing the projected interest rate path (with confidence intervals) in 2008Q1. In doing so, the bank underlined:

- its hope that the enhanced transparency would help the public better understand monetary policy actions, and thereby increase confidence in its ability to keep inflation near to target;
- the conditional nature of the interest rate forecast;
- the possibility that the policymakers might not entirely agree with the staff forecast.

A critical element in the success of this approach is that the framework that the policymakers and the staff use for analysis is known to, and understood by, the financial markets. The Czech experience illustrates that it is not necessary for effective IFT that the central bank present a single official forecast on which all policymakers and staff are supposed to agree.

[1] See Laxton, Rose and Scott (2009) for more discussion of designing an FPAS to support an IFT regime. Coats (2000) and Coats, Laxton and Rose (2003), describe the development of the FPAS at the CNB, a project that received technical assistance from the IMF.

1.2 Exchange rate policy as an extraordinary policy instrument: An event study[2]

In 2012, the Czech economy was mired in recession, because of a slowdown in the euro zone and domestic fiscal consolidation. While headline inflation rose above the target of 2 percent, it was expected to fall below target at the start of 2013, in view of the output gap and the fact that core inflation was already negative. The CNB reduced the policy rate to 0.05 percent—in effect, the zero interest floor (ZIF)—in November 2012.[3] Yet the outlook remained weak, and deflation risks were rising. Additional stimulus was appropriate, and the exchange rate looked like a more promising avenue than the main unconventional techniques that had been used in larger economies, i.e., forward guidance (FG) and quantitative easing (QE).

In November 2013, the CNB announced that it: "… will intervene on the foreign exchange market to weaken the koruna so that the exchange rate of the koruna against the euro is close to 27 CZK."[4] The koruna moved from 25.8 to the euro just before the announcement to almost 27 immediately afterwards, ending the day at almost exactly 27. The CNB did not need to intervene for long to move the rate to the desired floor—it bought foreign exchange on just two days. Yet since November 2013, the rate has remained higher than 27. Effective communications by the CNB were the key. These included the CNB's warning that it had virtually unlimited capacity to buy foreign exchange, if this were to prove necessary—the central bank can manufacture its own currency without limit. Moreover, the CNB noted that since under the prevailing circumstances the intervention would not be sterilized (the related expansion of the monetary base would be welcome), there would be no interest cost to the authorities.

In other communications measures, the CNB put detailed answers to questions about its foreign exchange policy on its web site; and included an explanatory box, "Using the exchange rate as an instrument to ease the monetary conditions" in the 2013Q4 Inflation Report. A forecast exercise reported in this box showed the (unfeasible) negative policy interest rate that would be needed to get inflation up to 2 percent in the absence of exchange rate intervention. In an alternative scenario, with policy keeping the exchange rate above 27 CZK/EUR, the inflation objective is achieved with a non-negative policy rate. A box in the subsequent (2014Q1) Inflation Report explained that in the small, open economy, exchange

---

[2] This section draws heavily on Alichi and others (2015).

[3] At the time this paper was prepared, the policy rate was still expected to remain at the ZIF at least to end-2015, given the economic weakness.

[4] In the subsequent Q&A, the CNB clarified that the intervention was one sided: "What does the CNB's exchange rate commitment mean for the future evolution of the koruna exchange rate? This means the CNB has undertaken to prevent excessive appreciation of the koruna below 27 CZK/EUR. On the stronger side of the 27 CZK/EUR level, the CNB is preventing the koruna from appreciating further by intervening on the foreign exchange market, i.e., by selling koruna and buying euro. On the weaker side of the 27 CZK/EUR level, the CNB is allowing the koruna exchange rate to float. In other words, the exchange rate will be close to CZK 27 to the euro or even weaker in the period ahead. Potential fluctuations to levels weaker than 27 CZK/EUR will be determined by supply and demand on the interbank foreign exchange market."

rate movements have fairly powerful and relatively reliable effects on aggregate demand and inflation (e.g., approximately 24 percent of the CPI is imported).[5]

A crucial aspect of the policy was the CNB's advice that the announced exchange rate floor could be changed over time as needed in response to new information about inflation and output. Financial market participants understood that monetary policy was not seeking to fix the exchange rate, but to boost economic activity and increase inflation and reduce the risks of bad deflationary outcomes. As demand remained weak in the first half of 2014, the CNB advised that the exit date for the floor CZK/EUR rate might be extended, and then, in mid-year, with inflation near zero, warned that the floor might be raised. In line with monetary policy objectives, the currency weakened further. Inflation expectations behaved exactly as hoped. Between September 2013 and April 2014 the Consensus Economics CPI inflation rate forecast for 2015 rose, by almost 50 basis points, to 2.2 percent (Table 1.1).[6] Long-term inflation expectations remained solidly on target. The expected overshoot in the consensus forecast was in line with the CNB's forecast.

Table 1.1 Consensus Economics Forecast of CPI Inflation in the Czech Republic

CPI Inflation Expectations (annual; percent)				
	2014	2015	2016	Long-term Target
September 2013 Survey	1.6	1.8	2.0	2.0
April 2014 Survey	1.2	2.2	2.0	2.0
Change (pps)	-0.4	0.4	0.0	0.0

Source: Consensus Economics

In April 2015 consensus of long-term forecasts, just after the collapse of the world oil price, the forecast of CPI inflation in the Czech Republic for 2015 fell considerably, but it showed a rebound to 1.7 percent for 2016 and 1.9 percent for later years (Table 1.2). The changes in expected inflation have thus apparently been exactly in line with the Czech monetary objectives. Other macroeconomic data, e.g., on industrial production, wages, confirm an adequate recovery of demand. The CNB decided that a further raising of the exchange rate

[5] Reduced-form econometric estimates of pass-through are admittedly not very reliable as the shocks driving the exchange rate, and the response of monetary policy, vary. However, a depreciation resulting from a deliberate monetary policy action, with the announced intention of raising the price level, would likely have a much stronger pass-through than one that reflected an external financial disturbance, with the central bank raising its policy interest rate so as to keep inflation on target.

floor was not needed. The exchange rate depreciation that did take place effectively alleviated the unwanted disinflationary pressures.

Table 1.2 also indicates that longer-term inflation expectations in the Czech Republic are close to the 2 percent target. In Japan and the Euro Area, however, longer-term expectations seem to be stuck at about 1 ½ percent.

Table 1.2. Consensus CPI Inflation Expectations

CPI Inflation Expectations and Deviations from Objectives in Parenthesis						
	Objective	2016	2017	2018	Cumulative Deviations from Inflation Objectives	IFT CB /1
Canada	2.0	2.1 (0.1)	2.1 (0.1)	2.0 (0.0)	0.2	Yes (1994)
Czech Republic	2.0	1.7 (-0.3)	1.9 (-0.1)	1.9 (-0.1)	-0.5	Yes (2002)
United States /2	2.3	2.2 (-0.1)	2.3 (0.0)	2.3 (0.0)	-0.1	Yes (2012)
Euro Area	2.0	1.2 (-0.8)	1.5 (-0.5)	1.7 (-0.3)	-1.6	No
Japan /3	2.0	1.0 (-1.0)	2.0 (0.0)	1.4 (-0.6)	-1.6	No

Source: Consensus Economics Quarterly Survey (April 2015).
1/ IFT CBs use consistent macro forecasts to explain how they are adjusting their instruments to achieve their output-inflation objectives.
2/ The implicit CPI inflation objective for the U.S. is estimated by the authors at about 0.3 percentage points above the Fed's official PCE inflation objective of 2.0 percent. This is based on the difference in long-term CPI and PCE inflation forecasts from Philadelphia Fed's Survey of Professional Forecasters.
3/ Annual CPI expectations for Japan are heavily affected by the VAT.

ANNEX 2
POLICY CREDIBILITY: EXCHANGE RATE AND ASSET PRICES AS SHOCK ABSORBERS OR AMPLIFIERS

2.1 The risk-adjusted uncovered interest parity (UIP) condition

This condition, under perfect foresight, may be written as

$$i_t - (i_t^f + \delta_t) = s_{t+1} - s_t ,$$

where i_t is domestic interest rate, i_t^f is foreign interest rate, δ_t is domestic risk premium, s_t is nominal price of foreign exchange. That is, the expected future change in the exchange rate compensates for any interest differential, such that the return adjusted for change in the exchange rate and the risk premium is the same in either currency.

One period ahead we have

$$i_{t+1} - (i_{t+1}^f + \delta_{t+1}) = s_{t+2} - s_{t+1} .$$

Going forward we have

$$i_{t+2} - (i_{t+2}^f + \delta_{t+2}) = s_{t+3} - s_{t+2} ,$$

$$\dots$$

such that this holds for any time t:

$$i_{t+k} - (i_{t+k}^f + \delta_{t+k}) = s_{t+k+1} - s_{t+k} .$$

Summing up all the equations, from time t to $t+k$, yields

$$i_t + i_{t+2} ... + i_{t+k} - (i_t^f + \delta_t) - ... - (i_{t+k}^f + \delta_{t+k}) = (s_{t+1} - s_t) + (s_{t+2} - s_{t+1}) + ... + (s_{t+k+1} - s_{t+k}) ,$$

or equivalently,

$$\sum_{j=0}^{k} i_{t+j} - \sum_{j=0}^{k} (i_{t+j}^f + \delta_{t+j}) = s_{t+k+1} - s_t .$$

Rearranging the terms, we get

$$\sum_{j=0}^{k} i_{t+j} = s_{t+k+1} - s_t + \sum_{j=0}^{k} (i_{t+j}^f + \delta_{t+j}) .$$

The same equation holds in real terms,

$$\sum_{j=0}^{k} r_{t+j} = z_{t+k+1} - z_t + \sum_{j=0}^{k} (r_{t+j}^f + \delta_{t+j}) ,$$

where r_t is the real interest rate, and z_t is the real exchange rate defined as

$$z_t = s_t + p_t^f - p_t .$$

2.2 Real exchange rate as shock absorber

Under normal times with active policy, a negative demand shock reduces inflation in the short run, but does not affect the long-run real exchange rate (z_{t+k+1}). An IFT central bank is expected in normal times to reduce the policy rate sufficiently to steer inflation back to target. This expectation would, through the UIP condition, lead to an immediate depreciation of the currency: the spot price of foreign exchange has to rise to the point that the expected decrease from then on compensates for the lower domestic interest rate.

Under a credible regime of aggressive policy responses, the expected medium-term inflation rate would also increase.[7] The decline in real interest rates would thus be greater than that in nominal rates. At the ZIF, the current nominal interest rate cannot go any lower, but under the aggressive regime people would expect that the future nominal interest rate would be at zero for longer, and because of the anticipated increase in inflation, real interest rates would decline. Thus in both normal times, and during when the ZIF is binding, we have ($\downarrow \sum_{j=0}^{k} r_{t+j}$).

Given that the long-run real exchange rate (z_{t+k+1}) and expected paths for foreign real interest rates $\sum_{j=0}^{k}(r_{t+j}^{f} + \delta_{t+j})$ do not change, this would result in a real depreciation ($\uparrow z_t$),

$$\downarrow \sum_{j=0}^{k} r_{t+j} = z_{t+k+1} - \uparrow z_t + \sum_{j=0}^{k}(r_{t+j}^{f} + \delta_{t+j}).$$

This helps support demand, through both exports and domestic expenditure switching (from foreign goods to domestic goods). Moreover, the longer the period for which monetary policy will hold the real interest rate below the neutral rate (i.e., the greater is k), the greater would be the jump in z_t, and hence the greater the monetary stimulus.

2.3 Real exchange rate as shock amplifier

At the ZIF, the exchange rate can act as a shock amplifier. If policy is passive, and not credible, following a negative demand shock people would expect the inflation rate in the future to be lower. Current and future short-term real interest rates could increase ($\uparrow \sum_{j=0}^{k} r_{t+j}$), resulting in a real appreciation ($\downarrow z_t$):

---

[7] A regime that targets the path of the price level would systematically produce this kind of response (Svensson, 1997).

$$\uparrow \sum_{j=0}^{k} r_{t+j} = z_{t+k+1} - \downarrow z_t + \sum_{j=0}^{k} (r_{t+j}^{f} + \delta_{t+j}) .$$

This would reduce net exports and further deepen the recession.

2.4 Asset prices as shock absorber or amplifier

A similar argument holds for asset prices as for the exchange rate. A credible aggressive policy response would cause increases in asset prices (through the positive impact on profits of the currency depreciation, and the effect of lower real discount rate on asset valuations). A non-credible, passive response would do the reverse. Thus depending on the policy regime, asset prices too may act as a buffer or an amplifier for the impact of shocks.

ANNEX 3
DEVELOPING A FORECASTING AND POLICY ANALYSIS SYSTEM[8]

3.1 The need for an FPAS

IT has brought about a considerable change in the orientation and process of research within central banks, giving a strong sense of direction to the work of staff economists, not just those working on the forecast, as well as to that of policymakers. The drive to increased transparency has strengthened this research orientation, as central banks have needed to call on evidence-based research to provide the rationale for their actions to a public that has been increasingly well informed on economic matters. There has been an internal payoff, in that staff economists have a clearer vision of how their work contributes to the formulation of monetary policy, and, looking forward, of how their contribution to this end might be made more effective.

In some central banks, the staff is expected to come up with a recommendation for the policy rate. In others, they simply provide analysis leading up to the making of the decision by the policymakers. In both cases, the input of the staff is simply to provide policymakers with a starting point for their deliberations. Nonetheless, it has turned out to be a very important input, one that allows policymakers to better understand in what ways their views differ from each other, and from the staff, and the sources and implications of those differences. The option of publishing the interest rate path further concentrates the minds of staff as well as policymakers on the main strategic task of policy formulation, which is to come up not only with the analysis to support the interest rate decision for the next MPC meeting and/or an interest rate proposal for the next MPC decision, but also with a view of how this decision fits in with a plan to return inflation to the long-run target path—i.e. a medium-term path for the policy rate.

In view of the increased demands on the analytical resources of the central bank, implementation of IFT is greatly facilitated by the development of a structured FPAS.

3.2 Essential FPAS components

Projection Team (PT). Its two main responsibilities are to ensure that the forecast is internally consistent, and based on the most recent data for key variables. PT output can be separated into two types: near-term forecasts (current and next quarter), and medium-term forecasts with alternative scenarios to highlight risks. We distinguish between the near term and medium term for two reasons. First, much of what determines near-term outcomes is often quite idiosyncratic, and therefore difficult to handle in a model designed to capture

[8]This section draws on Laxton, Rose and Scott (2009), which provides a thorough discussion of the topic.

business cycle dynamics. Expert staff using a wide range of detailed information (qualitative as well as quantitative) have a strong comparative advantage over a macroeconomic model in forecasting the near term. Second, expert assessment of current pressures in the economy helps improve the medium-term forecast, because macroeconomic developments tend to show a degree of persistence. Good near-term forecasts are usually almost completely judgmental.[9] The model takes over to help provide medium-term (and if necessary long-term) consistency, although even in the medium-term forecast staff judgment continues to play an important role. While a division of labor is necessary for efficiency, members of the staff should be aware of their responsibility for the forecast as a whole. An essential part of this is providing feedback, as required, to ensure that the forecast process and scenarios are internally consistent.

Historical and Near-Term Forecasting (HNTF) database. It should include the key macroeconomic variables, and extra detail, as the empirical basis for assessing and forecasting trends in the real economy and inflation. The database should be updated weekly and should be accessible to all staff.[10] The updating triggers ongoing filtering of new information, as analysts account for how and why a new outturn affects their view of the state of the economy. This involves discussions of data problems, special factors, and the technical issues of extracting trends from data. The output is information that can be used in formal reports to management and the public. These discussions may also lead to the recognition of *stylized facts*—simple quantitative relationships (e.g., ratios) that seem to be stable enough to shed light on how the economy works, and that a formal macro model should be able to mimic. In some central banks, the HNTF database serves as the foundation for an automated weekly reporting system, with standardized table and charts. This ensures that new information is assessed systematically, and keeps the MPC abreast of developments. The report would provide the basis for discussing risks associated with the last official forecast and other more recent monitoring. Indeed, within hours of a database update, the Projection Coordinator (PC, an economist at senior management level) could chair a short meeting with the PT and other staff on possible revisions to the near-term outlook.

Weekly update meeting with the MPC. The PC and other senior management would attend a meeting on the latest data once a week in normal times. The PC would highlight the aspects of recent data and anecdotal evidence that may affect the near-term outlook.[11] Given the

---

[9] Of course, various statistical methods for near-term forecasting can make an important contribution to the near-term forecast. Nonetheless, at the end of the day it is necessary for the professional economists to have a structured story behind the near-term forecast and not to allow it to become a black box.

[10] All the weekly database should be stored permanently so that they can be analyzed periodically. This allows economists to measure the extent of data revisions. Such knowledge is helpful in gauging uncertainty in the near-term forecast, and may indicate areas where data improvement would have a particularly large payoff.

[11] Weekly briefings to the MPC are common. In emerging market economies, the MPC may have to deal with frequent confidence shocks and large swings in asset prices and capital flows. For this reason, we favor weekly reports to the MPC in these countries, as much of the relevant information will be informal in nature and the

(continued…)

heavy volume of data that is released, the PC has to be selective. There is always a risk that weekly meetings will focus on the noise rather than the underlying trends. However, short weekly meetings can be used to dispose of most of the short-term data questions. Less frequent meetings are likely to be longer and less focused on such questions. It is very important that the decision meetings of the MPC are not cluttered with questions about the latest wiggles in the numbers.

Documentation. To develop and retain institutional knowledge, staff should document as much as possible in writing. Such documents provide an invaluable resource for new staff as they attempt to learn new tasks or improve on existing ones. The repository system should be simple and the notes should be accessible to all staff.

Core model. This provides macroeconomic consistency in the projection. It is essential that the model's properties broadly reflect the views of the MPC. In the early stages of an IFT regime, it will likely be easier to achieve this consensus with a small model, which may be elaborated over time. It is much better that a simple model be introduced as soon as possible, rather than aiming to introduce a complex model in one, long step. Even in the longer term, carefully considered analysis with a simple model will prove to be far superior to badly coordinated and under-resourced analysis with a complex model. MPC questions about individual sectors of the economy, or components of the macroeconomic forecast, can often be handled with satellite models that do not complicate the dynamics of the core model.

Model-based risk analysis. A key role for the model is for assessing risks to the baseline forecast. In every forecast there will be things that could change the outlook and policy response. The forecasting model is routinely used to compute confidence levels around the baseline (often shown as bands in MPR charts). This serves to remind everyone that forecasts are not exact, and that policy decisions should not be swayed by small errors.The model would be used to illustrate specific unusual risks to the baseline forecast, which would often involve disturbance outside the range of variation covered by confidence intervals. These alternative scenarios serve to warn market participants in advance about how monetary conditions might need to change in response to new information. By highlighting the risks and uncertainties surrounding the forecast, the institution will find it easier to communicate these points to observers and to deal with the effects of larger shocks as they arise.

Model-derived policy options. A wide variety of interest rate paths are generally consistent with achieving the long-run target for the rate of inflation within a medium-term horizon. In some situations, e.g., where the exchange rate seems particularly vulnerable, or where there are heightened risks of financial instability, the MPC might need to see one or more

---

MPC will need to feel well informed about potentially fast-changing circumstances. For those central banks where policymakers do not or cannot meet weekly, the information can be passed on via electronic means.

alternatives to the baseline short-term interest rate path. For example, one alternative might show a smooth change in the policy rate, while another might show overshooting in the rate.

3.3 Quarterly projection exercise

The exercise should be completely open and transparent to all staff involved. This can be facilitated by a series of meetings, supported by documents circulated beforehand and afterwards.[12] The process begins with a circulation of a calendar for key meetings. The schedule might begin as follows:

- a *main issues meeting*, with the PC and FPAS staff, discusses likely main issues for the forecast, based on written submissions;
- a *post-national accounts meeting* shortly after the release of the accounts, again with the PC and FPAS staff, assesses data quality and background information on special factors in the data; a short write-up summarizes the discussion;
- *near-term forecast meeting* with the MPC receives an update from the PC, and a presentation on the implications of the new information to the MPC.[13]

This last meeting discusses risks to the near-term forecast, and any related risks for the medium-term forecast. The MPC must understand the staff's judgment and will make suggestions for possible changes to the assumptions that will determine the near-term aspect of the forecast. There then follows a series of forecast rounds, as it takes several iterations to iron out inconsistencies in the initial assumptions scenario, and to build a consensus about the main emerging pressures on the economy. The first round serves to build on the near-term forecast and other information, for example revisions to estimates for potential output, to create a preliminary medium-term scenario. This cannot be expected to be fully consistent—that will be ensured by subsequent rounds. Brief meetings of staff follow each round, summarized in notes to make sure that everybody knows the exact assumptions to be used in the next round. It would normally take 3 or 4 rounds (i.e., up to 4 weeks of time) to get a convergent forecast.

After the final round, the PT writes a concise forecast report to be presented to the MPC just prior to the decision meeting. It explains the assumptions, and presents the forecast with a clear story line, and reader-friendly charts.[14] Where model revisions make a difference, these should be mentioned. But the focus should be on the medium-term picture.

The highlight day in the exercise cycle for the FPAS staff is the meeting with the MPC that

---

[12] See Laxton, Rose and Scott (2009) for a detailed account.

[13] The intent here is to make near-term forecasts only for those variables that can be assumed to be unresponsive to changes in monetary conditions. Variables such as interest rates and exchange rates should be allowed to adjust in response to changes in the official short-term policy rate.

[14] There should be a standard package of tables and charts. Staff may choose to add special charts or tables to illustrate a particular point.

takes place before the policy rate decision meeting.[15] A staff member presents the forecast briefly, at a high level, and focuses on the main story line, using visual aids drawn from the forecast write-up. The presentation goes more smoothly when made by one person; specialists can later amplify certain points, or reply to MPC questions. What is desired is a coherent, systematic analysis, starting from external conditions and moving to the outlook for the domestic economy and the implications for policy. It is especially important to highlight what has changed in the facts, or in the judgments of the staff, since the last MPC decision meeting. The presentation should conclude with a discussion of risks.

At central banks where staff own the forecast, production ends with the presentation to the MPC. The forecast paths published in the MPR would be set. If, however, the forecast is to be published as an official central bank forecast, the MPC might, after the presentation and discussion, ask for some changes.

A post-mortem meeting discusses what went well, and what needs to be done to improve the process. The issues discussed could range in complexity from changes in procedures or model structure or the database, to larger issues such as the development of the next generation of models designed to support IFT. The write-up of this meeting should include agreed concrete recommendation for improvements.

3.4 More on models

A core model for inflation-forecast targeting has to embody macroeconomic properties that make sense to the policymakers. This argues for a simple model, at least at the beginning, calibrated to produce plausible results in simulations of shocks or alternative policy rules.[16] A key requirement is a monetary transmission mechanism that has empirical support. For IFT, the model would incorporate forward-looking expectations.

To start with, a *gaps model* centered on 4 equations may be good enough. These equations explain the deviations from the long-run equilibrium values (set by exogenous long-term trends) for real GDP, inflation, market-determined interest rates and the exchange rate. (A closed-economy version, such as the one we present below in Annex 4, has just 3 equations, since the model has no exchange rate.) The use of such a model has helped to initiate dialogue between the staff and the MPC about issues like the appropriate policy response to the inflation forecast, the implications of various assumptions and alternative scenarios, and the risks to any proposed policy decision.

---

[15] Before decision meetings that fall between quarterly forecasts, the PT would provide the MPC with a quick update based on new data and the previous complete forecast.

[16] Equation by equation econometric estimation is unlikely to yield a system with plausible simulation properties. The modern approach to monetary policy modeling uses calibration to set parameter values.

Some additional features can be easily incorporated within the gaps model, e.g., the role of oil or commodity prices in the inflation process, or a labor market.[17] However, additional detail on other variables, e.g., components of the national accounts, is generally best provided through satellite models that do not add complications to the core model dynamics. Other small models, often single equations tailored to specific purposes, may provide inputs to the forecast or provide consistency checks. The benefit of maintaining a suite of ancillary models is that the core model, which provides the general overview of the economy, can be kept simple and transparent.

Monitoring and near-term forecasting models capture short-run trends. The basic premise is that real and nominal rigidities in the economy give short-run trends a certain momentum, which helps us forecast the near term. The models used for capturing these aspects of the data will typically be small, time-series models—often univariate—that are easy to estimate and maintain. While they may provide insight into the near term, lacking any structure they provide no insight about the reaction of the economy to imbalances or to economic policies.

Given a picture of likely short-run trends, we need to form a view on what this implies for the state of the economy. Signal extraction models provide insight as to how the current cycle compares with a typical business cycle, and on the extent to which a current trend may become permanent (which we might associate with supply), or mean-reverting component (which we could think of as a cyclical demand effect). Because an important objective should be to impose consistency in the projection scenarios, the methodology for computing the technical measure of the output gap should be consistent with the underlying structure of the core model.[18]

Under IFT the output gap is a summary statistic to help communicate how the central bank is managing the short-term output inflation trade-off. Ideally it is an index incorporating all information about the pressure of demand. For example, the Bank of Canada combines a technical measure of the output gap with other indicators of pressures on capacity in the economy and also incorporates the views of the policymakers in order to arrive at a final judgment on the estimated measure of the output gap, which it discusses in its MPR. The other indicators include employment, capacity utilization, labor shortages, average hours worked and average hourly earnings, money and credit growth, and inflation relative to expectations. The Bank also gathers information from its Business Outlook Survey on capacity utilization, labour shortages, and inflation expectations. All these measures are published on its website in tables that are updated one day after the Bank's most recent

---

[17] See, for example, Berg, Karam and Laxton (2006a, b).

[18] Such measures are much more efficient for forecasting than the measures derived by univariate models that ignore the links between inflation and the economy. Moreover, they will result in more robust policy analysis. See Laxton and N'Diaye (2002). Blagrave and others (2015) provides a simple multivariate filter for estimating potential output that is more robust than naive statistical filters.

announcement date for the target overnight rate, and are based on information available up to that date.

Some of the more technically advanced IFT central banks have shifted to a dynamic general equilibrium model as the core forecasting vehicle (e.g., the Bank of Canada, and the Czech National Bank). This is a far from trivial move. It requires highly specialized human capital, powerful computers and solution software, and large demands on data sources. As an intermediate step, the equations of the gaps model could be adjusted to bring in additional features. As an example, for economies undergoing large fiscal adjustment, a composite indicator of fiscal stance could be added to the output gap equation.[19]

3.5 Other aspects of the FPAS

Information technology. The importance of information technology is easily overlooked when thinking about developing the system. Yet, automating tasks has the benefit of reducing the room for human error, and it is essential for the reporting system. Effective information technology also has the benefit of allowing staff more time to think about the issues, rather than the details of data-processing and reports. Staff should have direct access to information technology experts who can facilitate the intense workflow and improve productivity.

Human capital. This poses challenging issues. The maintenance and improvement of the FPAS over time will depend on how well the central bank can develop and retain its internal human capital. Many of the skills necessary to operate an FPAS are highly specialized, and valuable in the private sector. In the early days of the system, it may be possible to use external consultants from other institutions with experience in the issues involved. Technical assistance from other central banks and the IMF has accelerated the development of expertise at many central banks. However in the end, an institution has to rely on its own resources. Rotation of staff, in and out of the PT from various divisions, is a good way to maintain a flexible work force, and cover for the current forecasting staff. It also reduces the risk of burnout, which is non-negligible given the demands and deadlines of the forecasting exercise.

An FPAS culture. This is hard to define precisely, since it involves a culture in which staff are connected to the process of informing policymakers, making a difference to policy, and credited for successful innovation and work. Management should encourage staff to use models to inform the actual conduct of monetary policy, with an understanding of their limitations. This can be important when questions from the MPC need to be qualified or reinterpreted in a way that makes sense in a model. In addition, when economists are well

[19] This is explained in some detail in Laxton, Rose and Scott (2009).

attuned to the requirements of policymakers, they are better placed to do model development and other research that helps policy and, over time, improves the quality of the FPAS.

ANNEX 4
THE MODEL

The closed-economy model used for simulations in the accompanying working paper is simple, but rich enough to study monetary policy issues.[20] This annex provides detail on the key equations and identities.

4.1 The IS curve

The first equation of the model is an aggregate demand function or output gap equation (IS curve).

$$y_t = \beta_1 * y_{t-1} + \beta_2 * y_{t+1} + \beta_3 * (lr_{t-1} - \overline{lr}_{t-1}) - \eta_t + \varepsilon_t^y$$
$$\beta_1 = 0.57; \beta_2 = 0.23; \beta_3 = -0.19$$

The output gap y_t (actual minus potential output) is a function of a one-period lag and a one-period lead of the output gap, the deviation of the lagged long-term real interest rate (lr_t) from its equilibrium value ($\overline{lr}_t$), and the bank lending conditions (η_t). The short-term real interest rate (r_t) is equal to the nominal federal funds rate (i_t) minus the annualized rate of the model-consistent forecast of inflation in core Personal Consumption Expenditures (PCE) over the next quarter (π_{t+1}).

$$r_t = i_t - \pi_{t+1}$$

The equilibrium short-term real interest rate is a weighted average of the steady-state level of the short-term real interest rate, the lagged equilibrium short-term real interest rate, and an error term.

$$\bar{r}_t = \rho * r^* + (1-\rho) * \bar{r}_{t-1} + \varepsilon_t^{\bar{r}}$$
$$\rho = 0.05$$

The long-term real interest rate is defined as a weighted average of the current and future short-term real interest rate. The weighting scheme is chosen to reflect the maturity structure of private sector credit, with the highest weights (0.35) at the medium-term (i.e. 1- and 3-year) maturities.

[20] Different versions of this model have been used in a number of papers. For example, Carabenciov and others (2008) contains a version for the United States alone, while Carabenciov and others (2013) uses an open-economy version, within the multi-country Global Projection Model.

$$lr_t = 0.1 * r_t + 0.35 * r4_t + 0.35 * (r4_t + r4_{t+4} + r4_{t+8})/3$$
$$+ 0.2 * (r4_t + r4_{t+4} + r4_{t+8} + r4_{t+12} + r4_{t+16})/5$$
$$r4_t = (r_t + r_{t+1} + r_{t+2} + r_{t+3}) / 4$$

In turn, the equilibrium long-term real interest rate is a weighted average (using the same weights) of the current, and a leading 4-quarter average, of the equilibrium short-term real interest rate.

$$\overline{lr}_t = 0.1 * \overline{r}_t + 0.35 * \overline{r}4_t + 0.35 * (\overline{r}4_t + \overline{r}4_{t+4} + \overline{r}4_{t+8})/3$$
$$+ 0.2 * (\overline{r}4_t + \overline{r}4_{t+4} + \overline{r}4_{t+8} + \overline{r}4_{t+12} + \overline{r}4_{t+16})/5$$
$$\overline{r}4_t = (\overline{r}_t + \overline{r}_{t+1} + \overline{r}_{t+2} + \overline{r}_{t+3}) / 4$$

The bank lending tightening variable (η_t), discussed in more detail below, reflects bank lending tightening conditions and thereby influences the output gap in the aggregate demand equation. It is constructed on the basis of the responses in Senior Loan Officer Survey of the Federal Reserve to the question of whether lending conditions have tightened or eased. Thus, an easing of bank lending tightening conditions, a reduction in BLT, would lead to an increase in aggregate demand and in the output gap.
Finally, an error term (ε_t^y) allows for shocks to the output gap—in practice these would be demand shocks.

4.2 Bank lending conditions

Banking lending conditions affect the output gap, but they are also affected by it. We assume that those responsible for bank lending look about a year ahead. They tighten or loosen credit on the basis of their expectations, which are conditional on the information set available today. During a cyclical upswing, with a positive output gap, lending conditions will ease. To separate out the effects of exogenous changes in bank lending conditions on the output gap, e.g., those resulting from a banking crisis, we model the deviations of the BLT from its equilibrium level as the sum of two parts, one that is proportional to future output gap (y_{t+4}) and another one which is a shock (ε_t^{BLT}). Changes that are greater or less than is typical in light of the expected economic situation are represented by:

$$BLT_t - \overline{BLT_t} = -\kappa_1 * y_{t+4} + \varepsilon_t^{BLT}$$
$$\kappa_1 = 20.1$$

In turn, the output gap is affected by a distributed lag of past ε_t^{BLT}, denoted by η_t, which takes the following form:

$$\eta_t = \theta_t * (0.04 * \varepsilon_{t-1}^{BLT} + 0.08 * \varepsilon_{t-2}^{BLT} + 0.12 * \varepsilon_{t-3}^{BLT} + 0.16 * \varepsilon_{t-4}^{BLT} + 0.20 * \varepsilon_{t-5}^{BLT}$$
$$+ 0.16 * \varepsilon_{t-6}^{BLT} + 0.12 * \varepsilon_{t-7}^{BLT} + 0.08 * \varepsilon_{t-8}^{BLT} + 0.04 * \varepsilon_{t-9}^{BLT})$$
$$\theta_t = 1.0708$$

This weighting (with a peak effect at the 5- and 6-quarter lags) is intended to reflect a pattern in which an increase in ε_t^{BLT} is expected to negatively affect spending by firms and households in a hump-shaped fashion, with an initial buildup and then a gradual rundown of the effects.[21] If lending conditions are easier than might have been anticipated on the basis of expectations of future economic behavior, the effect will be a larger output gap and a stronger economy, also in a hump-shaped fashion.[22]

4.3 The Phillips curve

The expectations-augmented Phillips curve is:

$$\pi_t = \lambda_1 * \pi 4_{t+4} + (1-\lambda_1) * \pi 4_{t-1} + \lambda_2 * y_{t-1} + \varepsilon_t^{\pi}$$
$$\lambda_1 = 0.70; \lambda_2 = 0.10$$

The core rate of inflation (π_t) is a function of the one quarter lag in year-on-year core inflation ($\pi 4_{t-1}$), and core inflation over the subsequent four quarters. Thus, there are both backward-looking and model-consistent forward-looking elements to expected inflation. The output gap term (y_{t-1}) embodies the short-term inflation-output trade-off. The error term (ε_t^{π}) can be interpreted as a supply shock.

Before turning to the determination of the policy interest rate, it is worth briefly tracing out the transmission mechanism from central bank policy rate actions to output and inflation. An increase in the policy interest rate leads to an increase in short-term real interest rates, which feeds into long-term real interest rates. The latter, with lags, reduces aggregate demand, via the output gap equation. The decrease in the output gap puts downward pressure on inflation over time.

4.4 Policy reaction

The model is closed with a policy reaction function for the federal funds rate. We experiment with three options.

---

[21] See Carabenciov and others (2008, 2013) for more discussion on the incorporation of the bank lending conditions into the Global Projection Model.

[22] This reduced form for the effects of financial conditions on the real economy captures insights from structural models, e.g., Benes, Kumhof and Laxton (2014a, b).

4.4.1 Inflation-forecast-based reaction function

The IFB reaction function has been used by a number of central banks (including the Bank of Canada and the Czech National Bank). The variant used in this study focuses on the forecast of year-on-year inflation three quarters in the future.

$$i_t = \gamma_1 * i_{t-1} + (1-\gamma_1) * [\bar{r}_t + \pi 4_{t+3} + \gamma_2 * (\pi 4_{t+3} - \pi^*) + \gamma_3 * y_t] + \varepsilon_t^i$$
$$\gamma_1 = 0.71; \gamma_2 = 0.91; \gamma_3 = 0.21$$

In this equation, among other things, the nominal federal funds rate (i_t) is a function of its own lagged value. This term has the effect of smoothing the federal funds rate, to reflect the fact that, in practice, central banks do not typically change the policy rate in large increments.[23] The policy rate responds to the equilibrium nominal interest rate, as measured by the sum of the equilibrium real interest rate ($\bar{r}_t$) and projected year-on-year core inflation ($\pi 4_{t+3}$). The cyclical response of the federal funds rate is driven by the forecast deviation of projected inflation from its target value (π^*), and by the output gap (y_t): these gap variables determine the policy response to deviations from the two targets of a dual mandate or flexible inflation targeting central bank. The projected year-on-year inflation rate is partly based on observed inflation (π_t) and partly on the model forecast of inflation ($\pi_{t+1}, \pi_{t+2}, \pi_{t+3}$). This formulation has the appropriate property that the real policy interest rate rises in response to an increase in inflation—with a short lag because of the smoothing feature in the adjustment of the nominal rate.

In contrast to the conventional Taylor rule, the IFB formulation ignores shocks to the system that are expected to reverse within the three-quarter policy horizon. More generally, the function allows the central bank to take account of all relevant information available to it on future developments over the three-quarter forecast horizon.

4.4.2 Taylor rule

The variant used in this paper is based on Taylor (1993).

$$i_t = \bar{r}_t + \pi 4_t + 0.5 * (\pi 4_t - \pi^*) + 0.5 * y_t + \varepsilon_t^i$$

The federal funds rate is a function of the equilibrium real interest rate ($\bar{r}_t$), the year-on-year core PCE inflation ($\pi 4_t$), the deviation of the inflation rate from the inflation objective (π^*),

[23] Woodford (2003) justifies interest rate smoothing by central banks as a way of keeping the policy signal clear. The markets would disregard as random noise the changes in a highly variable rate.

and the output gap (y_t). Deviations from the rule (e.g. policy experiments), are represented by ε_t^i .

4.4.3 Minimization of a loss function

The third approach involves minimizing a loss function that incorporates the principal objectives of the central bank in policy making. Given the loss function, the model ensures that the endogenous policy actions to bring inflation back to target over time, and close the output gap, are appropriate.

$$L_t = \sum_{i=0}^{\infty} [\alpha * (\pi 4_{t+i} - \pi^*)^2 + \beta * y_{t+i}^2 + \gamma * (i_{t+i} - i_{t+i-1})^2]$$

The quadratic formulation implies that errors or deviations are increasingly more important at the margin in the thinking of central banks. This is reasonable, because as policymakers are aware of the imprecise effects of their actions on the economy they ignore small errors. A useful monetary policy framework does, however, seek to avoid or mitigate major upheavals, e.g., recessions and deflation, or uncontrolled inflation.

The inclusion of both current and expected future values of output and inflation means that the central bank incorporates into its decision making any information currently available to it about likely developments over the next few quarters (including any effects of recent interest rate changes that may still be in the pipeline). The term with the squared change of the federal funds rate expresses policymakers' aversion to interest rate volatility, and gives the desired smoothness to the policy response.

We give the loss function two numerical calibrations. Each reflects the objectives of a dual-mandate central bank or, equivalently, a flexible inflation-targeting central bank. In the first calibration (DM1), there is equal weight (1.0) on the deviation of inflation from its target and the deviation of output from potential. In the second (DM2), the weight on the output gap is halved (to 0.5). Both calibrations have a weight of 0.5 on the squared variations of the nominal interest rate. In summary, the two sets of coefficients are:

DM1: Dual Mandate Central Bank (equal output and inflation weights)

$$[\alpha, \beta, \gamma] = [1.0, 1.0, 0.5]$$

DM2: Dual Mandate Central Bank (lower weight on output)

$$[\alpha, \beta, \gamma] = [1.0, 0.5, 0.5]$$

Table 4.1 Definitions

i_t	Federal funds rate (%)
r_t	Real interest rate (%) $r_t = i_t - \pi_{t+1}$
r^*	Steady-state level of real interest rate (%)
$\bar{r}_t$	Equilibrium real interest rate (%) $\bar{r}_t = 0.95 * \bar{r}_{t-1} + 0.05 * r^* + \varepsilon_t^{\bar{r}}$
$r4_t$	Four-quarter average real interest rate (%) $r4_t = (r_t + r_{t+1} + r_{t+2} + r_{t+3})/4$
$\bar{r}4_t$	Four-quarter average equilibrium real interest rate (%) $\bar{r}4_t = (\bar{r}_t + \bar{r}_{t+1} + \bar{r}_{t+2} + \bar{r}_{t+3})/4$
lr_t	Long-term real interest rate (%) $lr_t = 0.1 * r_t + 0.35 * r4_t + 0.35 * (r4_t + r4_{t+4} + r4_{t+8})/3$ $+ 0.2 * (r4_t + r4_{t+4} + r4_{t+8} + r4_{t+12} + r4_{t+16})/5$
$\overline{lr}_t$	Equilibrium long-term real interest rate (%) $\overline{lr}_t = 0.1 * \bar{r}_t + 0.35 * \bar{r}4_t + 0.35 * (\bar{r}4_t + \bar{r}4_{t+4} + \bar{r}4_{t+8})/3$ $+ 0.2 * (\bar{r}4_t + \bar{r}4_{t+4} + \bar{r}4_{t+8} + \bar{r}4_{t+12} + \bar{r}4_{t+16})/5$
P_t	PCE price index
p_t	Log of PCE price index $p_t = 100 * \log(P_t)$
π	Quarterly PCE inflation, annualized (%) $\pi_t = 4 * (p_t - p_{t-1})$
$\pi 4_t$	Year-on-year PCE inflation (%) $\pi 4_t = (\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3})/4$ $\pi 4_{t+3} = (\underbrace{\pi_{t+3} + \pi_{t+2}}_{\text{model forecast of inflation (depends on all inputs into forecast including monetary policy reactions)}} + \underbrace{\pi_{t+1} + \pi_t}_{\text{partly observable or monitored}})/4$ $\pi 4_{t+4} = (\pi_{t+4} + \pi_{t+3} + \pi_{t+2} + \pi_{t+1})/4$
π^*	Inflation objectives (2%)
y_t	Output gap
BLT_t	Bank Lending Tightening condition
ε_t^i	Deviation from the interest rate reaction function
ε_t^π	Supply shock
ε_t^y	Shock to the output gap

Annex 5
Minimizing the Loss Function

This appendix provides a technical description of the algorithm used in the loss-function minimization approach, based on a simpler version of the model.

Assume that the economy has the IS curve and the Phillips curve as follows.

$$y_t = \beta_1 y_{t-1} + \beta_2 \mathbb{E}_t y_{t+1} + \beta_3 (i_t - \mathbb{E}_t \pi_{t+1}) + \epsilon_{y_t}.$$
$$\pi_t = \lambda_1 \mathbb{E}\pi_{t+1} + (1-\lambda_1)\pi_{t-1} + \lambda_2 y_t + \epsilon_{\pi_t}.$$

The policymaker is choosing the whole path of the policy rate i_t (t=1, 2, …) to minimize an intertemporal quadratic loss function that takes into account the distance of inflation to its target, $(\pi_t - \bar{\pi})$, and the size of the output gap, y_t, with equal weights on both of them, and a discount factor of 1. The intertemporal loss functon is written as

$$L_t = \sum_{t=1}^{\infty} \mathbb{E}_t \left((\pi_t - \bar{\pi})^2 + y_t^2\right).$$

The Lagrangean of the problem is

$$\begin{gathered}\mathbb{L}_t = \sum_{t=1}^{\infty} \mathbb{E}_t\{(\pi_t - \bar{\pi})^2 + y_t^2 \\ +\mu_{1_t}\left(y_t - \beta_1 y_{t-1} - \beta_2 \mathbb{E}_t y_{t+1} - \beta_3(i_t - \mathbb{E}_t\pi_{t+1}) - \epsilon_{y_t}\right) \\ +\mu_{2_t}(\pi_t - \lambda_1 \mathbb{E}\pi_{t+1} - (1-\lambda_1)\pi_{t-1} - \lambda_2 y_t - \epsilon_{\pi_t})\},\end{gathered}$$

where μ_{1_t} and μ_{2_t} are Lagrange multipliers.

The first-order conditions are obtained by computing the partial derivatives of the Lagrangean with respect to i_t, y_t, π_t, μ_{1_t} and μ_{2_t} and setting them to zero. Note that the derivation is different for $t = 1$ and for $t > 1$, but the conditions can be made formally equivalent by setting the initial value of the Lagrange multipliers to zero, $(\mu_{1_0} = \mu_{2_0} = 0)$:

$$\frac{\partial \mathbb{L}_t}{\partial i_t} = \mu_{1_t}\beta_3 = 0,$$
$$\frac{\partial \mathbb{L}_t}{\partial y_t} = 2y_t + \mu_{1_t} - \mu_{2_t}\lambda_2 - \mathbb{E}_t\mu_{1_{t+1}}\beta_1 - \mu_{1_{t-1}}\beta_2 = 0,$$
$$\frac{\partial \mathbb{L}_t}{\partial \pi_t} = 2(\pi_t - \bar{\pi}) + \mu_{2_t} - \mu_{1_{t-1}}\beta_3 - \mu_{2_{t-1}}\lambda_1 + \mathbb{E}_t\mu_{2_{t+1}}\lambda_1 = 0,$$
$$\frac{\partial \mathbb{L}_t}{\partial \mu_{1_t}} = y_t - \beta_1 y_{t-1} - \beta_2 \mathbb{E}_t y_{t+1} - \beta_3(i_t - \mathbb{E}_t\pi_{t+1}) - \epsilon_{y_t} = 0,$$
$$\frac{\partial \mathbb{L}_t}{\partial \mu_{2_t}} = \pi_t - \lambda_1 \mathbb{E}\pi_{t+1} - (1-\lambda_1)\pi_{t-1} - \lambda_2 y_t - \epsilon_{\pi_t} = 0.$$

From the first condition, it is obvious that $\mu_{1_t} = 0$ in each period and the system simplifies to

$$2y_t = \mu_{2_t}\lambda_2,$$
$$2(\pi_t - \bar{\pi}) = -\mu_{2_t} + \mu_{2_{t-1}}\lambda_1 - \mathbb{E}_t\mu_{2_{t+1}}\lambda_1,$$
$$y_t = \beta_1 y_{t-1} + \beta_2\mathbb{E}_t y_{t+1} + \beta_3(i_t - \mathbb{E}_t\pi_{t+1}) + \epsilon_{y_t},$$
$$\pi_t = \lambda_1\mathbb{E}\pi_{t+1} + (1-\lambda_1)\pi_{t-1} + \lambda_2 y_t + \epsilon_{\pi_t}.$$

In this particular case, μ_{2_t} could be also substituted out using $\mu_{2_t} = 2y_t/\lambda_2$, but, in general, it is not possible to eliminate all the Lagrange multipliers.

When the zero interest rate floor is taken into account, the problem is transformed into a mixed complementarity problem (MCP):

$$\lambda_2\mu_{2_t} \geq 2y_t \perp i \geq 0,$$
$$2(\pi_t - \bar{\pi}) = -\mu_{2_t} + \mu_{2_{t-1}}\lambda_1 - \mathbb{E}_t\mu_{2_{t+1}}\lambda_1,$$
$$y_t = \beta_1 y_{t-1} + \beta_2\mathbb{E}_t y_{t+1} + \beta_3(i_t - \mathbb{E}_t\pi_{t+1}) + \epsilon_{y_t},$$
$$\pi_t = \lambda_1\mathbb{E}\pi_{t+1} + (1-\lambda_1)\pi_{t-1} + \lambda_2 y_t + \epsilon_{\pi_t}.$$

where $\lambda_2\mu_{2_t} \geq 2y_t \perp i \geq 0$ means that either $\lambda_2\mu_{2_t} = 2y_t$ and $i \geq 0$, or $\lambda_2\mu_{2_t} < 2y_t$ and $i_t = 0$.

Dynare uses the LMMCP algorithm to solve mixed complementarity problems. Below is the Dynare code corresponding to the above example.[24]

The simulation is done under perfect foresight as if no shocks were to hit the economy in the future. The optimal policy is computed *under commitment*, meaning that the policymaker is not going to reoptimize the policy in the future. In technical terms, the Lagrange multipliers are not reset to zero after the first period of the simulation.

As discussed in the paper, when the output gap is largely negative and conventional monetary policy being constrained by the zero interest rate floor, the policy recommendation derived from minimizing the loss function is to keep the interest rate at the floor for a relative long time, which would result in inflation modestly overshooting the target and output gap being positive for some periods before it closes.

One can imagine that in circumstances where the outlook starts to improve, it would become difficult for the policymaker to stick to his guns and he may decide to reconsider his optimal plan (to reoptimize) and raise interest rate earlier than warranted under the original contingent plan. This would be a departure from commitment and may damage the credibility of the policymaker. As a result, the commitment and credibility of the policymaker is crucial to the success of such strategy.

[24] This example of the code and a working version of Dynare with these features are available at www.douglaslaxton.org.

```
var i y pi;
varexo e_y e_pi;

parameters beta1 beta2 beta3 lambda1 lambda2 pi_bar;
beta1 = 0.6;
beta2 = 0.25;
beta3 = -0.2;
lambda1 = 0.7;
lambda2 = 0.1;
pi_bar = 2.0;

model;
[mcp = 'i > 0']
y = beta1*y(-1) + beta2*y(+1) + beta3*(i-pi(+1)) + e_y;
pi = lambda1*pi(+1) + (1-lambda1)*pi(-1) + lambda2*y + e_pi;
end;

planner_objective (pi-pi_bar)^2 + y^2;

ramsey_model(planner_discount=1.0);

histval;
y(0) = -2.0;
pi(0) = 1.0;
end;

steady;

perfect_foresight_setup(periods=50);
options_.stack_solve_algo = 7;
options_.solve_algo = 10;
perfect_foresight_solver;

rplot i;
```

ANNEX 6
FPAS: FROM PRINCIPLES TO PRACTICAL APPLICATION

This annex provides the operational tools (code and programs) to facilitate the implementation of the system, showing how the underlying macro model is used to generate the baseline forecast and conduct risk analysis—model examples of the U.S., Thailand and the Czech Republic economies designed to carry out forecasting exercises are referenced below and can be found at www.douglaslaxton.org. The following example programs are covered in this annex: (i) comparing optimal monetary policy based on a loss-function minimization approach with standard interest rate reaction, for both closed-economy and open-economy cases; (ii) measuring potential output based on multivariate filters' techniques that include information on output, unemployment and inflation; (iii) using a small-open economy monetary policy model to conduct forecast and risk assessments; and (iv) a complete set of programs to implement an FPAS, including reports for the baseline scenario, simulations of the model's solution for the response of macroeconomic variables to specific shocks (impulse response functions) and consistent alternative forecast scenarios.

6.1 Optimal monetary policy

Objectives:
This program employs a simple model of the U.S. economy presented in Clinton and others (2015) to compare three different policy options and responses, namely (i) an inflation-forecast-based reaction function; (ii) a Taylor rule with contemporaneous variables (inflation and output); and (iii) optimal monetary policy rule based on a loss function minimization technique—the subject of this module. The solution methods allow for the possibility of solving the model under the zero-interest rate floor.

What do I need to do?
Go to www.douglaslaxton.org and refer to the readme file.

Software requirements:
Matlab (2012) or newer; DYNARE.

Reference:
Clinton, K., C. Freedman, M. Juillard, O. Kamenik, D. Laxton, and H. Wang, 2015, "Inflation-Forecast Targeting: Applying the Principle of Transparency," IMF Working Paper (forthcoming).

6.2 Measuring potential output using a multivariate filter

Objectives:
These IRIS-based programs provide a framework to estimate potential output using a multivariate filter (MVF). MVF is based on a Phillips curve and a dynamic Okun's law

relationship linking the output gap and the unemployment. To help deal with end-of-sample problems, it also uses available information from Consensus Economics for forecasts of GDP growth and inflation. In addition, the filtering technique is designed to make it easy to impose judgment based on other information, e.g., measures of capacity utilization, participation rate, etc. The program also provides a comparison of the estimates derived from MVF with those from other univariate and bivariate filters.

What do I need to do?
Go to www.douglaslaxton.org and refer to the readme file.

Software requirements:
Matlab (2012) or newer; IRIS toolbox (version IRIS_Tbx_20130523 or newer). IRIS is freely available at www.iris-toolbox.com.

Reference:
Blagrave, P., R. Garcia-Saltos, D. Laxton, and F. Zhang, 2015, "A Simple Multivariate Filter for Estimating Potential Output," IMF Working Paper No. 15/79. Available at http://www.imf.org/external/pubs/ft/wp/2015/wp1579.pdf

6.3 Monetary Policy Model (MPM)

Objectives:
The objective of the MPM is to summarize the essential macroeconomic linkages, and the way monetary policy choices influence the economy and inflation—in other words, help policymakers decide on an appropriate interest rate path for monetary policy, consistent with achieving the inflation target (and other targets) over the medium term, under current macroeconomic conditions. The model is an open-economy, new-Keynesian model which, over the years, has provided a satisfactory representation of the key features of economies for monetary policy analysis. It consists of four basic behavioral equations which incorporates forward-looking expectations: an aggregate demand function (IS curve); an expectations-augmented Phillips curve; an uncovered interest parity (UIP) condition; and a monetary policy reaction function.

The IRIS-based programs consist of the following steps: data filtering to obtain initial conditions (options for either univariate or multivariate filtering using the full model structure); simulation of macroeconomic variables in response to shocks (impulse response functions); model validation based on rolling out-of-sample forecasts; preparation and comparison of baseline and alternative forecast scenarios.

What do I need to do?
Go to www.douglaslaxton.org and refer to the readme file.

Software requirements:
Matlab (2012) or newer; IRIS toolbox (version IRIS_Tbx_20130523 or newer). IRIS is freely available at www.iris-toolbox.com. Alternatively, the codes can be run in Octave (https://iris4octave.ogresearch.com/instructions) and a corresponding IRIS-for-Octave package.

6.4 A complete FPAS production system

Objectives:
These programs provide a complete forecasting and policy analysis system (FPAS). They consist of the technical steps of applying the relevant tools developed by a number of central banks over the years, including database management, model analysis and validation, as well as forecasts and risk assessments.

What do I need to know?
Go to www.douglaslaxton.org and refer to the readme file.

Software requirements:
Matlab (2012) or newer; IRIS toolbox (version IRIS_Tbx_20130523 or newer). IRIS is freely available at www.iris-toolbox.com.

References

Alichi, A., J. Benes, J. Felman, I. Feng, C. Freedman, D. Laxton, E. Tanner, D. Vavra, and H. Wang, 2015, “Frontiers of Monetary Policymaking: Adding the Exchange Rate as a Tool to Combat Deflationary Risks in the Czech Republic,” IMF Working Paper No. 15/74.

Alichi, A., C. Freedman, K. Clinton, D. Laxton, M. Juillard, J. Turunen, and H. Wang, 2015b, “Avoiding Dark Corners: A Robust Monetary Policy Framework for the United States,” IMF Working Paper (forthcoming).

Benes, J., M. Kumhof, and D. Laxton, 2014a, “Financial Crises in DSGE Models: Selected Applications of MAPMOD,” IMF Working Paper No. 14/56.

Benes, J., M. Kumhof, and D. Laxton, 2014b, “Financial Crises in DSGE Models: A Prototype Model,” IMF Working Paper No. 14/57.

Berg, A., P. Karam, and D. Laxton, 2006a, “A Practical Model-Based Approach to Monetary Policy Analysis—Overview,” IMF Working Paper No. 06/80.

Berg, A., P. Karam, and D. Laxton, 2006b, “A Practical Model-Based Approach to Monetary Policy Analysis—How-to-Guide,” IMF Working Paper No. 06/81.

Blagrave, P., R. Garcia-Saltos, D. Laxton, and F. Zhang, 2015, “A Simple Multivariate Filter for Estimating Potential Output,” IMF Working Paper No. 15/79.

Carabenciov, I., I. Ermolaev, C. Freedman, M. Juillard, O. Kamenik, D. Korshunov, and D. Laxton, 2008, “A Small Quarterly Projection Model of the US Economy,” IMF Working Paper No. 08/278.

Carabenciov, I., C. Freedman, R. Garcia-Saltos, D.Laxton, O. Kamenik, and P. Manchev, 2013, “GPM6 - The Global Projection Model with 6 Regions,” IMF Working Paper No. 13/87.

Clinton, K., C. Freedman, M. Juillard, O. Kamenik, D. Laxton, and H. Wang, 2015, “Inflation-Forecast Targeting: Applying the Principle of Transparency,” IMF Working Paper (forthcoming).

Coats, W., 2000, “Inflation Targeting in Transition Economies: The Case of the Czech Republic,” Prague, Czech National Bank.

Coats, W., D. Laxton, and D. Rose, 2003, “The Czech National Banks Forecasting and Policy Analysis System,” Prague, Czech National Bank.

Laxton, D. and P. N'Diaye, 2002, "Monetary Policy Credibility and the Unemployment-Inflation Nexus: Some Evidence from Seventeen OECD Countries," IMF Working Paper No. 02/220.

Laxton, D., D. Rose, and A. Scott, 2009, "Developing a Structured Forecasting and Policy Analysis System to Support Inflation-Forecast Targeting (IFT)," IMF Working Paper No. 09/65.

Svensson, L. E. O., 1997, "Inflation forecast targeting: Implementing and monitoring inflation targets," European Economic Review, June, 41(6), pp. 1111–46.

Taylor, J., 1993, "Discretion versus Policy Rules in Practice," Carnegie-Rochester Conference Series on Public Policy, Elsevier, 39(1), pp. 195-214.

Woodford, M., 2003, "Optimal Interest Rate Smoothing," The Review of Economic Studies, 70(4), pp. 861-886.