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Monetary and Capital Markets Department

# CHILE

## EVALUATION OF THE CENTRAL BANK OF CHILE FORECASTING AND POLICY ANALYSIS SYSTEM FOR INFLATION-FORECAST TARGETING

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## GLOSSARY

| | |
|---|---|
| BOC | Bank of Canada |
| CBOC | Central Bank of Chile |
| CNB | Czech National Bank |
| CPI | Consumer Price Index |
| DMA | Department of Monetary Analysis, CBOC |
| DSGE | Dynamic Stochastic General Equilibrium |
| FPAS | Forecasting and Policy Analysis System |
| FRB/US | Semi-Structural “Gap” Model, BOC, U.S. Federal Reserve Board |
| GDP | Gross Domestic Product |
| IFT | Inflation-Forecast Targeting |
| IFB | Inflation-Forecast Based |
| GPM | Global Projection Model |
| LENS | Semi-Structural “Gap” Model, BOC |
| MEP | Semi-Structural “Gap” Model, CBOC |
| MPM | Monetary Policy Meeting |
| MPR | Monetary Policy Report |
| QPM | Quarterly Projection Model, BOC |
| TOTEM | New-Keynesian DSGE Model, BOC |
| XMAS | New-Keynesian DSGE Model, CBOC |
| Year-over-year growth | Growth to current period from same period one year earlier; period as defined in context—i.e. year (annual growth), or quarter (4-quarter growth), or month (12-month growth) |

## PREFACE

At the request of the Central Bank of Chile (CBOC), the mission visited the central bank to assess and advise on the models and related processes used in support of the bank's policy of inflation-forecast targeting (IFT). The mission met with Governor Mario Marcel, and Board members Rosanna Costa, Pablo García, Alberto Naudon and Joaquín Vial. Acting Chief Economist, and head of the Department of Monetary Analysis (DMA), Miguel Fuentes coordinated CBOC input. Head of Medium-Term Forecasting, Jorge Fornero, was the main provider of information, and daily collaborator at the working level. For three weeks, before the full mission began, a team member watched the production of the March forecast, and its presentation to the Board (the monetary policy committee). He also observed the Monetary Policy Meeting for the March policy decision. The mission made presentations to CBOC staff on: forecast production at the CBOC and the Czech National Bank (CNB); forecasting accuracy (CBOC relative to the Consensus Economics survey, CNB and Bank of Canada (BOC)); techniques for merging forecasts results from different models; and core inflation.

The mission wishes to thank the Governor, members of the Board, and staff of the central bank for their attentive cooperation, for productive discussions, and for their hospitality.

This report presents the mission's assessment and main conclusions.

## EXECUTIVE SUMMARY

**The mission sought to assist the Central Bank of Chile (CBOC) forecasting and policy analysis system (FPAS) in 3 broad ways:**

- enhanced modeling capability;
- increased effectiveness of the staff forecast as input to Board policy decisions and risk assessments in support of IFT;
- improved processes.

**The CBOC FPAS is highly advanced.** It has all the desirable features of set-ups in central banks that have established successful inflation-forecast targeting (IFT) frameworks—IFT being the state of the art for flexible-inflation-targeting central banks. All Board members regard the model-based forecasts from this viewpoint, as essential inputs for their policy decisions. Most members have thorough knowledge of them.

**Forecast production is highly efficient and speedy.** The flat hierarchy of the CBOC FPAS, and frank, business-like discussions, facilitate forecast production and presentation. The high degree of independence afforded to the staff reflects confidence of the Board in their work.

**The CBOC applies relevant criteria to model selection.** A structure for revising, or eventually replacing, existing core models is in place. The bank seeks models that can provide credible, quantitative, macroeconomic narrative for forecasts and policy analysis, not just forecasting accuracy. In practice, the bank needs to be careful to apply these criteria, rather than the most advanced techniques.

**The FPAS uses two core models: a semi-structural "gap" model, MEP; and a DSGE model, XMAS.** MEP is a gap model, with a standard Phillips curve. XMAS is based on explicit utility-maximizing principles, and has more structural detail.

**The accuracy of CBOC model-based forecasts has been somewhat better than Consensus Economics, and close to that of the Czech National Bank and the Bank of Canada.** On this measure, the CBOC FPAS produces results in line with those at other leading inflation-targeting central banks.

**The CBOC has tended to over-predict the future policy rate.** In large part this is because the assumption for the underlying equilibrium rate has not been revised down to the same extent as estimates of the global equilibrium rate. In addition, the central bank should consider replacing the standard inflation-forecast-based reaction function with a loss-minimizing reaction function, which would produce smaller responses for small deviations from target, but would help keep the economy away from dark corners after large shocks such as the Global Financial Crisis (GFC).

**The two models provide different insights, and credible quantitative narratives, for issues and policy options.** The gap model presents a useful guide to short-run policy trade-offs between output and inflation. The simplicity of the structure is an asset in communicating how the central bank intends to manage this trade-off. The DSGE model can be used directly for analysis of complex fiscal policy and terms-of-trade issues, especially with respect to investment dynamics, and to implications for debt accumulation (public and net foreign).

**Because of their differing advantages, both models should be maintained.** The CBOC simply averages the two model-based forecasts. The mission proposed a structured approach to combining the separate forecasts, and for retaining the separate insights of the two models.

**Certain responses of the DSGE model to standard shocks suggest a reconsideration of model structure.** These include high sensitivity of the economy to policy rate changes, and large exchange rate movements in response to demand shocks.

**The CBOC should devote more resources to analyzing risks to the outlook—and to risk management strategies.** Board members ask for alternative scenarios at a forecast presentation the week before the Monetary Policy Meeting—this has not allowed staff enough time to produce model-based results and policy options. An extra week, at the start of forecast production, with an Issues Meeting, would be advisable.

**The current forecast-production set-up is stretched too thin, with no redundancy to allow for unexpected absences or demands.** A modest increase in the forecasting team, through a reallocation of Research Division resources, would be enough.

**Increased rotation between forecast production, on the one hand, and model development or special projects, on the other, would also reduce operational risks.** It would widen staff skill-sets, and reduce the risk of staff burnout.

**The mission examined the reaction of forward interest rates to the publication of CBOC forecasts.** In most cases the market anticipated the change in the policy rate quite well. After announcement dates, the yield curve tended to roughly follow the central bank forecast path.

**At the request of the CBOC, the mission looked at core inflation as a guide to policy decisions, and as a communications tool.** The bank should use core inflation with caution, especially as there has been a long-run uptrend in relative food prices.

**A regular review of the performance of monetary policy, with the participation of invited outside experts, at intervals of 5 years or less, would be useful.** It would serve central bank transparency and accountability, and guard against cumulative errors in forecasting assumptions.

## KEY RECOMMENDATIONS

| | Priority | Timeframe |
|---|---|---|
| **Forecasting and Policy Analysis System** | | |
| Retain important strengths of the current system:<br>• appropriately designed models<br>• system for forward-looking planning for future models<br>• full integration of model-based forecasts in monetary policy decisions, with a flat hierarchy, and clear and frank internal communications<br>• streamlined forecast production, with efficient use of resources<br>• autonomy of the staff to shape the baseline forecast and risk assessments. | Highest | Ensure sustain-ability |
| Publish review, taking stock of previous medium-term policy performance, and the policy framework. At least every 5 years. | High | September 2019 |
| ***Core models*** | | |
| Maintain a role for output gap consistent with its prominence in CBOC internal policy discussions and external communications:<br>• output gap for managing and communicating the short-run inflation-output trade-off<br>• structured integration of output gap into DSGE model XMAS. Mission team provided an option for structured technical solution<br>• incorporate copper prices in gap model. | High | September 2018 |
| Reconsider the exchange rate response to demand shocks.<br>Reconsider modeling of real exchange rate and country risk premium. Response to standard anticipated shocks over the forecast horizon should be modest. | High | September 2018 |
| Systematize the integration of the near-term forecast into the medium-term forecast. Similar technical approach as used for blending forecasts from 2 medium-term projection models (gap and DSGE).<br>Construct model-based confidence bands. | Medium | March 2019 |
| Re-examine the relative roles of output gaps and exchange rate pass-through in the inflation process, with particular reference to 2013–17. | High | October 2018 |
| Consider risk-management (loss-avoidance) approach to policy as alternative to linear reaction function. | Medium | 2019-20 |
| ***Suite of satellite models—medium term and near term*** | | |
| Continue with program to refine/extend existing satellite models (labor market, copper, non-core inflation). | High | June 2019 |

| | Priority | Timeframe |
|---|---|---|
| **Forecasting and Policy Analysis System** | | |
| Develop non-linear model with time to build, adjustment costs and irreversibilities to study investment and copper-price dynamics.<br><br>Develop GPM to incorporate endogenous copper prices for global scenarios. | | |
| Develop new DSGE model based on overlapping generations structure to study the effects of fiscal policies, pension funds and permanent changes in the terms of trade (copper and oil prices). | Medium | 2019-20 |
| ***Forecast production process*** | | |
| Provide well-considered, model-based assessments of macroeconomic risks and policy options.<br><br>Identify baseline and alternative scenarios involving fundamental international assumptions at a newly-created *Forecast Issues Meeting*, with Board and senior staff, before forecast production begins. This would take stock of the accumulated new data from the preceding forecast exercise. | High | September 2018 |
| Better exploit the value of the model-based approach, and ensure appropriate emphasis on medium-term, strategic issues.<br><br>Extend forecast production period by one week, to allow production time for model-based alternative scenarios to the baseline. | High | June 2018 |
| Provide appropriate back-up for forecast production.<br><br>Add an additional economist to forecast production, through a reallocation of Research Division resources. | Very high | September 2018 |
| Diversify individual staff skill sets, ensure appropriate focus of modeling, and reduce risks to forecast production schedule from turnover or burnout.<br><br>Consider increased staff rotation between forecast production on the one side, and core model development or special projects (including satellite model development) on the other. | Very high | 2018-onward |
| Improve cohesion between forecast methodology and internal and external communications.<br><br>Bring the integrated output gap-DSGE approach into the process of forecast production. | Medium | March 2020 |
| Consider revising weekly meetings to focus attention on risks in the medium-term forecasts. Qualitative messages about risks every week with some quantification of risks on a monthly basis. Emphasize automatic report generation to improve the efficiency of the production process.<br><br>In line with the preceding, consider shifting weekly meeting to Friday, in view of timing of major international data releases. Do a stock-taking for previous week's releases.<br><br>Put back larger questions to the Forecast Issues Meeting described above, or to a Forecast Update Meeting prior to inter-forecast Monetary Policy Meetings. | Low | March 2019 |

## I. Introduction

1. **The technical mission evaluated the forecasting and policy analysis system (FPAS) for flexible inflation targeting at the CBOC.** For our purposes flexible inflation targeting is inflation-forecast targeting (IFT), because the forecast of the central bank is in an important sense an ideal operating target, as it takes into account all known influences on the inflation rate, including policymakers' own preferences for the relevant trade-offs.[1]

2. **The fundamental objective of IFT is to stabilize long-run expectations of inflation at the target rate.** Useful inflation targeting is not about hitting a numerical target from year to year. Because the nature of economic shocks, especially in an open, commodity-exporting country like Chile, wide variations in the annual rate of inflation are to be expected. Credibility of the central bank target can nevertheless be maintained, and in fact has been maintained. The essential requirement here is that the policymakers have executed a clearly communicated, credible *systemic medium-term strategy* for returning inflation to target.

3. **The main instrument for this purpose is, in a narrow sense, the policy interest rate, but for policy strategy under IFT it is better to think of the policy rate more broadly, as an essential part of a more consequential instrument: the *capacity to manage expectations for the medium-term future path of the policy rate*.** The latter, the overnight interbank rate, is after all a very short-term rate that of itself does not influence the spending decisions of the bulk of the population or of firms. Changes in the policy rate will only affect macroeconomic variables in the way the central bank desires if they shift: the longer-term interest rates at which households and firms borrow and lend; or the exchange rate; or asset prices; or all of the preceding. This means that, for the policy transmission mechanism to be effective, changes in the policy rate have to appropriately affect expectations for the entire medium-term path of the policy rate. [2] In turn, this implies that good communications are also an essential part of the broadly defined policy instrument.

4. **The CBOC recognizes such fundamentals of monetary policy, explicitly and implicitly.** For example, Monetary Policy Report, September 2014: "The Board [the policy-making committee] has cut the monetary policy rate since June by 50 basis points, taking it to 3.5 percent, and *has continued to state that it will consider the possibility of making further reductions to the MPR* … it has lowered the MPR by 150 basis points since October 2013 and maintained an expansionary stance. This, together with the evolution of the domestic and external macroeconomic scenario has had a marked impact on the structure of market interest

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[1] For a discussion of Inflation-Forecast Targeting see Clinton and others, Adrian, Laxton and Obstfeld (2018), Al-Mashat and others (2018a,2018b,2018c,2018d) and Clinton and others (2017).

[2] Inflation-forecast-based reactions functions, which depend on the output gap, forecasts of inflation and the lagged policy rate, have been used for many years in inflation-forecast-targeting central banks. For a discussion of the properties of these reaction functions see Coats, Laxton and Rose (2003), Isard, Laxton and Eliasson (1999, 2001) and Laxton and Pesenti (2003).

rates. In particular, *long-term rates are now at or near their all-time lows. At the same time, the lower cost of bank funding has been transmitted to the lending rates for businesses and individuals*…" The emphasized phrases (our italics) highlight the bank's forward-looking statement about the policy rate, and the bank's positive view of the outcome for the transmission mechanism.

5. **A central job of the FPAS is to provide macroeconomic information to the policymakers that helps them form a strategic view on how the policy rate should move over the medium term.** This means that FPAS models must be judged on their ability to produce economically sensible results for policy strategy, and for other key variables, under relevant assumptions—for the baseline forecast, and for alternatives to the baseline—as well as on the contribution they make to forecasting accuracy. In case there is any doubt, we stress that, since the inflation rate is a macroeconomic variable far from the direct control of monetary policy, quantitative models of some kind are essential to the implementation of IFT. The question at hand is about what models are best designed for the task.

6. **For Chile, the Board of the central bank requires quantitative medium-term economic forecasts as inputs for the management of the medium-term policy trade-off.** The FPAS therefore needs the capacity to produce forecasts that show a path for the policy rate over the medium term consistent with policy objectives. This does not mean that the Board accepts the staff forecast in detail. Members may have substantive differences from it. But the staff forecast path for the policy rate is part of a coherent macroeconomic outlook. It can provide a quantitative, economically credible, narrative. Members may then use it as a point of reference when they are explaining their own views on the outlook, and when they are communicating the rationale for their decisions to a wider audience.

7. **Compared to other central banks, the CBOC's existing FPAS is highly advanced.** It has all the desirable features of set-ups in central banks that have established successful IFT frameworks. The models have useful policy-simulation properties, and the forecasting record is quite good relative to comparable forecasters. This has doubtless contributed to the good results of Chilean monetary policy, at times in the face of large terms-of-trade shocks, in stabilizing long-term inflation expectations, and reducing fluctuations of output. With all this in mind, the suggestions we have are for refinements to the system, rather than major changes.

8. **Section II of this report goes straight to an overview of workhorse FPAS models.** Section III is about organization and process of production for the quarterly staff forecast. Section IV looks at possible future directions for model development and use. We make suggestions for changes to organization and process, designed to improve the contribution of the FPAS to the making of monetary policy. Section V summarizes our evaluation. Our main recommendation is that the strengths of the current framework be maintained. Our other suggestions are intended to help in this regard.

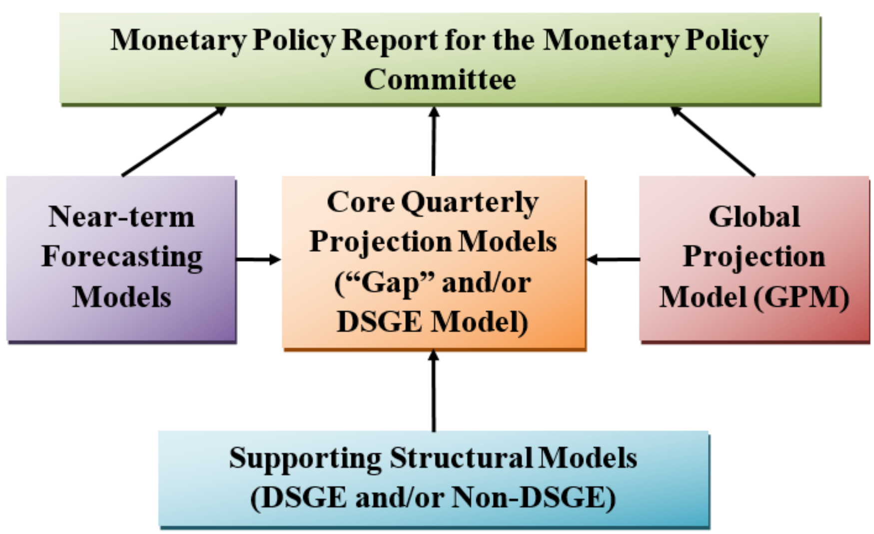
## II. Suite of FPAS models

### A. The two main forecast production models XMAS and MEP

9. **The CBOC Board relies on model-based forecasts as an essential input at the Monetary Policy Meetings (eight per year starting 2018) which set the policy interest rate.** The two models used for forecast production, XMAS and MEP, are monetary policy models, designed for medium-term policy simulations as well as forecasts. They are estimated from quarterly data. CBOC forecasters use them each quarter to produce a baseline forecast, and alternative scenarios that embody materially different assumptions from the baseline about the outlook. In practice, the baseline CBOC forecast, key aspects of which are published in the Monetary Policy Report, has been a simple average of the two model-based forecasts. The baseline and the alternative scenarios, taken together, help policymakers formulate strategies and manage risks.

10. **Figure 1 gives a simplified overview of the broad relationship between the different kinds of structural models used by CBOC forecasters.** Arrows indicate flows of information or inputs. Thus, the whole process generates a flow of macroeconomic information to the Board (the monetary policy committee). Near-term forecasting models and GPM produce results for the domestic and international economies, respectively, which are inputs to the core projection models. Likewise, various supporting structural (or satellite models) provide inputs to, or influence the calibration of, the core models.

Figure 1. Simplified Overview of the Suite of Structural Models




Source: IMF mission.

### Gap model MEP

**11. The older model MEP is a variant of the mainstream 4-equation open economy model ("gap" model) that has been widely used to investigate monetary policy issues over the past 20 years.** It is semi-structural in that it has an economically defendable structure of estimated equations, and is constrained to converge to a stable long-run equilibrium, but in that it is not founded on explicit dynamic optimizing concepts (Appendix 1).

**12. A standard inflation-forecast-based (IFB) reaction function for the policy interest rate eliminates over time deviations of inflation from the official target.[3]** The rate responds to deviations from desired levels of output and the model's forecast of inflation, with a smoothing factor to avoid sharp changes in the rate.

**13. Output in the model is non-resource-sector GDP.** Forecasts of sectoral specialists are added to the model-derived non-resource GDP to get the forecasts for total GDP. The resource sector is dominated by a few major copper-mining firms, from whom the bank's sectoral specialists receive a flow of information on business conditions, output, investment plans, and so on.

**14. The output gap, actual minus potential non-resource GDP, plays a key role in MEP.** An expectations-augmented Phillips curve drives the cyclical component of core inflation (the measure CPIEFE excludes food and energy prices). In the policy reaction function, its weight reflects policymakers' concern for deviations of output from its potential level in the short-run trade-off between output and inflation. The path of potential is exogenous to the model, and estimated from several satellite models, which use various techniques, including filtering the historical path of actual non-resource GDP.

**15. The real exchange rate is determined by its expected long-term equilibrium level and an uncovered interest parity (UIP) condition.** UIP does not hold exactly, because of the Chile country-risk premium, but if the risk premium is constant then changes in the real interest rate differential will cause changes in the real exchange rate that maintain constant the expected, exchange-rate adjusted, real differential. The exchange rate may jump, and overshoot, in response to various shocks.

**16. MEP contains additional features capturing assumed structural characteristics of the Chilean economy.** Notable among them are:

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[3] Adrian, Laxton, and Obstfeld (2018) use IFB reaction functions, and compare with loss-minimizing reaction functions, e.g., in Chapters 9 (on Canada) and 12 (on the United States).

- a fairly strong exchange rate pass-through on core CPI inflation relative to other economies with advanced IFT: a simulated exogenous exchange rate shock (e.g. a risk-premium shock) on impact has a pass-through of about 20 percent;[4]
- output gap and headline inflation in the core inflation equation—reflecting the wage and markup (i.e. cost push) components and the relative price mechanism;
- in simulation, the model produces standard responses, e.g., for shocks to demand and to core inflation (in effect, a supply shock), and to the policy reaction function.

**DSGE model XMAS**

**17. XMAS is a new-Keynesian DSGE model.** The inflation process is driven through the effects on markups and wage pressures of excess demand. Firm-specific fixed capital, wage contracts, and frictions in markets for goods and services, mean that output cannot adjust immediately to changes in demand. Firms encounter rising marginal costs in the short run as output rises, and falling marginal costs as it declines. This gives rise to the new-Keynesian Phillips curve.

**18. A fiscal policy rule has government spending adjust slowly over time to enforce the government budget constraint.** Long-run revenue growth is linked to the tax base in steady state.

**19. Output in the model is disaggregated into natural resource and non-natural resource sectors.** The natural-resource sector is modeled endogenously through investment adjustment costs and time to build.

**20. The IFB reaction function in XMAS for the policy interest rate is similar to that in MEP.** It contains the deviation between actual inflation and the official target, output growth relative to the growth of potential output (rather than the gap), and a smoothing term.[5] The reaction function looks ahead only one quarter. This raises a risk of instrument instability, as the effects of change in the policy rate are weak at such a short horizon. To take account of rigidities in the system, and lags in the effect of monetary policy, IFB reaction functions typically look further ahead—4 quarters is typical (examples are in Adrian, Laxton, and Obstfeld, 2018).

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[4] The pass-through is an empirical reduced-form coefficient, and not a structural parameter (García-Schmidt and García-Cicco, 2017). The estimated coefficient will vary depending on the monetary policy regime, among other factors. In advanced IFT economies, the pass-through has generally become very low because of the stability of inflation expectations at the target rate. However, if a credible IFT central bank deliberately uses the exchange rate as an instrument to achieve the target, the pass-through may be substantial (Alichi and others, 2015a). Such a strategy embodies the principle of monetary neutrality, by which, in equilibrium, at given real variables, all nominal values change in the same proportion.

[5] More precisely, there is no explicitly defined concept of potential output in the model; the rule uses the growth rate of total factor productivity.

**21. With respect to model evaluation, Appendix 1 draws attention to a few somewhat unusual simulation properties in the impulse-response functions for XMAS.** For example, macroeconomic variables are very responsive to changes in the policy rate; and the exchange rate is quite sensitive to net foreign liabilities, and hence to the current account balance. CBOC model builders might want to take a closer look at those aspects of model structure responsible for these responses.

### B. Satellite models

**22. Economists throughout the Research Division work with many small, purpose-built, models.** Results from other models can be viewed as information for forming judgment, which is an essential ingredient of any forecast.

**23. The International Section uses multiple satellite models in an eclectic approach.** The most wide-ranging, for the global forecast and general analysis, is GPM. The main international variables provided for the Chile medium-term forecast are the copper price, oil price, external activity and inflation (bilateral-trade weighted), and U.S. dollar exchange rates and interest rates. For each of these variables, the section uses a variety of models and estimation techniques. For example, for the price of copper, the section has three models, each focusing on an aspect of pricing behavior: an error-correction model for the near term; a semi-structural model for the medium term; and a long-run model, forecasts from which are routinely updated no more frequently than once a year, or following a major shift in the market. For all variables, expert judgment in the section plays a major role. In view of the wide-ranging nature of variables and issues, and the vast quantity of daily news, for the international economy, an agile eclectic approach is appropriate.

**24. We did not do an assessment of satellite models.** We would only suggest, that for each forecast variable, CBOC experts consider adopting a preferred model, and to use the results of other models as information for judgmental input. It is generally helpful to have a single preferred model, for purposes of organizing thoughts, and presentation.

## III. MODEL-BASED FORECAST PROCESS

### A. Organization

**25. The forecast is under the auspices of the Research Division, which has 4 departments:**

- Economic Modeling and Analysis (research on core forecasting models of the future, and applied research on topics relevant for the understanding of the economy and monetary policy decisions, e.g. micro-data-based measures of potential output and labor market conditions)
- Department of Macroeconomic Analysis (DMA) is responsible for the forecast and has 3 sections with self-explanatory titles:

    - *International*
    - *Conjuncture* (near-term forecasting)
    - *Medium-Term Forecasting*

- Economic Research (advanced macroeconomic and monetary policy research)
- Monetary Policy Strategy and Communications (responsibilities include writing the Monetary Policy Report).

**26. The models used by the Conjuncture and Medium-Term Forecasting Sections differ along the lines one would expect: more empirically based for the near-term forecast, more theoretically based for the medium-term.** The Conjuncture Section uses a variety of empirical models, e.g.: VARs, small estimated non-structural models, and leading-indicator models (Appendix 2). The emphasis is more on forecasting accuracy than on consistency with macroeconomic theory. The section also draws on its sectoral expertise for informed quantitative judgment.

**27. The combination of quickly up-dated equation estimates, and informed judgment easily beats a calibrated structural model for near-term forecasting accuracy, in Chile as elsewhere.** The Medium-Term Forecasting Section uses the XMAS and MEP models, which can produce more reliable forecasts over horizons longer than 2 quarters by incorporating endogenous feedbacks. These notably include feedback from the monetary policy interest rate, which is of growing importance as the horizon lengthens, and crucial for the inflation rate at the 2-year horizon and beyond.

**28. The near-term forecast provides initial conditions for the medium-term forecast.** The International Division provides results for the external economy, both short- and medium-term, that become assumptions for the medium-term forecast. The procedures used in both cases are eclectic, although the medium-term projections for the global economy are to a large extent model-based. The division uses GPM for the general picture, and satellite models for the copper price, foreign activity and inflation, US dollar exchange rates and interest rate.[6] The models do not just produce numbers, but help provide a quantitative narrative for the projections.

**29. Medium-term, or theoretical, considerations may affect the near-term forecast.** Since the near-term forecast sets the initial conditions for the medium-term forecast, there is some requirement for theoretical consistency in the former.

**30. The Conjuncture Section includes a fiscal policy expert responsible for near-term and medium-term forecasts of fiscal variables.** The fiscal rule followed by the government adjusts for the business cycle and for cyclical fluctuations in the copper price. The fiscal expert has responsibility for tracking the actual administration of the fiscal rule, and is therefore

[6] The medium-term forecast for the Chilean peso exchange rate is the responsibility of the Medium-Term Forecasting Section.

involved in ensuring that the model-based forecasts are consistent with the rule. This is an example of how communication between Conjuncture and Medium-Term Forecasting Sections may shape the assumptions of the forecast.

## B. Process

31. **The hierarchy—from the production of the forecast by staff economists to the presentation of the Board—is quite flat.** For the quarterly forecast, the flow upwards, from the Conjuncture Section and the Medium-Term Forecasting Section to the Board, is managed by the head of DMA under the supervision of the Chief Economist (head of the Research Division, Appendix 3). These 2 sections, as their names imply, are responsible respectively for the near-term (this quarter, and next quarter), and medium-term (beyond the next quarter) forecasts. The head of DMA is the main presenter of the forecast at forecast meetings with the Board.

32. **The time-schedule for forecast production is brief.** Typically, the staff forecast is finalized two weeks after the process kicks off with a staff meeting on the international outlook. Comparator IFT central banks, the Bank of Canada and the Czech National Bank, have a much lengthier production process. Appendix 3 provides detail on this, and other issues in the forecast production process.

33. **The independence afforded to staff and their supervisors means that no interventions from the Board slow the process at any stage.** The Board holds the relevant experts and section managers responsible for their own forecast assumptions, external and internal to Chile.

34. **The Chief Economist plays a key guiding role to provide coherence in the process.** This involves frequent contacts with the head of DMA and other staff. The Chief Economist also acts as a conduit between the Board and the forecasters, e.g. to ensure that the production process addresses the main concerns of policymakers.

35. **The head of DMA presents the staff baseline forecast, with sensitivity analyses, to the Board about one week before the Monetary Policy Meeting (MPM).** The Board may ask for alternative scenarios, with substantially different assumptions to the baseline, at this presentation. The Medium-Term Section then has essentially 2 days to produce the alternative scenarios for the final, pre-MPM, forecast presentation.

36. **At the policy meeting, the staff forecast, having been considered by the Board, becomes a CBOC forecast.** Board members may not agree with all, or even most, of the aspects of the staff forecast, but they nevertheless treat it as crucial input for their policy decision.

## C. Evaluation of the organization and process

### Efficiency and speed

37. **The staff have a high degree of autonomy.** The Board does not impose a view of how the staff forecast should look. One may say that only after the Board has used the forecast to

inform its decision at the Monetary Policy Meeting does the forecast become an official CBOC forecast: until then it is a staff forecast.

**38. Delegation of responsibility applies all through the FPAS.** For example, the head of the Research Division as well as section chiefs rely heavily on the judgments of sectoral experts, and hold them accountable for their input.

**39. There is close and effective consultation between DMA sections—Conjuncture, International, and Medium-Term Forecasting—on the forecast.** This allows sectoral specialists to make an appropriate contribution to assumptions underlying the medium-term forecast as well as the near term.

**40. Models are an indispensable part of the process.** Staff forecasters throughout DMA rely heavily on model-based analysis and forecasting, most systematically in the Medium-Term Forecasting Section. An overarching aim is to provide a coherent, quantitatively defendable, narrative for the outlook, for which models are the logical tool.

**41. Staff are diligent in distinguishing how judgment, versus simple model-derived output, influences their forecasts.** Thus, forecast presentations to the Board are quite transparent about the quantitative implications of staff judgment. In turn, the Board expresses, and acts on, broad confidence in the expertise of the staff.

**42. Speed of production in large part reflects efficiency of the CBOC FPAS—i.e. of the forecasting team (FT), of the flat hierarchy, and of the overall work environment at the CBOC.** Communications between different levels, and across sections and divisions, are effective. Discussions and meetings are cordial and frank, without undue back and forth.

**Apparent operational vulnerabilities**

**43. While the relatively small staff, limited turnover, and compressed schedule may enhance efficiency, these features also imply costs and risks:**

- the CBOC does not derive full return from its investment in the core models
- the FPAS is subject to operational risk.

**44. There is little capacity in the system to cope with extra policymaker demands or unexpected staff absences.** The lack of redundancy means that while resources are adequate to produce a model-based baseline forecast, they are insufficient for well-adapted model-based alternative scenarios within the allotted time schedule, especially if demand for such scenarios is not voiced early in the process.

**45. The forecast production schedule allows only a few days for the staff of the FT to derive a Board-requested alternative scenario.** The International Section does not have sufficient time to assess the full international implications of a global shock such as to metals prices or U.S. interest rates. The FT does not have sufficient time to carefully adapt technical model assumptions to a requested substantive macroeconomic shock. Experience at other central banks suggests that a forecasting team would usually require about 5 days to do a well-designed model simulation.

**46. Operational risk derives from unexpected staff turnover and burnout.** Intensive work effort over a prolonged period of time is stressful, and can lead to departures of key staff, meaning a loss of hard-to-replace human capital. Retention of staff with accumulated on-the-job training for highly specialized work is a huge asset.

## IV. Directions for CBOC Macroeconomic Forecast Modeling

### A. Assessment of current XMAS and MEP models

**47. The analysis of CBOC model-based forecasts since 2009 indicates that they have performed marginally better than the Consensus Economics survey of forecasters (Appendix 4).** This is similar to the situation in other leading IFT central banks. The Bank of Canada and the Czech National Bank perform somewhat better, on the measures we use, than the CBOC, but since the sample period is short, one cannot draw strong conclusions from this. Furthermore, forecasting accuracy, viewed ex post, may not be a reliable indicator of the value of the forecasting exercise, especially in view of the conditionality of the process. For example, policy may respond to the prediction of a bad outcome, and thereby create an ex post forecasting error.[7] In this case, the forecast gives a correct signal, and the ex post forecasting error is, in context, a desirable result.

**48. The main value added produced by the staff for the Board is not better numbers, but a credible macroeconomic narrative that can help policymakers form their own views, and act as a point of reference for their deliberations.** For example, if they differ with the outlook in a model-based staff forecast, the source of the difference—e.g. differing assumptions about exogenous variables, or differences in views from the dynamics in the models—should become clear from the process of debate and from the results of model-based sensitivity analyses, etc. In addition, a model provides a tool that allows the bank's economists to incorporate newly arriving information into the outlook for the economy in a logical, consistent and understandable way.

**Adopting DSGE Models at the Bank of Canada (BOC) and the Czech National Bank (CNB)**

The BOC's QPM model, developed in the early 1990s, was designed specifically to support forecasting and policy analysis under the regime of inflation targeting (Duguay and Longworth, 1998, provides background). Key features similar to those in later DSGE models were: a well-defined steady state; a nominal anchor provided by an IFB policy reaction function; and rational (model-consistent) expectations. The set-up was intuitively appealing

[7] The 2009 international fiscal expansion coordinated by the G20 is an outstanding example.

to policymakers, as the movements in most of the main macro variables (e.g., GDP, the unemployment rate, the policy interest rate) could be viewed in terms of deviations, or gaps, from long-run equilibrium. Thus, they could identify an expansionary monetary policy with a policy rate below the long-run equilibrium rate; or disinflationary pressure with a negative gap between current and potential GDP. More important was that QPM could be used as a practical tool for the implementation of inflation-forecast targeting. Monetary policy was represented by an interest rate reaction function calibrated to bring the rate of inflation back to the official target, from the starting rate, in a way that was not disruptive to the real sector, in line with a basic principle of IFT (Freedman and Laxton 2009).

The model builders calibrated the coefficients of QPM to ensure that the simulation properties of the system corresponded to mainstream views on how the economy worked. To this end, they drew on a wide variety of evidence, of which traditional econometric estimation was only one part. (A purely econometric approach does not generally result in a useful monetary policy model. Even ignoring that available data series are usually too short to allow estimates within an acceptable margin of confidence, a pure empirical approach in principle cannot yield models that permit analysis of policy options, because these would generally mean a change in the behavior that generated the historical data (CBOC 2003, and Berg, Karam and Laxton 2006).

While useful for the purpose, QPM lacked explicit micro foundations—it was a semi-structural, rather than a full structural, model. It was not well equipped to handle shocks that might have complex dynamic implications for real variables—e.g. fiscal policy changes, or terms of trade shocks. The BOC switched to a DSGE model after 2005. TOTEM added 2 features that QPM lacked: (1) multiple production sectors, each with demand functions for factor inputs, and a pricing schedule; and (2) explicit optimizing behavior—firms maximize profits, while consumers/workers maximize a utility function in consumption and leisure. A perceived advantage of TOTEM was that the richer behavioral structure vis-á-vis QPM would yield more realistic responses to shocks that might involve sectoral adjustments over time, e.g. terms-of-trade shocks.

At the broad level, the major difference perceived by policymakers from the switch in models was the disappearance of the traditional Phillips curve, which in QPM drove the cyclical component of inflation as a function of the output gap. They had become very familiar with this concept over many years. In contrast, TOTEM provided an explanation for unemployment in terms of rising marginal costs, with firm-specific capital stocks adjusting only slowly to shifting patterns of output. BOC policymakers did not find these aspects intuitive, and have preferred to see the inflation forecast presented as a function of the output gap (i.e. a Phillips curve). The forecasting team has therefore translated TOTEM-derived results from “pressure on marginal costs” to the “output gap.”. Over the past couple of years, the BOC has returned somewhat to a semi-structural approach. Thus, as well as the 2011 version TOTEM II, the BOC is now using LENS, a semi-structural model on the lines of the Federal Reserve’s FRB/US, with a Phillips curve for inflation (Dorich, and others, 2013; Gervais and Gosselin, 2014). It uses standard econometric estimation to set parameters, with lower weight on theoretical priors than TOTEM II.

While the latter remains the main vehicle for the medium-term forecast, and for simulation of alternative policy options, LENS carries more weight for forecasts up to a year ahead, because of better forecasting properties over this horizon. Throughout the quarter century of inflation targeting, the BOC has always retained a very prominent narrative for the output gap in its policy announcements and explanations.

CNB economists built the semi-structural QPM-gap model rapidly, after the adoption of inflation targeting in 1998. It was a useful forecasting tool, but had evident weaknesses, which in large part stemmed from the very short time series available for estimating parameters, and the enormous structural shifts in the Czech economy in the 1990s (Adrian, Laxton, and Obstfeld, 2018, Chapter 10). Under these circumstances it was not surprising that QPM-gap had some implausible simulation properties, and the need for a model in which policymakers could have more confidence became quite pressing. In 2008, the forecasting team brought their current QPM-DSGE model into service (Andrle and others 2009). Tests indicated that the central bank would be sacrificing nothing in terms of forecasting accuracy by adopting the new model. The richer structure generates answers to questions about the macro outlook with more efficiency (less need for ad hoc judgments), and with greater confidence in the results. However, QPM-DSGE did not cope well with the real-world nonlinearities exposed in the steep and prolonged post-global crisis recession—e.g., the zero lower bound on the policy interest rate, which ruled out further conventional monetary easing.

These 2 cases illustrate that no model is useful for every issue that might confront forecasters or policymakers. Time-series extrapolations or thoughtless model simulations throw up economically nonsensical results if pushed beyond a short horizon. Bearing this in mind, an effective FPAS deals with the known weaknesses of the core forecasting models through a *process* that allows modification by judgment—the better a model is, the less need for process to cover the cracks, but there is always the need for a systematic way to bring in the insights from other models (e.g. satellite models for the drop in potential output during a recession cause by a severe financial crisis), and from the judgment of experts.

**49. XMAS-based quarterly forecasts have been somewhat more accurate than MEP-based.** This conclusion derives from an analysis of root-mean-squared errors (Appendix 5). The difference is generally small, but quite significant for output growth. The relative advantage of the enhanced behavioral content of the DSGE model is clearest for forecast horizons longer than 3 quarters, as one would expect.

**50. Regarding the policy interest rate, there is no material difference in the forecasting accuracy from the two models**. In both cases, the RMSE at the 8-quarter horizon is quite large, equivalent to about 125 basis points. Perhaps the policy reaction function (it is similar in the 2 models) does not closely reflect the actual policy preferences of the CBOC Board. Closer examination indicates a tendency to overestimate the future rate. This suggests either that the CBOC was overestimating the underlying equilibrium interest rate, or that headwinds were persistently stronger than the central bank forecasters foresaw.

**51. A reaction function based on minimization of a quadratic loss function might be more realistic**. This would imply relatively small responses of the policy rate to disturbances when the economy is near a long-run equilibrium position (i.e. small output gap, inflation near target). However, if the shock is large, or if the starting position is already well away from long-run equilibrium, the responses would be much larger. That is, loss-minimization would imply strong aversion to large deviations from policy objectives.[8]

**52. The better overall performance of XMAS relative to MEP may be due to a better underlying behavioral structure, or to more attentive calibration, or to an input of assumptions better tailored to the model.** It is likely a combination of all three factors, because since 2010 CBOC model-builders and users have put much more time and effort into XMAS than into MEP.

## B. Underlying equilibrium variables

**53. One of the more profound difficulties that policymakers, forecasters and macroeconomic model builders, alike, have had to face since the mid-2000s is increased uncertainty about underlying equilibrium variables for variables like potential output, the real interest rate, and real exchange rates (Summers 2015).** Up to and including the period of the "Great Moderation," economists could reasonably assume that these fundamentals were stable. Since the global financial crisis, however, they have had to revise downwards their estimates of the neutral interest rate and potential output (growth and level). The recognition lag means that the revisions inevitably lag the actual developments.

**54. The CBOC should re-examine their process for forming assumptions about these variables, and allow for an increased degree of uncertainty.** The bank was quite quick to recognize a drop in potential growth during the commodities market recession of 2012-16. This implied a downward revision in the equilibrium interest rate, consistent with the XMAS model. However, this was relatively small compared to the extent of the estimated decline in the global equilibrium real rate, which affects directly a small open economy like Chile (e.g. Summers 2015). A process that allowed for more timely adjustment of the assumed neutral rate, and for increased uncertainty about the assumption, might be advisable. We recognize that this may not be easy. Some difficult technical issues arise, because of the link between the real equilibrium interest rate and the growth rate of potential output in a DSGE model.

## C. Models for the future

**55. The central bank should drive model development with a defined purpose, rather than to incorporate latest techniques.** This requires periodic re-assessment of the Board's needs. Validation criteria appropriate to the purpose of providing relevant macroeconomic forecasts and analysis for Board decisions would include:

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[8] An application to a U.S. model in Alichi and others (2015b) illustrates the technique.

- forecasting accuracy not just over time but relative to different shocks and states of the economy;
- ability to consider, and efficiently implement, alternative scenarios for monetary policy meetings.

**56. Satellite models can provide detail on causal mechanisms, as well as on disaggregated components of the macro variables in the core models.** For example, in the Chilean economy the exchange rate channel is a potent part of the monetary policy transmission mechanism. Core models capture this at the macro level with relatively high coefficients on the real exchange rate variable in output and inflation equations. They do not, however, attempt to provide detail on the causal mechanisms summarized in these coefficients. In reality, the timing and the strength of the overall responses depend on adjustments within various sectors which have differing degrees of sensitivity to the exchange rate—e.g. the tradables sector responds more rapidly than the non-tradables sector (Naudon and Vial, 2006). A satellite model could provide a description of the process. This would be preferable, in general, to building the increased detail into core models. Exceptions would be when it could be demonstrated that the increased complexity brought a payoff, in terms of the criteria mentioned above.

**57. The forecasting process has to deal with known or suspected weaknesses in the models.** Forecasts based on better models may require less judgmental adjustment, but no model is designed to answer all the relevant questions. The FPAS should include a transparent process for defining the issues to which judgment must be applied, and for providing appropriate solutions. Examples for Chile might include: the exchange rate transmission mechanism (as discussed above); and a possible bias in model policy reaction functions.

## D. Integrated XMAS-MEP forecasting: Recommendations for future model development and use

**58. CBOC forecast production is efficient, streamlined, and speedy.** There is not a steep hierarchy, and communications between the staff and the Board are cordial and frank. This environment is conducive both to sound macroeconomic analysis, and to informed decision making. Technically oriented staff make presentations directly to the Board and senior management.

**59. The central bank could, however, get more from its models in terms of risk assessments—i.e. sensitivity analyses or alternative scenarios.** This is very important, because this is where the major value of the model-based forecast lies. Good forecasting accuracy—and we underline that the CBOC model-based forecast performs relatively well in this regard—is an asset too, but alone not a sufficient basis for policy analysis and decision making. A useful model for monetary policy contains a coherent structure for the transmission mechanism from policy instruments to goals. This assists policy making, and in so doing it helps policymakers formulate a consistent macroeconomic narrative to communicate the rationale for their decisions.

**60. A modification of the forecast production schedule might help for this purpose.** One option would be to extend the forecast-production calendar, which is much shorter than in other

IFT central banks like the Bank of Canada and the Czech National Bank. We would keep a relatively short schedule, because the current CBOC process is impressively effective as it stands. An additional week at the start of the process, after the Board has seen, and responded to, an early version of the staff baseline forecast, might be enough. An Issues Meeting would be used to discuss major topics, including the main assumptions for the baseline, versus alternative scenarios. In addition, this meeting would spell out the implications of any revisions to the core models. A schedule of this nature would give the forecast team the time necessary to use the models, with adequate thought and consultation, to produce alternative scenarios to the baseline in line with the directions given by the Board.[9] The current compressed schedule does not permit this—it allows just a few days to produce the requested alternative cases—and the forecasting team is forced to rely heavily on their own judgment. This means that under the current process, the central bank loses much of the power of the model-based approach in which it has invested.

**61. A complementary option is a modest increase in forecast team staff, to allow a couple of economists to focus on a few model-based risk scenarios, relevant to the present conjuncture, but substantially different from the baseline.** They would work in parallel with the rest of the team, which would be putting together the baseline forecast. The staff would then present their alternative scenarios at an early forecast meeting with the Board. In any case, the staff should be bold in the assumptions they explore as alternatives to the baseline. This may involve challenges for the projected paths of underlying theoretical equilibrium variables. For example, the forecasters might explore the implications of a persistent shock to the neutral real interest rate. Such a shock might conflict with the equilibrium rate consistent with the balanced long-run growth path of the core model. There is a payoff to exploring changes that do not fit easily into the mold of the model. After all, the purpose of these sensitivity analyses is to help the Board develop strategies for events and developments outside the normal range—routine risks are covered by the confidence bands around the forecast paths for variables.

**62. Since the major macroeconomic risks confronting Chile often derive from complex shocks from the rest of the world, the CBOC might benefit from closer integration of its external forecasting with the model-based domestic forecasting.** For example, at the time of writing, the large fiscal expansion enacted in the United States, with the US economy at near full-employment, could have sizable implications for global interest rates, activity, and commodity prices. Such vast implications can only be explored adequately with the assistance an explicit numerical model of the global economy. A version of the GPM model, already used at the CBOC, might be used more extensively in this regard.

**63. An issue is whether the CBOC should continue using a two-model (XMAS and MEP) approach.** In recent years, FPAS modeling has concentrated on XMAS, and MEP has not been consistently updated. The question therefore amounts to whether or not MEP should be dropped.

[9] Adrian, Laxton, and Obstfeld, 2018, Chapter 4, contains a general discussion of design for an effective FPAS; Laxton, Scott and Rose, 2009, presents a detailed practical guide.

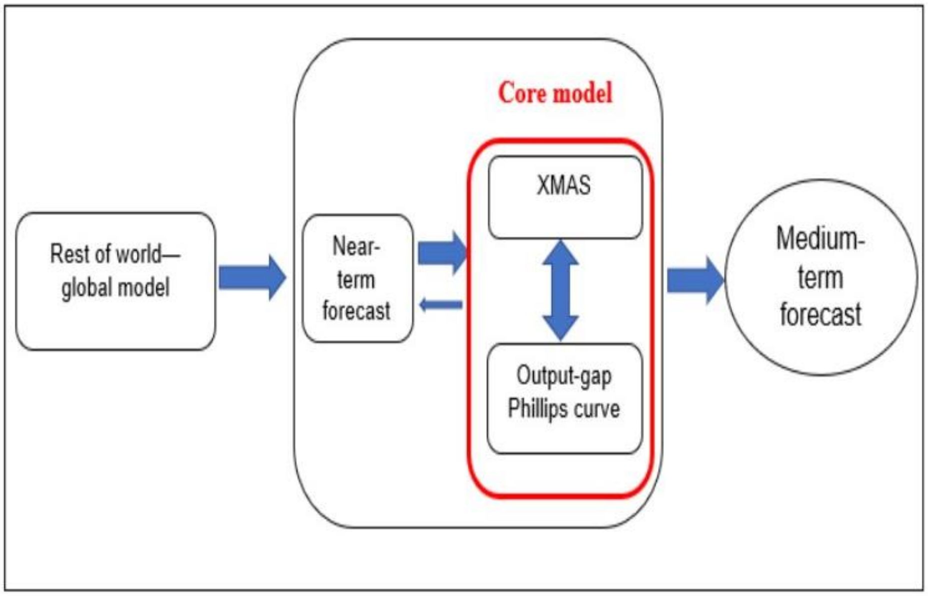
**64. In our view, the output gap, as used in MEP, is a useful concept for analyzing and communicating how the central bank manages the short-run trade-off between output and inflation.** Whereas this trade-off is clear and intuitive in the Phillips-curve equation in MEP, it is somewhat less so in the DSGE modelling of inflation used in XMAS.[10] Thus, policymakers generally find it easy to explain their choice of policy trade-off in terms of a Phillips curve, but less easy to explain how pressure of demand on marginal costs relates to the trade-off that they have chosen. Indeed, in central banks using a DSGE core forecasting model policymakers often employ a narrative for public communications that translates the DSGE concept of demand pressure into the more intuitive concept of the output gap (examples are in the MPR of the Bank of Canada, and intermittently in that of the CBOC). This translation of concepts is valid, because within the structure of the DSGE models, potential output, and hence the output gap, is implicit.

**65. This would suggest integrating the Phillips-curve-style model (MEP) into the new-Keynesian approach of XMAS.** Beneš and others (2010) propose a systematic methodology for integrating different forecasts that can be adapted for this purpose. It essentially involves combining the model-based forecasts, with weights inversely proportional to their historical standard errors (Appendix 6).

**66. A similar methodology can be used to integrate systematically the near-term and medium-term forecasts.** This would allow better recognition of the width of bands of uncertainty around short-term baseline forecast paths than under the current system, in which the near-term forecast is simply imposed as initial conditions. Figure 2 outlines the format: the arrows indicate direction of input. The central oblong nests XMAS, the output-gap Phillips-curve model, and the near-term forecast process. The red oblong inside it encompasses the recommended core model, which is the DSGE model XMAS integrated with the output gap Phillips curve. The thin arrow from the core model to the near-term forecast indicates relatively small feedback.

[10] Core inflation is, appropriately, the dependent variable in these equations. The staff make forecasts of the non-core component of headline inflation outside these models. Appendix 7 contains a general discussion of the uses of core inflation in monetary policy.

Figure 2. Schema for CBOC Model Integration




Source: IMF mission.

**67. MEP is in need of updating and restructuring.** As model development efforts have gone into XMAS, MEP has suffered. As argued in more detail below, we think it still has a useful role, for management of the policy trade-off, and for risk analyses. The main structural change that seems necessary is to incorporate the copper price, and to put the focus on overall GDP, rather than just non-minerals GDP. Commodity-cycle dynamics—especially copper price changes, and investment in the mining sector—play a central role in Chilean economic developments (e.g. Fornero and Kirchner 2018).

**68. Changed long-run environment—or headwinds?** The recognition lag means that in real time a change in an underlying real variable shows up as a repeated shock over a run of quarters—i.e. economic headwinds (adverse shocks) or tailwinds (favorable shocks). The challenge here for forecasters and policymakers is to decide if there has been a permanent shift, or if the shock will soon die out. In the short run, it may not matter much if policy makers treat a permanent change as temporary, as long as they recognize that the change has taken place. However, over time, lack of recognition could lead to a cumulative bias in the stance of policy.

**69. The case for a regular, backward-looking, review.** One way to moderate damage from the recognition lag would be to have a regular backward-looking review of the performance of monetary policy, with the participation on invited outside experts, at intervals of 5 years or less.[11]

[11] In Canada the inflation-target agreement between government and central bank has a duration of 5 years (e.g. Bank of Canada 2016). On its renewal there are extensive reviews of performance by outside experts, as well as Bank of Canada insiders. This arrangement has worked well.

More important, such a review would increase the accountability of the central bank for its own past actions. While it is a very good thing that monetary policy has become more forward-looking, it is important for any organization to stop, once in a while, and take a hard look back at what it has actually achieved.

**70. The CBOC might consider publishing the path of the policy interest rate in the staff forecast.** The Board wishes to provide a clear message about the future path of the interest rate following its policy rate announcements, yet longer-term market rates have not systematically reacted in the desired way. Several IFT central banks (e.g. Reserve Bank of New Zealand, Czech National Bank, and Sveriges Riksbank) have found that publication of a numerical path is the best way to avoid any ambiguity in this regard. The fact that the staff, rather the Board, is responsible for the forecast makes it quite feasible for the CBOC to take this step, as Board members may express reservations about a particular path—the staff forecast being the most important, but not the only input to policy decisions.

## V. Conclusions and Recommendations

**71. The CBOC has a sound, efficient forecasting and policy analysis system (FPAS)**. It compares well with any of the other central banks that have established successful frameworks for inflation-forecast targeting. CBOC staff employ state-of-the-art macroeconomic models. The Board has full confidence in their work, and affords them a high degree of independence for producing the forecasts that are used to make policy decisions at monetary policy meetings. The organization does not have a steep hierarchy; communications are easy both across sections and divisions, and over different levels. The forecasting team is small, and produces forecasts with impressive speed.

**72. The overriding priority is to retain the strengths of the current framework.** From here, the CBOC is in a good position to stay abreast of the developments in other advanced IFT central banks. Our recommendations for improvement are therefore for continued improvement, rather than radical changes to the tried and tested set-up. This said, any organization, even one at the forefront, must change to get the most from ongoing developments in technology and ideas, and to be ready to face the challenges that the ever-evolving environment may throw up.

**73. The two core models—MEP, the more traditional model, with an output-gap Phillips curve, and XMAS, the newer DSGE model—both have value and should be maintained.** Forecasts derived with both compare quite well in terms of accuracy to those of Consensus Economics, and those of benchmark IFT central banks, the Bank of Canada and the Czech National Bank. While this may reflect good judgment, it does nevertheless provide some support to the models. More important is that the latter help provide forecasts that embody a coherent quantitative macroeconomic narrative.

**74. The gap model, by its nature, highlights the short-run trade-off between inflation and output in analyses of economic shocks and related policy options.** It can therefore help policymakers to navigate the trade-off over a medium-term horizon, and to communicate their strategy in terms of widely-understood macroeconomic theory. Gap models also can be used for risk analyses that would be technically very difficult for a DSGE model.

**75. The DSGE model can answer complex questions that the gap model is not equipped to answer**. These include exogenous changes that may have important long-run implications for real variables, or for the accumulation of net assets or liabilities. These would include terms-of-trade shocks or many aspects of fiscal policy (e.g. Kumhof, and Laxton 2009).

**76. We recommend a process to integrate insights from the two approaches.** The mission team presented a technique to achieve this. A similar technique can be used to provide a systematic blending of the near-term forecast with the model-based medium-term forecast.

**77. As a counterpart to the speed and efficiency of the CBOC FPAS, there are some costs.** While resources are just about adequate for production of the baseline forecast each quarter, the compressed schedule does not allow sufficient time to do well considered simulations of alternative scenarios, with substantially different assumptions from the baseline. This means that the bank does not get full value from its considerable investment in models. After all, a major benefit of a model-based approach is the capacity to develop alternative scenarios consistent with standard macroeconomic thinking.

**78. Some operational risks are evident.** The tight production schedule, and relatively small forecasting team, implies long hours and stress for staff. There is no redundancy in the system, so it is not well placed to deal with unexpected departures of staff, or a sudden increase in the demands of senior managements. This problem could be reduced by increasing the team by one economist, and by increased rotation of staff between forecast production and model development. This would increase the pool of staff with appropriate skills in both functions, and hence provide back-up, as well as enriching the working environment.

**79. The CBOC might consider some changes to maintain a focus on medium-term, strategic issues in forecast production and presentation.** An Issues Meeting, of Board with forecasters, could discuss the major issues for the baseline forecast, and to illustrate risks and policy options, relevant assumptions for alternative scenarios. This meeting would take place a week before the start of the current forecast production schedule—which would in effect be extended by one week, up front. To relieve stress on the system, and in line with the suggestion for more staff rotation, model-builders, rather than the baseline forecasters, could do the simulations for the alternative scenarios.

**80. For improved transparency and accountability, and to mitigate the risk of a cumulative bias in policy decisions, the central bank might consider publishing a regular, backward-looking review of performance.** We would recommend such a review, with participation by invited outside experts, at least every 5 years.

**81. No radical reforms of the CBOC FPAS are desirable, as the positive results from the existing system speak for themselves.** Despite some major terms-of-trade shocks, and fluctuations in the actual rate of inflation (both headline and core), long-term inflation expectations have stayed steady at the 3 percent target rate. Likewise, monetary policy during the period of IFT has helped Chile avoid large cyclical movements in economic activity and employment.

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## Appendix 1. Structures and Properties of the Two Core Models XMAS and MEP

### Structure and Properties of MEP

**82. Mini-MEP is a semi-structural gap model with four core equations: IS curve; Philips curve; monetary policy reaction function; and an uncovered interest rate parity condition that allows for a risk premium (UIP).** Okun's law relates the unemployment gap to the output gap. There is an exogenous block for external variables. The model does not incorporate copper prices, and output in the model is restricted to *non-mining* GDP. This restricts the model's ability to provide forecasts and analyses of the effects of important terms of trade shocks on inflation and output in the economy as a whole.

**83. A backward-looking equation describes the evolution of the output gap.** It relates the output gap to its past values, current and lagged real interest rate gaps, and foreign output gaps, and to the lagged real exchange rate gap and the non-copper terms of trade gap**.** Notably, the IS equation does not include the future output gap and is specified in terms of first differences. It essentially represents an error-correction process which tends to close the output gap over time. Monetary policy influences the output gap through current and past real interest rate gaps.

**84. Foreign activity enters the output-gap equation through current and lagged foreign output gaps.** The latter which refer to advanced and emerging-country trading partners. The real exchange rate gap affects the output gap with a lag. A positive real exchange rate gap, which means a depreciated exchange rate relative to fundamentals, increases the output gap, reflecting the net exports channel. The equation also includes non-copper terms of trade. An unfavorable shock for Chile, such as international oil price increase, has a negative impact on the terms of trade and on the lower output gap.

**85. The Philips curve is specified in terms of core inflation, defined from the CPIEFE index which excludes food and energy.** Core inflation is determined by its expected future value, past headline inflation, the output gap, and the change in the real exchange rate gap. The inclusion of headline inflation in the equation for core inflation reflects the fact that core goods production uses non-core products as input. Therefore, an increase of headline inflation leads to pressures for core inflation to rise. In the same manner, depreciation of the real exchange rate pushes core inflation up through its imported components.

**86. Monetary policy responds to future and past core inflation as well as to the output gap.** The monetary policy reaction function is specified in terms of the deviation of the policy rate from its neutral level, the interest rate gap. The lagged interest rate gap in the equation reflects policymakers' smoothing preferences. The policy rate reacts to one-quarter-ahead annual core inflation and current output gap.

**87. The UIP equation relates the US-Chile interest rate differential to expected USD/CLP exchange rate depreciation as well as country risk premium.** The country risk premium is an observable variable, measured on the basis of JP Morgan EMBI index. The equation is specified in terms of interest rate gaps. The US interest rate gap is the deviation of US nominal policy rate from its steady state value which is calibrated at 2 percent.

**Core Blocks of MEP**

**IS curve**

$$\Delta y_t = -a_1(y_{t-1} + y_{t-2}) - a_2(y_{t-1} - y_{t-2}) - a_3(r_t - rn_t + r_{t-1} - rn_{t-1}) + a_4(y_t^{em} + y_{t-1}^{em}) + a_5(y_t^{av} + y_{t-1}^{av}) + a_6 tcr_{t-1} + a_7 tisc_t + \vartheta_t^y,$$

where $y$ stands for output gap, $r$ for real interest rate in annual terms, $rn$ for neutral real interest rate in annual terms, $y^{em}$ for output gap of emerging economies, $y^{av}$ for output gap of advanced economies, $tcr$ for real exchange rate gap with increase meaning depreciation, $tisc$ for non-copper terms of trade gap with increase meaning favorable terms of trade change, and $\vartheta^y$ for stochastic disturbance which is an AR(1) process. The real equilibrium exchange rate is assumed to be constant.

**Philips curve**

$$\pi_t^{SAE} = b_t E_t \left[\pi_{t+1}^{SAE} - \frac{1-\gamma}{\gamma}\Delta tcr_{t+1}\right] + b_2 \pi_{t-1}^{IPC} + b_3 y_t + \frac{1-\gamma}{\gamma}\Delta tcr_t + \vartheta_t^{\pi},$$

where $\pi^{SAE}$ stands for quarterly (non-annualized) core inflation in deviation from target, $\pi^{IPC}$ for quarterly (non-annualized) headline inflation in deviation from target, $\vartheta^{\pi}$ for stochastic disturbance which is an AR(1) process, and $E_t$ is the expectation operator.

**Monetary policy reaction function**

$$i_t - in_t = c_1(i_{t-1} - in_{t-1}) + (1 - c_1)\left(c_2 E_t\left[\sum_{i=0}^{3} \pi_{t+1-i}^{SAE}\right] + c_3 y_t\right) + \xi_t^i,$$

where $i$ stands for nominal policy interest rate (annual rate), and $\xi^i$ for Gaussian stochastic disturbance.

**UIP equation**

$$\frac{i_t - in_t}{4} - \frac{i_t^{ext}}{4} - \frac{\rho_t^{embi}}{4} = E_t[deus_{t+1}] + \vartheta_t^{UIP},$$

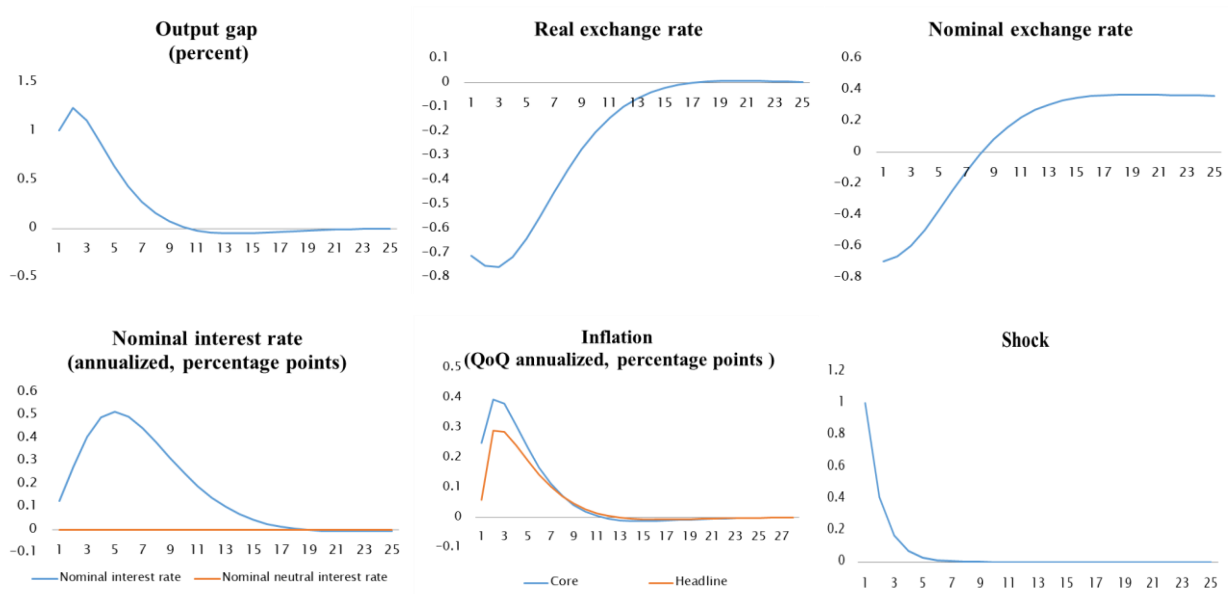
where $i^{ext}$ stands for deviation US monetary policy interest rate from its steady state value of 2% in annual terms, $\rho^{embi}$ for country annual risk premium gap, which assumes a constant equilibrium risk premium (measured by the JP Morgan EMBI index), $deus$ for nominal exchange rate depreciation, and $\vartheta^{UIP}$ for stochastic disturbance which is an AR(1) process.

## IMPULSE-RESPONSE FUNCTIONS OF MEP

88. **Overall, the responses are fairly standard.** A selection is in Figures A1.1-A1.4. All the charts show deviations from the steady state. The bottom right panel in all cases shows the time profile of the assumed shock.

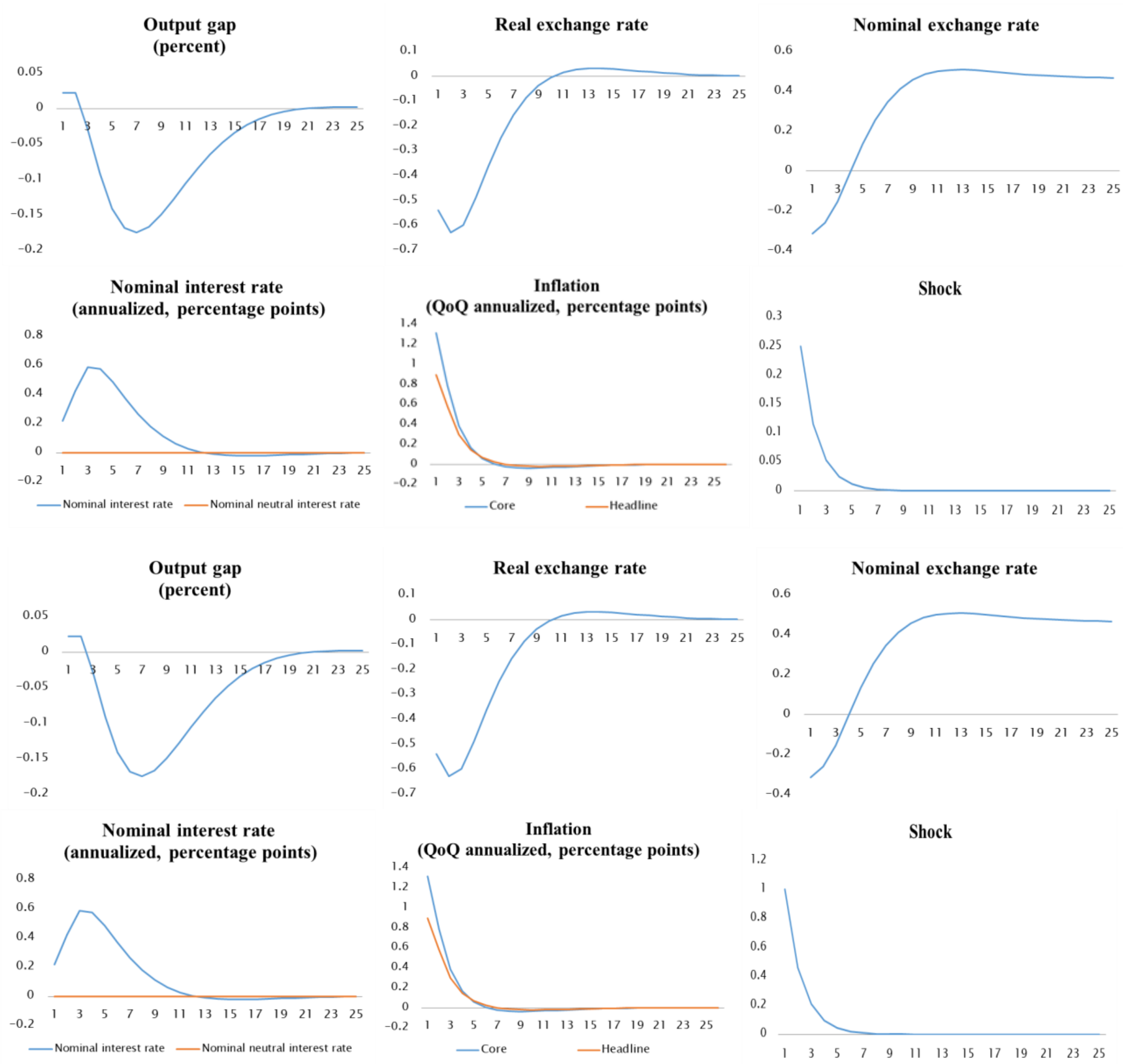
**89. The shock to the country risk premium has a large but transitory impact on inflation (Figure A1.4).** The absence of second-round effects may be questionable for Chile in view of the *Unidad de Fomento* price indexation in wage and other contracts. The nominal exchange rate depreciates by around one percent leading to 0.15 percentage points higher core and 0.25 percentage points higher headline inflation on impact. However, inflation converges back to the target almost instantaneously in the second quarter. Monetary policy in the model does not need to react to the deviations from target, because it is forward-looking, and looks through the one-off increase in inflation.

Figure A1.1. Output Gap Shock



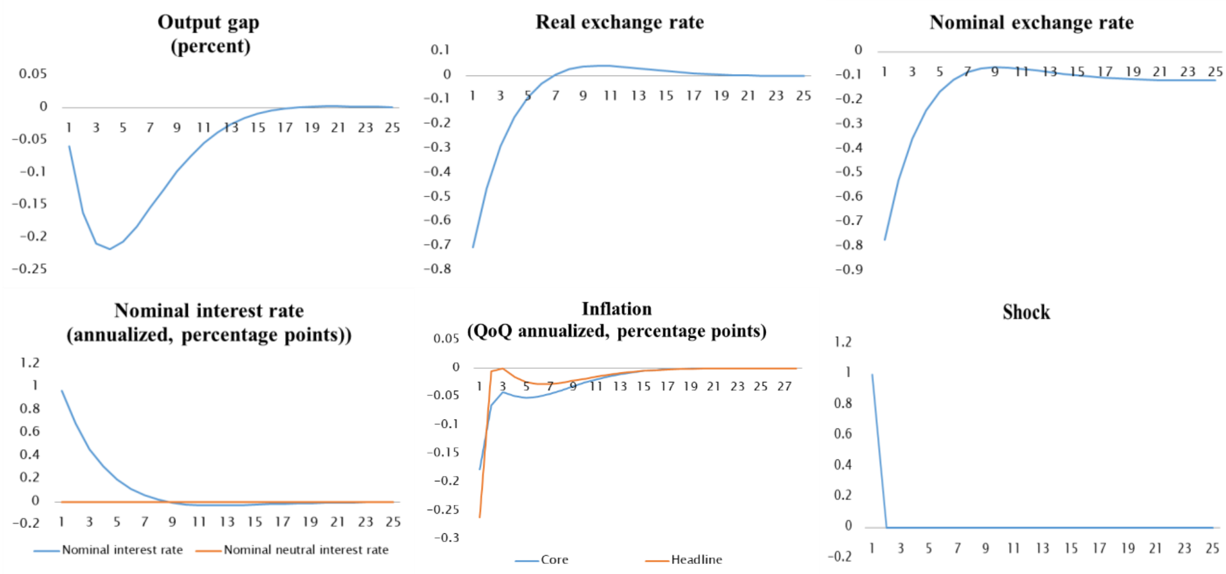

Source: CBOC.

Figure A1.2. Core Inflation Shock



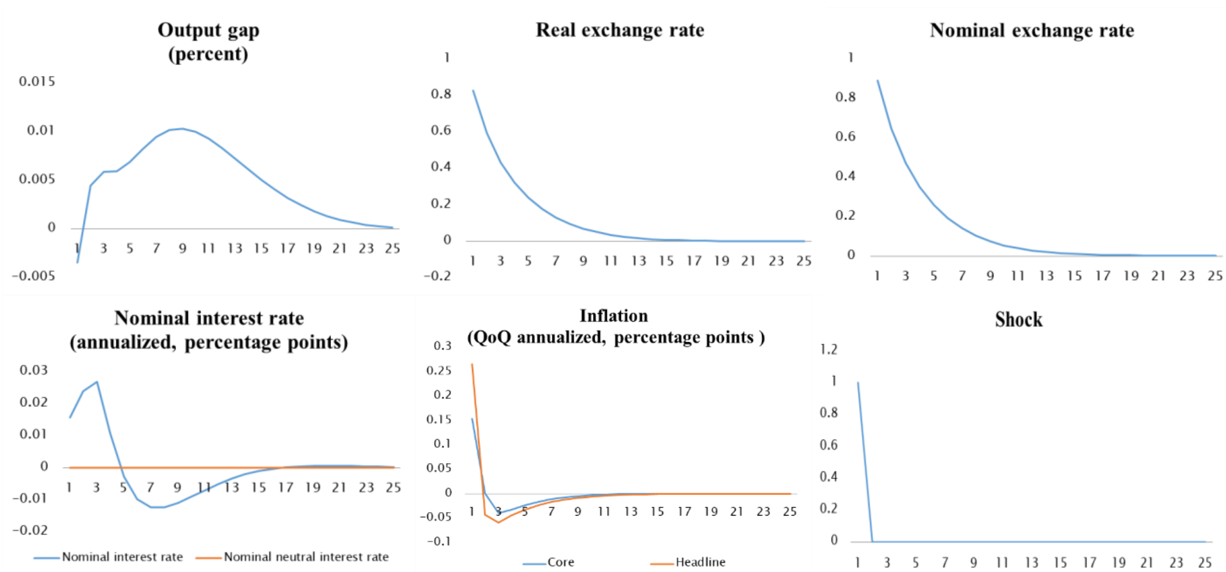

Source: CBOC.

Figure A1.3. Monetary Policy Shock




Source: CBOC.

Figure A1.4. Country Risk-Premium Shock



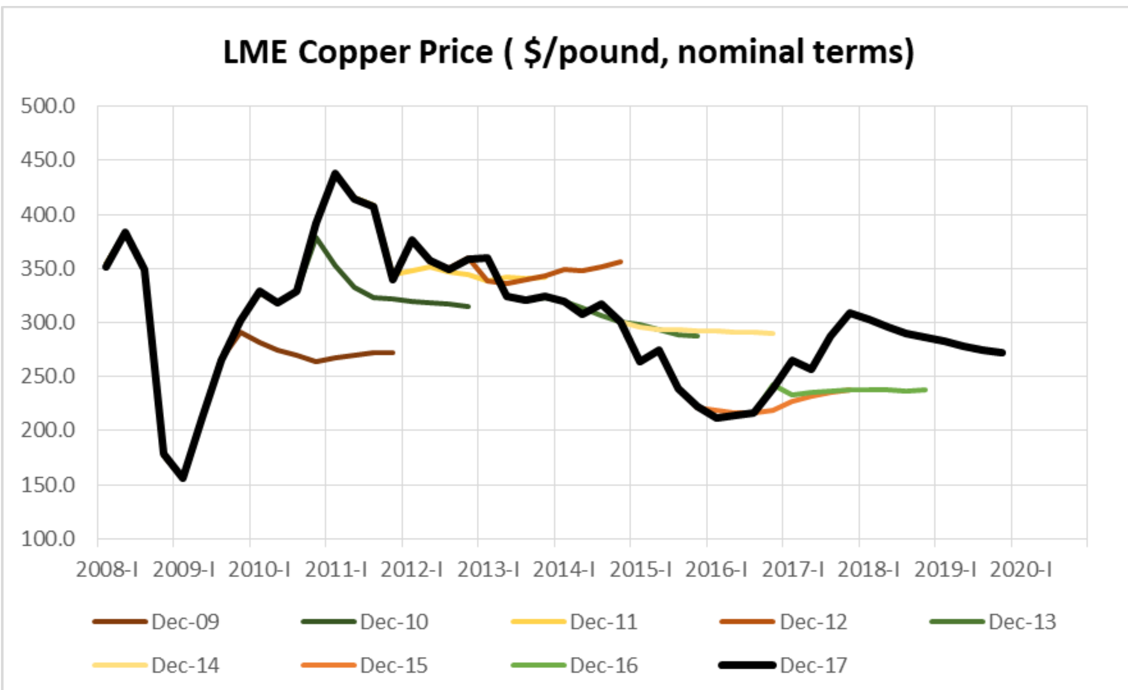

Source: CBOC.

### STRUCTURE AND PROPERTIES OF XMAS

**90. XMAS is based on the previous DSGE model MAS (Medina and Soto 2007).** Additional features of XMAS include an endogenous commodity sector, a more disaggregated government sector, and variable capital utilization. XMAS does not feature unemployment (extensive margin), and includes only hours worked (intensive margin). Currently, a new version of XMAS, in which unemployment is due to search and matching frictions, is under development. This new version can serve as a useful satellite model supporting the main forecasting models until it is fully developed, and tested in actual forecast exercises.

**91. Commodity prices, especially copper, are important drivers of the business cycle in Chile.** Copper price movements have considerable spillovers to the rest of the economy through investment, government, and exchange rate channels. Investment in the mining sector after the GFC has been one of the most important drivers of investment growth variability. Figure A1.5 illustrates the historical CBOC forecasts since December 2009. The chart suggests a tendency for mean reversion in the forecast. As the figure shows, there have been big surprises, a first-order concern for monetary policy.

Figure A1.5. CBOC Copper Price Forecasts




Source: CBOC.

**92. XMAS features an endogenous commodity producing sector with quadratic investment adjustment costs (specified in terms of investment growth) and time to build of 6 quarters.** The modeling of the commodity sector is based on Fornero et al, (2014). The sector has capital-intensive production, variable capital utilization, and sector-specific investment efficiency. The government owns 33 percent of the sector and taxes profits of the rest, which is foreign-owned. The aggregate technology trend for the sector in the model is consistent with the balanced growth path, but can temporarily deviate from it.

**93. Government spending in XMAS is disaggregated into consumption, investment, transfers, and stabilization of domestic oil prices.** The latter is a sort of variable subsidy with zero mean in the long run. The model includes a menu of taxes: consumption; labor income; capital income; dividend income; and private commodity profits. Government debt is in foreign currency.

**94. Government follows a structural balance rule, which reacts to the deviation of tax revenues from its potential and the deviation of the government income from the commodity sector from its long-term reference value.** Tax potential is defined as non-commodity tax revenues when economy is in the steady state. The long-run reference price of the commodity is in essence an average of endogenous price forecasts for the next 10 years.

**95. The inflation-forecast-based policy reaction function in XMAS reacts to deviations from target of current and expected inflation--both headline *and* core, with both measures net of indirect taxes.** Monetary policy also reacts to deviations of GDP growth from technology growth. The latter makes up for the concept of the output gap, which is absent from the model. Multi-sector DSGE models with complex structures typically have difficulty in defining the concept of potential output, and hence a gap concept. Model-consistent concepts of potential output exist in theory, but the derived measures from typical DSGE models are sensitive to technical assumptions, etc.

### IMPULSE RESPONSE FUNCTIONS OF XMAS

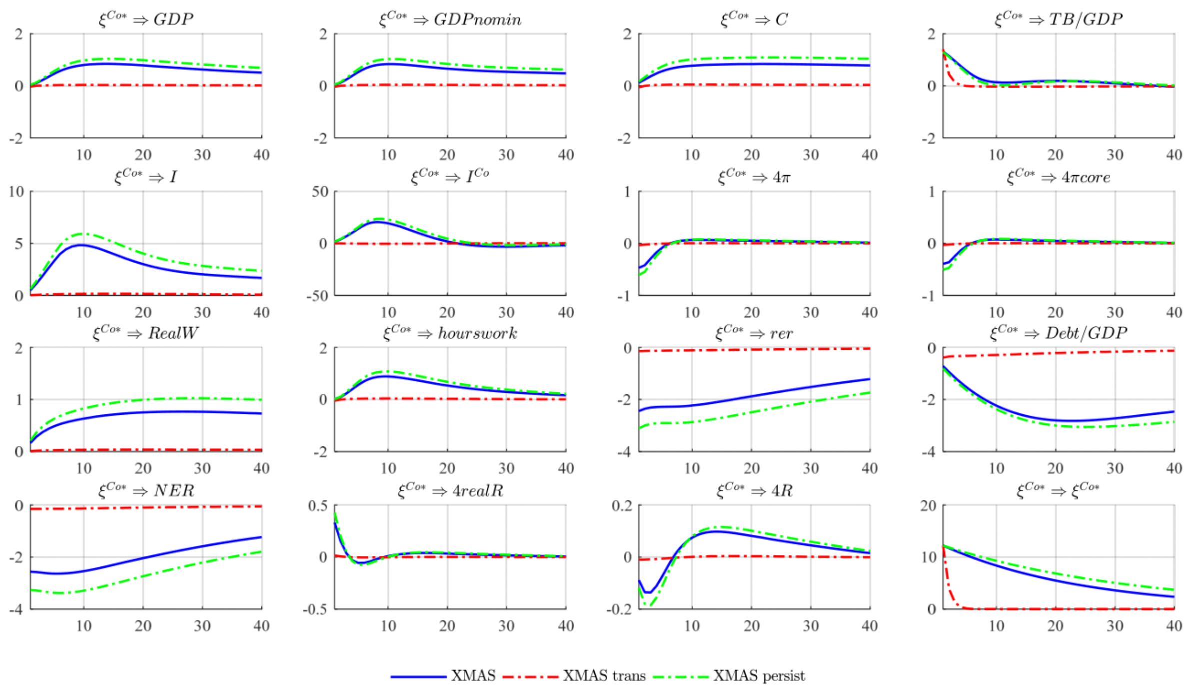
**96. Figures A1.6-A1.9 illustrate impulse response functions for selected shocks.** These relate to: international copper and oil prices, consumption preferences, monetary policy, government investment, and investment efficiency. Here again, in all figures the bottom right panel includes the shock profile. The initial size of the shock is equal to one standard deviation. The figures represent the deviations of variables from their steady state values. The definitions of variables are presented following the figure A1.9.

**97. The figure A1.6 shows the impulse response functions for international copper price shocks.** These start at 12 percent in the first quarter, and taper off with different persistence parameters. The blue line is the baseline; the green and red dashed lines represent the contrasting cases of very high or of negligible persistence.

**98. The positive terms of trade shock, in the 2 more persistent cases, leads to a significant increase of investment in the mining sector.** Investment builds up gradually due to adjustment costs and time-to-build requirements; mining investment peaks in about 10 quarters at level 25 percent above control. Consumption increases gradually reflecting higher wealth and income. The trade balance goes into surplus, which leads to an appreciation of the real exchange rate to bring back the economy to the steady state external balance. The appreciation of real and nominal exchange rates helps to explain the fall in inflation despite higher investment and consumption.

**99. The same initial shock with negligible persistence, has almost no effects.** Notably, investment in the mining sector does not pick up as investors anticipate correctly that prices are higher only temporarily.

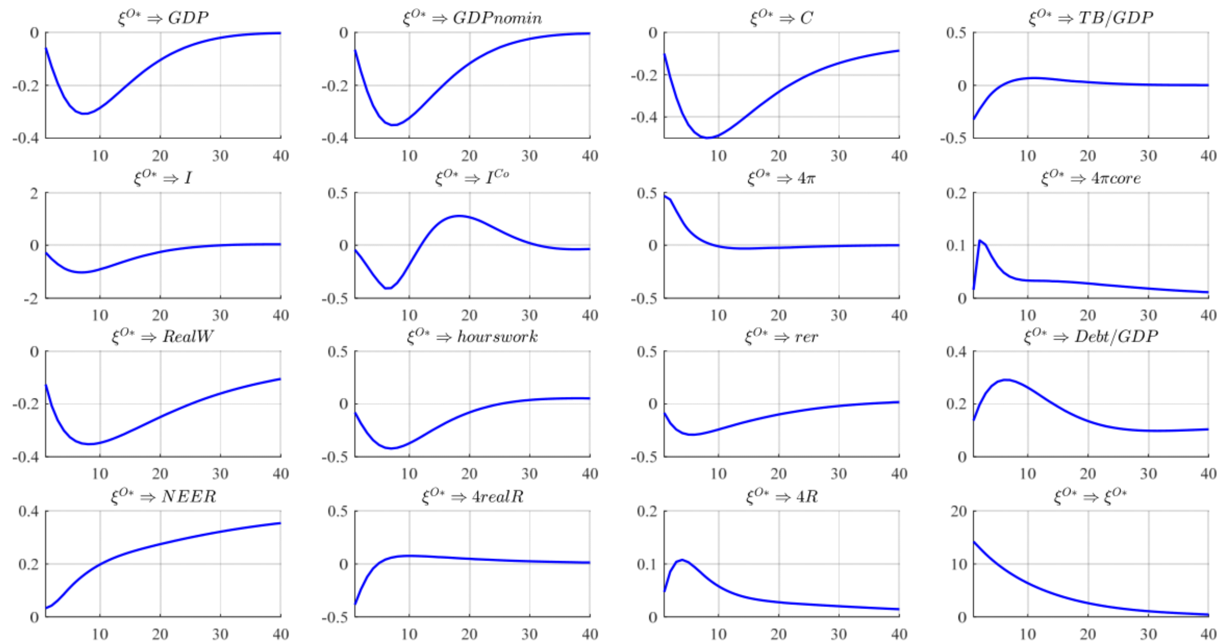
Figure A1.6. International Copper Price Shock




Source: CBOC.

**100. The simulated persistent international oil price shock represents a negative terms of trade shock (Figure A1.7).** The initial oil price increase is 15 percent. The trade balance goes into deficit. Headline inflation increases on impact by about 0.5 percentage point, and about half that after 4 quarters. There is little persistence in the inflation process itself, the persistence of the higher rate is mainly due to the persistence of the oil price shock.

Figure A1.7. International Oil Price Shock

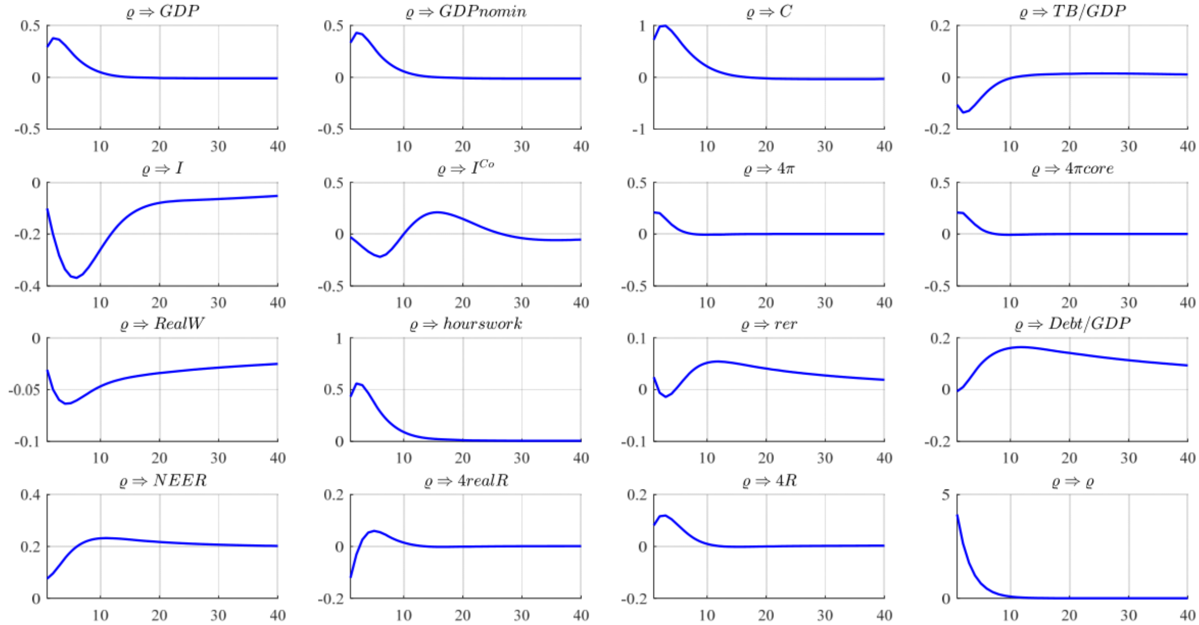



Source: CBOC.

**101. Following the oil price increase, the simulated real-exchange-rate response is an appreciation.** This is not the standard response expected for an oil importer.

**102. The consumption preference shock involves a one percent increase in consumption spending (Figure A1.8, third quadrant, top row).** Investment drops substantially, a classic crowding-out effect, as the policy interest rate rises to offset the inflationary pressures. The response of the exchange rate to this shock is a real depreciation. In effect, the movement in the trade balance, and that in the interest differential, go in opposite directions. The increased policy rate would appreciate the peso, but a strong effect from the trade balance results in the deprecation. This is a model property worth exploring.

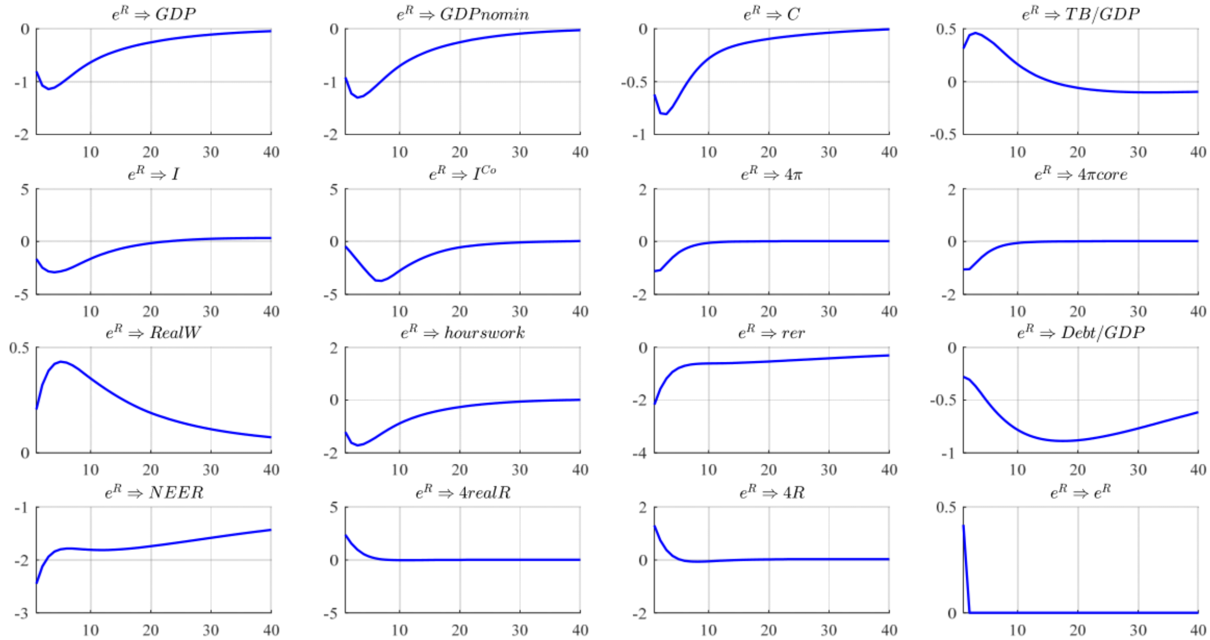
Figure A1.8. Consumption Preference Shock




Source: CBOC.

**103. The direction of response to a transitory monetary policy is standard, but the size of the responses of output and inflation are quite large (Figure A1.9).** The simulated shock translates to a 1 percent increase in the policy rate in the initial quarter dropping to zero after the fourth. Output drops by one percent in the short run, and stay below control for many quarters. Again, a model property to reconsider.

Figure A1.9. Monetary Policy Shock




Source: CBOC.

Variable definitions: GDP for real GDP; GDPnomin for non-mining GDP; C for consumption; TB/GDP for the ratio of trade balance to GDP; I for investment; $I^{Co}$ for investment in the commodity sector; 4π for annualized headline quarter-over-quarter inflation rate; 4πcore for annualized quarter-over-quarter core inflation; RealW for real wage; hourswork for hours worked; rer for real effective exchange rate; Debt/GDP for the share of government debt to GDP; NEER for nominal effective exchange rate; 4realR for real interest rate in annual terms; 4R for annualized nominal interest rate.

## APPENDIX 2. NEAR-TERM FORECASTING SYSTEM

### GENERAL PROCESS

**104. Near-Term Forecasting Section is split into two groups, one dedicated to inflation and the other one to real sector variables.** The forecast for monthly data has a horizon of six months, and the quarterly forecast horizon is two quarters. Both are updated monthly.

**105. Near-term forecasts are input for the model-based medium-term forecast.** They provide numbers for the current quarter (nowcast) and for the next quarter. In the future, this may be extended one quarter.

**106. For some variables, the Near-Term Forecasting Section provides the medium-term forecast.** These are non-core CPI inflation (28 percent of headline CPI), and the output for the natural resources sector (14 percent of GDP), defined as mining, electricity and fishing.

**107. The Section uses numerous models.** Parameters are derived through standard estimation. For some prices indexation rules apply. The Section uses a wide range of high-frequency data, such as prices published weekly by industry organizations. Anecdotal evidence collected by sector specialists helps form expert judgment, which is a crucial input for the Section's forecasts. Interaction with the Medium-Term Section may, for some variables, result in modifications for the quarter ahead, to ensure a model-consistent set of initial conditions for the medium-term forecast.

### INFLATION FORECASTS

**108. Statistical time-series models are used to forecast CPI inflation and its components (Table A2.1).** A bottom-up approach applies ARIMA models (SARIMA) to all 15 components, which are then aggregated. Forecasts for monthly inflation—headline and two measures of core (CPIEFE and CPIX)—are also derived with threshold autoregressive (TAR) models. [12]

**Table A2.1. Time-Series Models**

| Models | Applied to |
|---|---|
| SARIMA | All 15 CPI components[13] |
| TAR | Headline CPI<br>CPIEFE<br>CPIX |

Source: IMF mission.

[12] CPIEFE and CPIX are exclusion-based measures of core inflation. The CPIEFE excludes the groups food and energy from the headline CPI, whereas the CPIX excludes subsets of those groups, which are fruits and vegetables and fuel. Those core inflation measures correspond, respectively, to 72 percent and 91percent of the headline CPI.

[13] The 15 CPI components are the following: food, fruits and vegetables, meat, housing, housing equipment, clothing, transportation services, communication services, health services, education, recreational services, indexed prices, public transportation, financial services, and fuel.

**109. Economic models are also used for core inflation, disaggregated into services and goods components (Table A2.2).** In the case of services, estimated equations (Phillips curves) provide the price elasticities to the output gap, wage rates, the external price of oil and the nominal exchange rate.

**Table A2.2. Economic Models**

| Groups | Elasticities of |
|---|---|
| Services | Output gap<br>Wages<br>External price of oil<br>Nominal exchange rate |
| Goods | Nominal exchange rate |

Source: IMF mission.

**110. The estimated equations for goods inflation, Phillips curves and VARs, include sizable exchange-rate pass-through.** For services, the assumption is that the exchange rate influences only transportation services, which comprise 10 percent of total services. Forecasts therefore depend to a significant extent on assumptions about the future exchange rate.

**111. In general, elasticity parameters are updated yearly.** In the forecasting process, the Medium-Term Section provides the output gap measure whereas the International Section provides the external price of oil is based on forecasts.

**112. The forecast of food inflation differentiates Fruits and Vegetables (fresh food) from Rest of Food (processed).** The forecast for fresh food inflation considers only the observed seasonal pattern. That for processed food is based on quarterly VEC models, which include external food inflation, the nominal exchange rate, and wage rates.

**Table A2.3. Forecasting Food Inflation**

| Groups | Determinants |
|---|---|
| Fruits and Vegetables | Seasonal pattern |
| Rest of Food | VEC models with:<br>• External price of food<br>• Nominal exchange rate<br>• Wages |

Source: IMF mission.

## REAL SECTOR FORECASTS

### Quarterly GDP

113. **The GDP forecast is based on both demand-side and supply-side factors (Table A2.4).** For demand, two specifications of mixed-data-sampling (MIDAS) models are applied: with cointegration and without cointegration. Separate forecasts are derived for: aggregate GDP; GDP excluding natural resources; private consumption; investment; and imports and exports.

**Table A2.4. Forecasting Quarterly Output**

| Models | Applied to |
|---|---|
| MIDAS<br>• with cointegration<br>• without cointegration | Demand side:<br>• GDP<br>• GDP without natural resources<br>• private consumption<br>• investment<br>• imports<br>• exports |
| Bridge models | Supply side:<br>• GDP<br>• GDP without natural resources<br>• Natural resources<br>• Mining<br>• Electricity<br>• Fishing<br>• Construction<br>• Retail<br>• Manufacturing<br>• Services |

Source: IMF mission.

114. **The supply-side forecast uses bridge equations.** Monthly ARIMA models are used to complete the nowcast for the current quarter. Separate forecasts are generated for: aggregate GDP; GDP without natural resources; the natural resources sector and its components (mining, electricity and fishing); construction; retail; manufacturing; and services.

115. **The near-term forecast gives more weight to the demand-side approach (MIDAS), since it has more economic content.** The focus is quarterly. Data and forecasts for the monthly activity index IMACEC are aggregated to quarterly to guarantee consistency.

**Monthly output forecast**

**116. Forecasts for IMACEC are based on the supply side only.** Four specifications of Bayesian VAR models (BVAR) are used to forecast the aggregate, and its 11 sectors[14]. The specifications cumulatively add the following components to a standard small open economy structure: financial sector; monetary sector and export-import interactions. Alternative forecasts for these variables derive from ARIMA models that integrate the X-13-ARIMA-SEATS program.

**117. Estimated regression equations are used to forecast manufacturing-sector activity as well as aggregate IMACEC.** The main indicator variables for the aggregate are: energy consumption; and the sentiment index of the Entrepreneurs Sentiment Survey. For the manufacturing sector, the model includes the installed capacity indicator, and the Entrepreneurs Sentiment Survey index.

**Table A2.5. Forecasting Monthly Output**

| Models | Applied to |
|---|---|
| BVAR<br>X-13-ARIMA-SEATS | • IMACEC<br>• 11 sectors |
| Standard time series | • IMACEC<br>• Manufacturing sector |

Source: IMF mission.

**118. Principal components models are applied to forecast investment and the construction sector.** A consistency check ensures that investment, on the demand side, corresponds to construction, on the supply side.[15] The main indicators these models are for: concrete production; employment in construction; sales of construction material; the Construction Entrepreneurial Survey; and in the case of investment, copper prices.

**Natural resources output**

**119. The forecast for the natural resources production is mainly based on investment plans, leading indicators and anecdotic evidence.** Models play a secondary role. The quarterly

[14] The IMACEC sectors are: Energy, Retail, Construction, Mining, Agricultural, Manufacturing, Financial services, Transportation, Education, Health and other services, Public services.

[15] The difference of those two variables comes from the real estate trading service, which is a small component of construction sector.

forecast for this sector by the Near-Term Section enters as a predetermined variable in the model-based medium-term forecast.

**120. Natural resources output comprises 14 percent of GDP.** It consists of three sectors: mining (10 percent of GDP), electricity production (3 percent) and fishing (1 percent, but volatile). The most important inputs for each forecast are:

- mining sector:
  - copper production for next years: new entries to the market;
  - investment plans
- electricity sector:
  - energy generation
  - source data (diesel, hydro, unconventional)
  - scenarios based on climatic forecasting
  - published 5-year investment plans
- fishing sector:
  - monthly catch reported by fishing companies
  - yearly fishing limit set by the government.

### ALTERNATIVE MEASURES OF THE OUTPUT GAP

**121. In addition to the official measure of the output gap, provided by the medium-term forecasting unit, the Near-Term Section derives alternative measures based on these indicators**:

- energy consumption (bandpass filter cycle)
- installed capacity utilization (Entrepreneur Sentiment Survey)
- unemployment rate for 25–54 years-old males (group with high participation rate);
- official unemployment rate relative to an estimate of NAIRU, with demographic adjustment for structural changes in labor force participation[16]
- self-employment relative to wage employment (an indicator of slack).

### OTHER SECTORS

**122. The Near-Term Section's fiscal expert provides the forecast for fiscal variables.** These include government spending components, as well as a supply-side estimate of public services.

**123. GDP and inflation forecasts are used to forecast labor market variables:**

- wage employment
- nominal wage rates (indexed to the Unidad de Fomento)

[16] The adjustment in the NAIRU is to correct for the recent trend of lower participation rates of young people, which is usually a group with a high unemployment rate.

- labor income for the wage-employed.
- self employment.

### ISSUES IN NEAR-TERM FORECAST

**124. Two broad issues might be highlighted:**

- seasonal adjustment: often a source of disturbance in quarter-over-quarter growth rates; parameters known to be unstable must be taken as given.
- the eclecticism of the near-term forecasting system—judgment essentially decides the forecasts, but it is influenced by models to an extent that is difficult to quantify—this may be inevitable given the wide array, and varying nature, of relevant information.

## APPENDIX 3. ORGANIZATION AND SCHEDULE FOR FORECAST

### ASPECTS OF THE CBOC FPAS

**125. The CBOC FPAS operates in a flat organizational hierarchy.** The head of the Department of Macroeconomic Analysis (DMA) reports to the Chief Economist (i.e. the head of the Research Division) who reports to the Board (Table A3.1). The former, assisted by the head of the International Section of the department, presents forecasts to the Board, including to the Monetary Policy Meeting (MPM).

**Table A3.1. Organization Chart for Forecasting Function in the Research Division of the Central Bank of Chile**

| | Board | | | | | |
|---|---|---|---|---|---|---|
| **Division** | **Research Division** | | | | | |
| **Department** | **Monetary Policy Strategy & Communication** | **Macroeconomic Analysis** | | | **Economic Modeling & Analysis** | **Economic Research** |
| **Section** | | **International** | **Conjuncture** | **Medium-term Forecasting** | | |
| **Functions** | Communications, Monetary Policy Report. | Foreign activity, prices, interest rates, USD. World commodity prices. | Inflation and real economy: nowcast, NTF, MTF for some variables (e.g. natural resources sector GDP). One fiscal expert. | MEP–semi-structural model. XMAS–DSGE. | Development of future generation of forecasting and satellite models.<br><br>Special research topics (e.g. structural issues, microdata etc.) | Advanced research for publication. Special projects. |
| **Economists and research assistants** | 8 | 10-11 | 12-15 | 5 | 15 | 15 |

Source: IMF mission.

**126. DMA makes a full, model-based, forecast quarterly to be presented just in time for the next MPM.** For the 4 “inter-forecast” MPMs, the department produces an update, model-based, but with the partial available information.

**127. The production team for the model-based forecast (FT) is relatively small.** It comprises at full complement 3 model operators (for the 2 core models) in the Medium-Term Forecast section. The team works intensively during the production process. Staff are committed, with appropriate technical skills. Rotation is relatively limited, with key members typically staying for terms of several years. This has the advantage that they build extensive knowledge in the area, and are adept operators of XMAS and MEP. The staff responsible for core model development are in the Economic Modelling and Analysis Department, thus detached from regular forecasting production.

128. **The time-schedule for forecast production is brief.** Typically, the staff forecast is finalized two weeks after the process kicks off with a staff meeting on the international outlook (Table A3.2). The Czech National Bank discussed below has a lengthier production process.

**Table A3.2. Illustrative Schedule for Forecast and Monetary Policy Meetings**
Month (T) with a Quarterly National Accounts Release and Full Forecast

| Week | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|
| **1** | | | | **Staff meeting External scenario** Update to previous forecast and MPR. Dry run for Week 2, Tues. | **Staff meeting Internal scenario** Update to previous forecast and MPR. Dry run for Week 2, Thurs. |
| **2** | IMACEC for month T-2 released | **Staff presentation to Board** External scenario. Trends update and forecast. | **Staff meeting** Chile baseline forecast and alternative Scenarios. Dry run for Week 3, Tues. | **Staff presentation to Board** Internal scenario. Review of outcomes relative to previous forecasts. | |
| **3** | | **Staff presentation to Board** Baseline forecast. | **Staff presentation to Board** Alternative paths for the MPIR: (1) for baseline assumptions; and (2) for different assumptions (e.g. external). | | **Staff and Board** Drafting Executive Summary, MPR. |
| **4** | National accounts for quarter ending T-3 published. | **Board Monetary Policy Meeting** MPIR decision. Treasury Sec attends. Exec Summary finalized. 6 pm: press release. | **Governor press conference** | Conference with business representatives. | |

MPR: Monetary Policy Report. MPIR: Monetary policy interest rate. NT, MT: near, medium term. MPM: Monetary Policy Meeting. IMACEC: CBOC Monthly Activity Index.

Source: Czech National Bank.

**129. Speed of production in large part reflects efficiency of the CBOC FPAS—i.e. of the FT, of the flat hierarchy, and of the overall work environment at the CBOC.** Communications between different levels, and across divisions are effective. Discussions and meetings are cordial and frank, without undue back and forth.

**130. There is, however, little capacity in the system to cope with policymaker demands or unexpected staff absences.** The lack of redundancy means that while resources are broadly adequate to produce a model-based baseline forecast, they are insufficient for well-adapted model-based alternative scenarios within the allotted time schedule.

**131. Thus, while the relatively small staff, limited turnover, and compressed schedule may enhance efficiency, these features also imply costs and risks:**

- the CBOC does not derive full return from its investment in the core models
- the FPAS is subject to operational risk.

**132. The CBOC production schedule allows only a few days for the staff for the FT to derive a Board-requested alternative scenario.** The International Section does not always have sufficient time to assess the full international implications of a global shock such as to metals prices or U.S. interest rates, unless those are flagged in advance at weekly meetings of staff with the Board outside of the forecasting schedule. The FT does not have sufficient time to carefully adapt technical model assumptions to a requested substantive macroeconomic shock. Experience at other central banks suggests that a forecasting team would usually require about 5 days to do a well-designed model simulation.

**133. Operational risk derives from unexpected staff turnover and burnout.** Intensive work effort over a prolonged period of time with no rotation of staff can be stressful, and can lead to departures of key staff. Difficult-to-replace human capital can walk out of the door. Retention of staff with accumulated on-the-job training for highly specialized work is a huge asset.

### CZECH NATIONAL BANK'S FORECAST PRODUCTION SCHEDULE

**134. The Czech National Bank forecast production schedule covers about 4 weeks, plus two weeks for drafting of the Inflation Report and preparation of Board's communication.** This allows the FT about a week to produce model-based alternative scenarios, with adequate input of judgement (week 4, Table A3.3.). Moreover, Board's requests for more fundamental alternatives are often pre-announced even one week earlier (week 3).

**Table A3.3. Czech Republic: CNB's Forecast Schedule**

| Meeting | Week | Day |
|---|---|---|
| Meeting on forecasting techniques and past forecast evaluation | 1 | (variable) |
| Issues meeting | 1 | (variable) |
| NTF presentation to the department | 2 | Mon |
| Meeting on initial conditions and forecast assumptions | 2 | Wed |
| Meeting with the Board on initial conditions | 3 | Mon |
| First version of the forecast | 3 | Thu |
| Meeting with the Board on alternative scenarios | 4 | Mon |
| Approval of the forecast | 4 | Wed |
| Drafting of the Situation Report / Inflation Report | 5 | Tue-Thu |
| Meeting on the monetary policy recommendation | 6 | Tue |
| CNB Board's monetary policy meeting | 6 | Thu |
| Post mortem meeting | 6/7 | (variable) |

Source: Czech National Bank.

## APPENDIX 4. COMPARISON OF FORECASTING ACCURACY VERSUS TWO BENCHMARKS: CONSENSUS ECONOMICS AND OTHER CENTRAL BANKS

**135. The official forecast published by the CBOC since 2010 is based on two quarterly core models.** These are XMAS (a DSGE model) and the older MEP (a standard, semi-structural, macroeconomic model). The published central bank forecast takes the average of the results from the two. The forecast is updated quarterly. The sample period covers all the complete calendar years for which both models have been in use, 2010-17.

**136. The forecast errors are defined as the difference between current data (i.e. the latest estimates for the outcomes) and the historical forecasts.** Current estimates contain revisions to the data that would have been available even during the quarters immediately after the forecasted year. Annual GDP growth refers to the growth from the previous to the current calendar year. For Canada and the Czech Republic, annual inflation refers to the change of the average of CPI index for the calendar year from the previous year. For Chile, in contrast, annual inflation refers to the twelve-month change to December—the results for Chile in this regard are therefore not comparable with those for Canada and the Czech Republic.

**137. The benchmarks chosen for this analysis of CBOC forecast accuracy are:**

- the survey of forecasters by Consensus Economics; and
- 2 IFT central banks—
    - the Czech National Bank (CNB), and
    - the Bank of Canada (BOC).

### CBOC VERSUS CONSENSUS ECONOMICS: STATISTICAL ANALYSIS

**138. Table A4.1 compares the root-mean-squared error, the average absolute error, and the bias (mean error), of annual forecasts of the CBOC and of the Consensus Economics survey of forecasts**. The error statistics refer to the forecast for the next year. The maximum lead time in the exercise is 6 quarters—i.e. the forecast made in September for the whole of the next calendar year. The minimum lead time is 1 quarter—i.e. the forecast made for the current calendar year in December. The Consensus Economics survey is conducted monthly; we select for each quarter the monthly forecast that corresponds most closely to the information set used for the CBOC quarterly forecast.

**139. Forecast errors, as expected, diminish as lead time shortens.** For example, the RMSE for the 6-quarter-ahead forecast of GDP growth by the CBOC, as published in the quarterly Monetary Policy Report (MPR), is 1.31 percent, and 1.35 percent for the GDP forecast by Consensus Economics. At the 1-quarter horizon the RMSE for both forecasts declines to a fraction of 1 percent.

## Table A4.1. CBOC MPR Forecast and Consensus Forecast Percent Forecasting Errors 2010-2017

**GDP growth**

| | CBOC | | | Consensus Economics | | |
|---|---|---|---|---|---|---|
| **Lead time in quarters** | **RMSE** | **Absolute** | **Bias** | **RMSE** | **Absolute** | **Bias** |
| **6** | 1.31 | 1.05 | 0.67 | 1.35 | 1.15 | 0.49 |
| **5** | 1.16 | 0.96 | 0.45 | 1.14 | 0.95 | 0.32 |
| **4** | 0.90 | 0.74 | 0.23 | 0.98 | 0.82 | 0.23 |
| **3** | 0.77 | 0.64 | 0.08 | 0.79 | 0.67 | 0.15 |
| **2** | 0.34 | 0.29 | 0.04 | 0.41 | 0.35 | 0.00 |
| **1** | 0.27 | 0.21 | -0.04 | 0.27 | 0.21 | -0.00 |

**CPI inflation**

| | CBOC | | | Consensus Economics | | |
|---|---|---|---|---|---|---|
| **Lead time in quarters** | **RMSE** | **Absolute** | **Bias** | **RMSE** | **Absolute** | **Bias** |
| **6** | 1.18 | 1.01 | -0.20 | 1.12 | 0.94 | -0.26 |
| **5** | 1.21 | 1.05 | -0.31 | 1.14 | 0.97 | -0.22 |
| **4** | 1.07 | 0.88 | 0.19 | 1.09 | 0.92 | 0.12 |
| **3** | 0.80 | 0.76 | 0.14 | 0.83 | 0.76 | 0.10 |
| **2** | 0.74 | 0.65 | 0.12 | 0.67 | 0.61 | -0.08 |
| **1** | 0.28 | 0.23 | -0.09 | 0.41 | 0.33 | -0.07 |

Source: IMF mission.

140. **With respect to output growth, the CBOC performed at least as well as Consensus Economics, and somewhat better on most measures**. The exception is the upward bias in the CBOC forecast. Consensus Economics too was somewhat over-optimistic, but slightly less so than the central bank.

141. **For the inflation forecasts, it is important to note that in Chile these relate to December/December rates.** These are by nature much more volatile than year/year rates. Hence

there are sizable errors even for the forecasts with just a one-quarter lead before the end of the year.

**142. Forecasting accuracy for CPI inflation was essentially the same for the CBOC and Consensus Economics**. The small 6-quarter-lead bias for both indicates that inflation was somewhat weaker than the expectations of both the central bank and the private sector during the 2010-17 period.

**143. The results thus broadly indicate that the model-based approach of the CBOC was at least as accurate as the eclectic approaches embodied in the Consensus Economics survey.** The central bank's forecast is the simple average of the results derived with the XMAS and MEP models. We look in Appendix 4 at which of the two may be a superior.

### Graphical analysis of the evolution of CBOC forecasts from quarter to quarter

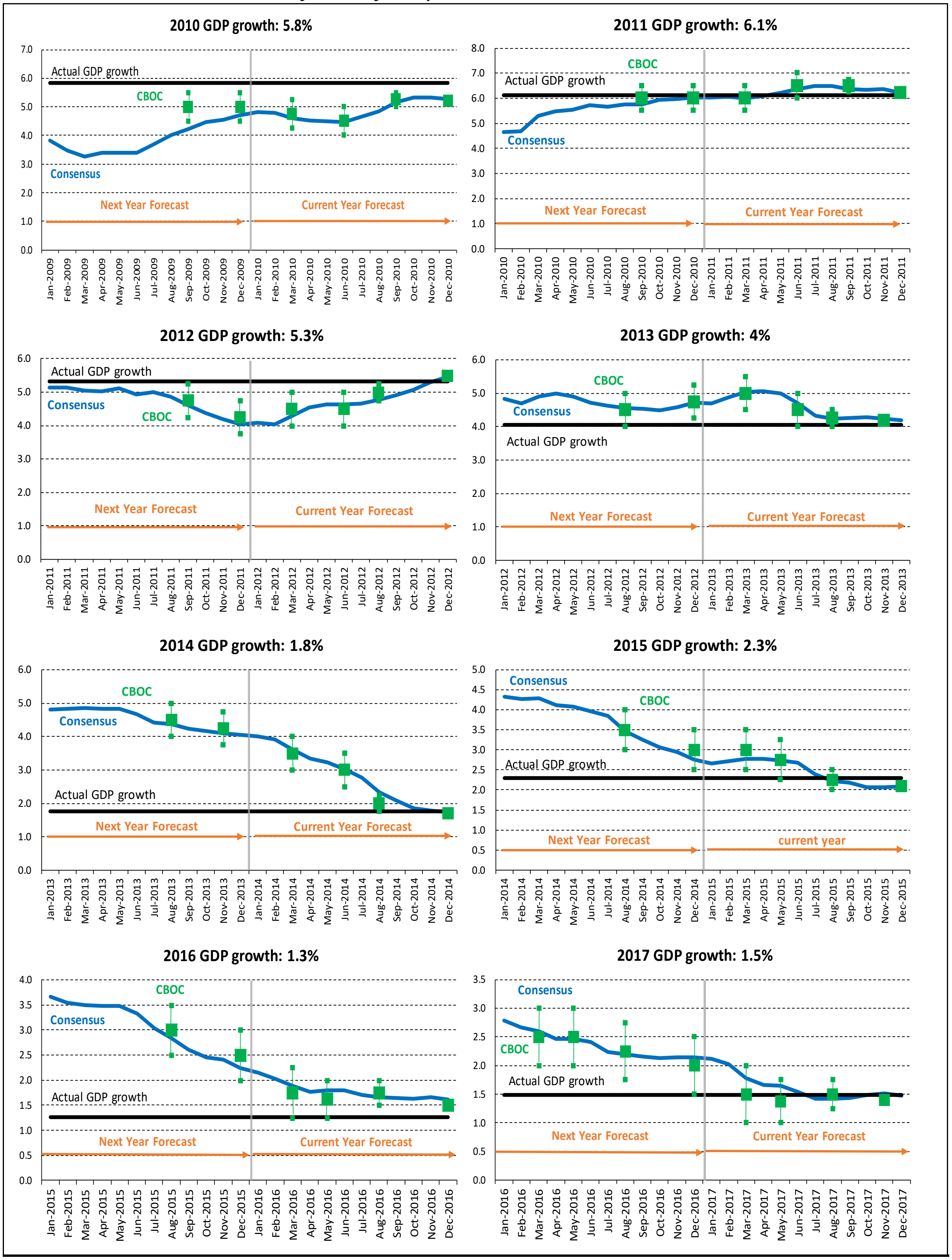
**144. The evolution of the forecast for each year through the shortening lead times reveals how the forecasters incorporated the arrival of new information.** Figure A4.1 is for the output forecast, Figure A4.2 for CPI inflation. The black horizontal line in each panel is actual GDP growth (the up-to-date estimate) for the year that is forecasted. The green bars in the panel represent the evolving quarterly CBOC forecast band, and the green dots are the midpoints of the bands. The lead time shortens going to the right, starting with a forecast horizon of 6 or 7 quarters, tapering off to a now-cast in the fourth quarter of the forecast year. The green line represents the average forecast from the monthly Consensus Economics survey, again for this year and the next. In each case, again as expected, the forecast moves closer to the actual as the lead time shortens.

**145. Examining a few interesting episodes with the help of Figure A4.1 and A4.2 adds context and color to the statistics.**

- **2010 GDP:** The earliest forecast plotted in the figure for this year was made in September 2009. It was a period of exceptional uncertainty. The aftermath of the global financial crisis clouded the outlook, and the large advanced economies were in deep recession. At the same time the large global fiscal stimulus coordinated by the G20 offered a chance for a rebound of global activity and commodity markets. The CBOC forecasted 5 percent growth for Chile in 2010. In early 2010, the bank shaved down its forecast in response to softer-than-expected data. However, in the second half of the year the news indicated a stronger global economy, and a booming market for copper and other commodities, led by an acceleration in China and other large emerging markets. The bank revised its forecast for Chile back up, to slightly above 5 percent. While this still fell significantly short of the actual outcome, GDP growth of 5.8 percent, the CBOC forecast showed good foresight, being well ahead of the Consensus Economics survey at the lead times of 6 and 5 quarters. If anything, the bank was somewhat too hasty in its downward revisions in the first half of 2010.

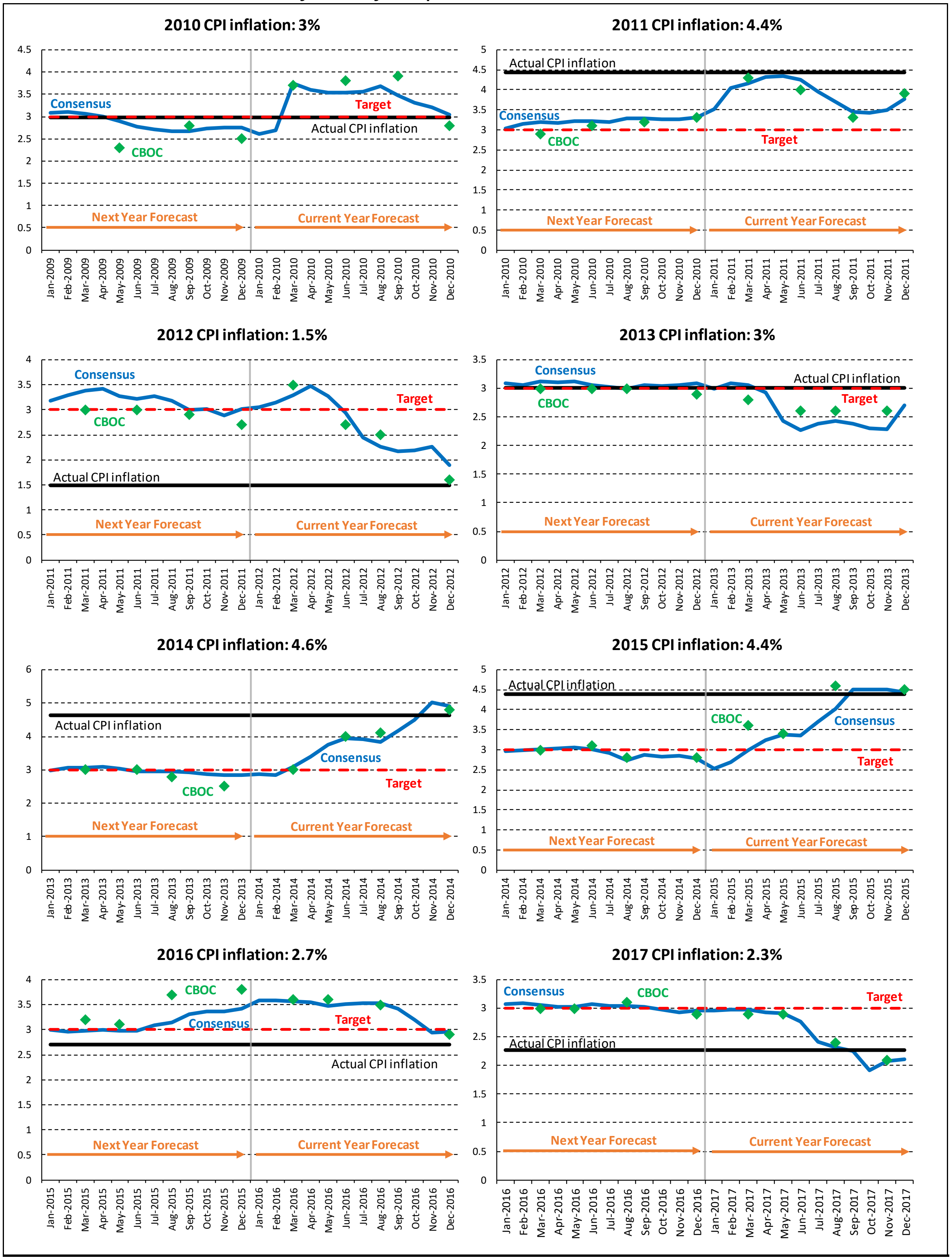
- **2010 CPI inflation:** In September 2009 the CBOC forecast for inflation in 2010 was less than 2.5 percent. Six months later, the bank raised the forecast to above 3.5 percent, and followed this with further increases in June and September, to 4 percent. Yet the actual rate for the year 2010 was exactly on target, at 3 percent. The Consensus Economics forecast was consistently closer to the outcome, and less variable than the central bank's. During this episode the eclectic approach captured in the Consensus Economics forecast outperformed the model-based approach of the central bank.
- **2011, 2012, 2014-17 CPI inflation:** In 3 of these years actual inflation came in above target, and the forecasts of the central bank underestimated inflation. In 2012, and again in 2016-17, actual inflation was below target, and the bank's forecasts overestimated inflation. This suggests a bias towards optimism—i.e. a tendency to project inflation closer to the bank's target of 3 percent than turned out in fact.

Figure A4.1. Evolution of GDP Forecasts
Monetary Policy Report and Consensus Economics




Source: IMF mission.

Figure A4.2. Evolution of CPI Forecasts
Monetary Policy Report and Consensus Economics




Source: IMF mission.

## CZECH REPUBLIC: CZECH NATIONAL BANK VERSUS CONSENSUS ECONOMICS

**146. Medium-term forecasting errors for output growth have been larger in the Czech Republic than in Chile.** This applies both to central bank and to Consensus Economics forecasts, as gauged by RMSE or by absolute average error (Table A4.2). However, the Czech Republic forecasts show no sign of the positive bias evident in the Chile forecasts. The latter to some extent may reflect the belated recognition of the decline in potential output growth in Chile after 2011.

### Table A4.2. CNB MPR Forecast and Consensus Forecast
### Percent forecasting errors 2010-2017

*Year-over-year change. Not directly comparable to Chile in Table A4.1.

**GDP growth**

| | CNB | | | Consensus Economics | | |
|---|---|---|---|---|---|---|
| **Lead time in quarters** | **RMSE** | **Absolute** | **Bias** | **RMSE** | **Absolute** | **Bias** |
| **6** | 1.61 | 1.31 | -0.17 | 1.87 | 1.58 | -0.05 |
| **5** | 1.44 | 1.16 | -0.45 | 1.62 | 1.34 | -0.31 |
| **4** | 1.24 | 0.88 | -0.60 | 1.37 | 1.03 | -0.48 |
| **3** | 1.21 | 0.82 | -0.64 | 1.31 | 0.97 | -0.55 |
| **2** | 0.78 | 0.61 | -0.46 | 0.97 | 0.67 | -0.53 |
| **1** | 0.34 | 0.28 | -0.11 | 0.52 | 0.37 | -0.31 |

**CPI inflation***

| | CNB | | | Consensus Economics | | |
|---|---|---|---|---|---|---|
| **Lead time in quarters** | **RMSE** | **Absolute** | **Bias** | **RMSE** | **Absolute** | **Bias** |
| **6** | 0.83 | 0.67 | 0.44 | 0.97 | 0.89 | 0.51 |
| **5** | 0.70 | 0.63 | 0.24 | 0.85 | 0.76 | 0.44 |
| **4** | 0.43 | 0.33 | 0.20 | 0.59 | 0.51 | 0.29 |
| **3** | 0.24 | 0.19 | 0.07 | 0.29 | 0.18 | 0.14 |
| **2** | 0.15 | 0.12 | 0.08 | 0.16 | 0.14 | 0.04 |
| **1** | 0.08 | 0.06 | -0.01 | 0.09 | 0.08 | 0.01 |

Source: IMF mission.

**147. The Czech forecasting errors for inflation also indicate some difficulties.** The RMSEs are quite large, and there is a sizable positive bias at the medium-term horizons, slightly greater for Consensus Economics than for the CNB. Since inflation fell short of target for much of the sample period, this bias indicates that both sets of forecasters were overoptimistic about the central banks prospects for reaching the target.

### CANADA: BANK OF CANADA VERSUS CONSENSUS ECONOMICS

**148. The forecasting errors for Canadian output growth have been remarkably low.** This applies to both RMSEs and absolute averages (Table A4.3). Moreover, the bias at all forecasting horizons has been negligible. The more predictable path of GDP than in Chile or the Czech Republic would have resulted from several differences in the Canadian economy, e.g.: the steady expansion in the United States, the major export market; relatively large size and diversification; and relative maturity, which means that its *potential* growth has been subject to less variation than that of Chile and the Czech Republic.

**149. For inflation too, the forecasting errors in Canada have been small.** However, there is a distinct upward bias, indicating that, just as in the Czech Republic, the forecasters underestimated the headwinds that the central bank would face over this period in reaching the 2 percent target.

## Table A4.3. BOC MPR Forecast and Consensus Forecast Percent Forecasting Errors 2010-2017[17]

### GDP growth

| | BOC | | | Consensus Economics | | |
|---|---|---|---|---|---|---|
| Lead time in quarters | RMSE | Absolute | Bias | RMSE | Absolute | Bias |
| 6 | 0.73 | 0.57 | 0.25 | 0.82 | 0.72 | 0.04 |
| 5 | 0.73 | 0.56 | -0.03 | 0.79 | 0.68 | -0.09 |
| 4 | 0.62 | 0.48 | -0.13 | 0.74 | 0.63 | -0.16 |
| 3 | 0.61 | 0.54 | 0.07 | 0.59 | 0.49 | -0.06 |
| 2 | 0.37 | 0.33 | -0.10 | 0.43 | 0.40 | -0.11 |
| 1 | 0.54 | 0.42 | -0.24 | 0.46 | 0.35 | -0.22 |

### CPI inflation

| | BOC | | | Consensus Economics | | |
|---|---|---|---|---|---|---|
| Lead time in quarters | RMSE | Absolute | Bias | RMSE | Absolute | Bias |
| 6 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| 5 | 0.30 | 0.30 | 0.30 | 0.46 | 0.46 | 0.46 |
| 4 | 0.20 | 0.20 | 0.20 | 0.44 | 0.44 | 0.44 |
| 3 | 0.21 | 0.17 | 0.13 | 0.34 | 0.27 | 0.27 |
| 2 | 0.13 | 0.13 | 0.03 | 0.19 | 0.17 | 0.17 |
| 1 | 0.04 | 0.03 | 0.03 | 0.07 | 0.05 | 0.04 |

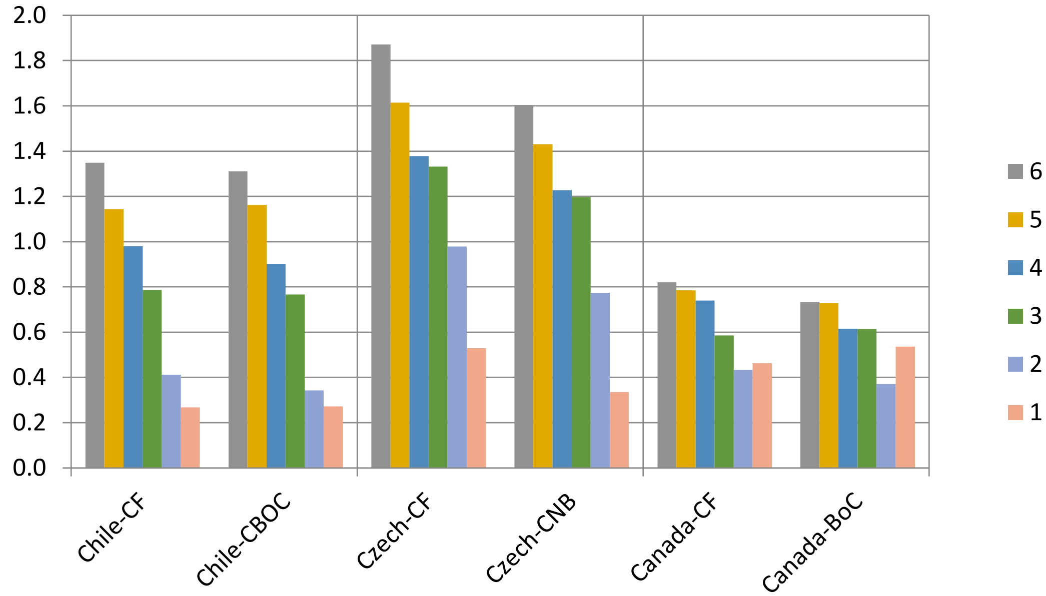
Source: IMF mission.

[17] For inflation forecasts only, the reports of 2016Q2-2017Q4 were used, as annual inflation forecasts before that were not a part of the reports.

**GRAPHICAL COMPARISON OF CENTRAL BANK AND CONSENSUS ECONOMICS FORECAST ERRORS ACROSS 3 COUNTRIES**

**152. Forecast accuracy for GDP in Chile is comparable to that in Czech Republic and Canada (Figure A4.3).** As in the RMSE statistics, we see again that Canadian GDP growth has been easiest to forecast, while Czech growth has been the most difficult. Central bank medium-term forecasts tend to beat Consensus Economics, but not by very much—only the CNB has consistently produced a substantially more accurate growth forecast than Consensus Economics. In this respect, the CBOC model-based forecasting process has yielded results for Chile that are broadly in line with those of the two central bank peers for their countries.

Figure A4.3. RMSE for GDP growth forecast with 6-to-1 quarter lead
2010-17: percent




Source: IMF mission.

## APPENDIX 5. FORECASTING PERFORMANCE COMPARISON BETWEEN THE TWO CORE MODELS

### ROOT-MEAN-SQUARED ERRORS

**153. A comparison of RMSEs for the 2 model-based forecasts suggests that XMAS-based quarterly forecasts have outperformed MEP-based.** Table A5.1 shows the details for growth of GDP, and of GDP excluding the natural resources sector (GDP rest); headline and core inflation; the policy interest rate; and real and nominal exchange rates (RER and NER). The year-over-year growth and inflation rates refer to the 4-quarter percentage increase.

The 2009 Q4 -2017 Q3 sample period is the entire period for which forecasts were based on both models.

**Table A5.1: Root Mean Square Errors 2009q4–2017q3**

**RMSE: Forecast DSGE Model (XMAS)**

| **Lead time in quarters** | **GDP** (y-o-y, p.p.) | **CPI** (y-o-y, p.p.) | **GDP rest** (y-o-y, p.p) | **CPI Core*** (y-o-y, p.p.) | **Policy rate** (Annual Basis, p.p.) | **RER** (Level) | **NER** (Level) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **1** | 0.81 | 0.12 | 1.01 | 0.09 | 0.05 | 0.95 | 3.99 |
| **2** | 1.06 | 0.54 | 1.26 | 0.48 | 0.13 | 2.81 | 22.69 |
| **3** | 1.42 | 0.79 | 1.73 | 0.77 | 0.30 | 3.49 | 31.82 |
| **4** | 1.61 | 0.93 | 1.93 | 1.05 | 0.46 | 3.99 | 39.06 |
| **5** | 1.84 | 1.03 | 2.05 | 1.19 | 0.74 | 4.58 | 45.55 |
| **6** | 2.17 | 1.12 | 2.44 | 1.17 | 0.96 | 4.72 | 54.07 |
| **7** | 2.20 | 1.11 | 2.35 | 1.11 | 1.16 | 4.56 | 58.24 |
| **8** | 2.30 | 1.20 | 2.35 | 1.21 | 1.30 | 4.35 | 61.88 |

**Evaluation from 2012q2-2017q3.*

**RMSE: Forecast GAP Model (MEP)**

| **Lead time in quarters** | **GDP** (y-o-y, p.p.) | **CPI** (y-o-y, p.p.) | **GDP rest** (y-o-y, p.p) | **CPI Core*** (y-o-y, p.p.) | **Policy rate** (Annual Basis, p.p.) | **RER** (Level) | **NER** (Level) |
|---|---|---|---|---|---|---|---|
| **1** | 0.81 | 0.12 | 1.02 | 0.09 | 0.04 | 0.95 | 4.10 |
| **2** | 1.07 | 0.55 | 1.26 | 0.48 | 0.15 | 2.80 | 22.95 |
| **3** | 1.39 | 0.88 | 1.60 | 0.86 | 0.35 | 3.30 | 31.78 |
| **4** | 1.64 | 1.08 | 1.71 | 1.31 | 0.54 | 3.69 | 39.64 |
| **5** | 2.07 | 1.23 | 2.03 | 1.59 | 0.73 | 4.35 | 44.93 |
| **6** | 2.49 | 1.28 | 2.55 | 1.60 | 0.93 | 4.68 | 53.73 |
| **7** | 2.58 | 1.26 | 2.70 | 1.54 | 1.12 | 4.65 | 56.89 |
| **8** | 2.78 | 1.22 | 2.87 | 1.43 | 1.28 | 4.79 | 59.37 |

Source: IMF mission.

**154. With respect to output growth, the superior performance of XMAS-based forecasts applies for both total GDP and non-natural resources-sector GDP.** For example, the difference in RMSEs at the 8-quarter forecast lead time is equal to 0.5 percentage point, an economically material difference. The advantage of XMAS tends to decline as the lead time shortens, and is negligible for lead times of less than 3 quarters. This is not surprising in that the relative advantage of the enhanced structural content of the DSGE model would count for less in the short-term forecast where judgement plays a key role.

**155. XMAS-based forecasts of inflation have also been more accurate, although the difference versus MEP-based is somewhat less marked.** The gain here derives from the projection for the core inflation component, the XMAS-based forecast RMSE at the 8-quarter lead time being 0.2 percentage point less than that for the MEP-based forecast. Again, at less than a 3-quarter lead time the difference in forecasting accuracy is minor.

**156. Regarding the policy interest rate, there is no material difference in the forecasting accuracy from the two models.** In both cases, the RMSE at the 8-quarter horizon is quite large, equivalent to about 130 basis points. The forecasting errors for the exchange rate are also of similar size for the two models. This is not surprising in that in general models do not forecast exchange rates well, and the high variability of the CLP exchange rate would pose an especially difficult case.

### MEAN ABSOLUTE ERRORS

**157. XMAS-based forecasts outperform MEP-based forecasts by a wider margin based on absolute errors.** Table A5.2 shows the details using the metric of absolute errors.

**158. XMAS-based GDP and non-natural-resources-sector GDP growth rate forecasts outperform MEP-based forecasts by a wide margin of absolute error.** For total GDP growth, the XMAS-based 8-quarter-ahead forecast absolute error is 0.6 percentage point lower compared to the MEP-based. After 4-6 quarters, the accuracy of XMAS is quite pronounced for non-mineral-sector GDP growth, the difference being 0.7 percentage point for the 8-quarter-ahead forecast absolute errors.

## Table A5.2: Absolute Errors 2009q4-2017q3

### XMAS-Based Forecast

| Lead time in quarters | GDP (y-o-y, p.p.) | CPI (y-o-y, p.p.) | GDP rest (y-o-y, p.p) | CPI Core* (y-o-y, p.p.) | Policy rate (Annual Basis, p.p.) | RER (Level) | NER (Level) |
|---|---|---|---|---|---|---|---|
| **1** | 0.59 | 0.09 | 0.81 | 0.07 | 0.02 | 0.59 | 2.43 |
| **2** | 0.94 | 0.46 | 0.99 | 0.39 | 0.08 | 2.20 | 17.84 |
| **3** | 1.21 | 0.67 | 1.31 | 0.66 | 0.24 | 2.95 | 26.56 |
| **4** | 1.37 | 0.79 | 1.55 | 0.91 | 0.38 | 3.37 | 33.42 |
| **5** | 1.53 | 0.84 | 1.70 | 1.06 | 0.60 | 3.79 | 40.75 |
| **6** | 1.75 | 0.95 | 1.93 | 1.08 | 0.78 | 3.99 | 43.92 |
| **7** | 1.74 | 0.96 | 1.85 | 1.01 | 0.98 | 3.89 | 46.03 |
| **8** | 1.70 | 1.04 | 1.74 | 1.10 | 1.12 | 3.60 | 47.54 |

### MEP-Based Forecast

| Lead time in quarters | GDP (y-o-y, p.p.) | CPI (y-o-y, p.p.) | GDP rest (y-o-y, p.p) | CPI Core* (y-o-y, p.p.) | Policy rate (Annual Basis, p.p.) | RER (Level) | NER (Level) |
|---|---|---|---|---|---|---|---|
| **1** | 0.59 | 0.09 | 0.83 | 0.07 | 0.02 | 0.59 | 2.47 |
| **2** | 0.94 | 0.47 | 1.00 | 0.40 | 0.09 | 2.17 | 18.00 |
| **3** | 1.18 | 0.74 | 1.23 | 0.73 | 0.28 | 2.74 | 26.79 |
| **4** | 1.32 | 0.91 | 1.33 | 1.11 | 0.46 | 3.09 | 33.68 |
| **5** | 1.69 | 0.99 | 1.68 | 1.40 | 0.61 | 3.58 | 39.69 |
| **6** | 2.06 | 1.08 | 2.15 | 1.42 | 0.78 | 3.94 | 43.10 |
| **7** | 2.15 | 1.09 | 2.37 | 1.33 | 0.98 | 3.98 | 45.19 |
| **8** | 2.32 | 1.07 | 2.48 | 1.24 | 1.11 | 4.06 | 46.23 |

Source: IMF mission.

**159. XMAS-based inflation forecasts too have been more accurate, based on absolute errors.** The higher accuracy of XMAS is more pronounced for core inflation forecasts. For example, the 8-quarter-ahead forecast absolute error is 0.14 percentage point lower for XMAS forecasts.

**160. Forecasts for policy interest rates fare similarly for both models.** The absolute error is quite large standing at around 110 basis points for 8-qaurter forecasts. Forecasts for real and nominal exchange rates show little accuracy, with no material difference between performances of the two models.

MEAN ERRORS (BIAS)

**161. Both model-based forecasts have an optimistic bias of considerable size with respect to output growth (Tables A5.3).** The estimated bias at the 8-quarter lead time is 1.5 percentage points for XMAS, and 0.8 percentage point greater than that for MEP.

**162. The medium-term inflation forecast bias, however, is negative.** And it is of similar size for the two models.

**Table A5.3: Mean Error (bias) 2009q4–2017q3**

**XMAS**

| Lead time in quarters | GDP (y-o-y, p.p.) | CPI (y-o-y, p.p.) | GDP rest (y-o-y, p.p) | CPI Core* (y-o-y, p.p.) | Policy rate (Annual Basis, p.p.) | RER (Level) | NER (Level) |
|---|---|---|---|---|---|---|---|
| 1 | -0.03 | 0.02 | -0.09 | 0.02 | -0.01 | -0.07 | -0.56 |
| 2 | 0.16 | 0.07 | -0.04 | 0.01 | 0.02 | 0.12 | -1.29 |
| 3 | 0.26 | 0.08 | -0.02 | -0.04 | 0.08 | 0.02 | -3.20 |
| 4 | 0.53 | 0.06 | 0.20 | -0.09 | 0.18 | 0.06 | -6.64 |
| 5 | 0.87 | -0.04 | 0.57 | -0.17 | 0.31 | -0.09 | -10.47 |
| 6 | 1.04 | -0.15 | 0.82 | -0.30 | 0.45 | -0.38 | -18.19 |
| 7 | 1.27 | -0.26 | 1.15 | -0.53 | 0.62 | -0.59 | -27.33 |
| 8 | 1.51 | -0.31 | 1.49 | -0.74 | 0.80 | -0.77 | -36.59 |

**MEP**

| Lead time in quarters | GDP (y-o-y, p.p.) | CPI (y-o-y, p.p.) | GDP rest (y-o-y, p.p) | CPI Core* (y-o-y, p.p.) | Policy rate (Annual Basis, p.p.) | RER (Level) | NER (Level) |
|---|---|---|---|---|---|---|---|
| 1 | -0.03 | 0.02 | -0.07 | 0.02 | -0.01 | -0.06 | -0.60 |
| 2 | 0.18 | 0.08 | -0.05 | 0.02 | 0.05 | 0.17 | -1.52 |
| 3 | 0.35 | 0.04 | 0.02 | -0.09 | 0.18 | -0.11 | -4.16 |
| 4 | 0.80 | -0.07 | 0.49 | -0.22 | 0.36 | -0.49 | -9.08 |
| 5 | 1.36 | -0.19 | 1.09 | -0.35 | 0.54 | -0.65 | -11.69 |
| 6 | 1.76 | -0.31 | 1.65 | -0.55 | 0.72 | -1.16 | -19.50 |
| 7 | 2.11 | -0.36 | 2.18 | -0.72 | 0.88 | -1.54 | -28.51 |
| 8 | 2.28 | -0.32 | 2.44 | -0.80 | 1.07 | -1.84 | -36.88 |

** Evaluation from 2012q2-2017q3.*

Source: IMF mission.

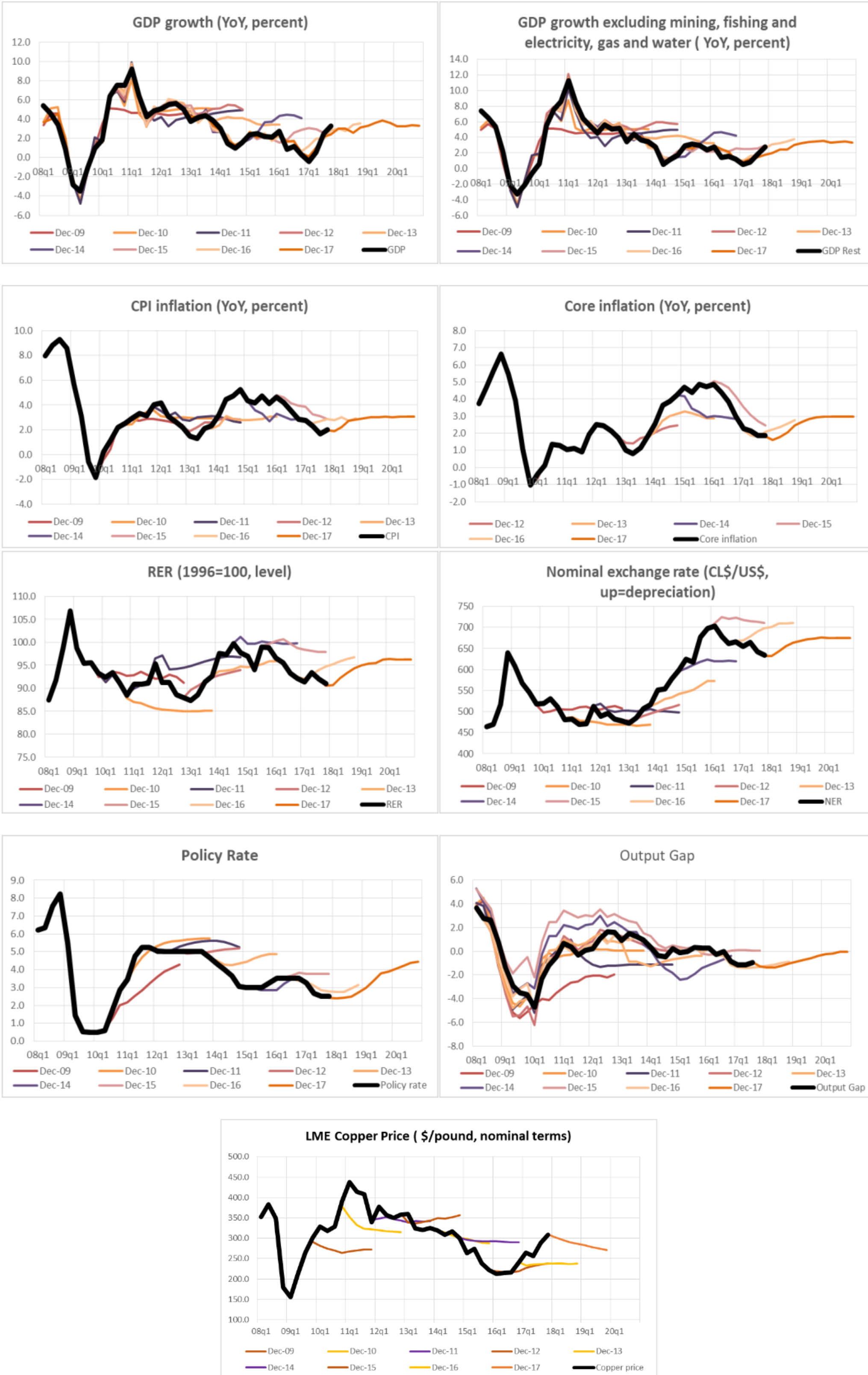
**163. There is nothing to choose between the two models with respect to the interest rate forecast.** Both show sizable upward bias at medium-term horizons.

### ROLLING FORECAST CHARTS

164. **Plot lines of the forecast paths at each point as time rolls forward show the visual pattern for the statistical analyses reported above (Figures A5.1 and A5.2).** For example, the pattern of over-predictions of output growth stands out. The medium-term forecasts, converging to 3 percent inflation, have been good, not surprisingly, as the CBOC has acted consistently to return inflation to target. Forecasts of interest rates and exchange rates though have not been so good.

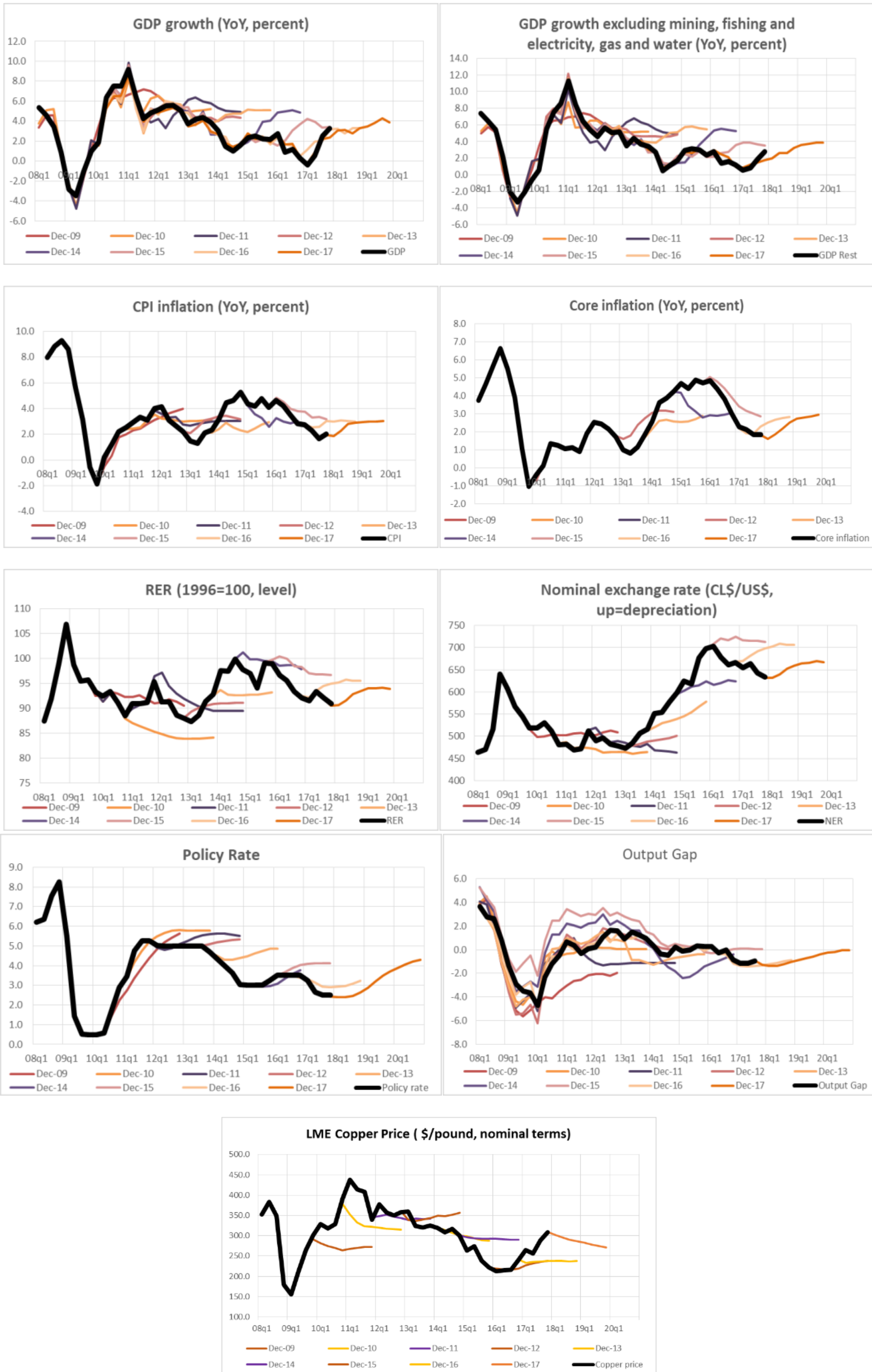
165. **The superiority of the XMAS-based forecasts, over the MEP-based, for GDP and GDP excluding natural resources is also evident visually.** Neither model dominates with respect to the interest rate or exchange rate forecasts.

Figure A5.1. Rolling Forecasts DSGE Model (XMAS) 2009q4–2017q3




Source: CBOC.

Figure A5.2. Rolling Forecasts GAP Model (MEP) 2009q4–2017q3




Source: CBOC.

## APPENDIX 6. STRUCTURED APPROACH FOR BLENDING NEAR-TERM AND MEDIUM-TERM FORECASTS

**166. The CBOC currently blends the forecasts from the DSGE model XMAS and the semi-structural gap model MEP by simple averaging.** Both models use identical near-term forecasts, for the current and next quarters, and medium-term forecasts from satellite models (e.g. for non-core inflation) to produce independent medium-term projections. These projections are then averaged at the end of the forecasting process to obtain the final medium-term forecasts.

**167. DSGE and gap models are complements rather than substitutes with important advantages for each class of models.** This warrants a use for both models, but leads to the question of combining the model results. DSGE models allow for more complex structures and detailed descriptions of the economy, while preserving the internal consistency via deep parameters embedded within the models. This allows the policy-makers to tell more nuanced stories. Examples in case of the CBOC include the detailed description of the government sector and the endogenous commodity production sector.

**168. On the other hand, the output gap is useful for evaluating, and communicating, output-inflation trade-offs that monetary policy faces.** In addition, it allows the monetary policy to follow a loss-minimizing strategy which is especially important during crises, when monetary policy aims at keeping the economy away from dark corners.

**169. This appendix proposes a structured approach for blending the medium-term forecasts from the two models.** It follows Beneš et al, (2010), which applies the method to combining any number of near-term forecasting models in a transparent yet flexible manner. The basic idea is to embed forecasts from different models within the structure of the main forecasting model via measurement equations. The forecasts from different models therefore inform the main projections, and show more clearly the degree of uncertainty around the forecast.

**170. Figure A6.1 illustrates the approach using an example of inflation forecast from Beneš et al, (2010).** The figure shows the measurement equations which relate inflation forecast to predictions from *n* different models/methods. The weighting of different model forecasts varies inversely with the standard errors of the *n* measurement equations.

Figure A6.1: Illustrative Example

$$\begin{array}{cccc} \pi_t = \hat{\pi}_t^1 + \varepsilon_t^1 \\ \vdots \quad \vdots \quad \vdots \quad \vdots \\ \pi_t = \hat{\pi}_t^n + \varepsilon_t^n \end{array}$$

Source: Beneš et al, (2010).

**171. The same structural approach can be used to blend the medium-term forecasts of the DSGE and gap models used in the CBOC.** Essentially, the gap model will be treated as the main forecasting model, and the forecasts from the DSGE model will be related to corresponding variables in the gap model via the measurement equations. Since the blending approach is symmetric, either model in principle could be used for the baseline. The choice of the gap model for producing the baseline could be more convenient, in that this would allow us to incorporate prominently into the integrate forecast the concept of the output gap, while bringing in the behavioral and structural insights of the DSGE model.

## APPENDIX 7. CORE INFLATION AS AN INDICATOR: USE WITH CAUTION

### CORE INFLATION USES

**172. Core inflation measures aim to screen out the most volatile components of the inflation rate.** Monetary policy decisions are based on assessments of persistent pressures on inflation, and should not react to transitory movements in the rate.

**173. The screening usually involves omitting items with very flexible prices, notably fresh food and energy.** Sometimes a statistical technique is used to select the items to exclude. For example, in addition to CPI excluding fresh food and energy, the Bank of Canada uses a measure which trims out the items with most variance, and another measure derived as the median of the distribution of the component changes. The argument in this Appendix applies regardless of which of these measures is preferred.

**174. For inflation-targeting-based monetary policy, a useful definition of core inflation refers to the rate of increase in the consumer price level that is most under the control of monetary policy in the short-to-medium term.** The central bank's policy rate actions transmit to the inflation rate via the pressure of demand. In a conventional model, this involves the Phillips curve. The relevant set of prices are *sticky prices*: they do not jump immediately to a new equilibrium level in response to shocks, but with lags over time—e.g. the original Phillips curve related the unemployment rate (a measure of excess supply) to the overall rate of change of wage rates (a famously sticky kind of price). Today, monetary policy models more often write the Phillips curve as an equation with core-CPI inflation as a function of the output gap.

**175. After domestic supply shocks, core inflation measures have often provided useful help to monetary policymakers.** For example, following bad agricultural harvests, the headline inflation may rise above target, but monetary policy need not react, because it will fall of its own accord once normal agricultural output resumes. Core inflation stays stable, sending a correct signal to policymakers.

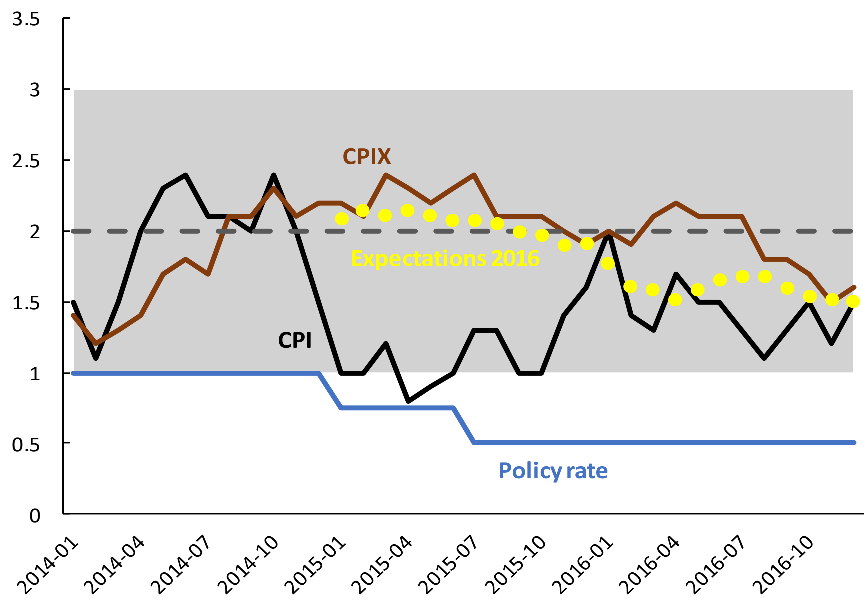
**176. However, core inflation is not a panacea for this type of problem.** It should always complement an economic analysis, rather than serve on its own as a gauge to indicate whether a policy adjustment is required.

### REASONS FOR CAUTION

**177. Any measure of core inflation will at some point include a relative price adjustment that shifts the measured rate, but does not call for a change in the central bank policy rate** (Schembri 2017). The problem will be more acute if the relative price changes are persistent. Food prices in Chile, which have been on an uptrend relative to the rest of the CPI, provide an example where core is systematically lower than headline inflation. Another case in point is the declining prices of clothing, early this decade, caused by intense retail competition. The persistent decline meant that core inflation was lower than the headline inflation for several years. On its own, then, core inflation is generally not a good gauge of pressures on the inflation rate.

**178. Situations in which the exchange rate changes may imply complexities for the interpretation of core inflation.** A good example of this is provided by Canada, a large oil exporter, following the 2014-15 oil price collapse. The negative terms of trade shock cause a sharp depreciation of the Canadian dollar against the US dollar, raising prices of non-energy imports. Core inflation rose above the 2 percent target (Figure A7.1). But the impact of the price collapse on domestic output was strongly negative, and the output gap widened. At the same time headline inflation fell to zero, because of the drop in energy prices. The disinflationary pressures soon predominated, and headline inflation stayed below target through 2016, leading to a decline in short-term inflation expectations. The Bank of Canada, appropriately, cut the policy rate twice in 2015, despite the misleading rise in the core rate of inflation.

Figure A7.1. Canada CPI Inflation: Headline, Core, Expectations




Source: IMF mission.

**179. The effect of an oil price drop on Chile, an energy importer, would be no less complex.** During the 2014-16 period, since copper prices fell too, and Chile's terms of trade in fact declined. The peso depreciated against the US dollar, and the measured core inflation rate reached 5 percent. The CBOC did not react strongly, but it did raise the policy rate 50 basis points in late 2015. In view of the weakness of Chilean output and inflation over the next couple of years, economists are still debating whether this was the right move.

**180. In any event, the exchange rate-inflation linkage for Chile is clearly strong.** The headline rate of inflation is very exposed to changes in the peso exchange rate, as almost 60 percent of the prices in the CPI are set in international markets (Table A7.2). The proportion of items in the CPIEFE index that have prices set in foreign currency is about 46 percent. Thus, core inflation in Chile, as well as headline, is quite sensitive to short-run variations in the exchange rate.

### Table A7.2. Factors for Pass-Through of Exchange Rate Changes to CPI Inflation

| CPI groups | | % of CPI | % affected by international prices | Detail |
|---|---|---|---|---|
| **CPIEFE** | **Goods** | 29% | 100% | Whole basket |
| | **Services** | 43% | 10% | Transportation |
| **Food** | | 19% | 84% | Excluding Fruits and Vegetables |
| **Energy** | | 9% | 98% | Excluding firewood |

Source: IMF mission.

**181. As a communications device, then, core inflation can be useful, and it can be awkward, depending on the circumstance.** Media commentary often refers to the published core inflation rate as "underlying" inflation or some such. This can be misleading for a couple of reasons. First, in a successful inflation-targeting regime, *the underlying inflation rate is the target rate*—3 percent in Chile. This is the rate to which inflation is expected to return. And on average, over the long run, the actual inflation rate will be close to 3 percent, notwithstanding variations of the measured core rate. In fact, core inflation is a poor predictor of future headline inflation (e.g., for Canada, Clinton 2006). Second, non-core items may undergo a trend relative price change. For example, in India and Chile, since 2000, the relative price of food has increased substantially. Core inflation has been systemically lower than headline inflation, and hence a biased indicator of headline inflation. Pointing to a core inflation rate close to target when the headline rate remains much above (or below) it only invites skepticism—especially as food and energy products constitute a higher percentage of the cost of the consumer basket for the median-income household than in the total-expenditure-weighted CPI.