FPAS Mark II Monetary-Policy-Relevant Output Gaps

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ABSTRACT

The preceding paper in this series laid the groundwork for doing current macroeconomic analysis using the MPMOD framework. Specifically, we delved into the historical narrative of the US economy in the context of MPMOD and fleshed out important analytical ideas during the time of COVID and COVID-related shocks. This edition provides an update of the MPMOD results with all variables updated to 2022 with an accompanying 10-year projection starting in 2023. In this edition, we add a Bank Lending Tightness (BLT) variable based on the Senior Loan Officer Opinion Survey. This variable serves as the primary motivation for a Case B scenario where a moderate credit tightening is underway which will reduce output enough so that recent disinflationary pressures continues and policy interest rates can already begin normalizing to their long-run neutral levels in order to avoid a more severe recession. We also provide the basis of a Case A scenario that turns off the new BLT variable under the assumption that this variable and analysis is not as reflective of an incoming credit crunch as in previous cycles.

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I. INTRODUCTION

This paper updates the results for MPMOD within the context of recent economic events and the associated evolving outlooks for the US economy. It focuses on the monetary-policy-relevant output gap, while the financial-cycle gap is covered in a sister paper.[2] The distinction is highly relevant for policymaking and is closely related to the "leaning against the wind" (LAW) debate; a deeper discussion about the debate can be found in Laxton and others (2019).

This paper continues a series of research papers that are meant to build upon the analytical ecosystem of the Forecasting and Policy Analysis System (FPAS) Mark II framework, an analytical framework for a new age of central bank policy and communication that is prepared to deal with heightened uncertainty during a period like the COVID pandemic or recent rising of geopolitical issues. The highly expansionary fiscal and monetary policies during the pandemic were critiqued by many at the time, including Olivier Blanchard and Lawrence Summers, who referred to this as the "worst economic policy of the past 40 years."[3] The primary concern articulated by Blanchard, Summers, and others was the failure to recognize that the massive fiscal stimulus and the resulting aggregate demand was already pushing up against aggregate supply translating into higher inflation. In addition, the "bad luck" shocks including the Russia-Ukraine conflict and China's "zero-covid" response to further waves of the virus, have led to the emergence of stagflationary risks that represent a major concern—and source of uncertainty—for policymakers, perhaps unlike anything seen in the West since the Great Inflation of the 1970s.

Why did the major central banks miss this inflationary wave so badly? One of the reasons was that the central banks of advanced countries treated their credibility as given, and therefore saw little risks of de-anchoring inflation expectations because of overheating economies.[4] In this paper, following Evans (2022)[5] we argue that another reason of overstimulation was the failure to recognize the important role that bottlenecks played in reducing aggregate supply, which should have reduced estimates of the true magnitude of deficient demand. In other words, the absolute size of the monetary-policy-relevant output gap was vastly overestimated signaling a need for a large stimulus.

There is no doubt that the pandemic and other large events, such as geopolitics, render any real-time measure of unobservables, such as potential output, highly uncertain. This is precisely why we advocate for frameworks like FPAS Mark II that can provide a comprehensive and systematic approach for managing this risk and uncertainty. This series of papers specifically provide multiple scenarios for thinking about the macroeconomic dynamics associated with a soft and hard landing that would require different trajectories of the short-term interest rate. Furthermore, we incorporate judgment which is informed by a wide array of available and relevant information. Indeed, no model can incorporate all the relevant features of the economy, and, of course, episodes such as the pandemic make this even more obvious. But this does not mean that policy makers cannot inform their real-time measures of policy-relevant latent variables with sensible and relevant information outside their existing models. In fact, we argue that this is their direct responsibility and provide a description of the treatment of the output gap by various institutions in the previous paper. Both monetary and fiscal policy during this period would have benefitted immensely from sensible

[2] See Avagyan and others (2023a).
[3] See Williams (2021).
[4] See Kostanyan and others (2022b, c).
[5] Charles Evans (October 2022). Going the Distance on Inflation Redux

measures of the output gap that adjusted for the supply-side implications of COVID-19-related shocks.[6]

This paper provides an update for the US economy and pulls together analysis by the Global Forecasting School (GFS). The paper illustrates the treatment of different unobservable variables such as the NAIRU and potential GDP in “real time,” particularly during periods of high uncertainty and volatility. In such an environment, where estimates come under political scrutiny, it can be natural to fall into a trap of treating it as “business as usual.” However, given these constraints, it should not impede us from doing such analysis and testing different judgments based on some simple economic logic. The paper provides a practical example for how an institution such as a central bank can implement judgment in service of communicating in a macroeconomic consistent manner the demand-side and the supply-side implications of different shocks (COVID-related lockdowns, social distancing, geopolitical tensions and uncertainty, financial sector developments, and macroeconomic policy responses, etc.).

We distinguish the terms “trend output” used for the Financial Cycle Model (FCMOD) and the concept of potential output developed with the Monetary Policy Model (MPMOD), which is based on the notion of imbalances between aggregate demand and supply in the goods and services markets. The monetary-policy output gap is constructed from MPMOD that includes: a Phillips curve; a dynamic Okun’s law equation; a monetary policy reaction function; a term-structure equation; and an equation that links the economywide output gap to measures of capacity utilization in the manufacturing sector. The exact model specification is based on a simplified version of a model presented in Alichi and others (2018). Using standard techniques for combining forecasts, this paper shows how to condition medium-term projections of actual and potential output on measures of trend output that can account for the financial cycle.

The remainder of the paper is organized in the following way. Section II summarizes MPMOD and the estimates developed in Alichi and others (2018). Section III updates the results and provides multiple scenarios for different cases that will be used as inputs for the Not the Fed Tealbook as part of the FPAS Mark II framework. In particular, we add Bank Lending Tightness to the model that motivates the Case B scenario where the future policy path could be lower than what is currently priced in financial markets. Section IV provides some concluding remarks.

[6] See Avagyan and others (2022a).

II. MPMOD ESTIMATES OF THE OUTPUT GAP AND POTENTIAL OUTPUT

The COVID-19 shock represented a novel type of economic and public health crisis. When thinking about unobservable variables like the NAIRU or potential output in the context of COVID, historical precedents are very difficult to come by, and there is an exceptional need for economists to make critical judgments when thinking about these variables as the crisis is unfolding. To factor in the effects of COVID, we have adjusted the first shock of the model—the level shock—so that the upward adjustments to the NAIRU are mirrored in downward adjustments to potential.[7] This is encapsulated by the notion that the decline in potential output was clearly reflected in large part to the lockdown policies that prevented people from working and in countries like the US, these people were correctly counted as unemployed. In other words, a meaningful share of the increase in unemployment in the first lock-down phase of COVID-19 in 2020 reflected an increase in the natural rate of unemployment. Allowing for some excess supply in the labor and goods market in this initial phase is consistent with the notion that aggregate demand fell by more than aggregate supply in the goods market, which is consistent with the basic idea that Covid-associated increases in uncertainty would trigger increases in precautionary savings and negative confidence effects on investment. The COVID shock also impacted aggregate demand, given that the consumption bundle was severely constrained and resulted in some additional savings for certain items in the basket (e.g. things like international travel) that could be consumed after the public health crisis had dissipated and the economy had recovered. These adjustments also reflect the work we have done looking at "real-time" retail and recreation activity from the Google mobility data. It is therefore plausible that a modeler could adjust such estimates in a relatively short time span following the onset of the pandemic. Although such adjustments are made with a wide degree of judgment, undertaking such analysis is necessary in times where historical precedents are virtually nonexistent, and not doing so risks underestimating the inflationary consequences of the pandemic.

MPMOD is based on Alichi and others (2018), which describes the model and estimation results in detail. The model is an extension of the simple multivariate filter presented in Alichi and others (2015). The basic idea behind the multivariate filter approach is to inform estimates of latent variables, such as the output gap, with theoretical relationships linking unobservable with observable variables. This is in sharp contrast to extracting measures of latent variables from purely statistical filters.

The original model included a Phillips curve, a dynamic Okun's law equation linking the unemployment gap to the output gap, and an equation that linked the output gap to the Fed's measure of capacity utilization in the manufacturing sector. The stochastic process for GDP included a persistent cyclical component as well as two shocks that could permanently change the level of potential output. The first shock to potential output accounts for simple level shifts, while the second shock can account for episodes when the growth rate of potential output deviates persistently from its long-term growth rate. The model has been extended to include a monetary policy reaction function and a model for 10-year bond yields. This allows us to estimate and project both the short-term equilibrium real interest rate, the 10-year term premium and 10-year bond yields. The current version of the paper extends the model to include the financial conditions described the index of Bank Lending Tightening (BLT) into the discussion. This allows to have detailed view about how the credit conditions affect the real demand in the economy that goes beyond the usual interest rate transmission channels.

[7] Fernald and Li (2021), in "The Impact of COVID on Potential Output," provide a good example of employing judgment in thinking about short-run reductions in potential output during the "extraordinary and unprecedented" crisis, and Fernald and Li (2022) also argue that the reductions in potential output represent a level shock.

The model[8] is estimated with annual data covering the period from 1980 to 2022. The list of standard macro variables used in the model includes real GDP, the unemployment rate, CPI inflation, the Fed's survey of capacity utilization, as well as 1-year and 10-year government bond yields. We use long-term CPI forecasts from the Congressional Budget Office (CBO) as a measure of the perceived long-term inflation target. Unlike Alichi and others (2018), which used a regularized maximum-likelihood procedure to impose priors in the estimation procedure, we present results based on calibrated versions of the model. Conditional on these parameters, we use the Kalman filter to compute the most likely evolution of all the latent variables in the system.

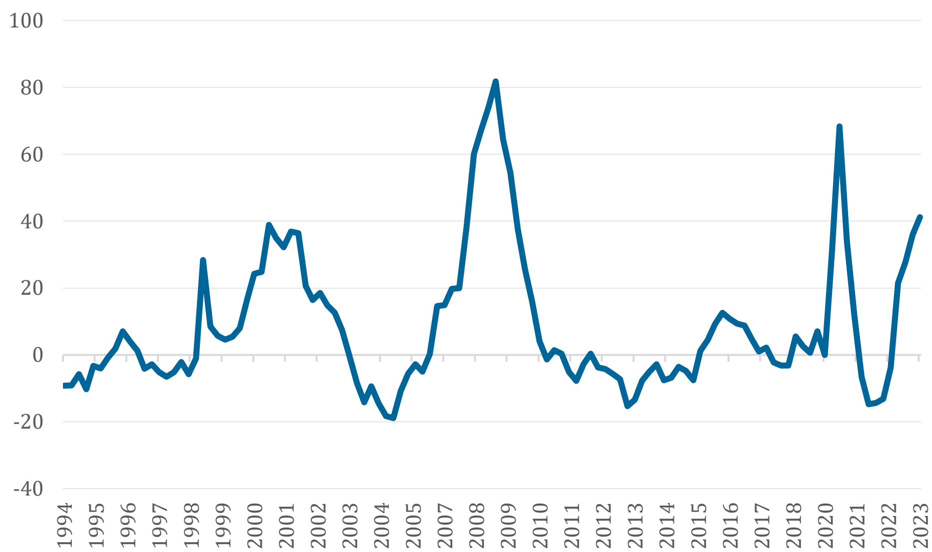
[8] Equations and parameters can be found in the appendix.

III. ADDING BANK LENDING TIGHTNESS

Our Case B scenario is a scenario for the economy that contemplates a future path of policy interest rates that would need to be lower than what is currently priced in financial markets to guide the economy to a stable equilibrium that is consistent with the objectives of the central bank. In previous editions of Not the Fed Tealbook, the Case B scenario was typically motivated by an impending recession beginning, in part due to a sufficiently restrictive policy stance that implicitly leads to tighter credit conditions. However, in this update we go one step further by explicitly adding Bank Lending Tightness to the model to help quantify the potential impact of tighter lending conditions based on BLT.

BLT is an unweighted average of the responses to four questions with respect to tightening terms and conditions in the Federal Reserve Board's quarterly Senior Loan Officer Opinion Survey on Bank Lending Practices. More precisely, for each of four questions on bank credit standards on loan applications, net tightening is equal to the sum of the percentage of banks responding "tightened considerably" and "tightened somewhat" less the sum of the percentage of banks responding "eased somewhat" and "eased considerably". These net tightening variables are each weighted by one quarter to give the overall BLT variable (See Appendix). It is worth noting that the net tightening responses from the survey outweigh the net easing responses on average over the sample period, indicating a bias in the variable.

Figure 1. BLT History



Source: Authors' Estimates

The model with financial-real linkages makes two substantive changes to the benchmark model set out in the Appendix. BLT Equation Block:

$$BLT_t = \overline{BLT}_t - 5 * \hat{y}_{t+1} + \varepsilon_{BLT,t}$$

$$\overline{BLT}_t = \overline{BLT}_{t-1} + \varepsilon_{\overline{BLT},t}$$

As shown in the first equation, banks are assumed to tighten or ease their lending practices in part depending on their view of the expected behavior of the economy 1 year ahead. That is, if the output gap is assumed to be positive (a strong economy), there will be a tendency to ease lending conditions, while if it is assumed to be negative (a weak economy), there will be a tendency to tighten lending conditions. At the same time, the BLT is anchored around an equilibrium level of BLT, which itself is a random walk.

We then add a distributed lag of BLT, η_t, into the output gap equation. Thus, if lending conditions are easier than might have been anticipated based on expectations of future economic behavior (positive $\varepsilon_{BLT,t}$), the effect will be a larger output gap and a stronger economy.

$$\eta_t = 0.5 * \varepsilon_{BLT,t} + 0.5 * \varepsilon_{BLT,t-1}$$

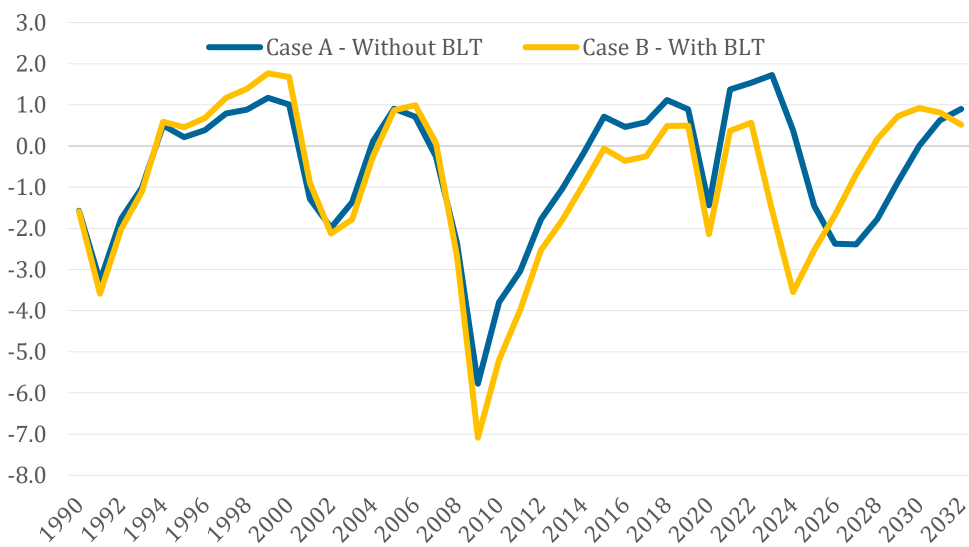
$$\hat{y}_t = \varphi_1 \hat{y}_{t-1} - \varphi_2 \widehat{rr}_t^{1Y} - \varphi_3 \widehat{rr}_{t-1}^{1Y} + \varphi_4 \varepsilon_{g_{\bar{y}},t} - \varphi_5 \varepsilon_{\bar{y},t} - 0.5 * \eta_t + \varepsilon_{\hat{y}_t}$$

The values of the coefficients imposed in the η_t equation is intended to reflect a pattern in which an increase of $\varepsilon_{BLT,t}$ (an easing of the bank lending conditions variable) is expected to positively affect spending by firms and households in a hump-shaped fashion, with an initial buildup and then a gradual rundown.

There are two ways of thinking about the way that the $\varepsilon_{BLT,t}$ variables function in the model. In the first, this proxy variable for financial tightening can be thought of as capturing the exogenous element in bank lending that has the potential to set in motion a weakening or strengthening economic situation. That is, those responsible for bank lending look forward to economic conditions for about a year in the future and tighten or loosen in part based on their expectations. If their actions are typical for the stage of the cycle, the interest rate variable itself may pick up the normal tightening and easing of terms and conditions on bank lending, and BLT would play little role in driving future economic developments. If, on the other hand, their actions are greater or less than is typical considering the expected economic situation, this could have a direct effect on the ability of borrowers to access funds and to make expenditures. A second interpretation puts less emphasis on the direct effects on expenditures of the tightening or easing of bank lending conditions. Rather, from this perspective, one can consider the $\varepsilon_{BLT,t}$ variable as reflecting the views of experts on the lending side of the economy with respect to future economic and financial conditions and thereby functioning as a very useful leading indicator of economic developments. There are several issues surrounding this variable. First, in the interpretation that focuses on the exogenous part of this variable, it is assumed that the part of financial-real linkages that propagates other typical shocks to the system is captured by the interest rate. This is not an unreasonable assumption, since the endogenous part of the financial accelerator mechanism intensifies the effects on the economy of other shocks and, in a macro sense, could be thought of as simply increasing the coefficient on the interest rate variable. Second, there could be an asymmetry between positive and negative shocks to BLT. While financial conditions that are tighter than typical will have the effect of preventing liquidity-constrained households and businesses from achieving their desired expenditures, beyond a certain point the easing of financial conditions may be less powerful in leading to increased spending. That is, once there is sufficient collateral to satisfy lenders of the safety of their loans, a further increase in the value of the collateral may not affect their behavior much. Third, it is possible that small changes in financial conditions will have relatively minor effects, and only changes beyond a certain critical threshold will have the capacity to bring about economically significant changes. Fourth, given the complexity of the financial-real linkages in the economy, BLT may not be able to capture all these types of linkages and therefore part of the analytical framework is to have other models and tools such as FCMOD and Not the BIS Credit Gaps to better analyze the financial cycle.

The historical comparison of the output gap from the model with and without BLT (See Figure 2) shows only modest differences in normal times (great moderation period) while the model with BLT wants to push the output gap more negative during and after the GFC. At the same time, the outlook of the output gap in each version reflects an economy that on the one hand is more resilient (Case A) to credit tightening standards and therefore the economy might require further increases in the policy rate to generate the slowdown further in the policy horizon that is required to bring inflation back to the target. Meanwhile, an alternative outlook under Case B scenario assumes that a slowdown in the economy due to tighter credit conditions is imminent and therefore there might be no need for any further increases in interest rates. Note that the observed postponement of lower growth in Case A relative to Case B implies a larger cumulative output loss hinting at the tradeoff for delaying the adjustment of the economy back to its long-run stable equilibrium if the necessary tightening of the conditions is not happening immediately.

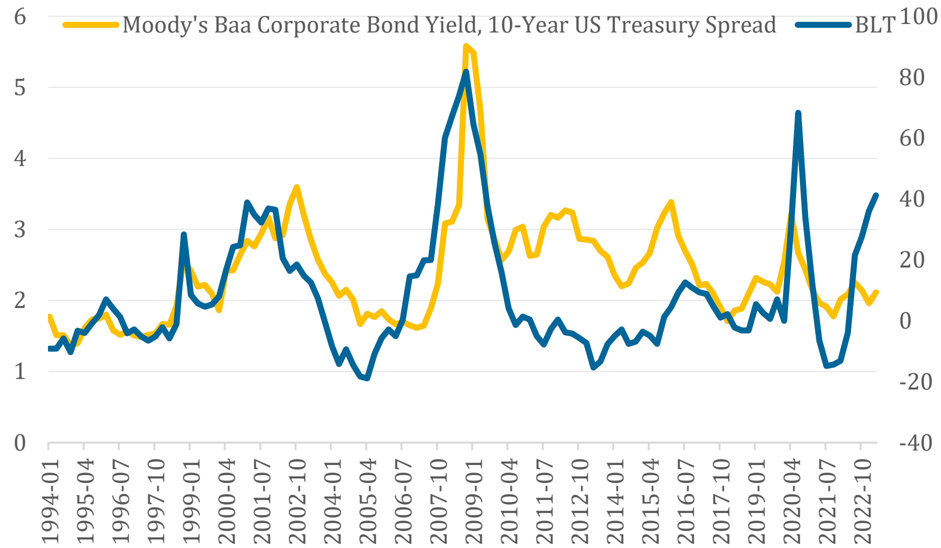
Figure 2. Output Gap with and without the BLT



Source: Authors' Estimates

The constructed two scenarios incorporate some prevailing beliefs about how the US economy could evolve based on views around our BLT variable. MPMOD with BLT (Case B) and without BLT (Case A) provides a practical modeling environment for "testing" those beliefs and it is precisely that reason why it is necessary to provide multiple scenarios since these differing perspectives can have major implications and risks on the future path for policy interest rates. In this case, these two scenarios represent the Case B and Case A scenarios in the FPAS Mark II framework, where Case B is a scenario that requires a lower interest rate than what is currently priced in financial markets – where the output gap is expected to turn negative sooner, while Case A is a scenario with higher interest rates – in part on account of an inherently stronger economy that pushes the output gap of an already overheated economy more positive. Our skepticism of the BLT and leaving it out of the Case A scenario reflects a divergence with market-based indicators of lending tightness exemplified by the spread between the Moody's Baa Corporate Bond Yield and the 10-Year US Treasury. This measure has not materially risen in the past few quarters suggesting tighter lending conditions in the BLT might be exaggerated and therefore the typical relationship between BLT and output may not hold in this current period, at least for the near time. The above discussion also highlights the underlying uncertainty with regard the standard unobservable variables in policy design and discussions as another essential source for uncertainty that signifies the scenario approach as a key mechanism to describe and communicate it under FPAS Mark II framework.

Figure 3. Is the BLT Relevant for an Imminent Recession?



Source: Authors' Estimates

Of course, this is not exhaustive. There are a multitude of other plausible scenarios where the economy could move, and it is encouraged within an FPAS Mark II institution that individual policymakers bring their own unique scenarios to the policy discussion.

Although this iteration of MPMOD is in annual frequency[9], we considered what the monthly and quarterly profile might look like for some variables, namely inflation, to get a sense of the plausibility of judgments made by the market and our estimates for the annual outlook.

[9] Future editions will feature an update to quarterly frequency.

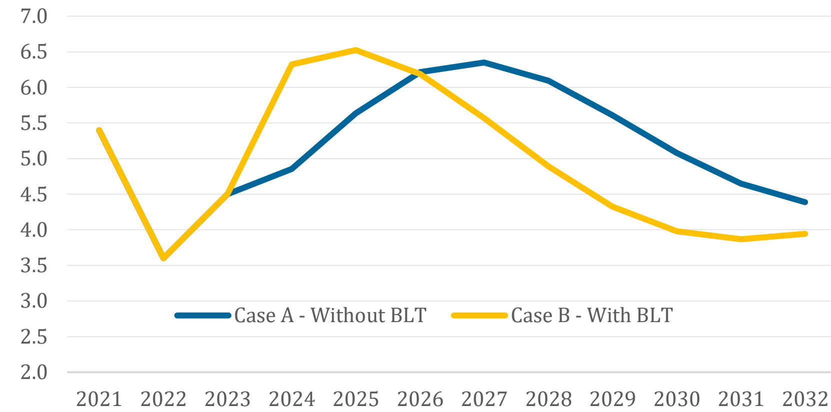
BOX 1: COMPARISON OF UNDERLYING SCENARIOS

Brief comparison of important Case A and Case B variables with an endogenous interest rate path for both.

The Case B scenario in many respects reflects a lot of current market expectations, where economic activity in 2023 is expected to already begin moderating below trend growth and this slowdown will contribute to a modest rise in the unemployment rate and this cooling of the labor market is enough to start slowing inflation more broadly, namely the service sector. Box 3 presents the historical overview along with the outlook for all the major variables in the Case B scenario.

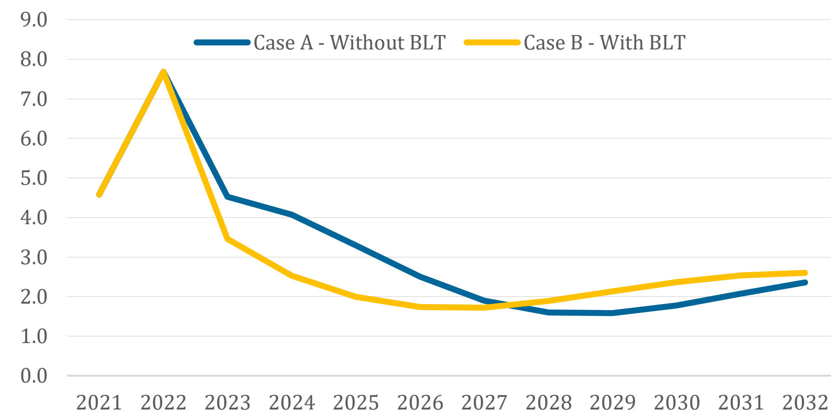
Future publications by the Global Forecasting School will continue to draw upon and expand this modeling framework to construct several other scenarios that incorporate different plausible underlying assumptions about where the economy is situated that would necessitate a tighter or looser policy stance than what is currently priced in financial markets.

Figure 4: Unemployment Rate



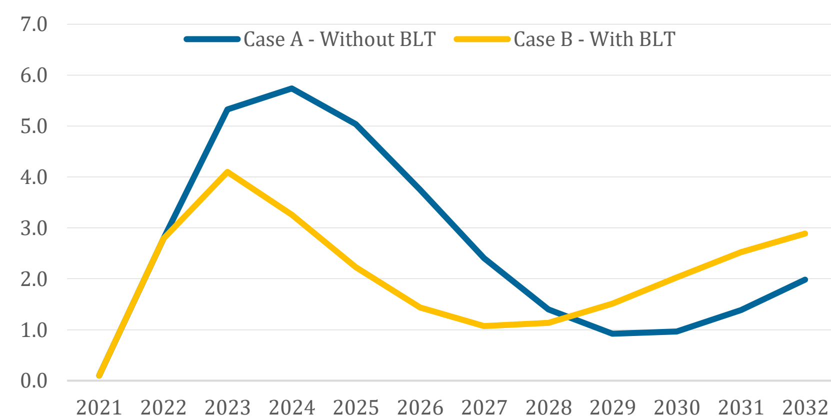
Source: Authors' Estimates

Figure 5: CPI Inflation



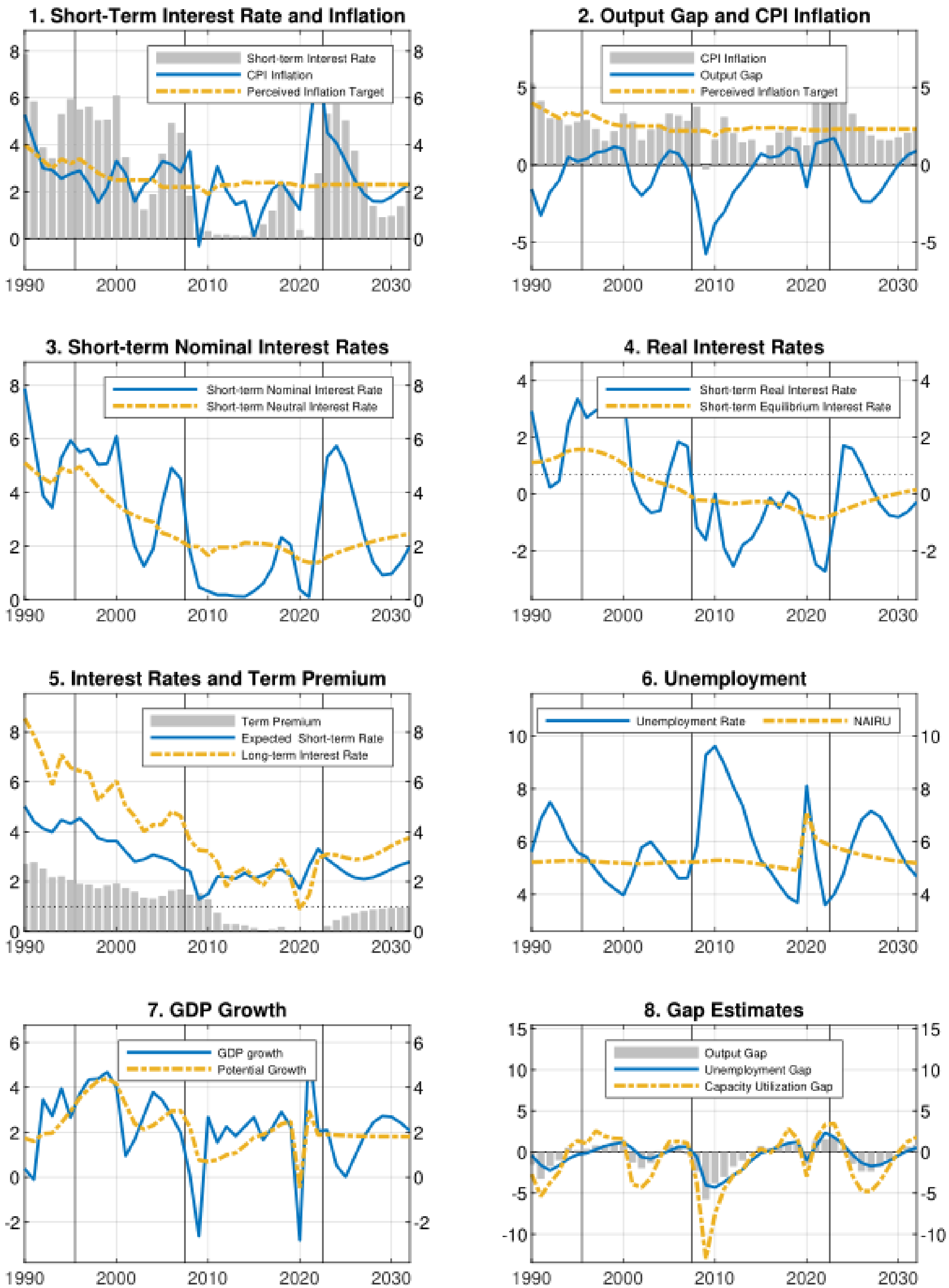
Source: Authors' Estimates

Figure 6: 1Y Nominal Interest Rate

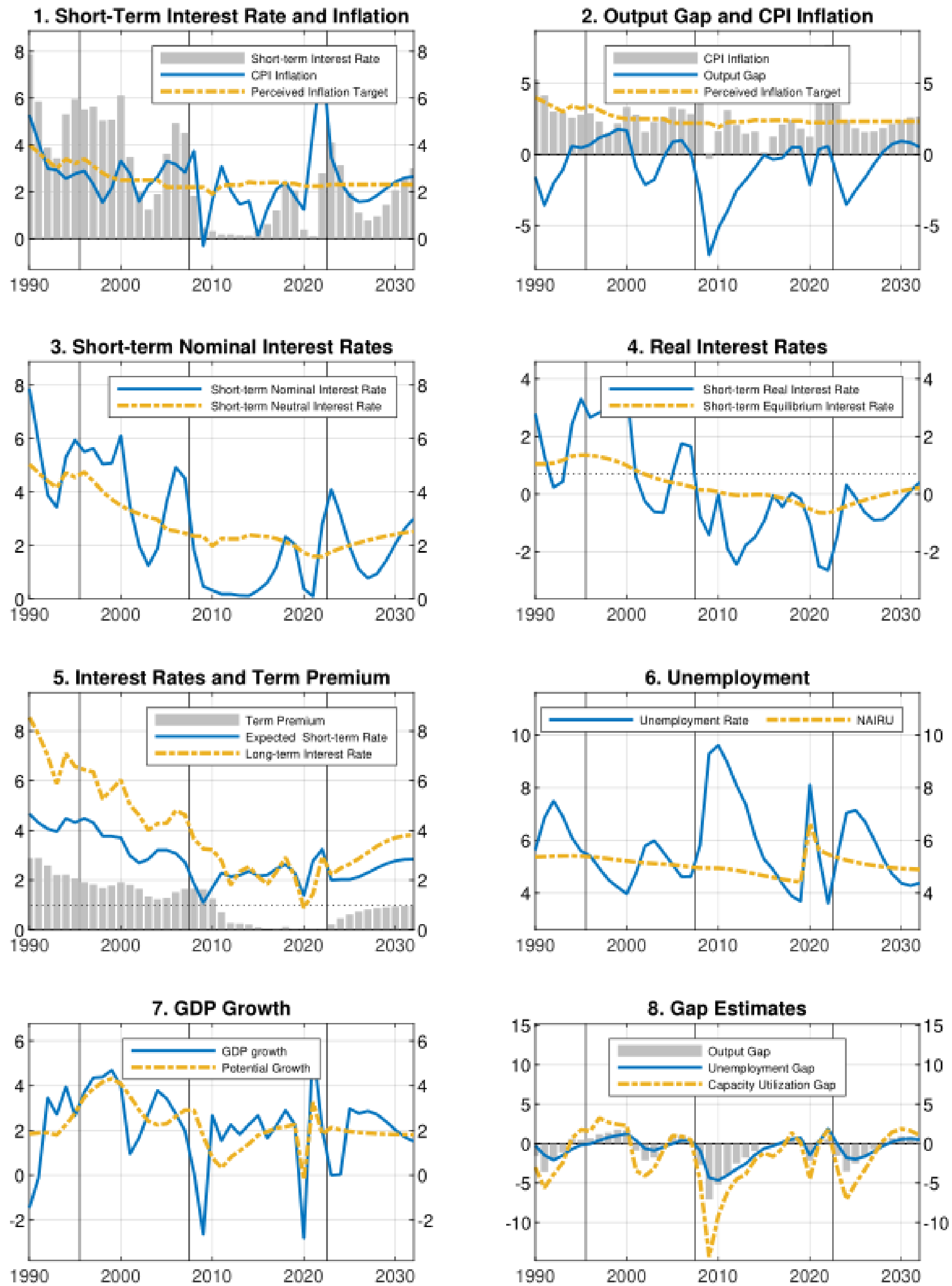


Source: Authors' Estimates

BOX 2: CASE A SCENARIO – WITHOUT BLT



BOX 3: CASE B SCENARIO – WITH BLT



IV. CONCLUSION

The "Not the Fed Tealbook" series will draw upon this update as an application of using the insights from satellite models for creating a more comprehensive and richer discussion about the economic outlook.[10] "Not the Fed Tealbook" is the Global Forecasting School's simulation of a state-of-the-art macroeconomic analysis and streamlined monetary policy note with limited resources, applied to the case of the United States. It serves as a testing ground for applications of the FPAS Mark II framework—including real-world applications of some of the ideas explored in this and other recent working papers of the Global Forecasting School of the Central Bank of Armenia. represents a simple and accessible working application of the FPAS Mark II framework that incorporates uncertainty, nonlinearities, and Alan Greenspan's 2004 formulation of "monetary policy as a risk management exercise."

This paper provides an update of the MPMOD approach considering the macro-implications of the banking credit conditions in the face of recent events in the US banking sector. The key insight of this paper concerns how to incorporate analysis during a highly volatile period where latent variables such as potential GDP, the NAIRU, and the neutral interest rate are likely jumping around based on the extreme conditions presented by the pandemic and other factors. In such scenarios, institutions tend to be reticent of "aggressively" changing these "trendy" variables, even though their qualitative statements and narratives about where the economy is today and what the underlying forces are indicate that, by all measures, these variables do need to be adjusted aggressively. The advantage of MPMOD is that it uses a structured economic framework that includes information about the labor market, financial markets, capacity utilization and economic relationships such as the Phillips Curve and Okun's Law, and importantly allows for short-term judgment of latent variables and provides a path for policy based on those judgmental implications. MPMOD should serve as a practical example for central banks and fiscal authorities on how to use this framework in a volatile period connected with COVID-related or financial shocks and its implication on managing the short-run output inflation tradeoff.

[10] See Papikyan and others (2022b, 2023a-h).

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APPENDIX

A. MPMOD Equations

In this section, we present the equations of the model. Parameter values and the standard errors of shock terms for these equations are estimated using Bayesian estimation techniques and are provided (see Table B1 and B2).

The output gap is defined as the deviation of real GDP, in log terms (y_t), from its potential level ($\bar{y}_t$):

(1) $$\hat{y}_t = y_t - \bar{y}_t$$

The stochastic process for output (real GDP) is defined by three equations, (2)-(6), and three types of shocks:

(2) $$\bar{y}_t = \bar{y}_{t-1} + g_{\bar{y},t} + \varepsilon_{\bar{y},t}$$

(3) $$g_{\bar{y},t} = (1 - \rho_{g_{\bar{y}}})g_{\bar{y},t-1} + \rho_{g_{\bar{y}}} g_{\bar{y}}^{SS} + \varepsilon_{g_{\bar{y}},t}$$

(4) $$\hat{y}_t = \varphi_1 \hat{y}_{t-1} - \varphi_2 \widehat{rr}_t^{1Y} - \varphi_3 \widehat{rr}_{t-1}^{1Y} + \varphi_4 \varepsilon_{g_{\bar{y}},t} - \varphi_5 \varepsilon_{\bar{y},t} - 0.5 * \eta_t + \varepsilon_{\hat{y}_t}$$

(5) $$g_t = y_t - y_{t-1}$$

(6) $$g_{\bar{y},t} = \bar{y}_t - \bar{y}_{t-1}$$

The level of potential output ($\bar{y}_t$) evolves according to trend potential growth ($g_{\bar{y},t}$) and a level-shock term ($\varepsilon_{\bar{y},t}$). Potential growth is also subject to shocks ($\varepsilon_{g_{\bar{y}},t}$), whose impact fades gradually according to the parameter $\rho_{g_{\bar{y}}}$ (a lower value means a slower adjustment back to the steady-state growth rate following a shock). Finally, the output gap ($\hat{y}_t$) is a function of contemporaneous and lagged values of the one-year real interest rate gap ($\widehat{rr}_{t-1}^{1Y}$) which is the deviation of short-term interest rate from its equilibrium level. The output gap equation also incorporates shocks to potential growth $\varepsilon_{g_{\bar{y}},t}$ and shocks to the level of potential output $\varepsilon_{\bar{y},t}$. It is also subject to shocks ($\varepsilon_{\hat{y}_t}$), which are interpreted as demand shocks (raise demand).

To help identify the three output shock terms, a Phillips Curve equation for inflation (π_t) is added, which links the evolution of the output gap (an unobservable variable) to observable data on inflation, according to the process:

(7) $$\pi_t = \lambda_1 \pi_{t+1}^e + (1 - \lambda_1)\pi_{t-1} + \lambda_3 y_t + \varepsilon_{\pi,t} - \lambda_4 \varepsilon_{\bar{y},t}$$

The last term allows the model to mimic the effects of shocks to productivity which lower marginal cost and therefore reduce inflation.
The inflation target, which can be time-varying, is modeled as a random walk:

(8) $$\pi_t^{Tar} = \pi_{t-1}^{Tar} + \varepsilon_{\pi_t^{Tar}}$$

The measure of inflation expectations that is used to calculate the real return on financial instruments is modeled as a linear combination of model-consistent expected inflation and lagged inflation:

(9) $\pi_t^e = \beta_1 \pi_{t+1}^e + (1 - \beta_1)\pi_{t-1}$

The real one-year interest rate is defined as the difference between the nominal one-year interest rate and expected inflation:

(10) $\mathrm{rr}_t^{1Y} = \mathrm{rs}_t^{1Y} - \pi_t^e$

To close the model, we introduce a policy interest rate reaction function, where the one-year nominal interest rate responds to the deviation of inflation from target and the output gap:

(11) $\mathrm{rs}_t^{1Y} = \alpha_1 \mathrm{rs}_{t-1}^{1Y} + (1 - \alpha_1)[\overline{rr}_t^{1Y} + \pi_t^e + \alpha_2(\pi_t - \pi_t^{Tar}) + \alpha_3 \hat{y}_t] + \varepsilon_{rs_t^{1Y}} - \alpha_4 \varepsilon_{\pi_t^{Tar}}$

The equilibrium real interest rate is modeled as a slow-moving autoregressive process that reverts to its long-run steady-state level ($\overline{rr}^{ss}$).

(12) $\mathrm{rr}_t^{1Y} = \overline{rr}_t^{1Y} + \widehat{\overline{rr}}_t^{1Y}$

(13) $\overline{rr}_t^{1Y} = \rho^{\overline{rr}^{1Y}} \overline{rr}_{t-1}^{1Y} + (1 - \rho^{\overline{rr}^{1Y}})\overline{rr}^{ss} + \varepsilon_{\overline{rr}_t^{1Y}}$

The model allows for longer-term bond yields to shed light on the estimates of the equilibrium real interest rate. Based on the expectations theory of the term structure, the interest rate on 10-year government bonds is modeled as the sum of the average expected future short-term interest rates over 10 years and a term premium.

(14) $\mathrm{rs}_t^{10Y} = \frac{\sum_{i=t}^{t+9} rs_i^{1Y}}{10} + \sigma_t^{Term} + \varepsilon_{rs^{10Y}}$

(15) $\sigma_t^{Term} = \rho^{\sigma^{Term}} + \sigma_{t-1}^{Term} + (1 - \rho^{\sigma^{Term}})\sigma^{Term,SS} + \varepsilon_{\sigma_t{}^{term}}$

(16) $\hat{u}_t = \bar{u}_t - u_t$

(17) $\bar{u}_t = (1 - \rho_{\bar{u}})\bar{u}_{t-1} + \rho_{\bar{u}} u^{ss} + g_{\bar{u},t} + \varepsilon_{\bar{u},t}$

(18) $g_{\bar{u},t} = \rho_{g\bar{u}} \rho_{\bar{u},t-1} + \varepsilon_{g_{\bar{u},t}}$

(19) $\hat{u}_t = \rho_{\hat{u}} \hat{u}_{t-1} + \tau \hat{y}_t + \varepsilon_{\hat{u},t}$

Here, $\bar{u}_t$ is the equilibrium value of the unemployment rate (the NAIRU), which is time varying, and subject to shocks ($\varepsilon_{\bar{u},t}$) and to variation in its trend ($g_{\bar{u},t}$), which is itself also subject to shocks ($\varepsilon_{g_{\bar{u},t}}$). This specification allows for long-lasting deviations of the NAIRU from its steady-state value.

Most importantly, equation (19) specifies an Okun's law relationship wherein the gap between actual unemployment and its equilibrium rate ($\hat{u}_t$) is a function of the output gap ($\hat{y}_t$).

Finally, we incorporate information from measures of capacity utilization rates in the manufacturing sector to help shed some light on the overall slack in the entire economy at a given point in time.

(20) $\hat{c}_t = \bar{c}_t - c_t$

(21) $\bar{c}_t = (1-\delta_2)\bar{c}_{t-1} + \delta_2 c^{ss} + g_{\bar{c},t} + \varepsilon_{\bar{c},t}$

(22) $g_{\bar{c},t} = (1-\delta_1)g_{\bar{c},t-1} + \varepsilon_{g_{\bar{c},t}}$

(23) $\hat{c}_t = \kappa\hat{y}_t + \varepsilon_{\hat{c},t}$

In the above, $\bar{c}_t$ is thse equilibrium value of the capacity utilization rate, which changes over time, and is subject to shocks ($\varepsilon_{\bar{c},t}$). The equilibrium capacity utilization rate grows at $g_{\bar{c},t}$, which is itself also subject to shocks ($\varepsilon_{g_{\bar{c},t}}$), with their impact fading gradually according to the parameter δ_2. This specification allows for permanent movements in the equilibrium capacity utilization rate. The capacity utilization gap, which is meant to capture the economic slack in the manufacturing sector, should be correlated with the measure of the overall economic slack in the economy ($\hat{y}_t$).

(24) $BLT_t = \overline{BLT}_t - 5 * \hat{y}_{t+1} + \varepsilon_{BLT,t}$

(25) $\overline{BLT}_t = \overline{BLT}_{t-1} + \varepsilon_{\overline{BLT},t}$

(26) $\eta_t = 0.5 * \varepsilon_{BLT,t} + 0.5 * \varepsilon_{BLT,t-1}$

B. MPMOD Parameters

Parameter	Calibration
$\boldsymbol{\rho_{g_{\bar{y}}}}$	0.3
$\boldsymbol{\varphi_1}$	0.7
$\boldsymbol{\varphi_2}$	0.4
$\boldsymbol{\varphi_3}$	0.4
$\boldsymbol{\varphi_4}$	0.3
$\boldsymbol{\varphi_5}$	0.8
$\boldsymbol{\lambda_1}$	0.4
$\boldsymbol{\lambda_3}$	0.1
$\boldsymbol{\lambda_4}$	0.1
$\boldsymbol{\beta_1}$	0.4
$\boldsymbol{\alpha_1}$	0.5
$\boldsymbol{\alpha_2}$	1.5
$\boldsymbol{\alpha_3}$	0.1
$\boldsymbol{\alpha_4}$	2.0
$\boldsymbol{\rho^{\overline{rr}^{1Y}}}$	0.9
$\boldsymbol{\rho^{\sigma^{Term}}}$	0.7
$\boldsymbol{\tau}$	0.5

$\boldsymbol{\rho_{\hat{u}}}$	0.4
$\boldsymbol{\rho_{\bar{u}}}$	0.1
$\boldsymbol{\rho_{g\bar{u}}}$	0.1
$\boldsymbol{\delta_1}$	0.1
$\boldsymbol{\delta_2}$	0.2
$\boldsymbol{\kappa}$	2.0

C. BLT Methodology

FRB Senior Loan Officer Opinion Survey on Bank Lending Conditions

The Bank Lending Tightness variable takes a simple average of all the following:

The Net Percentage of Domestic Banks Tightening Standards for:

Commercial and Industrial Loans
1. Large and Middle Market
2. Small

Commercial Real Estate
1. Construction and Land Development Purposes
2. Nonfarm Nonresidential Structures
3. Multifamily Residential Structures

Mortgage
1. GSE-eligible
2. Non-qualified Mortgage Jumbo
3. Qualified Mortgage Non-jumbo, Non-GSE-eligible
4. Government Mortgage Loans
5. Non-qualified Mortgage, Non-jumbo Mortgage Loans

Consumer Loans
1. Credit Cards
2. Excluding Credit Cards
3. Excluding Credit Cards and Auto Loans

Historical Components of BLT