Board of Governors of the Federal Reserve System
Washington, DC 20551

Supervisory Stress Test Documentation

Macroeconomic Model Guide

October 2025

This document provides details on the macroeconomic model that the Federal Reserve Board of Governors (Board) intends to use in the 2026 Supervisory Stress Test. Documentation on the other models that the Board intends to use in the 2026 Supervisory Stress Test is available at the following link: https://www.federalreserve.gov/supervisionreg/dfa-stress-tests-2026.htm

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A. Macro Model for Stress Testing

Central banks use a large and diverse set of models to simulate the economy and analyze economic and policy issues for a variety of purposes. These models differ along many dimensions, including size, economic structure and estimation or calibration approaches. There is no ideal model, and good practice is to choose a model that best suits the intended purposes and the roles it is meant to play.[1]

The macroeconomic model discussed in this document, the Macro Model for Stress Testing, was developed exclusively to assist the Board in making the annual stress test scenario development process more transparent and predictable, while maintaining an appropriate level of severity in the severely adverse scenario. The model plays several roles in the stress testing process.

First, the model provides the trajectories of the stress test scenarios for a handful of macroeconomic variables, including real and nominal gross domestic product (GDP), inflation rates, real and nominal disposable income, and short- and long-term interest rates. Rather than being specified with guides, the paths of these variables in the severely adverse scenarios are primarily determined by the equations of the Macro Model for Stress Testing, taking as inputs the constraints provided by the other variables' guides—most importantly, the path of the unemployment rate. Moreover, the Macro Model for Stress Testing is used to generate paths for all variables beyond the 13 quarters covered by the guides.

Second, the model provides a structure used to generate a baseline projection for the variables of interest, based, in part, on forecasts from the Blue Chip Economic Indicators and

[1] See the speech delivered by David Stockton "What Makes a Good Model for the Central Bank to Use?" at the Federal Reserve Bank of San Francisco in 2002 and available at https://www.frbsf.org/wp-content/uploads/panel_remarks.pdf.

Financial Forecasts surveys and economic projections from the Congressional Budget Office ("CBO"). The baseline projections of many variables are set to match the forecasts from external sources for the first 6 or 7 years of the projection period. The Macro Model for Stress Testing is then used to produce a baseline trajectory for these variables beyond that horizon. In addition, the equations of the Macro Model for Stress Testing are used to generate baseline paths for the variables for which reliable external sources of information are not available.

Larger-scale models used in policy institutions, like FRB/US and ECB-BASE, provide a broader and more detailed perspective on the economy and a tighter link to economic theory than the small model described here.[2] However, because of their broad scope and high level of detail, simulations with these models necessarily reflect the complex interaction of a wide range of assumptions, many of which are only tangentially related to the main concerns of scenario design for the supervisory stress test. Recognizing the high importance of simplicity and transparency in the scenario design process, in developing the Macro Model for Stress Testing, the Board has focused on robust empirical regularities relating to the relatively small number of variables relevant for the supervisory stress test.[3] Moreover, reflecting the principle of conservatism, the Macro Model for Stress Testing is specifically designed to reflect the adverse conditions that have characterized post-war U.S. recessions rather than provide a completely general model of the economy under all conditions; some modeling choices will reflect the objective of capturing

[2] Information and documentation about the FRB/US model can be found at: https://www.federalreserve.gov/econres/us-models-about.htm. ECB-Base is a model developed by the European Central Bank. For more information, see Angelini, E., & Bokan, N., & Christoffel, K., & Ciccarelli, M., & Zimic, S., 2019. "Introducing ECB-BASE: The blueprint of the new ECB semi-structural model for the euro area," Working Paper Series 2315, European Central Bank.

[3] Simplicity as favoring "those modeling approaches that allow for a more straightforward interpretation of the drivers of model results and that minimize operational challenges for model implementation." 84 FR 6668 (February 28, 2019) https://www.federalregister.gov/documents/2019/02/28/2019-03503/stress-testing-policy-statement

such dynamics.[4] In addition, the model parameters are either estimated from public data or calibrated using publicly available estimates of those parameters, from third-party sources whenever possible. Consequently, neither the equations nor the results of the Macro Model for Stress Testing should be viewed as necessarily representative of the economic or financial market forecasts or scenario analysis used in other contexts by the Federal Open Market Committee (FOMC), the Board, its staff, or anyone else associated with the Federal Reserve System.

Many models in both the academic literature and at central banks aim to provide a "structural" account of the economy; that is, a model built on explicit models of the optimal choices of households and firms, including their expectations of future conditions, and a general equilibrium framework, in which prices and quantities are jointly determined in order to equate supply and demand. Scenario design for the supervisory stress test does not require a structural model in this sense and, as previously indicated, the Macro Model for Stress Testing is instead built on simple and robust time-series relations directly relating the relevant set of scenario variables. However, in line with some theoretical asset pricing models, the Board recognizes the importance of expectations in the transmission of monetary policy and for that reason, the long-term interest rates in the model are consistent with the future expected values of the policy rates. In particular, model-consistent expectations are used for the simulation of the 5- and 10-year Treasury yields. While the Macro Model for Stress Testing does not feature general equilibrium

[4] In the 2019 Stress Testing Policy Statement, the Board defined conservatism as "given a reasonable set of assumptions or approaches, to use those that result in relatively more significant losses or lower revenue, all other things being equal." 84 FR 6668 (February 28, 2019) https://www.federalregister.gov/documents/2019/02/28/2019-03503/stress-testing-policy-statement

interactions, the scenario guides have been designed so that the co-movements of the variables are roughly consistent with the empirical evidence.

Overall, the Board proposes a simple macroeconomic model of the economy to support the implementation of the Policy Statement on the Scenario Design Framework for Stress Testing[5] and facilitate the communication of the model's structure and the results of the simulations. This document outlines and provides details about the equations of the proposed Macro Model for Stress Testing for the Board's stress testing program.

[5] *See* 12 C.F.R. pt. 252, appendix A.

B. Unemployment Rate

The Board specifies the underlying dynamics of the unemployment rate, UR, by assuming that its deviation from the estimated natural rate of unemployment, $URNAT$, follows an autoregressive representation of order 2, that is, a time series process in which its current value is a linear function of its own observations in the previous two periods (e.g., quarters) plus a white noise process.[6] The second-order autoregressive structure is a flexible and simple approach to represent cyclical dynamics in macroeconomics contexts.[7] The equation is estimated using the CBO estimates of the natural rate of unemployment with a sample starting in 1967 and ending in 2019.[8] The resulting estimated equation is:

Equation B1 – Unemployment rate

$$UR(t) - URNAT(t) = 1.65 * \big(UR(t-1) - URNAT(t-1)\big)$$
$$- 0.68 * \big(UR(t-2) - URNAT(t-2)\big) + e^{UR}(t).$$

The guide on the unemployment rate provides information about the trajectories to the peak and its decline to an end value after the peak is reached. As such, the dynamics of Equation B1 do not play any role in the determination of the unemployment rate path over the first 13 quarters of the simulation. However, as explained in detail in the later section "Long-term Interest Rates", the trajectory of the interest rates over the first 13 quarters depends, through the policy rule, on those of real GDP and core PCE inflation beyond the first 13 quarters. As the

[6] A white noise process is a sequence of random variables that are independently distributed and have a constant mean and variance over time.

[7] *See* Harvey, A. C., 1985. "Trends and Cycles in Macroeconomic Time Series." Journal of Business & Economic Statistics, 3(3), 216–227. and Hamilton, J. D., 1994. Time Series Analysis. Princeton University Press.

[8] *See* Brauer, D., 2007. "The Natural Rate of Unemployment: Working Paper 2007-06," Working Papers 18566, Congressional Budget Office, and Shackleton, R., 2018. "Estimating and Projecting Potential Output Using CBO's Forecasting Growth Model: Working Paper 2018-03," Working Papers 53558, Congressional Budget Office. The vintage of the CBO historical Data and Economic Projections used to estimate the current version of the equation is January 2025.

paths of real GDP and inflation are primarily determined by that of the unemployment rate, what happens to the unemployment rate beyond the first 13 quarters of the simulation still affects the trajectories of the 5- and 10-year Treasury yields over the reported period of the stress test scenario. Hence, the model must feature an equation for the unemployment rate, although the unemployment rate guide determines the first 13 quarters that are directly relevant in estimating revenues, expenses, and credit losses in the annual stress test.

The remainder of this section will show that Equation B1 provides a reasonable prescription for the decline in the unemployment rate once it reaches its peak and hence provides an adequate characterization of the unemployment rate beyond the stress test scenario horizon.

Figure B1 – Dynamic counterfactual: unemployment rate equation

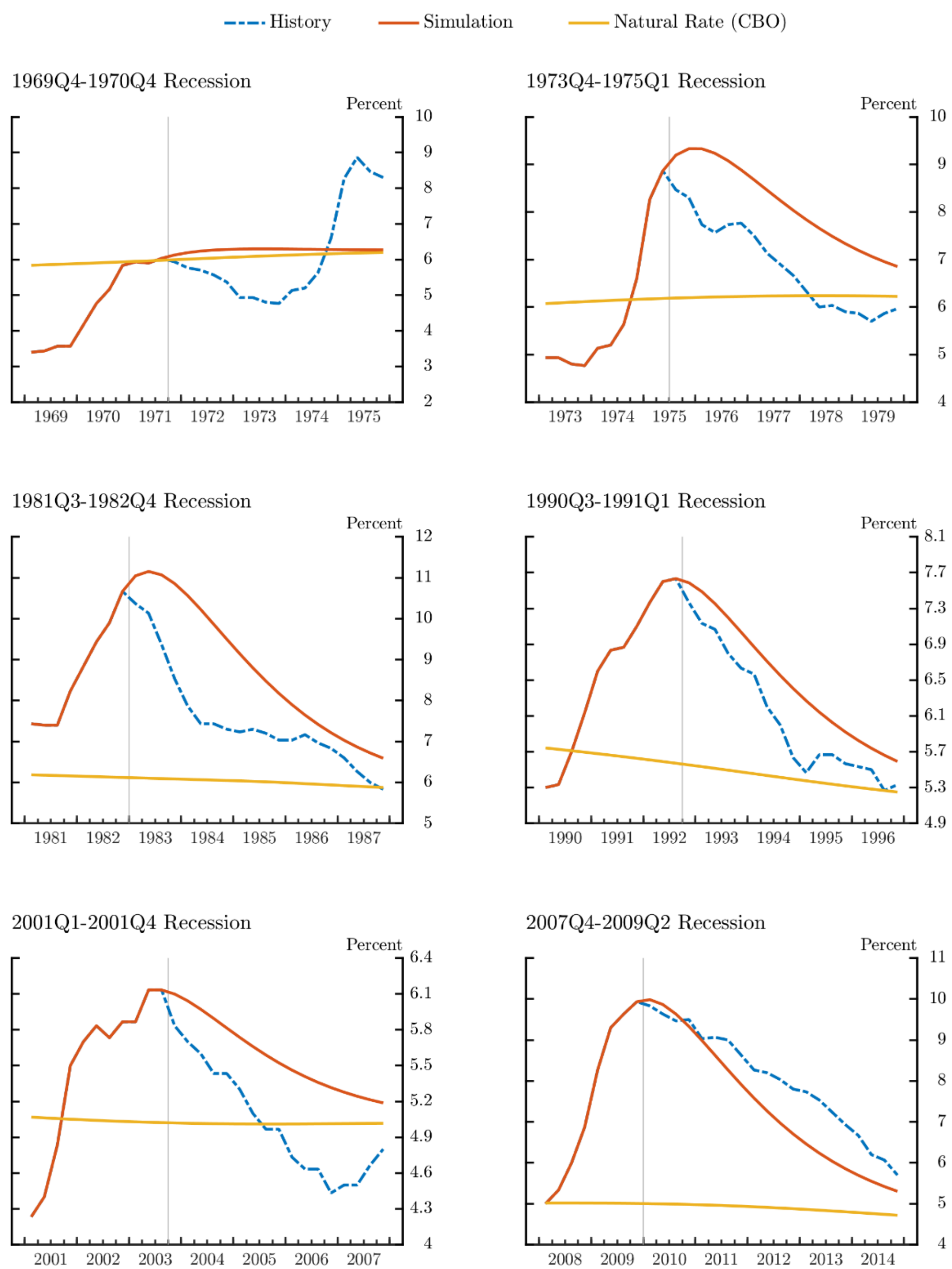
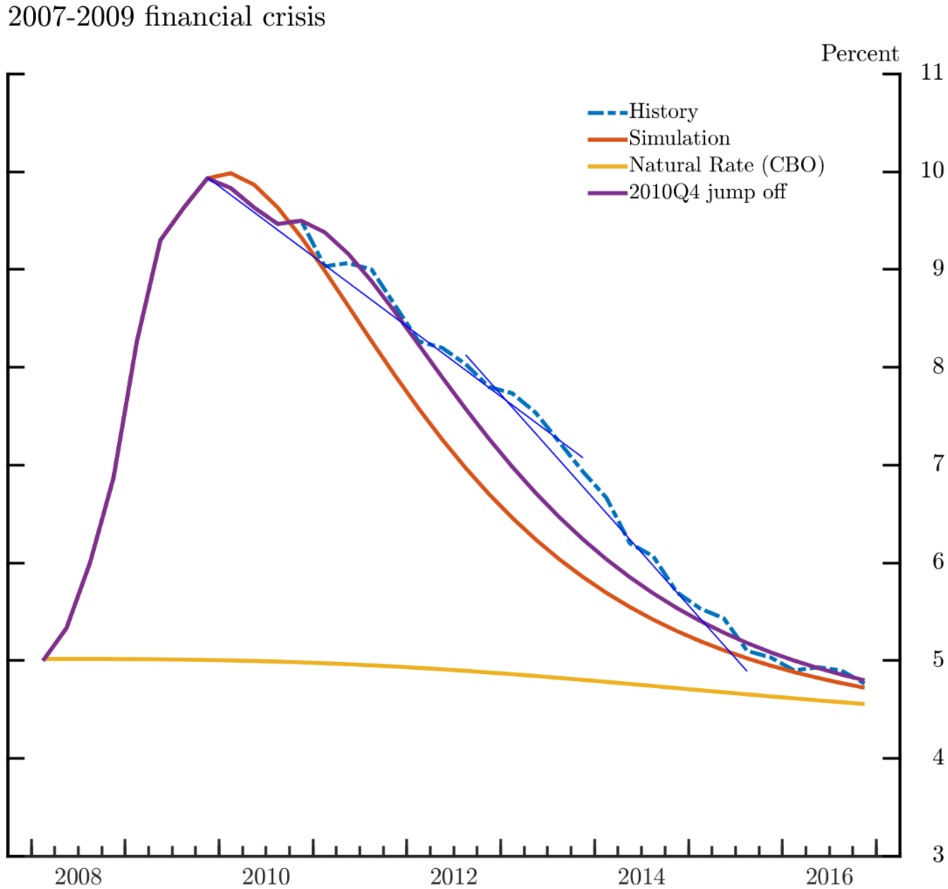


Figure B1 shows the predictions of the estimated equation using a dynamic simulation that jumps off from the peak in the unemployment rate for each recession; the equation is simulated over a period of several years. The panels reveal that the equation under-predicts the pace of the decline for most recessions except for the 2007-2009 financial crisis, for which the simulated path is slightly lower than the actual data. Figure B2 shows that the decline in the unemployment rate following the 2007-2009 financial crisis has two phases where the fall was initially very slow but then picked up in speed.[9] The period corresponding to the initial phase is, however, in part covered by the guide and the equation is only used beyond that period. As shown in Figure B2, if the dynamic simulation starts 13 quarters after the onset of the recession, taking the realization of the unemployment rate for that period as given, the equation performs much better at replicating the pace of the decline while preserving its ability to reproduce the timing of the unemployment rate's slowdown as it approaches the estimate of the natural rate of unemployment. In particular, relying on the guide and then the equation allows the model to capture the possibility of both a steep and severe increase in the unemployment rate and a very protracted recovery—both important features for the scenario design process, given the high salience of the 2007-2009 financial crisis episode to the scenario narrative underlying the severely adverse scenario in the annual stress test. It would likely be difficult to substantially improve on this equation while remaining in the class of linear model. Additionally, based on the evidence of the dynamic simulations over the 2007-2009 financial crisis, augmenting the equation with non-linear features would deliver only marginal improvements in fit at the cost of more complex and potentially fragile model dynamics. Indeed, the results depicted in Figure B2 shows that the equation predicts declines in the unemployment rate after 2010.The predicted levels are very close to the data in the first year of the simulation as well as the later years, as the series approaches the estimate of the natural rate.

[9] The two thin lines in figure B2 illustrate visually the change in the speed at which the unemployment rate declined following the series reaching a peak in the wake of the 2007-2009 financial crisis. The two lines are produced by fitting estimated linear models with an intercept and a time trend as regressors for the periods of 2009Q2-2013Q2 and 2013Q2-2015Q3, respectively.

Figure B2 – Unemployment during the 2007-2009 financial crisis and simulated trajectories



C. Real Gross Domestic Product

The Board determines real gross domestic product (GDP) using a version of Okun's Law, specified in growth rates:

Equation C1 – Real Gross Domestic Product

$$HGGDP(t) = 400 * \log\left(\frac{GDPT(t)}{GDPT(t-1)}\right) - 4 * \alpha * (UR(t) - UR(t-1)).$$

$HGGDP(t)$ is $400 * \log(\frac{GDP(t)}{GDP(t-1)})$, $GDPT$ is potential GDP and $\alpha = 1.4$.[10] The economic relationship commonly referred to as "Okun's Law" is a well-established regularity linking fluctuations in the unemployment rate to those of output. Since the seminal work of Okun (1962),[11] "Okun's Law" has become a simple rule of thumb used by economic forecasters to relate forecasts of real GDP to projections of the unemployment rate.[12] The Board proposes to adopt a "growth" version of the relationship—in contrast to a level specification[13]—both on the ground that it reduces dependency on unobserved variables, such as the natural rate of unemployment, and because it does a better job accounting for the dynamics of output around the 2007-2009 financial crisis, given the evolution of the unemployment rate and reasonable assumptions about the intercept term. See Appendix A for a more detailed analysis of this choice.

The empirically relevant value of the sensitivity parameter, α, will depend on the historical behavior of potential output, which is not directly observed and so must be inferred.

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[10] The Board uses the CBO estimate of real potential GDP as estimate of the series. The change in the unemployment rate is multiplied by the factor 4 as the annualized percentage change in GDP is being used.

[11] Okun, A., 1962. "Potential GNP Its Measurement and Significance." In Proceedings of the Business and Economics Section (pp. 98-103).

[12] McCarthy J., & Potter S. & Ng G. C., 2012. "Okun's Law and Long Expansions." Liberty Street Economics.

[13] The simplest level specification is $100 * \log\frac{GDP(t)}{GDPT(t)} = \gamma(UR(t) - URNAT(t))$.

The Board has considered two options for the intercept term $400 * \log(\frac{GDPT(t)}{GDPT(t-1)})$ — which will be denoted as $HGGDPT(t)$ — and estimated the corresponding value of α appropriate for each. The first option is to assume a constant growth rate over the estimation sample, that is, $HGGDPT(t)$ is constant. The second option introduces time-variation in the intercept, using the CBO estimates of the potential GDP growth, again in the interests of simplicity and transparency. The first two columns of Table C1 report the results of the regression of the Okun's Law equation over the full sample for the two intercept specifications.

Table C1 – Okun's Law estimation results

	1967-2019		1990-2019	
	Constant	Growth	Constant	Growth
Intercept Term	2.76	-	2.41	-
α	1.51	1.49	1.14	1.11

The results in the first two columns of the table indicate that the choice of the intercept does not significantly affect the value of the Okun's Law coefficient, which is about 1.5 in both cases.

The literature has considered the possibility that α may have changed over time.[14] The Board considered this possibility by running the same regressions over the 1990-2019 sample. Consistent with the previously cited analyses, the estimates of α are smaller at about 1.1.[15]

The results of Table C1 provide a range of estimates that by design reflects an average sensitivity over the different phases of the business cycles. However, in consideration of the

[14] See Gordon, R. J., 2010. "Okun's law and productivity innovations." American Economic Review, 100(2), 11–15; and Meyer, B., & Tasci, M., 2012. "An Unstable Okun's Law, Not the Best Rule of Thumb." Federal Reserve Bank of Cleveland Economic Commentary, 2012(8), 1–4.

[15] As again expected from the literature, when estimated, the value of the intercept (the constant growth rate of potential output) is noticeably smaller, reflecting a decline in underlying growth over time.

main objectives of the design process, the equation used in the model should be tailored to perform well under the adverse economic development consistent with the guide on the unemployment rate. To further explore the various specifications under conditions most relevant to the stress test, the performance of several alternative specifications in replicating the dynamics of GDP for the three most recent non-pandemic recessions is investigated through dynamic simulations, jumping off from the quarter prior to the official marking of the beginning of the recession. Figure C1 shows the dynamic simulations when the intercept is set to the estimated value of the intercept over the sample 1990-2019, that is, 2.41 percent, and Figure C2 presents the results of simulations when the CBO estimate of potential output is used to construct the intercept term. The results of the simulations show that there is no configuration of parameters and specifications that dominate or perform consistently better across recessions.

Figure C1 – GDP dynamic counterfactuals: constant intercept

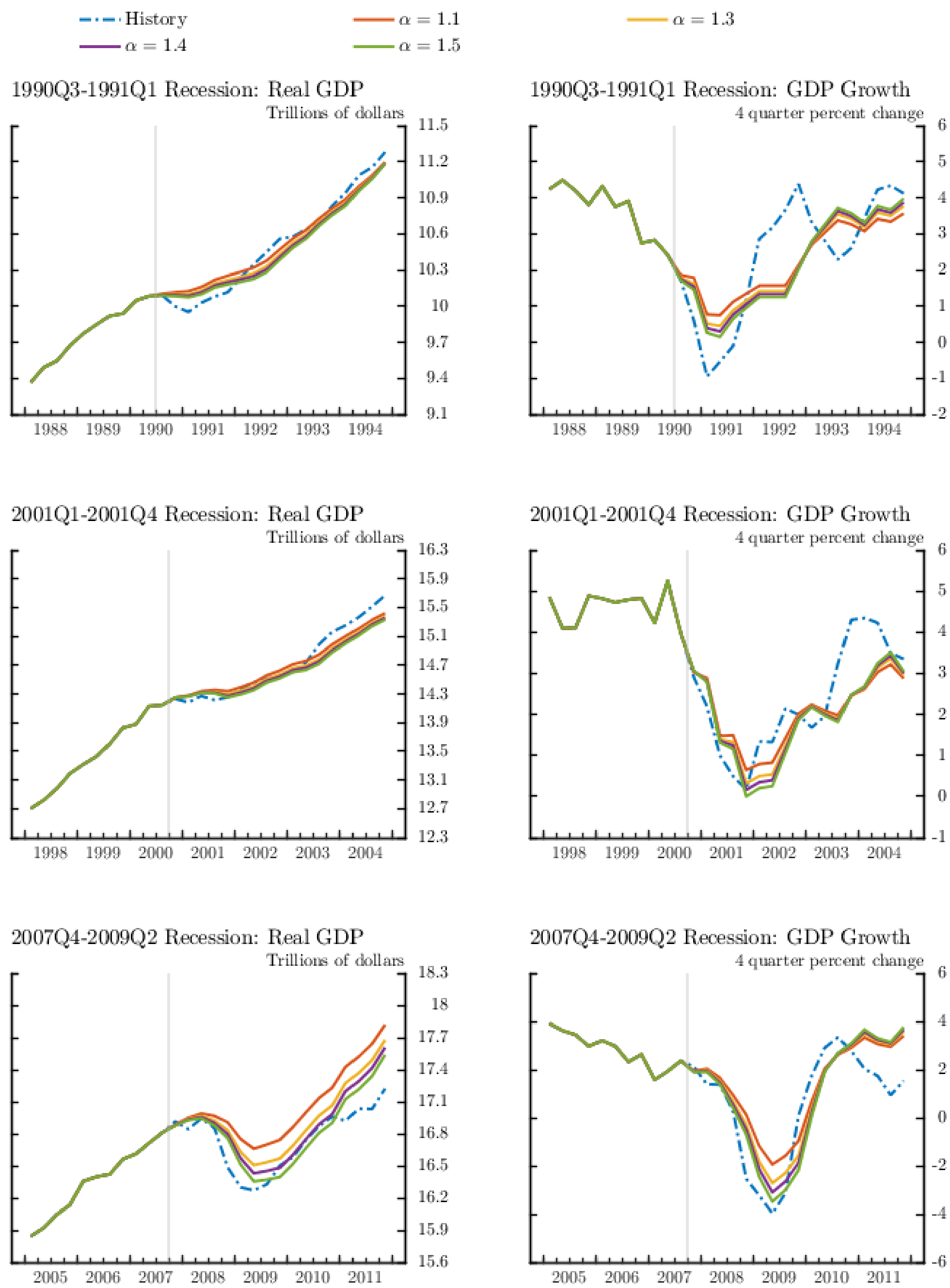
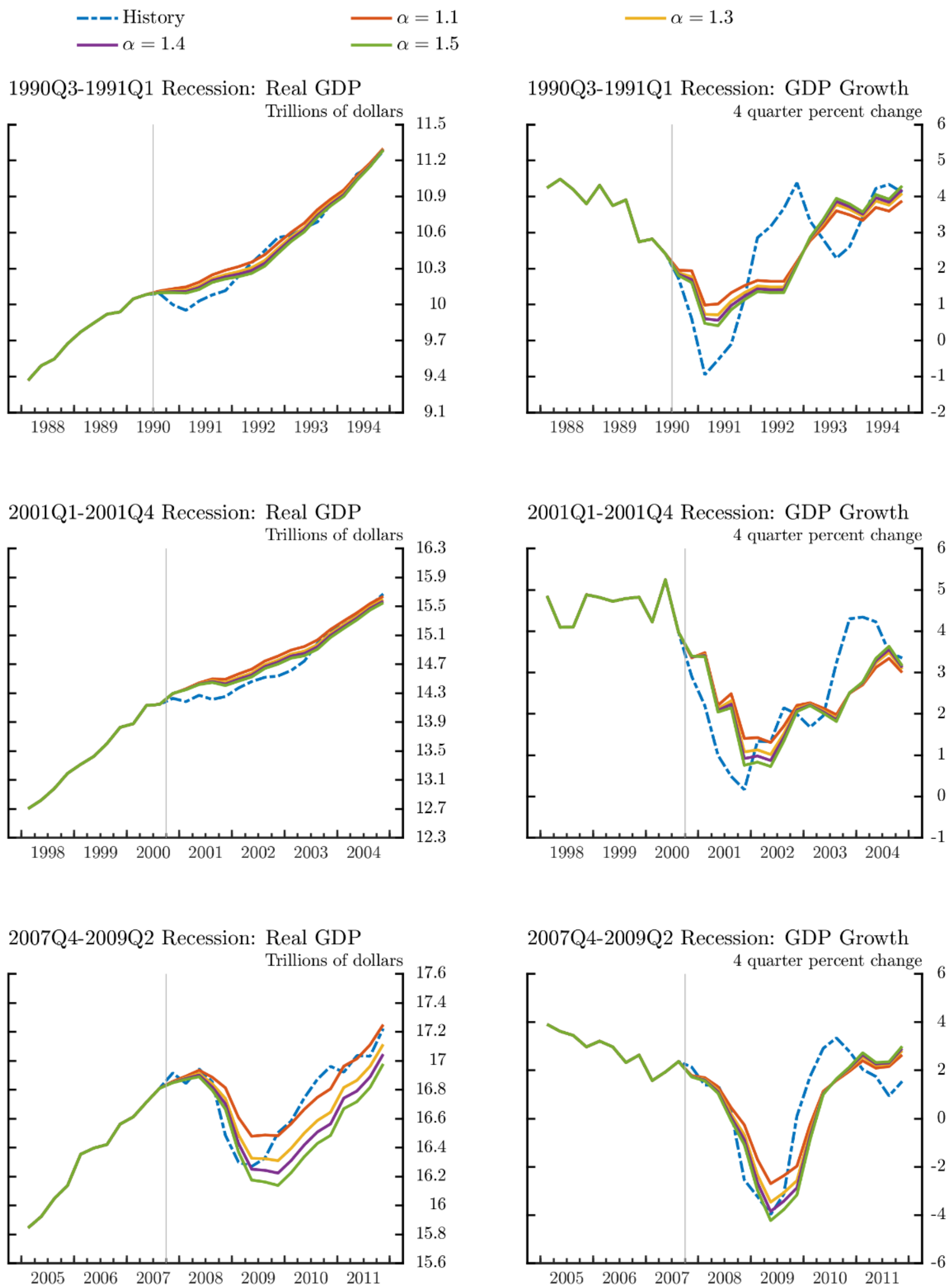


Figure C2 – GDP dynamic counterfactuals: potential growth intercept



Considering the scenario design process's emphasis on simulating adverse economic conditions that resemble those observed during the 2007-2009 financial crisis, the comparison of the bottom panels of both figures suggests that relying on an overall sample average as intercept rather than using estimates that more closely track and reflect the conditions of the actual economy at the time impairs the ability of the equation to account for the dynamics of GDP during the recession. Overall, on the basis of the evidence shown in Figures C1 and C2, the version of the rule with a coefficient of 1.4 and an intercept that reflects the economic conditions at the time (which is based on the CBO estimate of the output growth) performs satisfactorily at capturing the depth of the decline in output (in level terms) as well as the "growth" contour observed during that episode for GDP. More generally, economic research shows that recessions that are triggered by financial crises tend to be deeper and have slower recoveries than other recessions.[16] On these grounds, this specification would be a reasonable and valid choice.

The comparison of the panels of Figures C1 and C2 also reveals that the elasticity parameter alone does not identify the response of GDP by itself but does so in conjunction with the assumptions about the intercept term. This interaction matters especially if the intercept varies over time. For instance, given a fixed sensitivity coefficient, running the specification of Okun's law with an intercept that over-estimates the growth of potential GDP will understate the damage to output. As the bottom panels of Figure C1 suggest, an intercept that imputes some of the stronger underlying growth from the 1990s—as a constant intercept would imply—over the 2007-2009 financial crisis period implies output growth that is too strong relative to the assumed unemployment rate gap.[17] Consequently, the equation will fail to achieve the depth of the observed decline in output for that period, even for the largest values of the elasticity parameter

[16] See, for instance, Reinhart, C. M., and Rogoff, K. S., 2009. "The Aftermath of Financial Crises." American Economic Review 99 (2): 466–72; and Jordà, Ò., Schularick, M., & Taylor, A. M., 2013. "When credit bites back." Journal of Money, Credit and Banking, 45(s2), 3-28.

[17] For discussions and evidence about the evolution and decline in the trend or average GDP growth over time *see* Fernald J. G., 2015. "Productivity and Potential Output before, during, and after the Great Recession," NBER Macroeconomics Annual, University of Chicago Press, vol. 29(1), pages 1-51. ; and Stock J. H. & Watson M. W., 2012. "Disentangling the Channels of the 2007-2009 Recession," NBER Working Papers 18094, National Bureau of Economic Research, Inc.

considered here. The bottom panels of Figure C2 indicate that with an estimate of underlying growth that is more likely to be in line with that period, the same elasticity parameters can more than account for the downturn in output.

In short, the outcome of the simulation of GDP through a growth Okun's law rule also depends on the value of the intercept. Everything else equal, higher (lower) values for the intercept will correspond to smaller (larger) declines in output for positive changes in the unemployment rate.[18] The baseline path of potential GDP growth is based on the information from both the "Historical Data and Economic Projections" from the CBO and the Blue Chip Economic Indicators survey. This approach provides us with estimates that are up to date with the current and expected economic conditions, which the Board has shown is important to infer the response of real GDP to changes in the unemployment rate.

One last exercise is to compare the prediction of the selected Okun's Law rule with the scenario paths featured in the 2025 severely adverse scenario. Figure C3 shows the projection of the output gap implied by Equation C1 of the Macro Model for Stress Testing given the guidance on the unemployment rate and compares it to the corresponding outcomes in the 2025 severely adverse scenario. Figure C4 shows the same developments but in terms of level relative to that of GDP at the start of each simulation.

Table C2 indicates that these results are also in line with the magnitude of the effects on output observed during the 2007-2009 financial crisis. It is important to note that the changes in the unemployment rate implied by the guidance and used in the 2025 stress test severely adverse scenario are somewhat larger than those observed during the 2007-2009 financial crisis. This

[18] In the discussion of this section, an increase in the unemployment rate, in conformity with the guidance, is treated as the default case being discussed, hence characterizing the changes in output as being negative only.

result occurs because the current unemployment rate is lower than it was at the beginning of that recession, which means that the 2025 scenario has a larger increase in unemployment than occurred during the 2007-2009 financial crisis.

Table C2 – Magnitude of the decline in real GDP from peak to trough across recessions

Recession	Pre-recession max	Recession min	Percentage Change	Trough Date	Trough Quarter
1957-58	3237.4	3120.7	-3.60	1958Q1	3
1973-75	6150.10	5957.00	-3.14	1975Q1	6
1981-82	7492.40	7295.60	-2.63	1982Q1	3
1990-91	10090.60	9951.90	-1.37	1991Q1	3
2001	14271.70	14183.10	-0.62	2001Q1	1
2007-09	16943.30	16269.10	-3.98	2009Q2	7

Figure C3 – Output gap

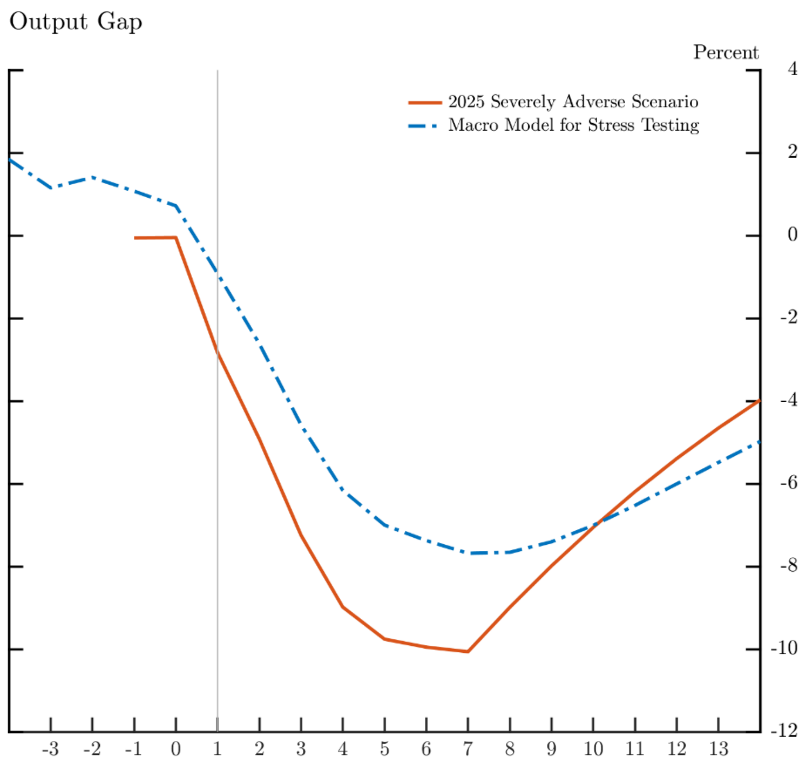
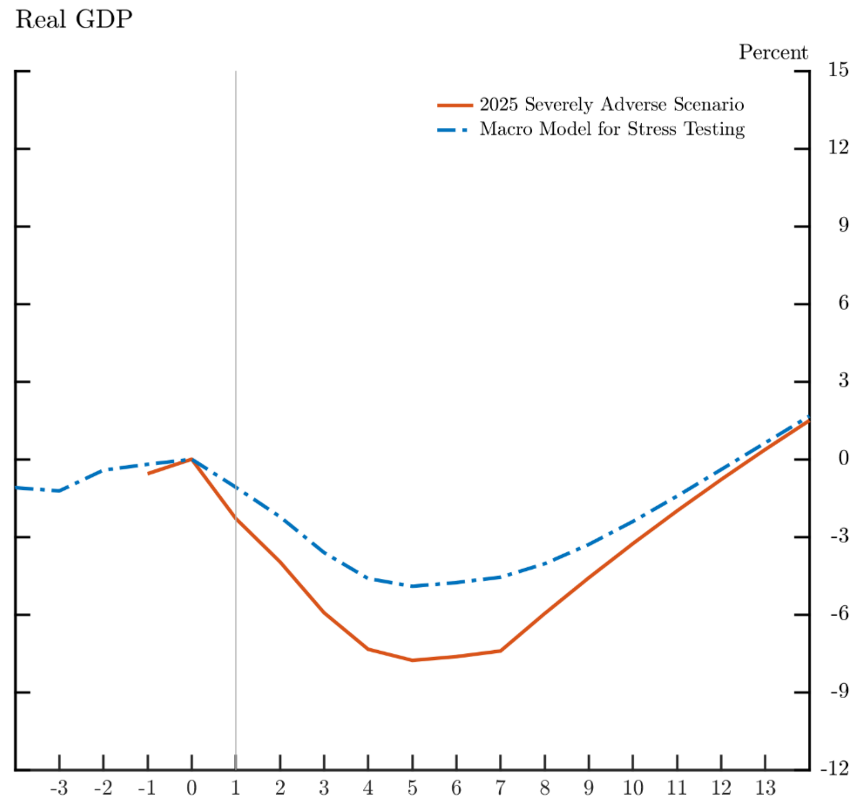


Figure C4 – Real GDP



D. Prices: PCE, CPI and GDP deflators

The Macro Model for Stress Testing specifies four measures of inflation, although ultimately their dynamics are primarily determined by a single one. While headline CPI inflation is the scenario's focal inflation variable, the behavior of the different inflation series, including CPI, is driven by that of core PCE inflation ($PICXFE$).[19] The latter concept is the key inflation factor that drives all of the other inflation rates in the model, as it excludes volatile components of PCE and CPI inflation and hence is more predictable and easier to model. Core PCE inflation also plays a key role in determining interest rates, as that measure of inflation enters the model's policy rule and, hence, directly determines the evolution of the model's interest rates. Besides headline CPI inflation, the Macro Model for Stress Testing also calculates inflation rates corresponding to the headline PCE deflator, which is in the model to deflate nominal disposable income, and the GDP deflator, which is used to calculate nominal GDP from real GDP. The model equation for core PCE inflation is:

Equation D1 – Core PCE inflation

$$\begin{aligned} PICXFE(t) \; = \; & 0.36 * PICXFE(t-1) \; + \; 0.23 * PICXFE(t-2) \\ & + 0.41 * PTR(t) \; + \; 0.08 * (UR(t) - URNAT(t-1)) \\ & + \; e^{PIXCFE}(t) \end{aligned}$$

The specification of this equation, along with its estimated parameters, is described in the 2015 speech "Inflation Dynamics and Monetary Policy" by Janet Yellen.[20] The equation originally proposed was estimated with an additional term meant to control for the effect of

[19] If $PCXFE$ is the core PCE price level then $PICXFE(t) \; = \; 400 * \log(\frac{PCXFE(t)}{PCXFE(t-1)})$. The same convention applies to the other inflation series, $PCNIA/PICNIA$, $PCPI/PICPI$, and $PGDP/PIGDP$.

[20] The speech is available at this link: https://www.federalreserve.gov/newsevents/speech/yellen20150924a.htm

changes in the relative price of core imported goods. This series is absent from the Board's suite of scenario variables and therefore is absent from the Macro Model for Stress Testing, making it irrelevant for the simulation; as a result, it is omitted. As also further described in the speech, PTR is the measure of long-run inflation expectations from the Survey of Professional Forecasters.[21] For the Policy Statement on the Scenario Design for Stress Testing,[22] the Board assumes that long-run inflation expectations remain anchored at the FOMC's longer-run goal of 2 percent.[23]

To assess the performance of this equation, dynamic simulations are produced over past recessions to assess how well the equation tracks the actual evolution of inflation during these periods.[24] Figure D1 shows the results of these simulations. The equation underpredicts the declines in inflation seen during the early 1990s and 2000s recessions. Understandably, it also has difficulty capturing the volatility in inflation seen during the 2007-2009 financial crisis. In the equation simulation, inflation remains at a pace similar to that preceding the recession before dropping sharply at the end of 2008 just to rebound a few quarters later. While the equation eventually captures the depth of the declines a few years into the 2007-2009 financial crisis, it does so sluggishly. This pattern and the underprediction by the equation of the 1990s and 2000s

[21] *Id.* As detailed in a footnote of the speech, long-run inflation expectations are proxied by the median forecasts of long-run PCE or CPI inflation reported in the Survey of Professional Forecasters, with a constant adjustment of 40 basis points prior to 2007 to put the CPI forecasts on a PCE basis. (Prior to 1991:Q4, the series is based on the long-run inflation expectations reported in the Hoey survey.)

[22] *See* 12 C.F.R. pt. 252, appendix A.

[23] https://www.federalreserve.gov/monetarypolicy/files/fomc_longerrungoals.pdf

[24] These simulations are run using the CBO estimates of the natural rate of unemployment ("January 2025" vintage) and the estimate of the long-run inflation expectations from the public release of FRB/US (mnemonic is PTR and June 2025 is the vintage of the public FRB/US release used to retrieve this variable. Two recent papers that use this series are: Chan, J., Clark, T. and Koop, G., 2018. "A New Model of Inflation, Trend Inflation, and Long-Run Inflation Expectations." Journal of Money, Credit and Banking, 50, issue 1, p. 5-53; and Ashley, R. & Verbrugge R., 2025. "The intermittent Phillips curve: Finding a stable (but persistence-dependent) Phillips curve model specification." Economic Inquiry, Western Economic Association International, vol. 63(3), pages 926-944, July.

recessions suggest that momentum of other factors, beyond those reflected in the equation, have influenced the evolution of inflation during the past three non-pandemic recessions. Accordingly, the Board augments the equation with shocks in the first year of the simulation in order to capture and replicate the contribution of these factors. The yellow lines in Figure D1 show the performance of the combination of the rule and the shocks.[25] As shown in Figure D1, the addition of the shocks substantially improves the fit for the 1990s and 2000s recessions. It also accelerates the decline in inflation during the 2007-2009 financial crisis in a way that is consistent with the data.

Figure D2 shows the proposed equation's prediction of inflation given the guidance about the unemployment rate in the 2025 stress test.[26]

The specification implies that the level of inflation immediately prior to the scenario matters for the inflation path. However, because the coefficient on lagged inflation is small (0.36), this effect is not very long-lived, as shown in Figure D2, which displays the results of simulations for different "jump off" inflation rates, ranging from 1.0 percent to 6.0 percent.[27] As expected, higher initial inflation leads to higher inflation in the simulation, but the effect is relatively modest eight quarters into the simulation, even for very high initial inflation.

[25] The shocks are calibrated by minimizing the sum squared errors implied by the equation and shocks over the three recessions relative of the actual data. The shocks are assumed to be the same in each quarter across all recessions, to capture a systematic pattern that is common and robust to the three recessions. Shocks are introduced only from the second to the fourth quarter of the dynamic simulation period as the Board prefers to insulate the procedure from the impact of the spike displayed by inflation in the first quarter of two of those recessions.

[26] In this simulation, the natural rate of unemployment is generated in accordance with the set of rules and specifications behind the construction of the baseline, and the long-run inflation expectations are anchored at the FOMC's longer-run goal of 2 percent.

[27] In the simulations shown in Figure D3, the natural rate of unemployment is set to 4.1 percent through the simulation and the initial value of the unemployment rate to 4.0 percent. The trajectory of the unemployment rate during the simulation is consistent with the 2025 stress test guide.

Figure D1 – Core PCE inflation equation: dynamic counterfactuals

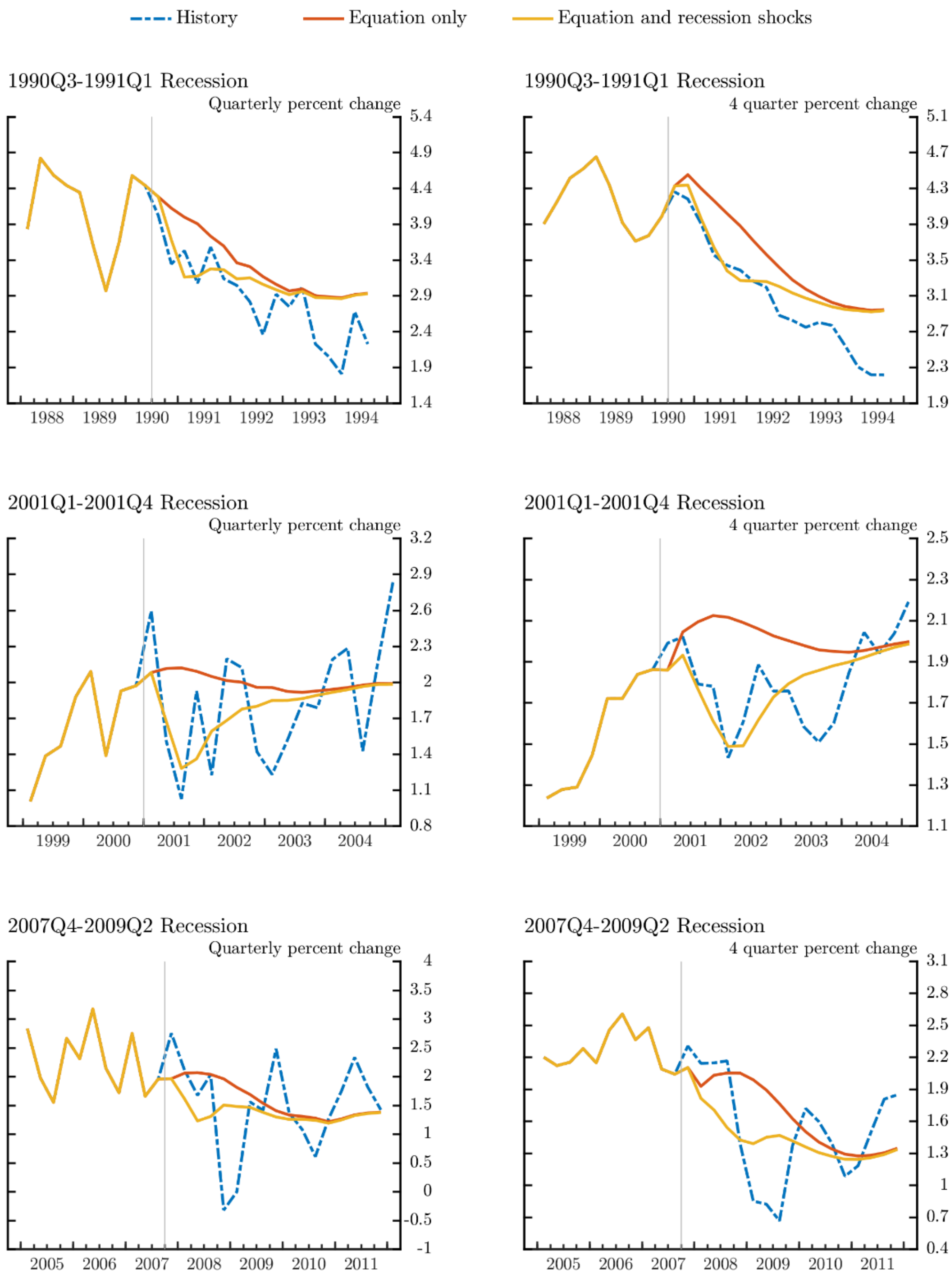


Figure D2 – Trajectories of core PCE inflation under adversely severe conditions

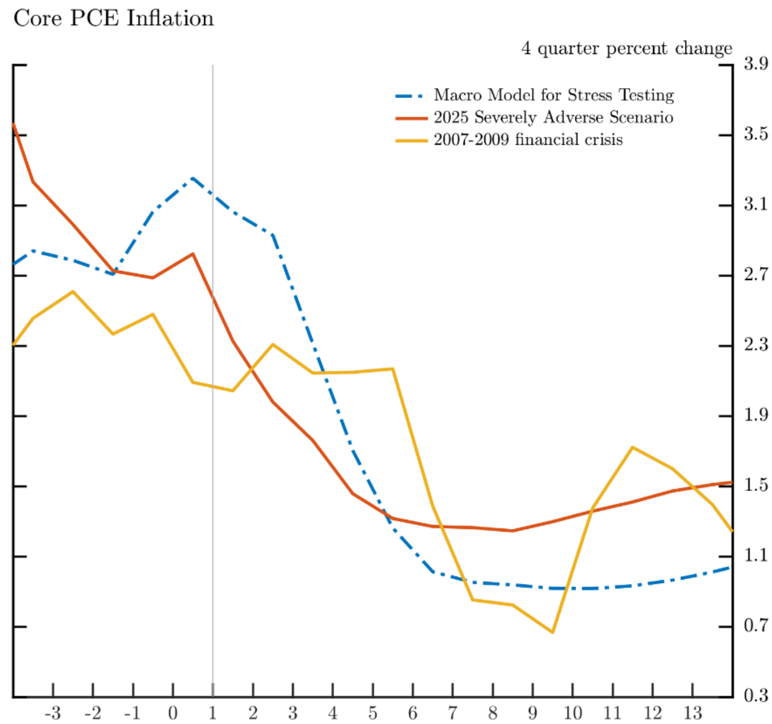
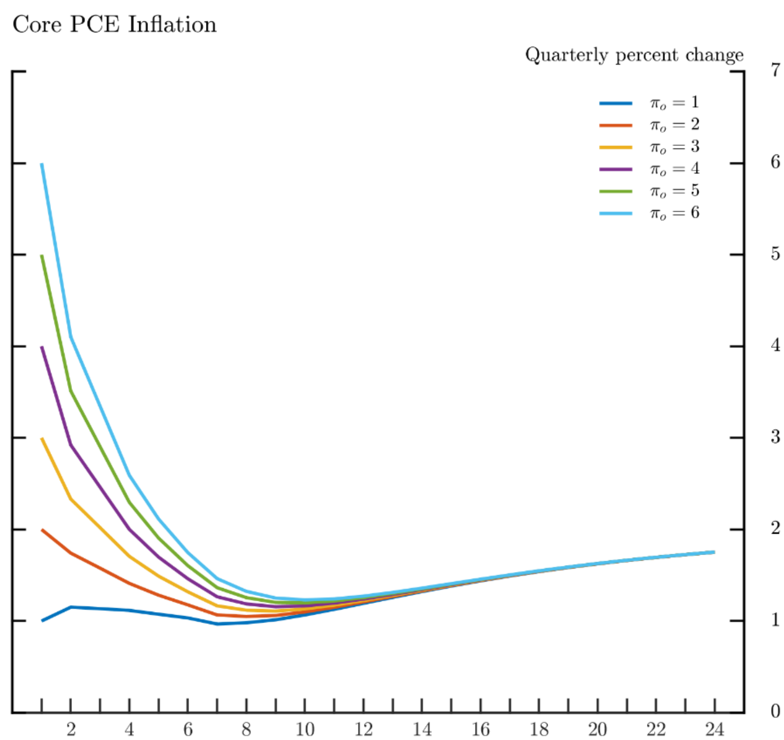


Figure D3 – Initial conditions and core PCE inflation, with π_0 representing starting inflation



The headline PCE inflation process is specified as core PCE inflation plus a term capturing the effects of fluctuations in inflation for food and energy consumption relative to core inflation. The distinction between core and headline inflation is not of central importance to the scenarios and so this term is assumed to follow an autoregressive process of order 1, allowing for some persistence while implying that its contribution will become zero overtime in the absence of shock. Headline PCE inflation is represented by the pair of equations:

Equation D2 – Headline PCE inflation

$$PICNIA(t) \ = \ PICXFE(t) \ + \ W^{PICNIA}(t),$$

Equation D3 – Headline PCE inflation wedge

$$W^{PICNIA}(t) = \ \alpha W^{PICNIA}(t-1) + \ e_W^{PICNIA}(t).$$

The process e_W^{PICNIA} is assumed to be white noise. Technically, the equation is estimated by applying the AR(1) operator $(1 - \ \alpha L)$ to the previous equation, where L is the lag operator (i.e., $Le_t = \ e_{t-1}$). The resulting equation is:

Equation D4

$$PICNIA(t) \ = \ \alpha PICNIA(t-1) + \ \left(PICXFE(t) - \ \alpha PICXFE(t-1)\right) + e_W^{PICNIA}(t).$$

The estimation sample is 1990-2019 and the nonlinear least squared estimate of α is 0.36. The estimated equation is therefore:

Equation D5

$$PICNIA(t) = PICXFE(t) + \ W^{PICNIA}(t),$$

where $W^{PICNIA}(t) = 0.36 * \ W^{PICNIA}(t-1) + \ e_W^{PICNIA}(t).$

The same strategy is employed to link CPI inflation to PCE inflation. An assessment of the equation's fit shows that $PICNIA$ is a much better basis to model CPI inflation than core PCE inflation. This result is expected since the concepts of CPI and headline PCE inflation both include the contributions from energy and food prices. However, in contrast to the relationship between headline and core PCE inflation, it is well-known that CPI inflation shows a consistent upward bias relative to PCE inflation. As a result, a constant is included in the equation and its regression. CPI inflation is represented in the Macro Model for Stress Testing by the pair of equations:

Equation D6 – CPI inflation

$$PICPI(t) = 0.48 + PICNIA(t) + W^{PICPI}(t),$$

Equation D7 – CPI inflation wedge

$$W^{PICPI}(t) = 0.11 * W^{PICPI}(t-1) + e_W^{PICPI}(t).$$

It is worth noting that the estimated value of the intercept is replaced in the simulation with that implied by the long-range estimates of the CPI inflation and PCE inflation in the Blue Chip Economic Indicators survey when constructing the baseline or simulating the adversely severe scenario.

The strategy is also employed to link GDP inflation to PCE inflation:[28]

Equation D8 – GDP inflation

$$PIGDP(t) = PICXFE(t) + W^{PGDP}(t),$$

Equation D9 – GDP inflation wedge

$$W^{PGDP}(t) = 0.45 * W^{PGDP}(t-1) + e_{W^{PGDP}}(\mathrm{t}).$$

Tables D1 and D2 report statistics about core and headline PCE inflation for the non-pandemic recessions since the beginning of the 1980s.[29] The change in prices is analyzed and reported in terms of four-quarter percent changes to smooth through the volatility of the quarterly

[28] The Board uses core PCE inflation to anchor GDP inflation as running the same regression with headline PCE inflation as the chief driver reduces the fit of the equation as measured by a lower R^2.

[29] The two recessions at the very beginning of the 80s are treated as one due to their proximity.

changes. The impact of the recession on inflation is characterized by comparisons of outcomes in the six quarters preceding the recession (labelled "Prior") versus outcomes in the eight quarters corresponding to the last two quarters of the recession and the subsequent six quarters (labelled "Post").[30] The first three columns of reported statistics report the highest inflation rate prior to the recession, the smallest value over the post-recession periods, and the difference between the two. The second three columns of statistics report the prior and post-recession medians, as well as the difference in medians.

While the totality of the results shows a wide range of values, which is not necessarily surprising given the volatile nature of inflation, especially headline inflation, the following patterns can nonetheless be discerned.

First, all measures of inflation show a negative change following a recession. Second, as expected, the changes calculated from the max/min approach are larger than those obtained from using the median statistics. The declines observed following the 1990s and 2000s recessions are smaller than those observed during the 2007-2009 financial crisis, which reflects a very fast and sharp decline in inflation at the end of 2008.

Table D1 – Core PCE inflation

Recession	Max/Min metric Core PCE Inflation			Median metric Core PCE Inflation		
	Max	Min	Change	Prior	Post	Change
1980/1982	9.68	4.15	-5.53	9.18	5.48	-3.71
1990/1991	4.65	2.89	-1.76	3.95	3.41	-0.54
2001	1.86	1.43	-0.43	1.72	1.68	-0.04
2007-2009 financial crisis	2.61	0.67	-1.94	2.41	1.23	-1.18

Notes: The entries of the first, second, fourth and fifth columns refer to annualized quarterly percentage change in inflation while the third and sixth columns show the

[30] The range of the "post" period is chosen to measure the effect on inflation once the full effects of the recessions have been reflected in the inflation process. As a result, the early quarters of the recessions were excluded from the calculations.

difference between the values reported in the entries of the two columns that precede them.

Table D2 – Headline PCE inflation

Recession	Max/Min metric Headline PCE Inflation			Median metric Headline PCE Inflation		
	Max	Min	Change	Prior	Post	Change
1980/1982	11.07	3.77	-7.30	10.63	4.52	-6.11
1990/91	4.82	2.50	-2.32	4.20	2.92	-1.28
2001	2.56	0.76	-1.80	2.49	1.69	-0.81
2007-2009 financial crisis	3.31	-1.20	-4.51	2.35	1.28	-1.07

Notes: See the notes of Table D1.

E. Nominal and Real Disposable Income

Modeling disposable income (DPI) from first principles would involve, from an accounting perspective, multiple components such as wages, profits, transfers and average tax rates. These components would in turn depend on many other factors that are not directly relevant to the scenario design process and from which the model accordingly abstracts. For example, wages should depend on the capital stock through effects on labor productivity, but neither the stock of capital nor the investment flows that generate it are variables directly relevant to stress scenarios.

This additional complexity can be circumvented by focusing on the strong and readily apparent relationship between disposable income and GDP. This relationship is then modulated by a proxy for the state of the business cycle (the unemployment rate, in this case), to capture important features of the data such as the tendency of DPI/GDP ratio to rise in recessions, in part due to higher transfer payments, as has been the case in recessions since the 1990s. More precisely, the dynamics of the nominal Disposable Income process, YDN, is determined by the equation:

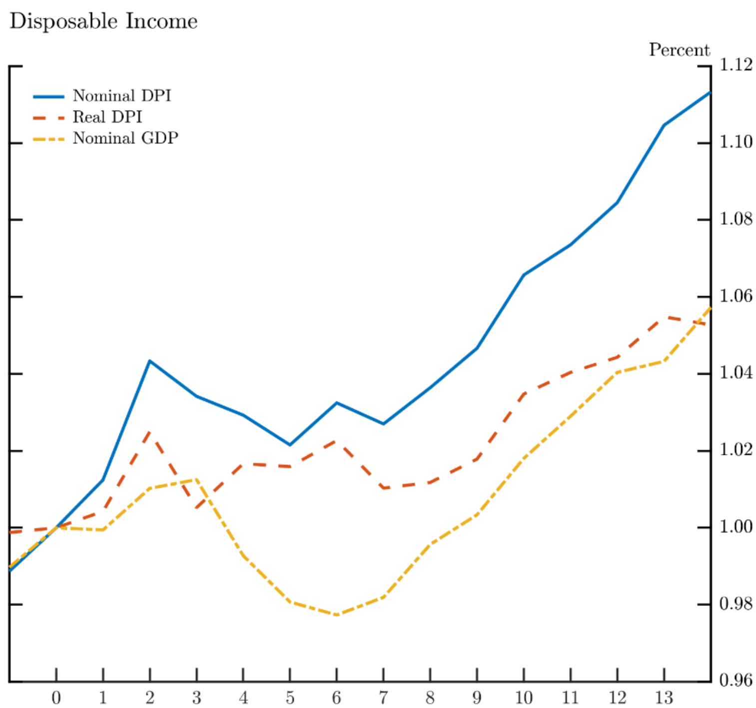
Equation E1 – Nominal disposable income

$$\frac{YDN(t)}{GDPN(t)} - \frac{YDN(t-1)}{GDPN(t-1)} = 0.0058 * (UR(t) - UR(t-1)).$$

The equation was estimated with a sample starting in 1967 and ending in 2019. This specification characterizes the dynamics of YDN relative to those of nominal GDP ($GDPN$). The estimates confirm the countercyclical dynamics of DPI, where DPI is typically stronger than GDP when the economy weakens, i.e. when $UR(t) - UR(t-1)$ is greater than 0, and somewhat weaker than GDP when the economy is expanding, i.e., when $UR(t) - UR(t-1) < 0$.

Figure E1 shows the evolution of nominal and real DPI over the 2007-2009 financial crisis.[31] Figure E2 shows the outcomes of the simulation based on the equation in the Macro Model for Stress Testing replication of the 2025 adverse stress scenario. The equation roughly captures the fact that real DPI hovers near its level at the time the recessionary event started while nominal DPI keeps growing through the period. Real disposable income is constructed by deflating its nominal counterpart with the headline PCE price level.[32]

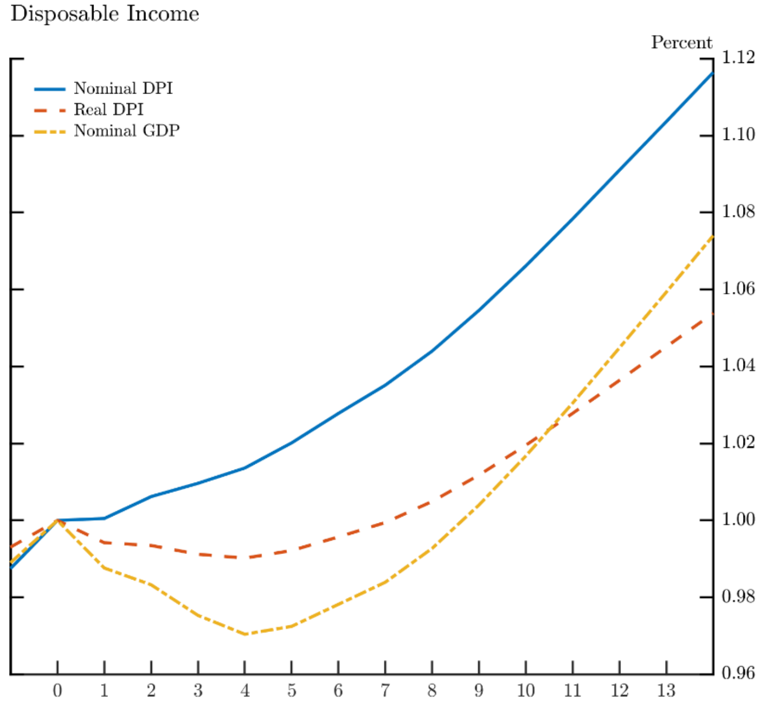
Figure E1 – Disposable personal income (historical data)



[31] The level of each series is normalized by dividing the series by the level of DPI either in 2007Q4 (when showing the Great Recession period) or in the quarter before the simulation begins.

[32] DPI is most often used as an indicator of household spending power and deflating nominal DPI by the headline PCE price level is appropriate if the relevant concept of household spending is similar to consumption in the National Income and Product Accounts.

Figure E2 – Disposable personal income (simulated data)



F. Monetary Policy (Fed Funds Rate) and the 3-month Treasury Bill Rate

The Board assumes that the Fed Funds rate, RFF, follows the prescription of a policy rule, $RFFINTAY$:

Equation F1 – Monetary policy rule

$$\begin{aligned} RFFINTAY(t) = {} & 0.85 * RFF(t-1) \\ & + 0.15 * \Big(RSTAR + \text{average}\,(PICXFE(t), 4) + 0.5 \\ & \quad * \big(\text{average}\,(PICXFE(t), 4) - PITARG(t)\big)\Big) \\ & + 0.15 * \mathbb{1}(XGAP(t) < 0) * XGAP(t) \\ & - 0.85 * \big(UR(t) - UR(t-2)\big) * \mathbb{1}(UR(t) > URNAT(t)) * \\ & \quad \mathbb{1}(UR(t) - UR(t-2) > 0), \end{aligned}$$

Equation F2 – ELB constraint

$$RFF(t) = \max\,(RFFINTAY(t), 0.125).$$

The effective lower bound ("ELB") is imposed whenever the policy rate is below 0.125. This assumption is consistent with the fact that the Board has never adopted a nominal policy rate below zero, and the views of members of the FOMC, who have suggested that they would apply a very high bar to conditions under which they would consider nominal policy rates below zero.[33] The standard part of the rule is a function of the natural rate of interest, $RSTAR$, the

[33] *See, e.g.*, Bernanke, Ben (2016). "What Tools Does the Fed Have Left? Part 1. Negative Interest Rates." Brookings Institution, March 18; Fischer, Stanley (2016). "Monetary Policy, Financial Stability, and the Zero Lower Bound." Speech by Stanley Fischer Vice Chairman Board of Governors of the Federal Reserve System at the Annual Meeting of the American Economic Association, San Francisco, California; and interview "Powell says the Federal Reserve is not considering negative interest rates" by Jeff Cox (CNBC) from May 13, 2020, available online at this link: Powell says the Federal Reserve is not looking at negative interest rates.

output gap, $XGAP$, and core PCE inflation.[34] This rule is used in the paper Chung et al. (2019).[35] As in that paper, the Board adds an adjustment to the rule whenever the economy deteriorates meaningfully. This adjustment is a function of the changes over two quarters in the unemployment rate.

The Board assumes that the path of the simulated Treasury 3-month bill rate matches that of the Federal Funds rate:

Equation F3 – 3-month Treasury bill rate

$$RTB(t) = RFF(t).$$

While in reality the two short-term interest rates deviate from each other because of liquidity risks, monetary policy expectations, and market functioning, modeling these factors in a simple and systematic way is quite challenging. Moreover, with the scenario narratives requiring a pronounced increase in unemployment and noticeable decrease in inflation, the policy rate quickly falls to the ELB and remains there for a prolonged period. Consequently, any difference between the policy rate and other short-term interest rates would generally be very small and immaterial to the outcomes of the simulation.

[34] The function average (X, n) indicates the average of variable X over the period defined by the current period and the last $n - 1$ periods. $\mathbb{1}(.)$ is an indicator function that is equal to 1 if its statement argument is true, and 0 otherwise.

[35] Hess T. Chung & Etienne Gagnon & Taisuke Nakata & Matthias Paustian & Bernd Schlusche & James Trevino & Diego Vilán & Wei Zheng., 2019. "Monetary Policy Options at the Effective Lower Bound : Assessing the Federal Reserve's Current Policy Toolkit," Finance and Economics Discussion Series 2019-003, Board of Governors of the Federal Reserve System (U.S.).

G. Long-term Interest Rates

The 5- and 10-year Treasury yields ($RG5$ and $RG10$, respectively) are specified as the sum of expected policy rates over the valuation horizon ($ZRFF5/ZRFF10$) and a term premium ($RG5P/RG10P$). See Cohen et al (2018) and Gürkaynak and Wright (2012). The corresponding equations are:

Equation G1 – 5-year Treasury yield

$$RG5(t) = ZRFF5(t) + RG5P(t),$$

Equation G2 – 10-year Treasury yield

$$RG10(t) = ZRFF10(t) + RG10P(t).$$

The expectational components are equal to the average of the quarterly short-term interest rates over the horizon corresponding to the maturity of the bond:

Equation G3 – 5-year expectational component

$$ZRFF5(t) = \frac{(RFF(t) + RFF(t+1) + \ldots + RFF(t+19))}{20}$$

Equation G4 – 10-year expectational component

$$ZRFF10(t) = \frac{(RFF(t) + RFF(t+1) + \ldots + RFF(t+39))}{40}$$

$RFF(t+i)$ denotes the estimated federal funds rate in quarter i of the scenario horizon.

H. Term Premiums

Term premiums play an important role in the generation of long-term yields, both in the baseline and in scenarios. The guidance on long-term yields only provides information about the trajectory over the early quarters of the simulation but no information regarding how the yields go back to their long-run values and what those values are. Accordingly, beyond the horizon of the guidance, the path of longer-term yields is determined, unless otherwise specified, endogenously in the model, through the paths of the term premiums and the expected federal funds rate implied by the scenario, consistent with the model equations for those variables.

Consequently, the main function of the term premium equations is to characterize their convergence towards their respective long-run value, or unconditional means, beyond the point determined by the guides. While many factors influence term premiums, including market assessments of current and future expected economic conditions, supply-demand imbalances and institutional factors, the Board considers a simple autoregressive process of order 1, i.e., an AR(1) process, as an adequate specification to fulfill this function. Any cyclical co-movement between term premiums and broader economic conditions is assumed to be incorporated in the guidance.

Determining the parameters in the specification is complicated by an apparent downward trend in the earlier decades of the sample in many influential term premium estimates, as illustrated in Figure H1, which presents estimates of the term premiums obtained by Kim and Wright using the methodology of Kim and Orphanides.[36] The nature of this downward movement has important implications for both the appropriate long-run level and the degree of

[36] Kim, D. H. & Wright, J. H., 2005. "An Arbitrage-Free Three-Factor Term Structure Model and the Recent Behavior of Long-Term Yields and Distant-Horizon Forward Rates," FEDS Working Paper No. 2005-33; Kim, D. H. & Orphanides, A., 2012. "Term Structure Estimation with Survey Data on Interest Rate Forecasts," Journal of Financial and Quantitative Analysis, 47 (February 2012): 241-272

persistence in the process. If the process is assumed to be stationary, i.e., deviations from a time-invariant long-run level are assumed to temporary, then, given these estimates, deviations must be very persistent and the long-run level significantly higher than the realized path over the last several decades. On the other hand, if the process is taken to display permanent shifts in the long-run level, the long-run level in the model should be calibrated to values more like recent realizations, while deviations from that time-varying long-run level might be relatively transient.

In what follows, we investigate the implications of different assumptions about the apparent downward trend in term premiums. For this purpose, the Board focuses on estimates from the Kim-Wright model previously presented. While this focus on the Kim-Wright model is not without loss of generality, the Kim-Wright estimates are produced by the Board and are thus one of the few public sources that can be assured to be reliably and consistently produced indefinitely into the future.[37]

The Board considers two ways to deal with the downward drift shown in the Kim and Wright estimates. The first approach is to estimate time-varying intercepts ($y_{rg10p_{1,t}}$ and $y_{rg5p_{1,t}}$) for the AR(1) specifications:

[37] It is known that the magnitude of the secular decline shown by the Kim and Wright estimates depends in part on the treatment of the end-points of the variables in the estimation of the term structure model, more specifically, whether these end-points are considered to be constant or to vary over time. While using survey forecasts to discipline the dynamics parameters of the term structure model, Kim and Wright still assume a system with a time-invariant long-run level. An alternative assumption is for the variables' end-points to vary over time, as proposed in Bauer and Rudenbusch (2018) and Crump et all (2016). (Bauer, M. D., and Rudebusch, G. D., 2020. "Interest Rates under Falling Stars." American Economic Review 110 (5): 1316–54; and Crump R. K. & Eusepi S. & Moench E., 2016. "The term structure of expectations and bond yields," Staff Reports 775, Federal Reserve Bank of New York.) Both papers argue that such a specification provides estimates of the term premiums that better reflects changing risks associated with Treasury securities.

An alternative source for publicly available term-premium estimates would be the estimates of Adrian, Crump, and Moench (2018), made available by the Federal Reserve Bank of New York at https://www.newyorkfed.org/research/data_indicators/term-premia-tabs#/overview and based on Adrian T. & Crump R. K., Moench E., 2013. "Pricing the term structure with linear regressions", Journal of Financial Economics, Volume 110, Issue 1, p. 110-138. As with Kim-Wright, this model assumes a time-invariant long-run level.

Equation H1 – 10-year term premium (time-varying intercept)

$$RG10P(t) = y_{rg10p_{1,t}} + y_{rg10p_2} * \left(RG10P(t-1) - y_{rg10p_{1,t}}\right) + e_{10}(t)$$

Equation H2 – 5-year term premium (time-varying intercept)

$$RG5P(t) = y_{rg5p_{1,t}} + y_{rg5p_2} * \left(RG5P(t-1) - y_{rg5p_{1,t}}\right) + e_5(t)$$

While formally inconsistent with the underlying Kim-Wright model, this approach could be viewed as a way of separating out highly persistent movements in the term-premium from the comparatively transient movements that are more relevant to scenario design over the horizon of a few years.

Estimating this model by maximizing the likelihood yields estimates of y_{rg10p_2} and y_{rg5p_2} for the 1990-2024 sample of 0.81 and 0.74 respectively.[38] By design, this approach attributes a significant fraction of the variation in the term premiums to the intercepts, and hence deviations from the time-varying long-run value are not very persistent.

An alternative approach is to estimate a model relying on a shorter sample (2000-2024), over which the downward drift is not as marked. This sample, while shorter, still spans three recessions – importantly including the 2007-2009 financial crisis. The downward trend over that smaller sample is far less apparent and largely absent since 2010. The fact that the observations in the early 2000s are within the range of the long-run values implied by the Blue Chip long-range forecasts since 2007 supports this view.[39]

Under this alternative specification, the intercepts of the term premiums are now time-invariant:

[38] For the purposes of this estimation exercise, the intercepts are assumed to be independent random walks.

[39] More precisely, the difference between the far end long-range forecast of the 10-year Treasury yield and that of the 3-month Treasury Bill rate ranges has been in a range between 0.7 and 1.5

Equation H3 – 10-year term premium (constant intercept)

$$RG10P(t) = y_{rg10p_1} + y_{rg10p_2} * (RG10P(t-1) - y_{rg10p_1}) + e_{10}(t)$$

Equation H4 – 5-year term premium (constant intercept)

$$RG5P(t) = y_{rg5p_1} + y_{rg5p_2} * \left(RG5P(t-1) - y_{rg5p_1}\right) + e_5(t)$$

The ordinary least square estimates of y_{rg10p_2} and y_{rg5p_2} (0.91 and 0.87, respectively) now show considerably more persistence.[40]

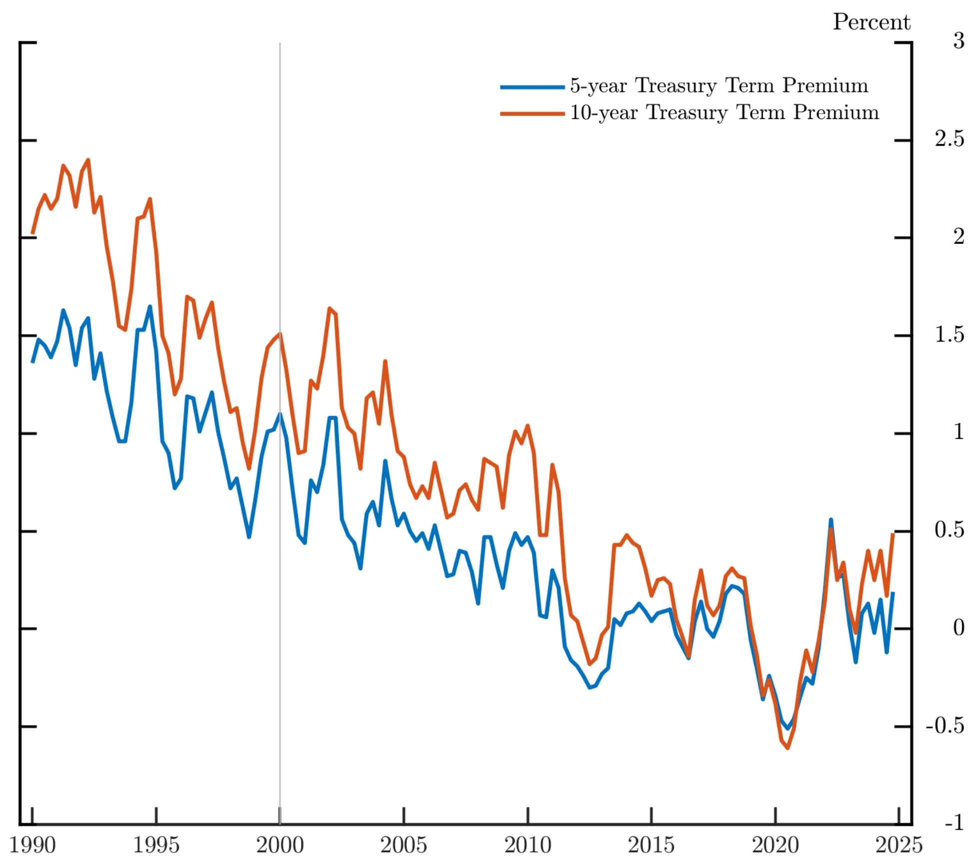
The difference in the estimated degree of persistence across the two specifications entails noticeable differences in the speed with which premiums will converge back to their long-run values. For example, for the 10-year premium, the relatively rapid convergence under the time-varying intercept specification entails that the number of periods it takes for the effect of an initial shock (or innovation) to decline to 10 percent of its initial magnitude is about 11 quarters, compared to 24 quarters assuming a constant intercept. Inspection of Figure H1 suggests that movements in the Kim-Wright term premiums during recessions are likely more consistent with that implied by the estimate of the time-varying specification. The Board therefore adopts the estimates of the time-varying specification for the degree of persistence coefficient of the 5- and 10-year term premium equations.

In principle, each approach has different implications for setting the long-run value of the term premiums. However, instead of relying heavily on model-based estimates, the Board will rely on survey information about expectations regarding the 10-year Treasury term premium from the Blue Chip long-range economic forecasts, which should incorporate a more

[40] This higher degree of persistence compared to the model with a time-varying long-run value is to be expected: that model could explain most highly persistent movements in the term premium through changes in the long-run value, leaving the autoregressive process to explain only transient movements, while the present model must explain everything with only the autoregressive process.

comprehensive information set than any given econometric model that we might estimate. Accordingly, the unconditional mean of the 10-year term premium process used in the generation of the baseline and scenarios is calculated as the difference between the long-range forecast of the 10-year Treasury yield and that of the 3-month Treasury bill rate. Since there is no corresponding long-range forecast of the 5-year Treasury yield, the unconditional mean of its term premium is calibrated as the difference between that of the 10-year term premium and 20 basis points. Appendix B provides the motivation and calculation behind the size of this adjustment. It should be noted that this determination of the long-run values of the term premiums is consistent with and further affirms the choice of the time-varying intercept specification.

Figure H1 – 5- and 10-year Treasury term premiums



I. Model Variables with Complete and Explicit Guides

With the exception of the unemployment rate, all the equations and variables discussed until now refer to variables for which that variable's equation in the model governs its behavior in scenarios. For the remaining variables, while the behavior of these variables is determined by their respective guides up to 13 quarters, the following equations generate baseline projections whenever outside forecasts are not available and are needed to produce a projection beyond the 13-quarter horizon of the guides. These variables are the BBB Spread, house price, equity price, VIX, mortgage rate, commercial real estate price and prime rate.[41]

i. BBB Spread

The equation of the BBB yield is given by:

Equation I1 – BBB yield

$$RBBB(t) = RBBBP(t) + RG10(t).$$

The process for the BBB spread is assumed to follow an AR(1) process. The estimated equation is:

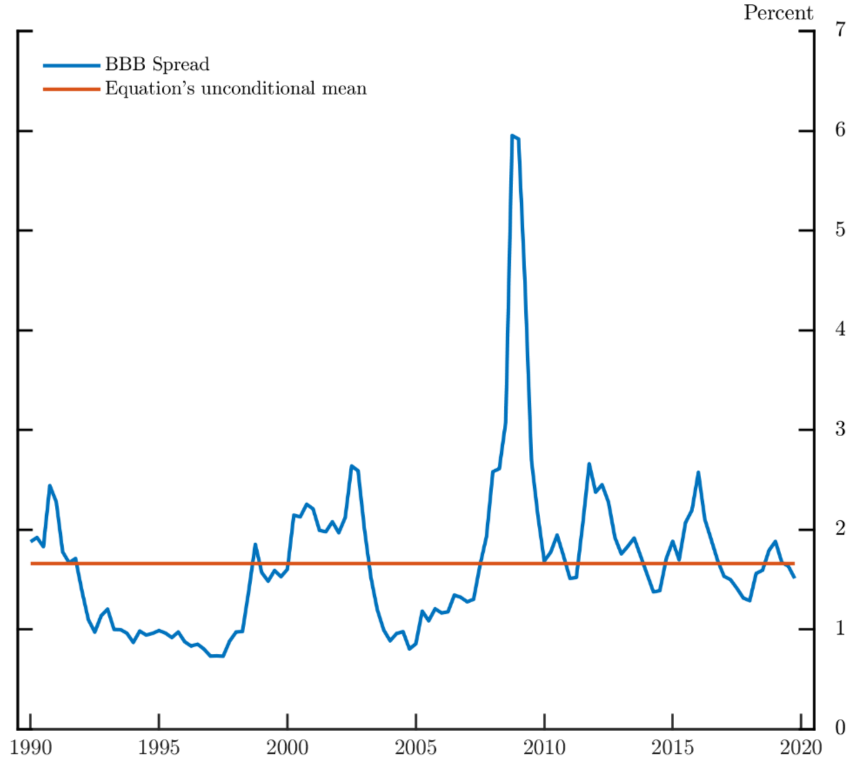
Equation I2 – BBB spread

$$RBBBP(t) = 1.66 + 0.87 * (RBBBP(t-1) - 1.66) + e^{BBBP}(t)$$

This equation is estimated with a sample starting in 1990 and ending in 2019. Figure I1 shows the BBB term premium series and the estimated unconditional mean of its equation.

[41] The reader is referred to the corresponding guide of these variables for more information about them.

Figure I1 – BBB spread



ii. <u>House Price</u>

Following the convention adopted by the HPI guidance, the dynamics of the house prices are characterized through those of its ratio relative to per capita disposable income, that is:

Equation I3 – Ratio of house price index to per capita disposable income (definition)

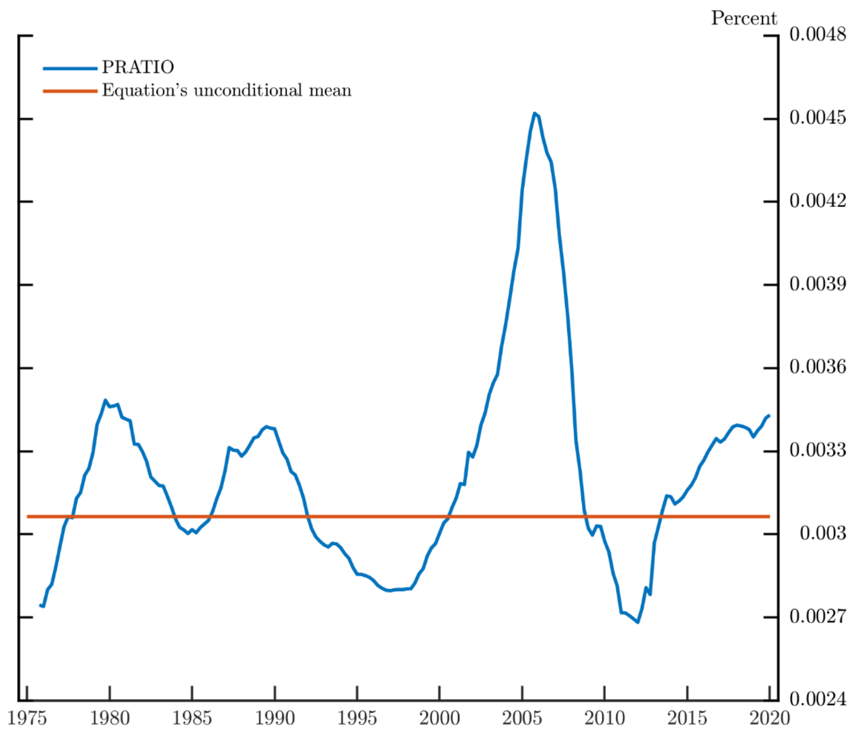
$$PRATIO(t) = PHOUSE(t) / \left(\frac{YDN(t)}{POP(t)/1000} \right).$$

As for the unemployment rate, the structure of an AR(2) process is adopted to characterize the dynamics of the $PRATIO$ series. The identification of the unconditional mean of the series proceeds as follows. As seen in Figure I2, the rise in house prices observed prior to the 2007-2009 financial crisis represents an unprecedented episode. As such, not including the most extreme observations in the calculation of a historical unconditional mean is the preferred option. The strategy of dropping any observation larger than the maximum value recorded by the series outside the window surrounding the 2007-2009 financial crisis is adopted.[42] The mean of the series over the sample period, excluding the aforementioned observations, is 0.003064. Taking this average as given, the AR(2) process for the $PRATIO$ series is estimated:

Equation I4 – Ratio of house price index to per capita disposable income (equation)

$$PRATIO(t) = 0.003 + 1.66 * (PRATIO(t-1) - 0.003) - 0.68 * (PRATIO(t-2) - 0.003) + e^{pratio}(t).$$

Figure I2 – PRATIO and equation's unconditional mean



iii. Equity Price

The equity price index, SP, is assumed in the baseline to grow with the rest of the economy:

[42] The largest value is 0.003480, recorded in 1979Q4.

Equation I5 – Equity price

$$\frac{SP(t)}{GDPN(t)} = \frac{SP(t-1)}{GDPN(t-1)} + e^{SP}(t).$$

However, this specification does not provide any mechanism for the stock market series to recover or return towards its baseline value after the large fall assumed by the "Equity Price" guide, beyond the specified end value at the 13-quarter mark. In order to ensure that the stock market relative to nominal GDP eventually returns (well beyond 13 quarters) to the original baseline ratio, $SP_{GDPN^{Baseline}}$, the equation used for the simulation of a severe stress scenario is:

Equation I6 – Scenario adjusted equity price equation

$$\frac{SP(t)}{GDPN(t)} = \frac{SP(t-1)}{GDPN(t-1)} - 0.1 * \left(\frac{SP(t-1)}{GDPN(t-1)} - SP_{GDPN^{Baseline}}(t)\right).$$

iv. <u>VIX</u>

The VIX equation is estimated from 1990Q1 to 2009. It relates the dynamics of the VIX to that of the BBB yield series ($RBBB$):

Equation I7 – VIX

$$VIX(t) = 9.3 + 9.9 * (RBBB(t) - RG10(t)) + 0.42 * \left(VIX(t-1) - 9.3 - 9.9 * \left(RBBB(t-1) - RG10(t-1)\right)\right).$$

As an example, the long-run value of the VIX according to this equation is about 25.7 when the long-run value of the BBB premium is 1.66.

v. <u>Mortgage Rate</u>

The residential mortgage rate is specified as a premium term, $RMEP$, over the 10-year Treasury yield:

Equation I8 – Residential mortgage rate

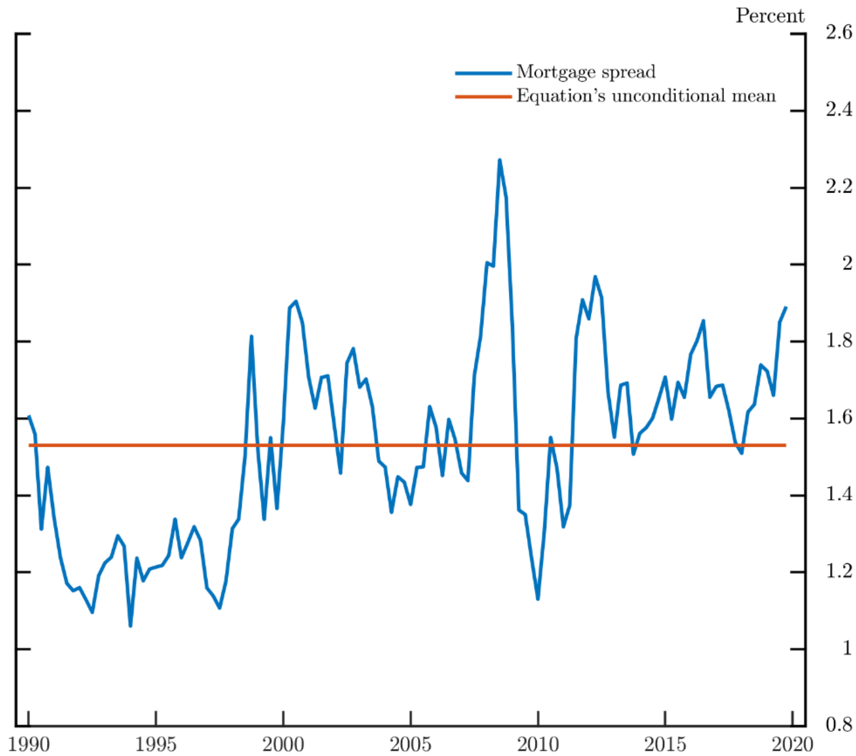
$$RME(t) = RG10(t) + RMEP(t)$$

The residential mortgage term premium is assumed to follow an AR(1) process, and its equation is estimated over the sample from 1990 to 2019:

Equation I9 – Residential Mortgage Spread

$$RMEP(t) = 1.53 + 0.85 * (RMEP(t-1) - 1.53).$$

Figure I3 – Residential mortgage spread



vi. Commercial Real Estate Price

Our specification of the commercial real estate price, CRE, is similar to that of the stock market, where the variable is tied to the evolution of the nominal GDP:

Equation I10 – Commercial real estate price

$$\frac{CRE(t)}{GDPN(t)} = \frac{CRE(t-1)}{GDPN(t-1)}.$$

And, as assumed for the stock market variable, the eventual return (well beyond the initial 13 quarters, the path of which is provided by the "Commercial Real Estate Price" guide) to the baseline is compelled by adopting the following specification when simulating stress scenarios:

Equation I11 – Scenario adjusted commercial real estate price

$$\frac{CRE(t)}{GDPN(t)} = \frac{CRE(t-1)}{GDPN(t-1)} - 0.025 * \left(\frac{CRE(t-1)}{GDPN(t-1)} - CRE_{GDPN^{Baseline}}(t)\right).$$

vii. Prime Rate

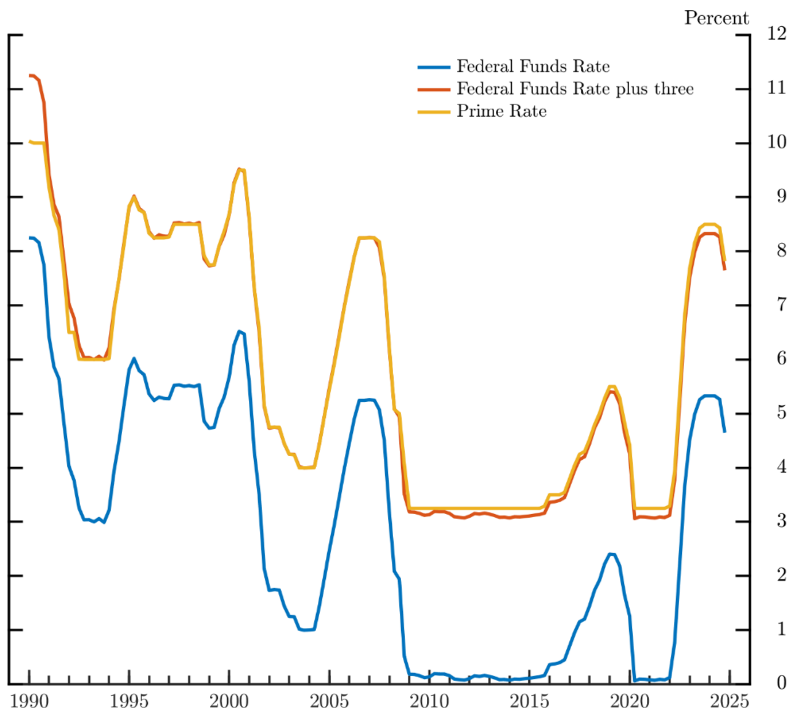
The equation of the prime rate reflects the fact that it is usually set about three percent higher than the federal funds rate:

Equation I12 – Prime rate

$$RPRIME(t) = RFF(t) + 3.$$

Figure I4 confirms that close relationship.

Figure I4 – Federal funds rate and prime rate



J. The Identities of the Macro Model for Stress Testing

The following equations are identities and definitions in the Macro Model for Stress Testing:

$$PCXFE(t) = PCXFE(t-1) * e^{\frac{PICXFE(t)}{400}}$$

$$PCNIA(t) = PCNIA(t-1) * e^{\frac{PICNIA(t)}{400}}$$

$$PGDP(t) = PGDP(t-1) * e^{\frac{PIGDP(t)}{400}}$$

$$PCPI(t) = PCPI(t-1) * e^{\frac{PICPI(t)}{400}}$$

$$XGAP(t) = 100 * \log\left(\frac{GDP(t)}{GDPT(t)}\right)$$

$$YD(t) = \frac{YND(t)}{PCNIA(t) * 0.01}$$

$$GDPN(t) = \frac{GDP(t)}{PGDP(t) * 0.01}$$

K. Exogenous Variables

The equations of the model outlined so far depend on exogenous variables, i.e., variables that do not have equations but instead are treated as fixed and whose values are set based on public information. The exogenous variables are population ($N16$), the natural rate of unemployment ($URNAT$), potential output and its growth rate ($GDPT$ and $HGGDPT$), the long-run inflation expectations (PTR), the policy objective for inflation ($PITARG$), the natural rate of interest rate ($RSTAR$).

Table K1 shows either the source of information or values used to set the path of these exogenous variables. The Board assumes that long-run inflation expectations remain anchored at the FOMC's longer-run goal of 2 percent.[43]

Table K1 – Data sources of exogenous variables

Exogenous Variables		
Variables	Mnemonics	Sources
Population	$N16$	CBO
Natural Rate of Unemployment	$URNAT$	CBO
Potential GDP	$GDPT$	CBO
Long-Run Inflation Expectations	PTR	2
Policy Objective	$PITARG$	2
Natural Rate of Interest	$RSTAR$	BC

Notes: CBO refers to the "Historical Data and Economic Projections" release from the Congressional Budget Office; BC refers to the long-range forecasts published in the Blue Chip Economic Indicators survey in March and October of each year.

[43] See FOMC longer-run goal at https://www.federalreserve.gov/monetarypolicy/files/fomc_longerrungoals.pdf.

The CBO is an authoritative federal legislative agency that provides on a regular and consistent basis nonpartisan economic estimates and forecasts. In particular, the CBO's estimates include economic statistical concepts that do not have observations in the data releases from government statistical agencies, such as potential GDP and the natural rate of unemployment.

L. List of variables and mnemonics

CRE: Commercial Real Estate Price

GDP: Real DGP

$GDPN$: Nominal GDP

$GDPT$: Potential GDP

$N16$: Population

$PCNIA$: Headline PCE Deflator (Price level)

$PCXFE$: Core PCE Deflator (Price level)

$PGDP$: GDP Deflator (Price level)

$PHOUSE$: House Price Index

$PICNIA$: Headline PCE Inflation (Logarithmic definition of growth)

$PIGDP$: GDP Inflation (Logarithmic definition of growth)

$PITARG$: Inflation Policy Objective

$PIXCFE$: Core PCE Inflation (Logarithmic definition of growth)

PTR: Long-Run Inflation Expectations

$RBBB$: BBB Yield

$RBBBP$: BBB Spread

RFF: Federal Funds Rate

$RFFINTAY$: Policy Rate

$RG5$: 5-year Treasury Yield

$RG5P$: 5-year Treasury Yield Term Premium

$RG10$: 10-year Treasury Yield

$RG10P$: 10-year Treasury Yield Term Premium

RME: Residential Mortgage Rate

$RSTAR$: Natural Rate of Interest

RTB: 3-month Treasury Bill Rate

UR: Unemployment Rate

$URNAT$: Natural Rate of Unemployment

VIX: VIX Index

XGAP: Output Gap

YDN: Nominal Disposable Income

YD: Real Disposable Income

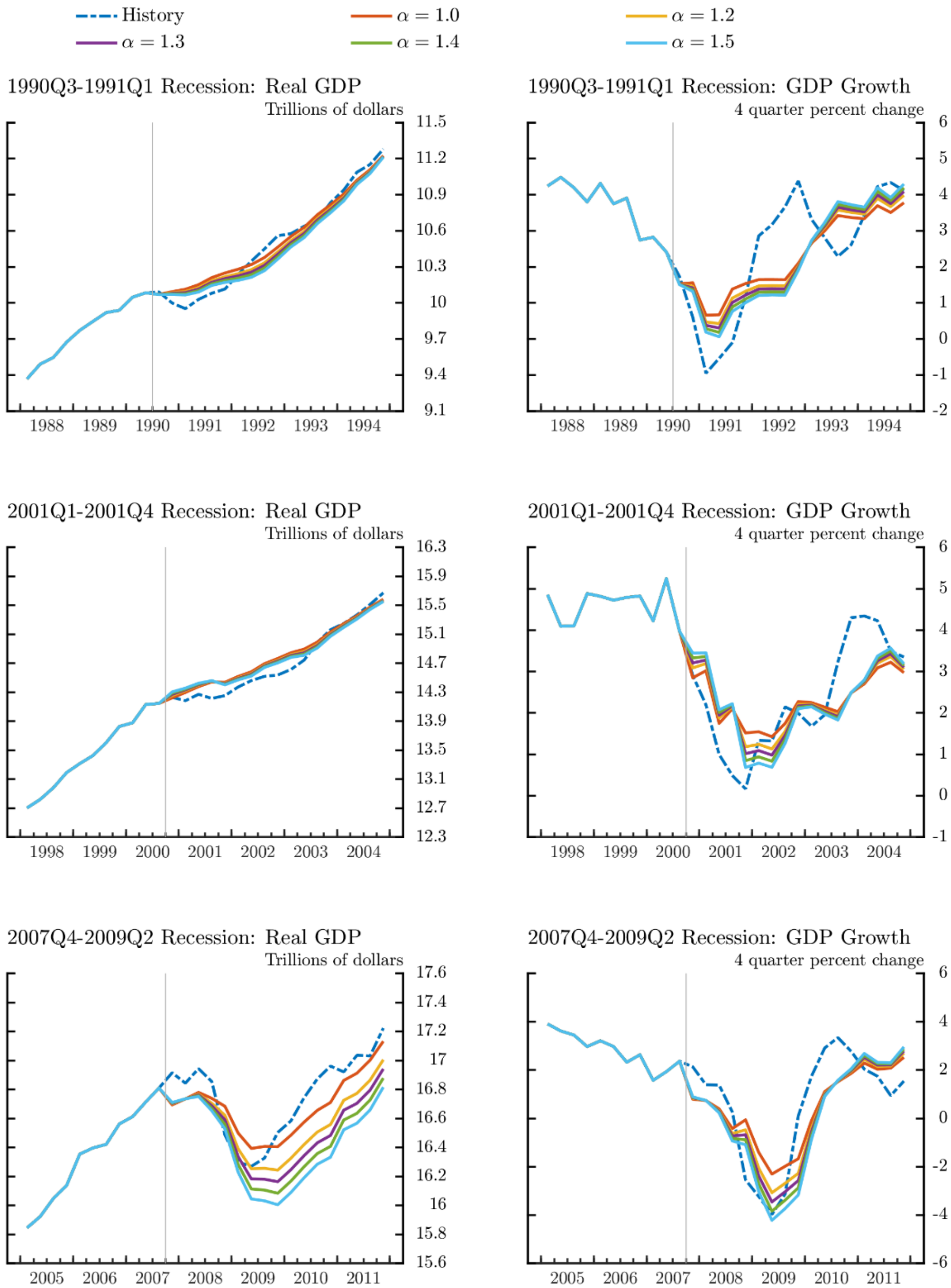
$ZRFF5$: 5-year Yield Expectational Component

$ZRFF10$: 10-year Yield Expectational Component

Appendix A. Level vs Growth Okun's Law specification

Figure AA1 reports the results of dynamic simulations for a specification of Okun's Law in levels over the (non-pandemic) recessions since 1990. These results should be compared to results for the growth rate specification shown in Figure C2 from the main text. The performance of the equations is shown for a series of coefficients ranging from 1.0 to 1.5. The bottom panels of Figure AA1 and C2 show that, while the growth rule with a coefficient of 1.4 does well at capturing both the magnitude of the decline in GDP and the contour of growth during the 2007-2009 financial crisis, there is no level rule that comes close to simultaneously replicating these two aspects of GDP. Given the ability of the growth specification to capture both the depth and contour of the evolution of real GDP during the 2007-2009 financial crisis, it has been adopted for the Macro Model for Stress Testing.

Figure AA1 – GDP level dynamic counterfactuals



Appendix B. Calibration of the long-range value of the 5-year Treasury yield

While the long-range forecasts from the Blue Chip Economic Indicators survey provide enough information to identify the long-run value of the 10-year Treasury yield and its term premium, there is no corresponding information about the 5-year Treasury yield. A simple average over history of the difference between the 10-year and 5-year yields would not provide an adequate estimate of the end value of the 5-year Treasury yield, as that difference tends to fluctuate in a systematic manner over different phases of the business cycles, as shown in Figure AB1. The objective is to calibrate a long-run value that conceptually corresponds to an economy that has settled to its long-run trends. Of course, such a state is ever-vanishing and more hypothetical than actual. The Board assumes that the estimates that would best approximate such economic conditions correspond to the difference between the long-run rates in the late and mature phase of an economic expansion. Figure AB1 shows that during these periods the difference between the two interest rates is at its lowest.[44] An average over the late phases of the four expansions that precede the pandemic is about 20 basis points, which is the value used to calibrate the end-value wedge between the 10-year and 5-year yields—which is entirely captured by the difference in the unconditional means of their respective term premiums.

[44] The Board identifies the period of 'late expansion' as that ending 2 quarters before the first official quarter of a recession and going back 2 years back from that final quarter.

Figure AB1. Difference between the 10-year and 5-year Treasury yields