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The Congressional Budget Office's Small-Scale Policy Model

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Abstract

The Congressional Budget Office's small-scale policy model (CBOSS) combines features of two existing models used to analyze fiscal policy into a single workhorse model. Currently, the multipliers model focuses on short-term demand effects, whereas the policy growth model focuses on long-run equilibrium effects. Unlike the two-model approach, CBOSS passes short-run effects through to the long run. CBOSS uses interest rates as a transmission mechanism for the "crowding out" of investment. The model also consistently treats the effects of policy in both the short and long run.

Keywords: macroeconomic models, fiscal policy, crowding out

JEL Classification: E2, E62, H3

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Introduction

The Congressional Budget Office's small-scale policy model (CBOSS) serves two main purposes:

- To determine in one model the short-run demand-driven responses and long-run supply-driven responses to policy changes; and
- To make both short- and long-run responses depend consistently on the fiscal policy under study.

To analyze the effects of many types of fiscal policy, CBO currently takes a weighted average of the results from two models. The multipliers model takes a Keynesian approach, focusing on the demand effects of policy, to determine the economy's short-run response.[1] The policy growth model (PGM), by contrast, focuses on the effect of changes in deficits on national saving to determine the economy's long-run response.[2] CBO weights the results from the two models together, with the weight on the PGM results gradually increasing over a specified number of years.

CBOSS is a parsimonious quarterly macroeconomic model that uses CBO's 30-year forecast as its baseline. The model's basic structure combines aggregate demand with aggregate supply, using an endogenous r^* (the Federal Reserve's target rate of interest) to restore the baseline balance between aggregate demand and aggregate supply in the long run. A policy that boosts aggregate demand without boosting aggregate supply causes r^* to rise, which eventually pushes aggregate demand back down by restraining consumer spending, private investment, and net exports. Some of the model's short-run behavior, such as that of inflation, is calibrated to be consistent with that in the model used to generate CBO's macroeconomic forecast, CMAC.[3]

The new model offers several advantages over the old framework. First, in CBOSS the direct effects on saving per dollar of deficit of two policies differ in the same way in the short and long run. In the current framework, policies may have different direct effects on saving per dollar of deficit in the short run, causing different effects on gross domestic product (GDP). However, all

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[1] For a general discussion, see Charles J. Whalen and Felix Reichling, *The Fiscal Multiplier and Economic Policy Analysis in the United States*, Working Paper 2015-02 (Congressional Budget Office, February 2015), www.cbo.gov/publication/49925. For an application, see John Seliski, Aaron Betz, Yiqun Gloria Chen, U. Devrim Demirel, Junghoon Lee, and Jaeger Nelson, *Key Methods That CBO Used to Estimate the Effects of Pandemic-Related Legislation on Output*, Working Paper 2020-07 (Congressional Budget Office, October 2020), www.cbo.gov/publication/56612.

[2] See Congressional Budget Office, "CBO's Policy Growth Model" (presentation, April 2021), www.cbo.gov/publication/57017.

[3] See Robert W. Arnold, *How CBO Produces Its 10-Year Economic Forecast*, Working Paper 2018-02 (Congressional Budget Office, February 2018), www.cbo.gov/publication/53537.

policies have identical direct effects on saving per dollar of deficit, and thus on GDP, in the long run. Second, CBOSS passes the short-run effects of increased demand on supply, through higher investment, into the long run. Third, CBOSS contains an explicit transmission mechanism, higher interest rates, by which increased federal stimulus "crowds out" private investment. A related advantage of CBOSS is that policy's effect on interest rates allows the model to determine the timing of the liftoff of interest rates from the zero lower bound. Finally, CBOSS gives a more realistic response of the capital stock to increased growth of the labor force, for example, from higher immigration, because in CBO's current framework growth of the labor force influences investment slowly.

CBOSS's Basic Structure

The core of CBOSS is the interaction between aggregate demand and aggregate supply (see Figure 1). The components of GDP—consumer spending, private investment, government consumption and investment, and net exports—are primarily functions of demand, as in FRB/US and IHS Markit's macro model. Aggregate supply (potential GDP) also has some direct effect on those components. For example, higher productivity boosts households' perception of their permanent income and thus their consumer spending. Aggregate supply is partly determined by GDP's investment component through its effect on the capital stock. GDP's nongovernment components depend on real rates of return, which depend on r^*. The level of r^* depends on the balance between aggregate demand and aggregate supply and helps restore that balance. Fiscal policy can affect both aggregate demand and aggregate supply.

Aggregate Demand

Aggregate demand equals private consumption (C) plus private investment (I) plus government consumption and investment (G) plus net exports (NX): $GDP = C + I + G + NX$. That basic structure is common to macroeconomic models. Unlike most such models, however, CBOSS has little additional detail. Private consumption and investment are simple totals, as are the two components of net exports, exports and imports. Only the government sector involves more detail because the model is designed to analyze fiscal policy.

CBOSS is a simultaneous model, meaning that variables in the model affect each other. For example, private consumption depends in part on labor income, labor income depends on GDP, and private consumption is a component of GDP. Sometimes feedback can be negative, such as when higher GDP boosts demand for imports, which then subtracts from GDP.

Fiscal policy can affect aggregate demand through several channels. Changes in G directly affect GDP. A reduction in taxes on income from labor or capital boosts personal consumption by increasing after-tax income and after-tax wealth. A reduction in the marginal tax rate on capital income also boosts private investment, whereas a reduction in the marginal tax rate on labor income boosts labor supply. Increased transfer payments to people raise consumer spending through an increase in disposable income but may reduce the supply of labor.

Private consumption, private investment, exports, and imports each depend on a real rate of return. The resulting negative impact of an increased rate of return on GDP offsets the impacts of fiscal policy on aggregate demand over time. A policy that boosts demand by more than supply raises interest rates, which then pushes aggregate demand back down.

Aggregate Supply

Aggregate supply depends on the supply of workers, stocks of private and public capital, and total factor productivity (TFP), the productivity of labor and capital. The supply of workers depends in part on the after-tax wage but is determined mainly by demographics. The stock of private capital depends on private investment, whereas the stock of public capital depends on investment by federal, state, and local governments. In particular, the stock of public infrastructure depends on government investment in infrastructure. TFP is exogenous in CBOSS.

Fiscal policy has two sets of effects on aggregate supply. The first set are direct effects. Changes in tax rates on labor affect the after-tax wage and thus workers' willingness to supply labor. Changes in tax rates on capital affect investment in private capital and thus the capital stock. Those two effects can interact; increased labor supply raises the productivity of capital and so leads to increased investment. Changes in investment in public infrastructure affect the amount of infrastructure. Second, fiscal policy also can affect aggregate supply through crowding out. A policy that boosts aggregate demand by more than it boosts aggregate supply will cause interest rates to rise. That increase will reduce demand in the economy's interest-sensitive sectors: private consumption, private investment, and net exports. Lower investment leads to a smaller capital stock than otherwise and thus lower potential GDP.

Rebalancing of Demand and Supply

In response to a change in the difference between aggregate demand and aggregate supply, CBOSS calculates the change in r^* needed to offset that change. r^* is the time-varying target rate of interest in an otherwise-standard Taylor rule with inertia. (That target rate of interest could be interpreted as the natural rate of interest, although it has a higher frequency of movement than typical measures of the natural rate of interest.) Because the model starts from the CBO baseline, the difference between GDP and potential GDP—the GDP gap—always eventually returns to its baseline value.

Changes in the GDP gap from baseline are not closed immediately because of a lag between a change in r^* and the later change in interest rates and because of lags between a change in interest rates and the responses by aggregate demand's components. Without those lags, CBOSS would collapse to an equilibrium model, similar to the PGM. The lags allow for short-run Keynesian responses to fiscal stimulus, as in CBO's multipliers model.

CBOSS endogenously determines the timing of the liftoff of the federal funds rate from the effective lower bound (ELB) in response to fiscal policy. When the inflation rate is low enough or the unemployment rate high enough, the Federal Reserve's desired real interest rate can imply a negative nominal interest rate. In such cases, the Federal Reserve sets short-term rates at the ELB, close to zero. If the calibration is accurate, the equation for the policy rate in the model indicates when a fiscal stimulus has boosted the Federal Reserve's desired real interest rate by enough that the nominal rate rises above the ELB.

Crowding Out

The distribution of rebalancing among private consumption, private investment, and net exports is determined by parameters derived from the literature. Investment's share of that rebalancing determines crowding out, the decline in private investment caused by a change in fiscal policy. The total amount of rebalancing depends on a policy's effect on aggregate demand and aggregate supply, so crowding out per dollar of deficit depends on the policy mix. In the PGM, by contrast, crowding out per dollar of deficit is the same for all policies.

Aggregate Demand

Aggregate demand, or GDP, consists of consumer spending, private investment, government consumption and investment, and net exports. The nominal components add up to nominal GDP. However, the real components do not add up to real GDP because of the use of chain weights (Fisher indexes) in determining real quantities. In CBOSS, real quantities are defined as nominal quantities divided by the GDP price index. That assumption allows the components of real GDP to be summed, thus simplifying the model. Implicitly, that assumption means that CBOSS assumes that all prices move by the same proportion from baseline levels in response to a shock.

Consumer Spending

Real consumer spending depends on after-tax labor income, transfers, the value of government bonds, the present discounted value (PDV) of after-tax income from U.S.-owned capital, and a basic subsistence level of consumption. The equation for real consumer spending in quarter *t*, C_t, is

$$C_t = c^* \sum_{i=0}^{7} \theta_i Y_{t-i}^* + c^c \sum_{i=0}^{7} \theta_i (Y_{t-i} - Y_{t-i}^*) + c^b \sum_{i=0}^{9} \zeta_i B_{t-i} + c^q \sum_{i=0}^{9} \zeta_i W_{t-i} + c_t^s Q_t^* + C_t^{add},$$

where c^*, c^c, c^b, c^q, and c_t^s are marginal propensities to consume (MPCs); θ_i and ζ_i are parameters; Y_{t-i}^* is the noncyclical portion of after-tax labor income in quarter $t-i$; Y_{t-i} is after-tax labor income, meaning that $Y_{t-i} - Y_{t-i}^*$ is the cyclical portion of after-tax labor income; B_{t-i} is the value of government bonds; W_{t-i} is the PDV of after-tax income from U.S.-owned capital; Q_t^* is potential GDP; and C_t^{add} is an add factor, or error term.

Government transfers are included in the noncyclical portion of after-tax labor income because they have a larger MPC than does the cyclical portion of labor income. *W* is the PDV of the after-tax income of domestic private capital plus a value for the net international investment position (NIIP). A subsistence level of consumption ($c_t^s Q_t^*$) is included because the other elements of the equation sum to less than consumption; a nonzero add factor would cause C/Q to vary with potential. The appendix describes the variables in the equation, the values of the MPCs and parameters, and the sources of those values.

The MPC for the cyclical portion of after-tax labor income (c^c) is assumed to be smaller than the MPC for the rest of after-tax labor income (c^*). Households presumably view noncyclical income as more permanent than cyclical income and will thus spend more of it. Lagged values of both income and wealth are included in the consumption equation because of household spending's gradual response to changes in economic circumstances.

The rebalancing of consumption acts through a wealth effect captured by W. An increase in the private rate of return, which depends on r^*, reduces the PDV of capital income, a component of wealth, in turn reducing consumer spending. The net effect of all the influences of rates of return on consumer spending, including that of the incentive to save, is combined in the effect of the private rate of return on wealth. Those interest rates' influences on consumption are combined because the net effect of interest rates on consumer spending is calibrated separately through the share of consumer spending in rebalancing. Including separate terms for the effects of interest rates on both wealth and the desire to save would complicate the model without effectively changing interest rates' net impact on consumer spending.

The add factor allows for effects of policy on consumer spending that differ from what the hard-coded coefficients imply. For example, a temporary tax cut on labor income should affect consumption differently than a permanent tax cut, but labor income has a single tax rate. The add factor allows the two policies to have different effects on consumer spending.[4]

An alternative to changing the add factor would be to change the MPCs. However, those MPCs also govern second-round effects of a change in policy, such as increased consumer spending by workers who receive more income from producing goods and services purchased as the result of a tax cut. Nothing indicates that the MPCs for those second-round effects would vary by policy.

Private Investment

Private investment is modeled as the product of the number of workers needing new capital (new worker-units of capital) and the capital per worker embodied in that capital (investment per worker-unit of capital). That modeling strategy results from an assumption of ex post fixed proportions between capital and labor. Businesses don't go back and adjust existing capital to be used by a different number of workers from that originally intended. In practice, that means

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[4] For an example of MPCs that differ by policy, see John Seliski, Aaron Betz, Yiqun Gloria Chen, U. Devrim Demirel, Junghoon Lee, and Jaeger Nelson, *Key Methods That CBO Used to Estimate the Effects of Pandemic-Related Legislation on Output*, Working Paper 2020-07 (Congressional Budget Office, October 2020), www.cbo.gov/publication/56612.

investment is more responsive in the short run to a change in demand (the investment accelerator) than to an identical percentage change in the cost of capital.

The equation for real private investment in quarter *t*, I_t, is

$$I_t = U_t \varphi_t + I_t^{add},$$

where U_t is the number of new worker-units of capital in quarter *t* at an annual rate, φ_t is investment per worker-unit of capital, and I_t^{add} is an add factor.

New Worker-Units of Capital. The number of workers needing new capital are workers whose capital has depreciated plus net new workers, or

$$U_t = \delta \cdot \left[\sum_{i=0}^{28} \xi_i^x L_{t-1-i}^x + \sum_{i=0}^{30} \xi_i^* L_{t-1-i}^*\right] + 4 \cdot \left[\sum_{i=0}^{28} \xi_i^x \, \Delta(L_{t-i}^x) + \sum_{i=0}^{30} \xi_i^* \, \Delta(L_{t-i}^*)\right],$$

where δ is the annual depreciation rate; ξ_i^x and ξ_i^* are parameters, with $\sum_{i=0}^{28} \xi_i^x + \sum_{i=0}^{30} \xi_i^* = 1$; L_j^* is noncyclical household employment in quarter *j*; L_j^x is $Q_j \, L_j^*/Q_j^*$, a measure of demand for workers (*Q* is real GDP); and $\Delta\left(L_j^x\right)$ and $\Delta\left(L_j^*\right)$ denote the quarterly changes in L_j^x and L_j^*, respectively.

L_j^x represents the aggregate demand faced by investing firms, scaled by the number of workers needed to meet a dollar of demand. Investment also depends on noncyclical demand. Firms expect actual demand to eventually return to potential demand, so potential demand influences their expectations for how much capacity they need to add now to meet future demand. Investment responds differently to cyclical and noncyclical shifts in demand.

Investment per Worker-Unit of Capital. The specification for investment per worker-unit of capital added in quarter *t*, φ_t, is discussed in the appendix. Investment per worker-unit of capital depends positively on noncyclical productivity of new capital, Q_t^*/L_t^*, and on capital's coefficient in the production function, α (capital's importance in production). Investment per worker-unit of capital depends negatively on the marginal effective tax rate on capital; on the depreciation rate, δ; and on the private rate of return, the combined cost of debt and equity faced by firms and that is influenced by *r**.

In CBOSS, the crowding out of investment works through investment per worker-unit of capital. Fiscal stimulus increases aggregate demand relative to aggregate supply, pushing up interest rates. Those higher interest rates boost the hurdle rate of return required to make more investment per worker profitable, leading to less investment per worker. Essentially, the higher the cost of capital, the less new capital per worker a business purchases.

Government Consumption and Investment

CBOSS treats most consumption and investment by the federal government as exogenous, determined by current law. The only endogenous portion is consumption of fixed federal government capital, a measure of the services provided by government capital, which depends on past investment by the federal government. CBOSS also includes an option to make consumption and investment by the federal government vary endogenously with potential GDP. That option allows spending to deviate from current law with economic circumstances.

Consumption and investment by state and local government is modeled as depending on current and past values of GDP and potential GDP. Higher GDP implies higher state and local tax revenues, allowing state and local governments to boost spending. The equation for real consumption and investment by state and local governments in quarter *t*, G_t^{SL}, is

$$G_t^{SL} = g_t^{SL}\left[\theta_{SL}\sum_{i=0}^{14}\frac{Q_{t-i}}{15} + (1-\theta_{SL})\sum_{i=0}^{6}\frac{Q_{t-i}^*}{7}\right] + dep_t^{SL},$$

where g_t^{SL} is a scaling factor, θ_{SL} is a parameter equal to the estimated share of G_t^{SL} that depends on GDP, and dep_t^{SL} is consumption of fixed state and local government capital. Consumption of fixed state and local government capital depends on past investment by state and local governments.

Government consumption and investment is the only major GDP component in CBOSS that does not depend on rates of return. State and local governments might cut back on spending when higher interest rates boost the cost of debt, but the model does not include that possibility.

Net Exports

Imports and exports depend on GDP, potential GDP, and the real interest rate on 10-year U.S. Treasury notes, which is influenced by r^*.

Real Imports. The equation for real imports in quarter *t*, M_t, is

$$M_t = m_t\sum_{i=0}^{2}\frac{Q_{t-i}^*}{3}\left[1 + \sum_{i=0}^{2}\zeta_i^M\left(\frac{Q_{t-i}}{Q_{t-i}^*} - 1\right)\right]\frac{r_A^P}{r_A^P - \theta_{RM}\sum_{i=0}^{9}[\zeta_i^{RNX}(r10_{t-i}^a - \overline{r10}_{t-i}^a)]},$$

where m_t is a scaling factor, ζ_i^M are parameters governing how procyclical are imports, r_A^P is the average private rate of return over a historical sample, θ_{RM} is a parameter governing imports' share of rebalancing, $r10_{t-i}^a$ is the adjusted real interest rate on 10-year U.S. Treasury notes, $\overline{r10}_{t-i}^a$ is the baseline level of $r10_{t-i}^a$, and ζ_i^{RNX} parameters govern the timing of interest rates' effect on net exports. Changes in imports resulting from changes in interest rates are modeled as changes from baseline.

The sum of the ζ_i^M parameters is greater than 1, implying that a 1 percent increase in aggregate demand (GDP) relative to baseline pushes imports up by more than 1 percent. One reason is that imports tend to be concentrated in more cyclical parts of the economy, such as goods. A second reason for the procyclicality of imports is that as increased demand causes some businesses to run up against capacity constraints, some customers turn to foreign alternatives.

Higher U.S. interest rates increase imports because they boost the value of the dollar in relation to foreign currencies, making foreign goods and services cheaper in dollar terms. That response occurs over several quarters mainly because real imports react gradually to changes in the relative price of imports.

Real Exports. The equation for real exports in quarter *t*, X_t, is similar to that for imports:

$$X_t = x_t \sum_{i=0}^{2} \frac{Q^*_{t-i}}{3}\left[1 + \sum_{i=0}^{2} \zeta_i^X \left(\frac{Q_{t-i}}{Q^*_{t-i}} - 1\right)\right] \frac{r_A^P}{r_A^P + \theta_{RX} \sum_{i=0}^{9} [\zeta_i^{RNX} (r10^a_{t-i} - \overline{r10}^a_{t-i})]}.$$

Variables and parameters are analogous to those in the equation for imports.

Like imports, exports rise with aggregate demand, though the effect is not direct. Rather, a stronger U.S. economy leads to increased U.S. imports, boosting foreign GDP. That higher foreign GDP then leads to increased imports of goods and services from the United States—that is, higher U.S. exports. Some U.S. exports also are used as inputs to goods that are then reimported into the United States, so increased demand for U.S. imports boosts some U.S. exports.

Imports are more procyclical than exports, so an increase in U.S. GDP relative to potential causes net exports to decline. In mathematical terms, the sum of the ζ_i^M parameters is greater than the sum of the ζ_i^X parameters, and m_t is greater than x_t.

Interest rates have a larger effect on exports than on imports; that is, $\theta_{RX} > \theta_{RM}$. The reason is that prices in dollars tend to be stickier than prices set in foreign currencies. When the dollar rises in response to higher interest rates, neither prices of imported goods nor prices of U.S. exports in dollar terms move by much. So, the relative prices of U.S. imports and domestically produced items change by less than the relative foreign-currency prices of U.S. exports and foreign-produced items.

Aggregate Supply

Aggregate supply, or real potential GDP (Q^*), is modeled as the sum of a Cobb–Douglas function of economywide potential TFP (A), the stock of private capital (K), noncyclical household employment (L^*), the stock of public infrastructure (KI), and depreciation of the stock of government capital ($depG$):

$$Q_t^* = A_t {K_t}^{\alpha} {L_t^*}^{1-\alpha} {KI_t}^{\gamma} + depG_t.$$

Potential TFP is exogenous in CBOSS. The coefficients on private capital and labor sum to 1. If the coefficient on public infrastructure is included, the sum of coefficients is greater than 1. In the model, the portion of the equation excluding *depG* is expressed in first differences so that a change in α does not change the level of potential GDP.

Capital Stocks

Each capital stock grows according to a perpetual inventory equation: The current quarter's stock is the undepreciated stock from the prior quarter plus new investment. The stock of private capital depends on private investment. The stock of government capital depends on investment by federal, state, and local governments. That stock's direct contribution to GDP is the Bureau of Economic Analysis's estimate of the consumption of fixed government capital.

The stock of public infrastructure, part of the total stock of government capital, depends on investment by federal, state, and local governments in public infrastructure. Public infrastructure is assumed to be 80 percent as productive as private capital as measured by the marginal product of capital.[5] The stock of public infrastructure and its coefficient measure the contribution to output of public infrastructure not already captured through the stock of government capital and its coefficient. That is, the total effect of public infrastructure capital through both *KG* and *KI* adds 80 percent as much as an equivalent amount of private capital through *K* alone.

Labor Supply

CBOSS models noncyclical household employment (labor supply) as the combination of two types of changes from its baseline level. First, labor supply can differ from its baseline level because of an exogenous component that depends on demographics. Immigration is an important source of exogenous variation in labor supply. An increase in working-age immigrants would boost labor supply. Second, labor supply can differ from its baseline level owing to changes in decisions by workers on whether to supply labor. Those decisions are modeled as depending on the ratio of after-tax compensation to noncyclical consumption. Noncyclical consumption depends not only on after-tax compensation but also on transfers and wealth. A reduction in the marginal tax rate on labor income boosts labor supply through a substitution effect because working boosts after-tax compensation by more than it boosts consumption. By contrast, an increase in the factors supporting consumption reduces labor supply through an income effect. For example, higher transfer income may discourage some work. Higher wealth may induce some older workers to retire.

[5] See Congressional Budget Office, *Effects of Physical Infrastructure Spending on the Economy and the Budget Under Two Illustrative Scenarios* (August 2021), www.cbo.gov/publication/57327.

Household employment (L) is determined by labor supply and the GDP gap through Okun's law. According to Okun's law, the ratio of employment to noncyclical employment depends on the ratios of GDP to potential GDP in the current quarter and the previous five quarters.

Inflation

The annualized rate of price inflation, π, is determined by an expectations-augmented Phillips curve with an anchor to the rate of inflation targeted by the Federal Reserve, π^*:

$$\pi_t = \sum_{i=1}^{12} \rho_i \, \pi_{t-i} + \left(1 - \sum_{i=1}^{12} \rho_i\right)\pi^* + \theta^{Q\pi} 100 \left(\frac{Q_t}{Q_t^*} - 1\right)$$
$$+ Ds_t \theta^{s\pi} \left[s_t \left(\frac{Q_t}{Q_t^*} - 0.9\right) - \bar{s}_t \left(\frac{\bar{Q}_t}{\bar{Q}_t^*} - 0.9\right)\right] + \pi_t^{add},$$

where ρ_i, $\theta^{Q\pi}$, and $\theta^{s\pi}$ are coefficients and π^{add} is an add factor. Also, if the dummy variable *Ds* is set to 1, inflation is influenced by a measure of supply constraints, *s*. The default value of *Ds* is zero.

GDP's exceeding potential GDP exerts upward pressure on inflation, but inflation tends to return toward the Federal Reserve's target over time because that target influences expectations. If *Ds* is set to 1, the presence of supply constraints ($s > 0$) augments the normal effect of an increase in GDP on inflation, increasing the slope of the Phillips curve.

Interest Rates, Rebalancing, and Crowding Out

CBOSS uses interest rates to rebalance supply and demand in the long run. In the first year or two of a change in policy, GDP's response to a change in policy is determined mainly by a policy's effect on demand. Beyond that period, changes in interest rates lead to a rebalancing of demand and supply, pushing the GDP gap back toward its baseline level. The Federal Reserve's target real interest rate, r^*, is endogenous in CBOSS. Changes in r^* restore the baseline balance between demand and supply in the economy.

Changes in private investment form part of the rebalancing of demand and supply, a response known as crowding out. If fiscal policy stimulates demand by more than supply, an increase in interest rates is required to rebalance demand with supply. Those higher interest rates cause private investment to fall, resulting in lower potential GDP in the long run.

Interest Rates

The short-term rates in CBOSS are the federal funds rate and the yield on 3-month Treasury bills. The nominal federal funds rate is determined by a standard Taylor rule, subject to the ELB on nominal interest rates. In that rule, the federal funds rate depends positively on inflation, the ratio of GDP to potential GDP, and r^*. The response of the federal funds rate to those drivers is assumed to be gradual. The yield on 3-month Treasury bills runs off the federal funds rate. An increase in the ratio of federal debt to GDP boosts Treasury rates relative to private rates. The baseline value of *r** is the real federal funds rate that would equate GDP and potential GDP if potential GDP and its lags replaced GDP and its lags in the demand equations, and all interest rates moved with the federal funds rate—that is, if term premia and risk premia remained at baseline levels.

The long-term rates in CBOSS are the yield on 10-year Treasury notes and the combined rate of return on private debt and equity. The change in the real 10-year Treasury rate from baseline is modeled as a weighted average of the change in the real Treasury bill rate from baseline and the change in *r** from baseline, plus an exogenous shift factor for the term premium. Nominal long rates depend on expected inflation, modeled as a function of current inflation. The combined private rate equals the 10-year Treasury rate plus a risk premium less the boost in Treasury rates relative to private rates from more federal debt.

Rebalancing

Changes in endogenous *r** are needed because a Taylor rule alone will not fully restore the GDP gap to baseline for a permanent change in fiscal policy. To see why, suppose the increased GDP and inflation that resulted from fiscal stimulus boosted interest rates by enough to return the GDP gap to baseline. That is, higher interest rates would reduce consumption, investment, and net exports until they offset the increase in government spending. Then the Taylor rule would also return interest rates to baseline, and GDP would again increase relative to potential. With *r** exogenous, permanent fiscal stimulus results in a permanent rise in GDP relative to potential and permanently higher inflation.

The method of calculating the change in *r** from baseline consists of two steps. First, potential values of each component of GDP are created, in which all occurrences of GDP in the equations are replaced by potential GDP, all occurrences of employment are replaced by noncyclical employment, and all interest rates are made contemporaneous functions of *r**. Second, a search is made for the *r** that restores that noncyclical concept to its level in the baseline in each quarter.

For example, an increase in federal government purchases boosts potential government consumption and investment. An increase in *r**, which reduces the potential values of private consumption, private investment, and net exports, is needed to bring the sum of the components of potential GDP back to its baseline level.

The relative shares of consumption, investment, and net exports needed for rebalancing are determined by updating the parameters CBO previously used to determine crowding out, as discussed further in the appendix. Part of that update reflects the economy’s changing composition. The papers surveyed to inform CBO’s previous estimates used data from a time when the shares of private investment and trade were different from what they are now. The relative importance of exports and imports has increased, whereas the importance of private investment relative to consumption plus international trade has fallen. Also, the parameter that determines the amount of crowding out per dollar of federal deficit is replaced by a parameter applied to the gap between GDP and potential GDP. The appendix further describes the shares of final demand needed for rebalancing.

Crowding Out

Crowding out of private investment occurs when fiscal stimulus causes interest rates to rise, raising the cost of new investment and thus leading firms to buy less new capital. In CBOSS, the magnitude of that rise in interest rates depends on the magnitude of the increase in the gap between GDP and potential GDP resulting from the fiscal stimulus. To restore that gap to its baseline level, interest rates rise above baseline levels. The size of the impact of higher interest rates on private investment depends on investment's share of rebalancing.

In CBOSS, crowding out depends on the increase in the gap between demand and supply rather than on the change in the deficit. Consequently, a policy that is more effective at boosting demand will result in more crowding out than a policy that is less effective at boosting demand even though both policies cause the same change in the deficit. The latter policy affects demand less because more policy dollars are saved, reducing the hit to investment. That result differs from that obtained with the PGM, in which crowding out depends solely on the change in the deficit.

Government Debt's Effect on Interest Rates

In CBOSS, a rise of 1 percentage point in the ratio of federal debt to GDP boosts interest rates on federal debt by 2.5 basis points (0.025 percentage points), in line with research by Gamber and Seliski.[6] That effect on interest rates is from the level of debt exclusive of the effect of deficits, whereas the effect on interest rates discussed in the previous section is from changes in the debt—that is, from changes in federal spending and taxes.

CBOSS's framework implies that debt must raise r^* to affect interest rates. Debt affects r^* through a wealth effect on consumer spending. (The debt-to-GDP ratio also affects the spreads between the federal funds rate and Treasury rates.) However, some Ricardian effect is apparent because the economywide MPC for federal debt is smaller than the MPC for other types of wealth. Evidently, some households expect that taxes will rise or that future transfers will be cut as a result of higher debt now.

Alternatively, one can think of debt's effect on interest rates through a savings lens. The investment-savings identity implies that private saving can be used in three ways: to fund private investment, buy foreign assets, or buy government debt. The first two uses boost both demand

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[6] See Edward Gamber and John Seliski, *The Effect of Government Debt on Interest Rates*, Working Paper 2019-01 (Congressional Budget Office, March 2019), www.cbo.gov/publication/55018.

and supply: They boost demand by giving households more wealth, and they boost supply either by increasing the domestic capital stock or by increasing net income from abroad (part of potential gross national product). However, government debt boosts demand, through a wealth effect, without boosting supply (except insofar as it funds infrastructure). The resulting increase in the demand–supply gap requires higher interest rates.

Whereas fiscal stimulus–induced crowding out of investment per dollar of deficit depends on the type of fiscal policy, crowding out of investment per dollar of deficit resulting from higher federal debt is independent of fiscal policy. That latter form of crowding out depends only on the level of debt, not on the policy that produced that debt. A permanent rise in federal spending would raise interest rates owing to both the direct effect of current spending and the effect of past spending on the level of debt.

Simulation Properties of CBOSS

Several scenarios, all relative to baseline, illustrate CBOSS's simulation properties:

- A "permanent" increase in federal government consumption and investment;
- A temporary increase in federal government consumption and investment;
- An increase in public infrastructure investment;
- A "permanent" reduction in the federal marginal tax rate on labor income; and
- Faster growth of labor supply, such as from increased immigration.

Higher Government Consumption and Investment

The model's properties are first examined using a deficit-financed increase in real federal government consumption and investment of $100 billion per year in 2012 dollars.[7] The increase begins in the third quarter of 2022 and is "permanent."[8] The baseline for all scenarios is CBO's May 2022 forecast for the U.S. economy.

Initially, real GDP rises by more than $100 billion, implying a short-run multiplier (the ratio of the total change in GDP to the direct effect of a policy on GDP) greater than 1 (see Figure 2). The multiplier is greater than 1 for two reasons. First, increased GDP generates more income for households, part of which they spend, boosting GDP's consumption component. Second,

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[7] In the model, each "real" variable equals its nominal quantity divided by the deflator for GDP rather than by its own deflator. Consequently, the hypothetical rise in spending directly produces a $100 billion increase in real GDP per year.

[8] A truly permanent deficit-financed stimulus with no offsetting rise in revenues would violate the transversality condition, in which the change in the PDV of all future revenues must equal the change in the PDV of all future outlays. In a model run solving over a finite horizon, "permanent" means "through the end of the scenario."

businesses invest in more capital to meet higher demand, boosting GDP's investment component, which includes inventory investment. Working in the opposite direction, net exports decline as imports satisfy some of the increase in aggregate demand. However, the increase in consumer spending and investment outweighs the decline in net exports in the short run. Higher private investment, as well as the portion of the increase in federal investment directed toward infrastructure, boosts potential GDP above baseline.

The increase in GDP relative to potential GDP causes price inflation to increase. To prevent a permanent rise in price inflation, the Federal Reserve boosts interest rates above their baseline levels to rebalance demand and supply. Those higher interest rates reduce consumer spending, private investment, and net exports, pushing GDP back toward baseline. The permanent reduction in private investment pushes potential GDP below baseline by an amount that grows over time. GDP falls below baseline by more than potential GDP from 2025 through 2031 to bring price inflation back down to baseline levels after its initial acceleration.

The Source of Short-Run Effects: Lags Between r^* and GDP. Fiscal policy affects GDP by more than potential GDP in the short run because of lags between a change in r^* and its effect on GDP. Put another way, the rebalancing of demand and supply in response to a change in demand occurs gradually. First, interest rates respond gradually to r^*; the Federal Reserve typically does not make large changes to its policy rate but instead adjusts it gradually. Second, the components of GDP respond gradually to changes in rates of return.

Eliminating the lags between a change in r^* and its effect on GDP in CBOSS eliminates the change in the GDP gap from baseline (see Figure 3).[9] In Figure 3, the lines for the changes in GDP and potential GDP from baseline with no lags between r^* and GDP are nearly identical. With the right calibration, that scenario would duplicate results from the PGM, in which GDP is constrained to move with potential GDP.

The results show the hysteresis from the effects of lags between r^* and GDP. Those lags allow potential GDP to rise above its baseline level for a few years, whereas without those lags potential GDP would begin to fall below baseline levels almost immediately. The decrease of potential GDP from baseline is permanently smaller when the model contains lags between r^* and GDP. That result highlights one advantage of CBOSS over the agency's two-model structure: the pass-through of short-run effects into the long run.

Effects of Assumptions About Monetary Policy. Monetary policy affects the speed of the rebalancing of demand and supply in response to a change in fiscal policy. Consequently,

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[9] In this scenario, only the lags between r^* and the federal funds rate, and between rates of return and consumer spending, investment, and net exports, have been eliminated. All other lags in the model, such as those between income and consumption, remain in place.

assumptions about monetary policy can have important effects on the estimated impact of a change in fiscal policy.

If the Federal Reserve were to hold real interest rates exogenous at baseline levels, no crowding out of investment and no reduction in consumption and net exports from higher interest rates would occur. Real GDP would remain well above baseline throughout the simulation interval. However, inflation also would remain above baseline rates.

Under circumstances of low inflation and high unemployment, such as in 2020, the ELB constrains the Federal Reserve from setting the federal funds rate at the negative value implied by a Taylor rule. In such cases, interest rates would not rise above baseline in response to a change in fiscal policy until the Federal Reserve's desired interest rate rose above the ELB. In that scenario, GDP would rise more in the short run than with a Taylor rule. The timing of an increase in the federal funds rate above the ELB is endogenous in CBOSS. From a baseline of CBO's July 2021 forecast, a $100 billion annual increase in federal consumption and investment would hasten the timing of liftoff from the ELB by more than a quarter.

When constrained by the ELB, the Federal Reserve can employ quantitative easing, in which Treasury securities or the securities of government agencies are purchased, even though those purchases do not affect the federal funds rate. Such purchases reduce the gap between short- and long-term rates. In CBOSS, that reduction would be implemented by a reduction in the term premium.

Components of GDP. Though all subject to the forces of rebalancing, GDP's nongovernment components behave differently, especially in the short run (see Figure 4). Consumer spending in the short run rises as households' income increases but then falls below baseline as a result of both rebalancing and the downward trend in overall GDP. Because consumer spending is much larger than the other GDP components, the long-run downward trend of GDP subtracts more in absolute terms from consumer spending than from the other GDP components even though the percentage decline is smaller. The decline in consumer spending would be even larger but for the positive wealth effect from increased government debt. That positive wealth effect is partly offset by reduced net foreign assets as higher trade deficits hurt the United States' NIIP.

Private investment rises well above baseline levels in the first two years of the policy experiment as an inventory cycle augments accelerator effects on fixed investment. As GDP falls back to baseline, those effects go into reverse, pulling GDP well below baseline levels over the next few years of the simulation. In the longer run, private investment is below baseline because of both rebalancing and GDP's overall downward trend.

Unlike consumer spending and private investment, net exports fall below baseline in the short run because the rise in GDP draws in more imports. In the long run, as a result of rebalancing, net exports follow a downward trend; higher interest rates push the dollar up relative to foreign currencies, making U.S. goods and services less competitive. Because net exports are negative, the downward trends in GDP and potential GDP are a net positive, reducing imports by more than exports.

Interest Rates and Inflation. A permanent increase in federal consumption and investment above baseline levels would temporarily raise inflation above baseline levels but would permanently raise interest rates above baseline levels (see Figure 5). Price inflation would rise above baseline because of the increase in GDP relative to potential GDP. The stronger economy would put upward pressure on both wages and prices. After a few years, tighter monetary policy would push the ratio of GDP to potential GDP below baseline, causing inflation to recede back to baseline rates.

Interest rates would rise above baseline both to prevent a permanent rise in inflation (reflecting a permanent rise in r^*) and to bring inflation back to baseline (reflecting a temporary rise in r exceeding that in r^*). In the longer run, the increase in interest rates above baseline would trend slightly upward because of the gradual increase in the debt-to-GDP ratio relative to baseline as deficits accumulate. That increase would be even larger if not for the adverse effect of reduced net exports on the United States' NIIP. A lower NIIP equates to a reduction in the wealth of U.S. households. The resulting downward pressure on consumption would put downward pressure on interest rates.

If not for the net effect of increased federal debt and lower NIIP, the difference in the federal funds rate from baseline would narrow over time, as shown in Figure 5. That is because the ratio of the increase in federal government consumption and investment to GDP declines as GDP rises.

As reduced investment pushes the ratio of potential GDP to the private capital stock below baseline levels, the marginal product of capital (MPK) would rise above baseline levels, as shown in Figure 5. The MPK, equal to the ratio of capital income to the capital stock, is used to determine the change in interest rates from baseline in the PGM. The private rate of return in CBOSS moves similarly over time to the federal funds rate and thus rises by more from baseline than the MPK. The qualitative difference between the two measures is that the MPK divides capital income by the replacement cost of capital, whereas the private rate of return divides capital income by the market value of capital. In the short run, fiscal stimulus does nothing to the replacement cost of capital but reduces the market value of that capital.

That result highlights a major difference between CBOSS and the PGM. In CBOSS, fiscal stimulus boosts interest rates, leading to reduced investment, in turn leading to a lower capital stock. In the PGM, fiscal stimulus directly reduces investment through some channel that does not include higher interest rates, leading to a lower capital stock, which then gradually pushes interest rates higher.

Temporarily Higher Government Consumption and Investment
Examining the effects of a temporary fiscal stimulus highlights CBOSS's short-run dynamics. For that scenario, the $100 billion annual increase in real federal government consumption and investment lasts just one year, from the third quarter of 2022 through the second quarter of 2023.

Fully Endogenous *r*.* Under the assumption of a Taylor rule with *r** fully endogenous, the economy responds nearly identically through mid-2023 to the temporary policy as to the permanent policy (see Figure 6).[10] That is because the model has no explicit forward-looking behavior; households and businesses have the same expectations about the future as in the historical data used to calibrate the model.

In mid-2023, as the policy is removed, GDP plunges below baseline. That is because the lagged effects of the tighter monetary policy implemented from mid-2022 to mid-2023 to prevent the fiscal stimulus from causing a permanent rise in inflation remain, whereas the positive effects of the fiscal stimulus disappear. Once GDP falls below baseline, the Federal Reserve reduces interest rates, and the gap between GDP and potential GDP returns to its baseline level. However, both GDP and potential GDP are permanently lower because the additional federal debt built up during the period of fiscal stimulus causes interest rates to be permanently higher than in the baseline.

The cumulative difference in the GDP gap from baseline from 2022 to 2040 is roughly zero. That result is not a coincidence; indeed, it is necessary for the model to have good long-run properties. One can think of a permanent change in government spending as a continuous series of temporary changes. For the GDP gap to average to zero for a permanent change, it must average to zero for each temporary change. However, most macroeconometric models show that the cumulative GDP gap from a temporary increase in spending is positive, which is indeed the result in CBOSS when *r** is not endogenous.

Incomplete Endogeneity of *r*.* For a policy known to be temporary, inflation's behavior in the model may justify forward-looking behavior by the Federal Reserve when setting interest rates. With *r** fully endogenous, inflation would fall below baseline in 2024 and remain below baseline for several years (see Figure 7). If instead *r** is only partially endogenous in the quarters preceding the anticipated reversion of government spending to baseline levels, inflation would not overshoot its baseline level. Figure 7 shows the effect of higher federal spending on inflation if the endogeneity of *r** is reduced by increasing amounts as the end of stimulus approaches.

With *r** fully endogenous, it would rise above baseline by roughly the same amount during each quarter that the fiscal stimulus is in place and then would drop back roughly to baseline (see Figure 8). In response, the federal funds rate would gradually rise over those four quarters before

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[10] A slight difference is caused by a dummy variable for the response of *r** to a permanent policy.

gradually retreating. With a forward-looking Federal Reserve, the rise of r^* above baseline would decline as the policy's expiration approached. The federal funds rate would rise by less than with a fully endogenous r^*, especially in the quarters immediately before stimulus was expected to end.

Reducing the endogeneity of r^* would boost the cumulative change in the GDP gap from baseline during the 2022–2040 period from roughly zero to $18.6 billion, or almost 19 percent of the fiscal stimulus. Because of the lags between changes in r^* and changes in GDP, most of the increase in GDP relative to a simulation with fully endogenous r^* would not occur when GDP is already above baseline but rather when GDP is below baseline (see Figure 9).

Higher Federal Spending on Infrastructure

An increase in federal spending on infrastructure would have different effects from those caused by a broader increase in federal spending because better infrastructure benefits private-sector productivity, whereas broader spending does not. The policy experiment is an increase in nominal federal grants-in-aid for infrastructure spending of $50 billion per year from 2022 to 2031, funded by larger deficits. That policy is modeled on scenario 2 in a CBO report.[11]

As with a permanent increase in federal consumption and investment, both real and potential GDP initially rise above baseline (see Figure 10). However, real GDP remains above baseline levels for much longer and averages above baseline levels. The reason for that is infrastructure investment's positive impact on potential GDP. An increased stock of public infrastructure adds to potential GDP both directly, because the Bureau of Economic Analysis includes depreciation of government capital in government consumption, and indirectly, through the impact of increased infrastructure on private-sector productivity. Those positive impacts are partially offset by the impact of crowding out on private investment.

The GDP gap remains above baseline levels longer for an increase in infrastructure spending than for a rise in general government consumption and investment because the increase in infrastructure spending is assumed to be gradual. In CBOSS, the Federal Reserve responds to current conditions. Thus, the initial increase in interest rates will be smaller for a policy that builds gradually, even if the expected change in spending a few years out is identical, because the initial increase in activity is smaller. GDP falls below potential in the 2030s as the Federal Reserve unwinds higher inflation and then rises above potential in the 2040s after the central bank overshoots. Compared with the CBO study's findings, the effects on potential GDP are qualitatively similar, but GDP fluctuates more.

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[11] Congressional Budget Office, *Effects of Physical Infrastructure Spending on the Economy and the Budget Under Two Illustrative Scenarios* (August 2021), www.cbo.gov/publication/57327.

Lower Marginal Tax Rates on Labor Income

To facilitate comparisons with an increase in federal consumption and investment, federal marginal tax rates on labor income were reduced beginning in the third quarter of 2022 by an amount that, on a static basis (that is, before economic feedback), reduces real federal revenues by $100 billion per year (in 2012 dollars). As with an increase in spending, that reduction in taxes is financed with larger deficits.

The spending and revenue scenarios yield differences. One is that multiplier effects are smaller for a reduction in tax rates than for an increase in spending. The reason is that a portion of the tax cut is saved, whereas the entire spending increase adds to demand. In the early years of the scenarios, that means a smaller rise in the GDP gap for a tax cut (see Figure 11). In the later years of the scenario, however, the smaller positive effect on aggregate demand of the tax cut causes less crowding out of investment than the larger positive effect on demand of increased spending. That result leads to less-adverse long-run effects on potential GDP and GDP. Another difference between the spending and revenue scenarios is that a reduction in marginal tax rates boosts labor supply, which has a larger and more immediate positive supply-side effect than the increase in services provided by government capital stemming from higher federal investment. That leads to a larger positive response of potential GDP in the short run and contributes to the smaller decline in the long run.

Faster Growth of the Labor Force

CBOSS also can be used to analyze the effects of faster growth of the labor force—for example, due to increased immigration. In that scenario, the growth rate of the exogenous component of noncyclical employment was boosted by 0.1 percentage point per year beginning in the first quarter of 2022. Real grants-in-aid and federal consumption and investment were left at baseline values. Depending on the scenario’s details, that assumption might require adjustment.

Faster growth of the labor force would trigger faster growth of potential GDP (see Figure 12). However, the private capital stock’s gradual response to stronger employment and GDP would cause potential GDP to lag behind the labor force. Businesses respond to faster growth of employment and expected employment by increasing investment. However, the higher rate of investment takes time to translate into an increase in the capital stock that is proportionate to the increase in the labor force. The average lag is almost three years. Nonetheless, the capital stock responds to increased employment much faster than in the PGM.

GDP Gap. From 2023 through 2027, the increase in GDP above baseline is larger than the increase in potential GDP above baseline because of the investment accelerator. As employment expands, businesses try to supply capital for their new employees to use. In CBOSS, businesses also respond to growth of noncyclical employment, assuming that actual employment will gradually converge to noncyclical employment. That demand for more capital causes investment to increase proportionately more than potential GDP, causing GDP to rise by more than potential.

Interest Rates. Interest rates rise above baseline levels beginning in late 2022 as the accelerator effects on investment begin to cause GDP to outpace potential. Because interest rates respond slowly to economic conditions, they continue to rise until 2028, when the GDP gap returns to its baseline level. After that, interest rates move back toward baseline levels, eventually falling below baseline levels. The reason is that a higher level of GDP coupled with a similar level of federal debt means a lower debt-to-GDP ratio. That lower ratio puts downward pressure on interest rates that offsets the upward pressure from increased investment to support faster accumulation of capital.

Effects of Temporary Fiscal Stimulus When Supply Constraints Affect Inflation

The simulation properties of CBOSS in 2022 and 2023 change considerably if one activates the effect of supply constraints on inflation. The initial increase in inflation from a temporary increase in federal consumption and investment is nearly three times as large when GDP is assumed to interact with supply constraints in causing inflation (see Figure 13).

Also, inflation recedes back to baseline much more slowly when supply constraints affect inflation. Because supply constraints are assumed to ease over time, the Phillips curve is steeper when inflation is being added to the economy than when being removed. The Federal Reserve must then work harder to get rid of the additional inflation, so removing it takes longer.

The additional restraint imposed by higher interest rates is reflected in a larger fall below baseline for GDP (see Figure 14). The GDP gap, instead of recovering to baseline by early 2026, remains below baseline for more than 15 years. The continued restraint is necessary to bring inflation down. Unlike the standard case, in which the cumulative GDP gap through 2040 is $18.6 billion, the cumulative gap over that period is now −$101.8 billion. The net decline in the GDP gap more than reverses the initial $100 billion of stimulus.

In the simulation, supply constraints affect GDP only indirectly, through their effect on interest rates because of higher inflation. However, supply constraints could also affect GDP directly, if certain items become unavailable and consumers or businesses do not fully replace purchases of those items with other purchases. For example, the shortage of semiconductor chips for new vehicles could lead a household to postpone buying a new vehicle rather than increase spending on other goods and services by the amount not spent on the vehicle. One way to implement that behavior in CBOSS would be to create an alternative concept of potential GDP that depends on supply constraints. Doing so would mute the positive short-run impact of fiscal stimulus even more than shown here.

Appendix

The Congressional Budget Office's small-scale policy model (CBOSS) employs several other equations besides those presented in the main text. Those equations, their underlying data, and the calibration of parameters are explored in more depth here.

Potential Gross Domestic Product

Production Function

In CBOSS, real potential gross domestic product (real potential GDP; represented as Q^*) is modeled as the sum of depreciation of the stock of government capital (*depG*) and everything else (Qxd^*). Depreciation of government capital is included in the national income and product accounts (NIPAs) as part of government consumption. That depreciation is separated out from the rest of potential GDP because it does not affect private-sector output apart from the impact of public infrastructure, which is included in Qxd^*.

Growth of real potential GDP excluding depreciation of government capital is modeled as a function of growth of economywide potential total factor productivity (A), the stock of private capital (K), noncyclical household employment (L^*), and the stock of public infrastructure (KI):

$$dlog(Qxd_t^*) = dlog(A_t) + \alpha_t \cdot dlog(K_t) + (1 - \alpha_t) \cdot dlog(L_t^*) + \gamma_t \cdot dlog(KI_t).$$

The equation is expressed in first differences so that variations in α over time do not affect the level of potential GDP, which they would if K did not equal L^*.

Capital Stocks

Capital stocks are calculated using the perpetual inventory method. For private capital:

$$K_t = I_t/4 + [1 - (\delta - \delta_A)]^{1/4} K_{t-1},$$

where δ is the average annual depreciation rate of private capital and δ_A is an adjustment to that depreciation rate. Investment and depreciation are divided by 4 to convert annualized data to a quarterly frequency. Stocks of government capital and public infrastructure use similar formulas.

The Labor Input to Production

Noncyclical household employment (L^*) is the product of an endogenous component, measuring the effect of after-tax compensation on labor force participation, and an exogenous component, L^E, capturing everything else. In the baseline, L^E equals L^*. Changes in immigration or labor force participation would be modeled as changes in L^E.

The endogenous portion of L^* depends on the ratio of after-tax compensation per employed worker, $w(1 - \tau^L)$—where w is compensation per worker and τ^L is the marginal tax rate on labor income (discussed below)—to noncyclical consumption per worker (*cp*). By itself, a higher after-tax wage boosts labor participation. But if a higher wage is matched by an equal increase in noncyclical consumption, the incentive for more participation disappears.

The noncyclical consumption used in *cp* excludes the cyclical portion of consumption and half the portion of consumption financed from wealth. Part of wealth is excluded because it is less relevant for the typical supplier of labor than is labor income, either because wealth is held by retirees or because it tends to be more concentrated than labor income.

The equation for L^* in quarter t, L_t^*, is

$$L_t^* = L_t^E \left(\frac{mv\left[\frac{w_t(1-\tau_t^L)}{cp_t}, 4\right]}{mv\left[\frac{\overline{w}_t(1-\overline{\tau}_t^L)}{\overline{cp}_t}, 4\right]} \right)^{\beta_L},$$

where $mv[x,4]$ denotes a 4-quarter moving average of x, a bar over a variable denotes its baseline value, and β_L denotes the substitution elasticity of labor supply.

Data and Calibration

Baseline potential GDP is taken from CBO's latest forecast. The value of α is determined by calibrating the equation for compensation per employee (see below). The value of γ is set so that the total effect of an extra dollar of infrastructure capital on potential GDP is 80 percent as large as the effect of an extra dollar of private capital. Potential total factor productivity (A) is backed out by inverting the equation for Qxd^*.

For the last year for which fixed assets are available from the Bureau of Economic Analysis, the private capital stock for the final quarter of that year is set equal to that year's stock of fixed private capital plus inventories. Government capital stocks for the final quarter of that year equal the bureau's estimates. In later quarters, capital stocks are cumulated using perpetual inventory equations. The value of δ is set to 0.054, the weighted average of the value for private fixed capital over the 2009–2018 period, and a value of zero for inventories. Δ_A is set to 0.002 so that the equation holds over history. B_L is set to the implied substitution elasticity of labor supply from a CBO tax model.

Domestic Incomes

Gross domestic income is assumed to be the sum of labor income; capital income derived from the measured capital stock; capital income derived from sources other than the measured capital stock, such as market power and unmeasured intangible capital; and taxes on production and imports (other than property taxes, which are included in capital income), less the statistical discrepancy. Taxes on production and imports are levied at rate t^Y on GDP excluding government depreciation and thus equal $t^Y Qxd$. Capital income from sources other than measured capital accounts for $1/e$ of income, where $-e$ can be thought of as the price elasticity of demand.

Labor Income

Labor income is labor compensation plus a share of proprietors' income, as in CBO's macroeconomic forecasting model (CMAC). Labor income per worker, *w*, is labor income divided by household employment, *L*. (CBOSS uses household employment [the number of people working] rather than establishment employment [the number of jobs] because CBO produces a noncyclical estimate of household employment.)

Labor income per worker is given by

$$w_t = (1 - t_t^Y)\left(1 - \frac{1}{e_t}\right)(1 - \alpha_t)\frac{Qxd_t^*}{L_t^*}.$$

The equation implicitly assumes that:

- Taxes on production and imports fall proportionately on labor and capital at rate t_t^Y;
- An increased level of capital income from sources other than measured capital (from $1/e$) reduces both labor income and capital income from measured capital;
- Labor income varies with 1 minus capital's coefficient in production (α); and
- Compensation per worker responds to noncyclical GDP per worker rather than GDP per worker.

Household employment, *L*, is determined from GDP by using a variant of Okun's law:

$$L_t = l_t L_t^* \sum_{i=0}^{5} \theta_{t-i}^{Y,E} \frac{Q_t}{Q_t^*},$$

where *l* is a time-varying parameter close to 1 and $\theta^{Y,E}$ are estimated coefficients summing to 1. This version of Okun's law combines the responses of the unemployment rate and labor participation to the ratio of GDP to potential GDP.

Net Capital Income

Capital income is GDP less labor income less the statistical discrepancy (assumed exogenous in real terms) less taxes on production and imports other than property taxes. Net capital income (Y^K), the basis for capital taxes, is capital income less economic depreciation (equal to the lagged private capital stock times its depreciation rate plus depreciation of government capital).

Data and Calibration

Income data are taken from the NIPAs. T^Y is equal to taxes on production and imports, excluding property taxes, divided by *Qxd*. The value of $1/e$ is zero for general government and for other sectors equals its estimated value in CMAC for sectors using private nonresidential capital. Values for α are found by inverting the equation for *w*. The $\theta^{Y,E}$ coefficients combine estimates from CMAC of the effects of the GDP gap on both labor force participation and the unemployment rate. The parameter *l* is set so that the Okun's law equation holds exactly.

Government Sector

Federal Taxes

Three components of real federal taxes are endogenous in CBOSS: taxes on production and imports other than property taxes, taxes on labor income, and taxes on net capital income (including property taxes). Miscellaneous other receipts are assumed exogenous in real terms. Those receipts include returns on assets, current transfer receipts, the current surplus of government enterprises, and receipts from the rest of the world.

Federal taxes excluding miscellaneous other receipts, T^F, are given by

$$T_t^F = t_t^{Y,F} Qxd_t + \tau_t^{L,F} \bar{\Upsilon}_t^{L,F} \bar{w}_t L_t + \tau_t^{L,F} (w_t - \bar{w}_t) L_t + \tau_t^{K,F} Y_t^K + T_t^{F,add},$$

where $t^{Y,F}$ is federal taxes on production and imports as a share of *Qxd* (an average tax rate); $\tau^{L,F}$ and $\tau^{K,F}$ are marginal federal tax rates on labor income and net capital income, respectively; $\Upsilon^{L,F}$ is the baseline ratio of average to marginal federal tax rates on labor; and $T^{F,add}$ is an add factor. As above, a bar above a variable denotes its sample average. The expression $\tau^{L,F}\,\Upsilon^{L,F}$ is also $t^{L,F}$, the average federal tax rate on labor income. In that formulation, an increase in labor income coming from increased employment (L) is taxed at the average rate, whereas an increase in labor income from an increase in compensation per employee (w) is taxed at the marginal rate. The add factor, which is zero in the baseline, can be used if the static estimate of a change in revenues from a policy differs from the change in revenues indicated by the equation.

State and Local Taxes

State and local taxes excluding miscellaneous other receipts, T^{SL}, are given by

$$T_t^{SL} = t_t^{Y,SL} Qxd_t + t_t^{L,SL} w_t L_t + t_t^{K,SL} Y_t^K,$$

where $t^{Y,SL}$, $t^{L,SL}$, and $t^{K,SL}$ are average state and local tax rates on production excluding property taxes, labor income, and net capital income, respectively. Property taxes are grouped with corporate taxes as a tax on capital income.

Transfers to People

Transfers to people at both the federal and state and local levels are countercyclical, meaning they fall as employment rises relative to noncyclical employment. Real federal transfers, V^F, are given by

$$V_t^F = v_t^F Q_t^* - Q_t^* \sum_{i=0}^{5} \theta_i^{V,F} \left(\frac{L_{t-i}}{L_{t-i}^*} - 1 \right),$$

where v^F is the ratio of the noncyclical portion of transfers to potential GDP and $\theta_i^{V,F}$ are estimated coefficients governing the response of transfers to changes in employment.

The equation for real state and local transfers, V^{SL}, is similar:

$$V_t^{SL} = v_t^{SL} Q_t^* - \theta^{\mathrm{V,SL}} Q_t^* \left(\frac{L_t}{L_t^*} - 1\right).$$

Unlike the case with federal transfers, lags of employment do not seem to matter empirically.

Government Consumption and Investment

Real consumption and investment by the federal government, G^F, is exogenous except for depreciation of federal government capital. The equation is

$$G_t^F = Gxd_t^F + depG_t^F,$$

where Gxd^F is federal government consumption and investment excluding depreciation, and $depG^F$ is depreciation of federal government capital. The main text discusses the equation for consumption and investment by state and local governments.

Other Components of Primary Deficits

The other components of the primary deficits of the federal government and state and local governments are treated as exogenous. The most important components are federal grants-in-aid to state and local governments (S). Grants-in-aid add to the federal deficit and subtract from the sum of state and local deficits. The remaining components of the primary deficits (collectively ψ^F and ψ^{SL}) equal miscellaneous components of government spending, such as subsidies, minus miscellaneous revenues.

The primary federal deficit, D^F, is given by

$$D_t^F = G_t^F + V_t^F + S_t - T_t^F + \psi_t^F.$$

The equation for the primary deficits of state and local governments is similar, except that grants-in-aid are a subtraction:

$$D_t^{SL} = G_t^{SL} + V_t^{SL} - S_t - T_t^{SL} + \psi_t^{SL}.$$

Accumulation of Government Debt

The rate of accumulation of government debt depends positively on the primary deficit and interest rates. The growth of real debt is reduced by higher inflation, all else equal. For real federal debt (B^F), the equation is

$$B_t^F = B_{t-1}^F \frac{p_{t-1}}{p_t}\left[1 + \sum_{i=1}^{36} \theta_i^{BF10} \frac{r10_{t-i}}{400} + \sum_{i=0}^{3} \theta_i^{BF3} \frac{r3_{t-i}}{400}\right] + \frac{D_t^F}{4} - \frac{dep_t^F}{4} + \theta^{BFY} Q_t^* + B_t^{add},$$

where p is the price index for GDP, $r10$ is the yield on 10-year Treasury notes, $r3$ is the three-month T-bill rate, θ^{BFY} and θ_i^{BF10} and θ_i^{BF3} are estimated coefficients, and B^{add} is an add factor, needed partly because the unified deficit (the actual cash deficit) differs from the NIPA deficit. The sum of θ_i^{BF10} and θ_i^{BF3} is constrained to 1. Several variables are divided by 4 because they are annualized, but the equation measures the quarterly change in debt. Depreciation is subtracted because no outlay is associated. The potential GDP term improves the fit of the equation and its properties.

The equation for the total debt of state and local governments is similar:

$$B_t^{SL} = B_{t-1}^{SL} \frac{p_{t-1}}{p_t} \left[c^{SL} + \sum_{i=1}^{40} \theta_i^{BSL10} \frac{r10_{t-i}}{400} \right] + \frac{D_t^{SL}}{4} - \frac{dep_t^{SL}}{4} + \theta^{BSLY} Q_t^*,$$

where c^{SL}, θ_i^{BSL10}, and θ^{BSLY} are parameters. No add factor is present because CBO has no forecast of B^{SL} to match. The θ_i^{BSL10} parameters are constrained to sum to 1.

Data and Calibration

Marginal federal tax rates on labor income and on capital income come from CBO's Tax Analysis Division. The variable $\Upsilon^{L,F}$ is calculated so that $T^{F,add}$ is zero in the baseline. State and local average tax rates are found by dividing the relevant category of revenue by its tax base.

The $\theta_i^{V,F}$ are derived from regressions for the Supplemental Nutrition Assistance Program and federal transfer payments through state unemployment insurance. $\theta^{V,SL}$ is derived from regressions for Medicaid and other state and local transfers. The equations for transfers are inverted to obtain v_t^F and v_t^{SL}.

To obtain the coefficients in the debt equations, initial equations were estimated using polynomial distributed lags on $r10$ and $r3$. Long moving averages were then used to replicate the fit from those lags and the coefficients on the moving averages were then constrained to 1.

Net Foreign Assets and Incomes

Net International Investment Position

The change in the net international investment position (NIIP) is net exports plus net factor income from abroad plus net revaluations. When the equation is converted to reals, net revaluations are replaced by net revaluations other than from price growth:

$$N_t = N_{t-1} + \frac{X_t}{4} - \frac{M_t}{4} + \frac{Q_t^N}{4} - \frac{Q_t}{4} - \theta^{eN}\theta^{re} \left[\begin{array}{c} \theta^{e0}(r10_t - \overline{r10}_t) + \\ (1-\theta^{e0}) mv(r10_{t-1} - \overline{r10}_{t-1}, 6) \end{array} \right] \overline{N}_{t-1}^{US} + N_t^{add},$$

where Q^N is real gross national product (GNP), θ^{eN} is the elasticity of the dollar value of U.S.-owned assets abroad with respect to the exchange rate, θ^{re} is the effect of interest rates on the exchange rate, N^{US} is the value of U.S.-owned assets abroad, and N^{add} is an add factor. The term in brackets captures the net revaluation of N from a change in the exchange rate of the dollar owing to a change in interest rates. GNP less GDP is net factor income from abroad.

Net Factor Income From Abroad

Net factor income from abroad is income earned by U.S.-owned factors (including labor) overseas less income earned by foreign-owned factors in the United States. Real net income is modeled as real net private factor income (n^P) less real interest paid on foreign-owned federal debt (n^G).

Foreign-owned federal debt (N^G) is assumed to remain at its baseline share of total debt:

$$N_t^G = \bar{N}_t^G \frac{B_t^F}{\bar{B}_t^F}.$$

Real interest paid on foreign-owned federal debt in the prior quarter is modeled as a deviation from its baseline level and uses the same interest rate structure as the equation for federal debt:

$$n_t^G = N_{t-1}^G \frac{p_{t-1}/\bar{p}_{t-1}}{p_t/\bar{p}_t}\left[\frac{\bar{n}_t^G}{\bar{N}_{t-1}^G} + \sum_{i=1}^{36} \theta_i^{BF10} \frac{(r10_{t-i} - \overline{r10}_{t-i})}{100} + \sum_{i=0}^{3} \theta_i^{BF3} \frac{(r3_{t-i} - \overline{r3}_{t-i})}{100}\right].$$

In recent years, net private factor income has been strongly positive, whereas the private portion of the NIIP (N^P; equal to $N + N^G$ because N^G is a debit to NIIP) has been negative. One way to model that discrepancy would be to break both n^P and N^P into their domestic and foreign components and to apply a separate rate of return to each. The simpler approach taken in CBOSS is to calculate the combined real rate of return (r^I) on U.S.-owned assets overseas and foreign-owned assets in the United States and determine the "missing" private NIIP (N^{PM}) needed to generate n^P by applying that return to actual plus missing NIIP:

$$n_t^P = r_t^I(N_{t-1}^P + N_{t-1}^{PM}) = r_t^I(N_{t-1} + N_{t-1}^G + N_{t-1}^{PM}).$$

In the CBOSS equation for GNP, or GDP plus net factor income from abroad, r^I is held exogenous at its baseline level. Because returns in the United States are a subtraction from GNP, the relationship is complicated between r and an endogenous r^I needed to get GNP to move in the right direction when r rises. However, insofar as foreign rates rise with U.S. rates, a fraction θ_{RN} of an increase in n^G resulting from higher rates is assumed to be offset with higher n^P:

$$Q_t^N = Q_t + \bar{r}_t^I(N_{t-1} + N_{t-1}^G + N_{t-1}^{PM}) - n_t^G + \theta_{RN}(n_t^G - \bar{n}_t^G).$$

Data and Calibration

θ^{eN} is assumed to be 0.5 on the basis of its value in CMAC. θ^{re} equals 0.03 and θ^{e0} equals 2/3 on the basis of an equation for the exchange rate used to calibrate the equations for net exports (see below). θ_{RN} is assumed to equal 0.5. N^{PM} is determined by inverting the equation for n^P.

Consumer Spending

As shown in the main text, the equation for consumer spending is the sum of spending from five sources: noncyclical after-tax labor income plus transfers, cyclical after-tax labor income, the market value of U.S.-owned private capital, government bonds, and a basic level of consumption. An add factor also is present.

Labor Income

After-tax labor income is labor compensation less taxes on labor income. The noncyclical portion, *Y**, which also includes government transfers, *V*, is

$$Y_t^* = \left(1 - \tau_t^{L,F} \overline{Y}_t^{L,F}\right) \overline{w}_t L_t^{*av} + \left(1 - \tau_t^{L,F}\right)(w_t - \overline{w}_t) L_t^{*av} + V_t,$$

where L^{*av} is a weighted average of current and past values of *L**, with weights the same as in Okun's law; that is, $L_t^{*av} = \sum_{i=0}^{5} \theta_{t-i}^{Y,E} L_t^*$. L^{*av} is used instead of *L** so that a labor supply shock does not fully create its own demand immediately.

The cyclical portion of after-tax labor income is

$$Y_t - Y_t^* = \left(1 - t_t^{L,F}\right) w_t (L_t - L_t^{*av}).$$

The cyclical portion of transfers is grouped with noncyclical labor income because much of it goes to households that have little or no savings. Thus it has a relatively high marginal propensity to consume (MPC), like noncyclical labor income.

Wealth Effects

The market value of U.S.-owned private capital is the present discounted value of the after-tax income from existing domestic private capital plus adjusted NIIP ($N+N^{PM}$). The present discounted value of after-tax domestic capital income is

$$W_t^D = \frac{(1 - t_t^K)(1 - t_t^Y)\left[\alpha_t \left(1 - \frac{1}{e_t}\right) + \frac{1}{e_t}\right]\left[\theta^{QW} Qxd_t + (1 - \theta^{QW}) Qxd_t^*\right]}{\delta + r_{avg}^P + \theta^{rW}\left(r_t^P - r_{avg}^P\right)},$$

where t^K is the average tax rate on capital income, θ^{QW} and θ^{rW} are coefficients, r^P is the combined rate of return on private debt and equity, and r_{avg}^P is the value of r^P in the fourth quarter of 2019. Markets are assumed to be forward looking, so investors put some weight on current output (*Qxd*) and some weight on its potential value, to which the actual will gradually return. W^D is not intended to match any particular data series but is instead a model construct.

Add Factor

The add factor for consumption serves two purposes. First, it smooths out c_t^s. c_t^s could be chosen so that the consumption equation solves for forecast levels exactly without an add factor, but c_t^s could then fluctuate sharply from quarter to quarter depending on the baseline forecast for consumption and its determinants. Putting some of those fluctuations into the add factor allows for smoother c_t^s. Second, as discussed in the main text, the add factor allows for effects of policy on consumer spending that differ from what the hard-coded coefficients imply.

Calibration

Basic Equation. The MPC from noncyclical labor income, c^*, is set to 0.8. The ratio of the MPC from cyclical labor income, c^c, to c^*, 0.57, is taken from a similar concept in the multipliers model. The MPC from private wealth, c^q, equals 0.045, the MPC from housing wealth reported in a CBO study.[1] c^q combines wealth and income effects, so it may exceed typical MPCs estimated from wealth alone. The time patterns of θ_i and ζ_i are based on estimates for the consumption equation in CMAC.

The MPC on government bonds, C^b, is set to 0.028, the value needed so that an increase of 1 percentage point in the ratio of federal debt to GDP boosts the federal funds rate by 2.5 basis points, in line with research by Gamber and Seliski.[2] That c^b is smaller than c^q implies some Ricardian effect. Households appear to expect about one-third $(1 - 0.028/0.045)$ of existing government debt to eventually be paid for by higher taxes and lower transfers.

A raw time series for c^s is found by setting c^{add} to zero and inverting the consumption equation. Actual c^s are the Hodrick-Prescott–filtered values of that series. An add factor is then calculated to make the equation for consumer spending solve exactly.

Private Wealth. In the equation for W^D, θ^{QW} is assumed to be 0.5. Given an estimate for c^q, θ^{rW} is calibrated to achieve the correct share of rebalancing for consumption.

Private Investment

The equation for investment per worker-unit of capital added in quarter t, φ_t, is

$$\varphi_t = \Omega_t \frac{Q_t^I}{L_t^*} \frac{(1 - \theta^{TI}\tau_t^K)(1 - \tau_t^Y)\alpha_t \left(1 - \frac{1}{e_t}\right)}{\delta + r_{avg}^P + \theta^{rI}\left(\sum_{i=0}^{7} \zeta_i^{ri} r_{t-i}^P - r_{avg}^P\right)},$$

where Ω is a scaling parameter close to 1, Q^I is a weighted average of current and lagged values of Qxd and Qxd^*, and θ^{TI}, θ^{rI}, and ζ_i^{ri} are parameters, with $\sum_{i=0}^{7} \zeta_i^{ri} = 1$. Private investment is boosted by increased labor productivity and by a higher α but is reduced by increased tax rates and a higher private rate of return. Fiscal stimulus initially boosts both Qxd and r^P, but the net effect on investment is negative, and that effect grows over time.

Calibration

The parameters in the equation for new worker-units of capital in the main text are based on parameters in the equations for investment in CMAC. The weights on current and lagged values

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[1] See Congressional Budget Office, *Housing Wealth and Consumer Spending* (January 2007), https://tinyurl.com/CBObp2007 (PDF, 362 KB).

[2] See Edward Gamber and John Seliski, *The Effect of Government Debt on Interest Rates*, Working Paper 2019-01 (Congressional Budget Office, March 2019), www.cbo.gov/publication/55018.

of Qxd and Qxd^* in Q^I and the ζ_i^{ri} parameters in the equation for φ also are based on parameters in the equations for investment in CMAC. θ^{TI}, the elasticity of investment with respect to tax-induced changes in the cost of capital, is set to 0.7, the value CBO used in estimating the effects of the 2017 tax act.[3] θ^{rI} is calibrated to achieve the correct share of rebalancing for investment. The level of r^P, discussed further in the section on interest rates below, is calibrated so that the scaling parameter Ω is roughly 1.

Similar to the calibration of c^s, a raw time series for Ω is found by setting I^{add} to zero and inverting the investment equation. Actual Ω are the Hodrick-Prescott–filtered values of that series. I^{add} is then calculated to make the equation for private investment solve exactly.

Net Exports

To estimate ζ_i^M and ζ_i^X, the parameters governing the cyclicality of imports and exports, an equation was estimated for the change in real net exports as a share of total trade as a function of the change in Q_{t-i}/Q_{t-i}^* and exchange rates. That equation is used to determine both the time patterns of ζ_i^M and ζ_i^X and the GDP gap's total effect on net exports. A similar equation was estimated for real imports to get $\sum \zeta_i^M$, which is 2.68. To get the correct total effect of the GDP gap on net exports, $\sum \zeta_i^X$ is set to 1.75.

In CBOSS, real imports and exports depend directly on interest rates. In fact, imports and exports depend on exchange rates, which in turn depend on interest rates. The coefficients governing the timing of the effect of interest rates on real imports and exports, ζ_i^{RNX}, combine the results from two equations. The first is the equation described above. The second is an equation for the change in the exchange rate as a function of current and lagged interest rates.

Interest rates have a larger effect on exports than on imports, so θ_{RX} is assumed to be twice as large as θ_{RM}. θ_{RM} is then calibrated to achieve the correct share of rebalancing for net exports.

Inflation

The equation for inflation is

$$\pi_t = \sum_{i=1}^{12} \rho_i \, \pi_{t-i} + \left(1 - \sum_{i=1}^{12} \rho_i\right)\pi^* + \theta^{Q\pi} 100 \left(\frac{Q_t}{Q_t^*} - 1\right)$$
$$+ Ds_t \theta^{s\pi}\left[s_t\left(\frac{Q_t}{Q_t^*} - 0.9\right) - \bar{s}_t\left(\frac{\bar{Q}_t}{\bar{Q}_t^*} - 0.9\right)\right] + \pi_t^{add}.$$

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[3] See Congressional Budget Office, *Key Methods That CBO Used to Estimate the Macroeconomic Effects of the 2017 Tax Act—Supplemental Material for* The Budget and Economic Outlook: 2018 to 2028 (April 2018), p. 3, https://tinyurl.com/CBOsm2017 (PDF, 173 KB).

The expected rate of inflation, π^e, is subtracted from nominal interest rates to obtain real interest rates. Inflation expectations are informed by past inflation and assume that inflation will gradually revert toward target inflation:

$$\pi_t^e = \theta^{\pi e} \sum_{i=0}^{7} \lambda_i \pi_{t-i} + (1 - \theta^{\pi e})\pi^*,$$

in which $\theta^{\pi e}$ and λ_i are coefficients. The λ_i values sum to 1.

Calibration

The inflation equation is calibrated based on the equation for the core personal consumption expenditures (PCE) price index in CMAC. That equation contains the expected change in the GDP price index in the year ahead from the Survey of Professional Forecasters. Because that variable, unlike π^*, varies over time, an equation for it is estimated based on past values of PCE price inflation. Those effects of past inflation on the survey measure of expectations are combined with the effects of past inflation in the PCE price equation to derive ρ_i. $\theta^{Q\pi}$ is set to 0.05 so that a 1 percent rise in Q/Q^* leads to roughly a 0.1 percentage-point acceleration of price inflation after a year.

The measure of supply constraints, *s*, is the global supply chain pressure index from the New York Federal Reserve.[4] In the baseline, *s* is assumed to gradually return to its sample average of zero by the fourth quarter of 2023. A value of 0.9, rather than 1, is subtracted from the ratio of GDP to potential GDP so that a value of *s* below zero does not lead an increase in GDP to reduce inflation. The parameter $\theta^{s\pi}$ is estimated, holding the other parameters in the equation at the values determined above.

In the equation for expected inflation, the λ_i values are based on the equation estimated for the survey measure of expected inflation. In that equation for the survey measure, the coefficients on lagged inflation sum to less than 1. Because CBOSS uses expected inflation to determine long-run interest rates, $\theta^{\pi e}$ is set to the fraction of a shock to inflation that would remain in the survey measure of expected inflation after 10 years, 0.42.

Interest Rates

Short-Term Interest Rates

The equation for the nominal fed funds rate, *R*, is determined by a Taylor rule, subject to the effective lower bound (ELB), R^{ELB}:

[4] See Gianluca Benigno, Julian di Giovanni, Jan J. J. Groen, and Adam Noble, "Global Supply Chain Pressure Index: May 2022 Update," Federal Reserve Bank of New York Liberty Street Economics (May 18, 2022), https://tinyurl.com/FRBNYlse2022.

$$R_t = \max\left[\begin{array}{c} R_t^{ELB}, \lambda^R\left(r_t^* + \pi^* + \theta^{\pi R}[mv(\pi_t, 4) - \pi^*] + \theta^{QR}\left[\frac{Q_t}{Q_t^*} - 1\right]\right) \\ +(1-\lambda^R)R_{t-1} + R_t^{add} \end{array}\right],$$

where λ^R, $\theta^{\pi R}$, and θ^{QR} are coefficients and R^{add} is an add factor. When not constrained by the ELB, the federal funds rate responds positively to the target real interest rate, target inflation, the gap between actual and target inflation, and the GDP gap. The real federal funds rate is the nominal rate minus expected inflation.

Deviations of the nominal rate on 3-month Treasury bills, $R3$, from baseline echo deviations of the federal funds rate from baseline. The level of federal debt also has an impact:

$$R3_t - \overline{R3}_t = R_t - \bar{R}_t + \theta^{BR} sh^{R3}\left(\frac{B_{t-1}^F}{Q_t^*} - \frac{\bar{B}_{t-1}^F}{\bar{Q}_t^*}\right),$$

where θ^{BR} is the percentage-point increase in federal interest rates from a rise of 1 percentage point in the ratio of federal debt to potential GDP, and sh^{R3} is the share of that increase accounted for by a reduction in the spread between private rates and government rates.

Rates on 10-year Treasury Notes

The deviation of the nominal yield on 10-year Treasury notes ($R10$) from its baseline level is the weighted sum of two terms—the deviation of the nominal rate on 3-month Treasury notes from its baseline level and a composite of factors affecting longer rates, R^L—plus a term premium:

$$R10_t - \overline{R10}_t = \theta^{s10}(R3_t - \overline{R3}_t) + (1 - \theta^{s10})R_t^L + r_t^{TP},$$

where θ^{s10} is the weight on the short-term rate and r^{TP} is the term premium.

The primary factor in R^L is the contemporaneous change in r^* from baseline. Just as in the short run, the change in r^* feeds only gradually into rates. That effect is modeled by cumulating the change in r^* from baseline as $r10ch^*$:

$$r10ch_t^* = \lambda^R(r_t^* - \bar{r}_t^*) + (1 - \lambda^R) r10ch_{t-1}^*.$$

The other factors determining R^L are expected inflation and the direct effect of federal debt on Treasury rates. When those are summed, the equation for R^L is:

$$R_t^L = r10ch_t^* + \pi_t^e - \bar{\pi}_t^e + \theta^{BR} sh^{R3}\left(\frac{B_{t-1}^F}{Q_t^*} - \frac{\bar{B}_{t-1}^F}{\bar{Q}_t^*}\right).$$

All else equal, a greater ratio of federal debt to GDP boosts yields on federal debt. Higher interest rates usually boost the dollar. However, increased federal debt, by increasing the supply of U.S. assets relative to foreign demand for them, would probably put downward, not upward, pressure on the dollar. Consequently, in the equations for imports and exports, the real 10-year Treasury rate ($r10$) is adjusted for the effect of federal debt:

$$r10_t^a = r10_t - \theta^{BR} sh^{R3} \frac{B_{t-1}^F}{Q_t^*}.$$

Private Rate of Return

The real private rate of return, r^P, used in the equations for private wealth and private investment, equals the real 10-year Treasury rate plus the combined risk premia on private debt and equity, *rp*, less the effect of federal debt on the spread between the federal funds rate and Treasury rates:

$$r_t^P = r10_t + rp_t - \theta^{BR} sh^{R3} \left(\frac{B_{t-1}^F}{Q_t^*} - \frac{\bar{B}_{t-1}^F}{\bar{Q}_t^*} \right).$$

Data and Calibration

In the equation for the federal funds rate, R^{ELB} is set equal to R in quarters in which $R < 0.20$ and equal to 0.20 otherwise. λ^R is set to 0.25, greater than the values of 0.2 in CMAC and 0.15 in the inertial Taylor rule in the FRB/US model but consistent with the multipliers for the first and second years after a fiscal shock in a CBO analysis.[5] $\theta^{\pi R}$ is set to 1.5, the value in CMAC. θ^{QR} is set to 0.06, which produces the same instantaneous change in R as though θ^{QR} were 0.5 and r^* were exogenous. For periods when the federal funds rate exceeds the ELB, R^{add} is calculated so that the equation for R holds exactly. For periods in which the federal funds rate is at the ELB, that calculation is adjusted for the estimated impacts of the determinants of R, were they effective.

In the equation for the 3-month Treasury bill rate, θ^{BR} is set to 2.5, in line with the Gamber–Seliski research cited above. The parameter sh^{R3} is set to 0.24 on the basis of a regression of the change in the AAA bond rate on the change in the 10-year Treasury yield. In the equation for the 10-year rate, θ^{s10} is set to 0.58 on the basis of a regression of changes in the 10-year rate on changes in the 3-month rate.

The real private rate of return, r^P, moves over time with a weighted average of the real mortgage rate and the combined real yield on the debt and equity of nonfinancial corporate business from CMAC. Based on investment shares, the weights are ¼ on the mortgage rate and ¾ on debt and equity of nonfinancial corporate business. rp_t is set so that the equation for r^P holds exactly.

Endogenous *r**

CBOSS calculates r^D, the endogenous change in r^* from baseline, in two steps. In the first step, noncyclical versions of each component of GDP (C^*, I^*, G^*, X^*, M^*) are calculated. To do that, each occurrence of Q_{t-i} or Qxd_{t-i} in each component of GDP and its determinants (such as W for

[5] See Congressional Budget Office, *How CBO Analyzes the Effects of Changes in Federal Fiscal Policies on the Economy* (November 2014), www.cbo.gov/publication/49494.

consumer spending) is replaced by Q^*_{t-i} or Qxd^*_{t-i}, each occurrence of L_{t-i} is replaced by L^*_{t-i}, and all the interest rate terms are made functions of r^D. In the second step, CBOSS searches for the r^D that restores the baseline ratio of $C^* + I^* + G^* + X^* - M^*$ to Q^*. To allow for incomplete endogeneity of r^*, r^D is multiplied by the dummy variable D^r:

$$r_t^* = \bar{r}_t^* + D_t^r r_t^D.$$

The process is adequate to fully restore the GDP gap to baseline for a temporary change in the budget deficit. However, a larger change in r^* is necessary for a permanent change in the budget deficit. For a permanent increase in the budget deficit, r^D must rise by an additional amount to offset the increase in the next year's consumption implied by the current increase in federal debt. To produce that larger change in r^*, C^* is boosted by an amount (C^r) that varies positively with the growth of federal debt and negatively with the speed of adjustment of interest rates to r^*:

$$C_t^r = D_t^P \lambda^C \left(\frac{1}{\lambda^R} - 1\right)^{\chi} c^b \; d\left(\frac{B_t^F}{Q_t^*}\bar{Q}_t^* - \bar{B}_t^F\right),$$

where D^P is a dummy variable equal to 1 when a policy is permanent, λ^C and χ are parameters, and $d()$ denotes a first difference. Values of 1.7 for λ^C and 0.25 for χ perform well in restoring the baseline balance between GDP and potential GDP.

Shares of Rebalancing

The starting point for estimating the shares of rebalancing in CBOSS is the CBO study used to estimate changes in private saving and net inflows of foreign capital (that is, reductions in net exports) in the policy growth model (PGM).[6] Changes in private saving and net inflows of foreign capital can be translated into changes in private investment and net exports; in the PGM, an additional dollar of federal deficit reduces ("crowds out") private investment by 33 cents and net exports by 24 cents. However, that CBO study linked deficits alone to private saving and net inflows of capital, whereas CBOSS assumes that the effects of policies on demand influence those variables. Thus, more analysis is needed to tease out the effect of a dollar of demand on consumer spending, private investment, and net exports.

The CBO study offers some evidence that changes in private saving (the "private-saving offset") vary by policy:

> Giavazzi, Jappelli, and Pagano (2000) report that the private-saving offset ranges from 10 cents to 50 cents when increases in deficits come from greater government spending on consumption goods and services and

[6] See Jonathan Huntley, *The Long-Run Effects of Federal Budget Deficits on National Saving and Private Domestic Investment*, Working Paper 2014-02 (Congressional Budget Office, February 2014), www.cbo.gov/publication/45140.

> that it ranges from 50 cents to 97 cents when increases in deficits come from lower taxes. (Huntley 2014, p. 4)
>
> Röhn (2010) . . . estimates a very high offset in response to policies that affect government revenues and very low offsets from other policies that affect deficits, such as changes in spending on public investment. (p. 5)

Calibrating the shares of rebalancing requires two steps: inferring the shares of rebalancing implied by the studies in Huntley (2014) and updating those shares for changes in the composition of GDP since the sample periods used in those studies.

To begin the first step, a stylized "average" fiscal policy is created. That policy assumes that changes in government consumption and investment (including changes at the state and local level due to changes in grants-in-aid), taxes on capital, and changes in outlays and revenues affecting disposable personal income (everything else) are proportional to their shares of federal revenues plus spending excluding interest and depreciation. Those shares are calculated for the sample period in each study and then averaged across the studies. Samples typically begin in the early 1970s and end anywhere from the early 1990s to 2008. The resulting average fiscal policy is assumed to produce the 43-cent rise in private saving and 24-cent net inflow of foreign capital per dollar of deficit reported in Huntley (2014). A technical revision boosts the rise in private saving to 45 cents per dollar of deficit.[7]

The average policy's direct impacts on the components of demand in CBOSS can be calculated from assumptions about MPCs from different policies. The difference between those direct impacts and the impacts in Huntley (2014) can be attributed to rebalancing. For example, the direct impact of the average policy is to boost private saving by 28 cents per dollar of deficit. But private saving is assumed to rise by 45 cents per dollar of deficit, indicating rebalancing of 17 cents. The amount of rebalancing is 24 cents per dollar of deficit for net exports and 35 cents for private investment (33 cents – 2 cents for the technical revision + 4 cents to offset the positive direct impact of fiscal policy). Normalizing those estimates so that they sum to 1 implies shares of rebalancing of 0.22 for consumer spending, 0.32 for net exports, and 0.46 for private investment.

The second step in calibrating the shares of rebalancing is to update those shares for changes in the composition of GDP since the sample periods used in those studies. As noted, the data used in the studies typically begin in the early 1970s and end anywhere from the early 1990s to 2008. Since then, the share of investment in consumption plus investment plus trade has fallen,

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[7] One paper surveyed in Huntley (2014) examines the private-saving offsets from two sources of increased deficits: greater government consumption and investment, and lower taxes. The private-saving offset for lower taxes is much larger than that for government consumption and investment. The survey weights the two estimates equally. However, lower taxes have an MPC closer to that of the average fiscal policy. Putting a larger weight on that estimate raises the overall average private-saving offset from 43 cents per dollar of deficit to 45 cents.

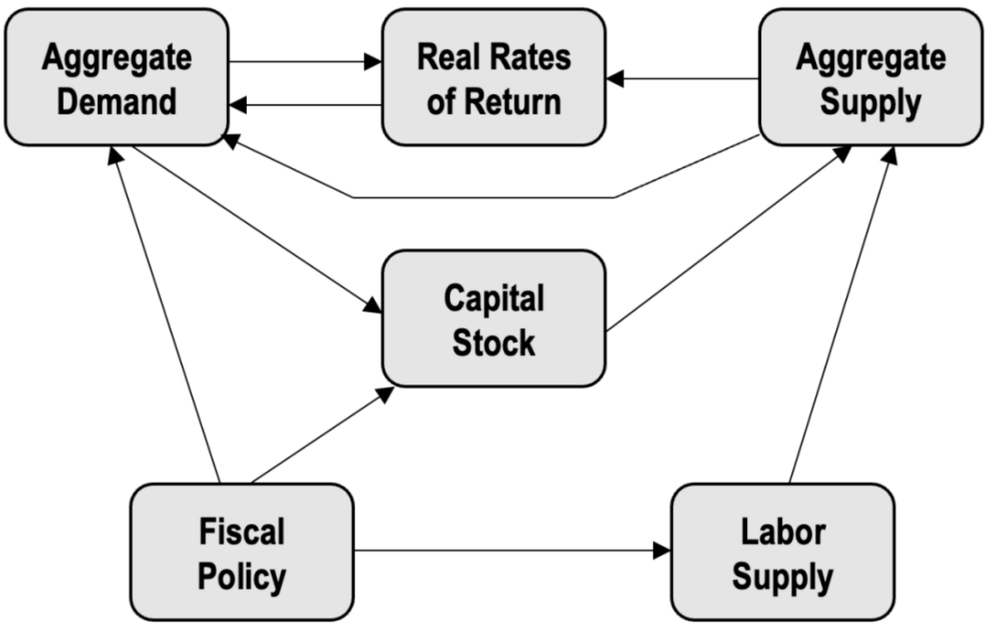
whereas the shares of both imports and exports have risen. Adjusting the shares of rebalancing obtained above for the change in the composition of the economy results in shares of rebalancing of 0.23 for consumer spending, 0.39 for net exports, and 0.38 for private investment. Those shares are used to set the parameters that determine the responsiveness of consumption, investment, exports, and imports to interest rates.

The fact that investment's share of rebalancing in CBOSS exceeds the 33 percent crowding out of investment per dollar of deficit in the PGM does not imply more crowding out in CBOSS than in the PGM. The precise degree of crowding out in CBOSS depends on the fiscal policy generating the deficit because rebalancing is applied only to the fraction of the deficit that results in increased demand. The break-even MPC is 0.87, in which case both CBOSS and the PGM yield 33 cents of crowding out per dollar of deficit. (In CBOSS, 33 cents is 38 cents × the MPC of 0.87.) For policies with higher MPCs, CBOSS implies more crowding out per dollar of deficit than the PGM. For policies with MPCs lower than 0.87, CBOSS implies less crowding out per dollar of deficit than the PGM.

Figures

Figure 1. [Return to Text]

Interaction Among Economic Elements in CBOSS



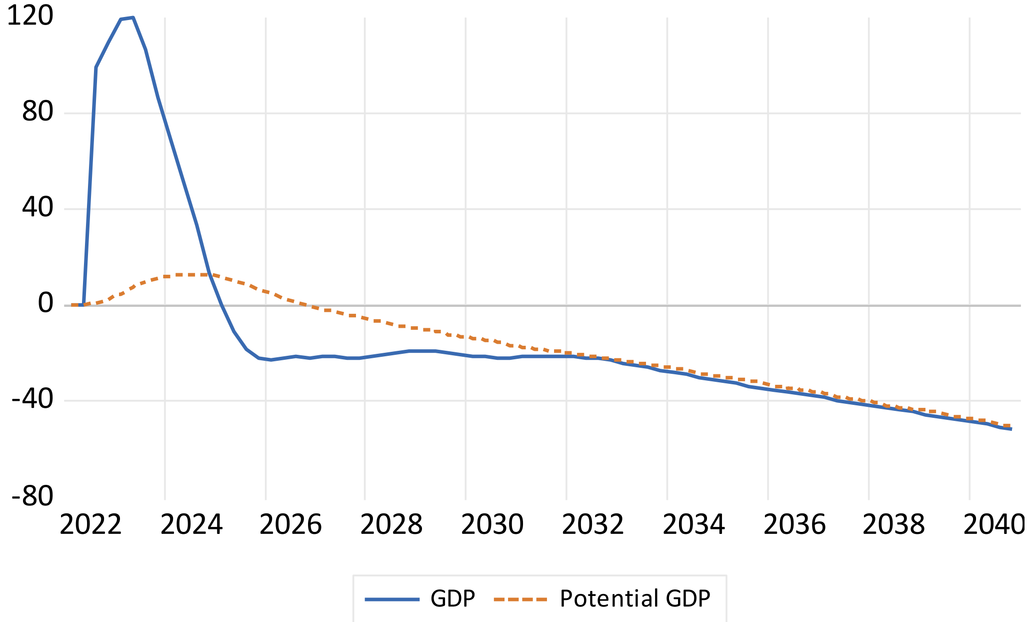
Source: Congressional Budget Office.

CBOSS = the Congressional Budget Office's small-scale policy model.

Figure 2. [Return to Text]

Effect on GDP and Potential GDP of Permanently Increased Federal Spending

Change from baseline, billions of 2012 dollars; Taylor rule with endogenous *r**



Source: Congressional Budget Office.

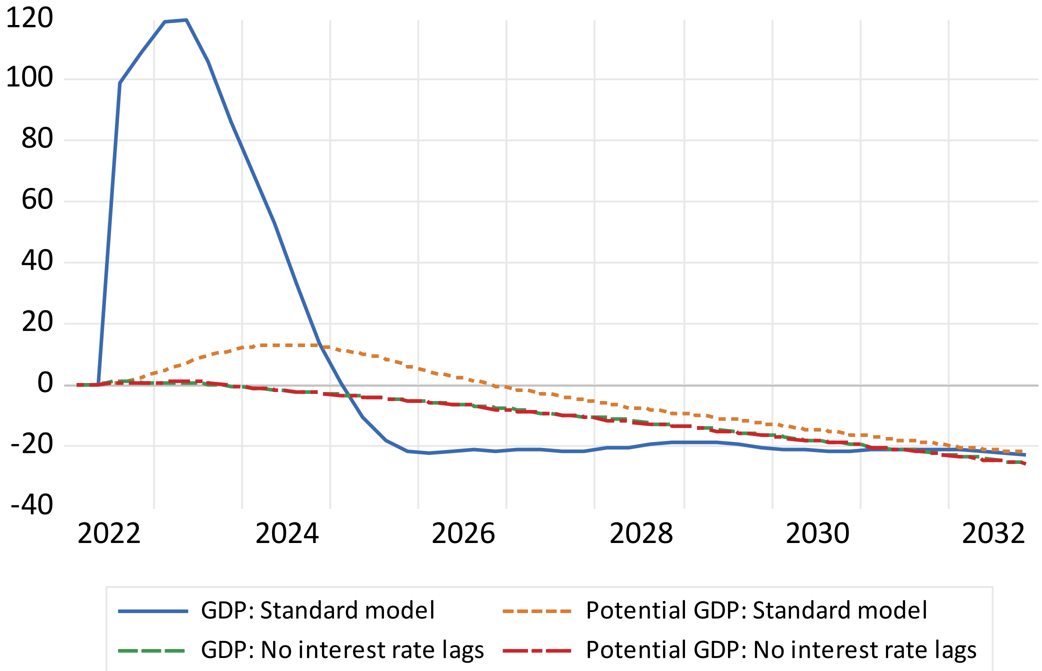
The policy experiment is a "permanent" increase in real federal government consumption and investment above baseline of $100 billion per year beginning in the third quarter of 2022. A truly permanent increase in government spending financed with deficits introduces some theoretical difficulties, so permanent means "through the end of the forecast horizon."

GDP = gross domestic product.

Figure 3. [Return to Text]

Short-Run Effects Stem From Lags Between *r** and GDP

Change from baseline, billions of 2012 dollars, in response to higher federal spending



Source: Congressional Budget Office.

The policy experiment is an increase in real federal government consumption and investment above baseline of $100 billion per year beginning in the third quarter of 2022. Monetary policy is set according to a Taylor rule with *r** endogenous.

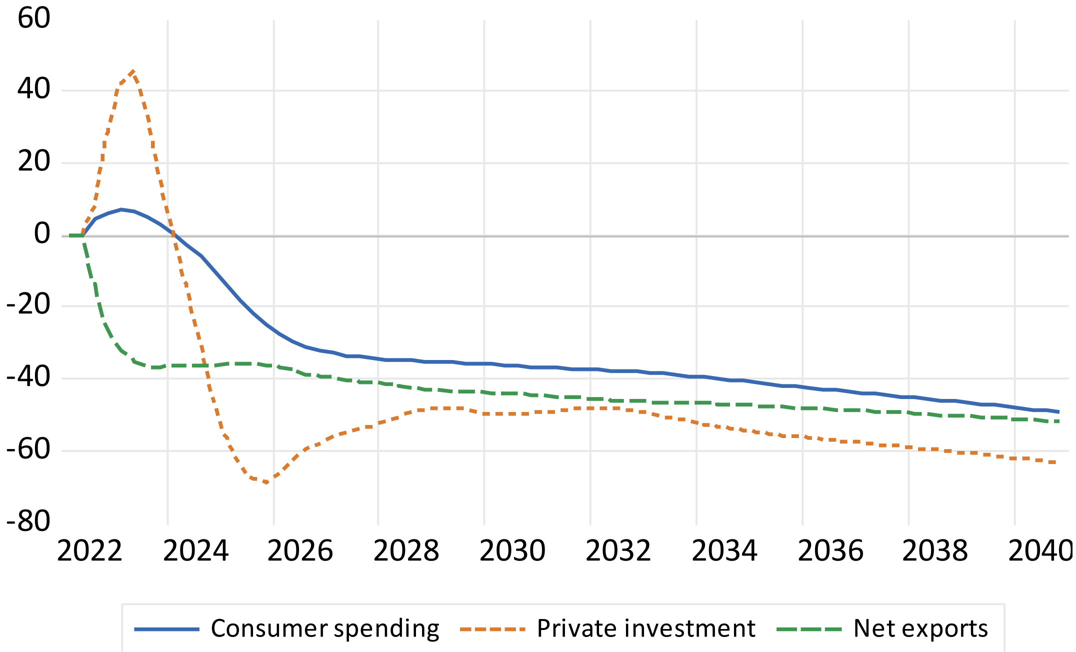
In the "No Lag" scenario, lags between *r** and real rates of return and between real rates of return and GDP are eliminated. All other lags, such as between income and consumer spending, are retained.

GDP = gross domestic product.

Figure 4. [Return to Text]

Higher Federal Spending's Effect on GDP's Private-Sector Components

Change from baseline, billions of 2012 dollars, in response to higher federal spending



Source: Congressional Budget Office.

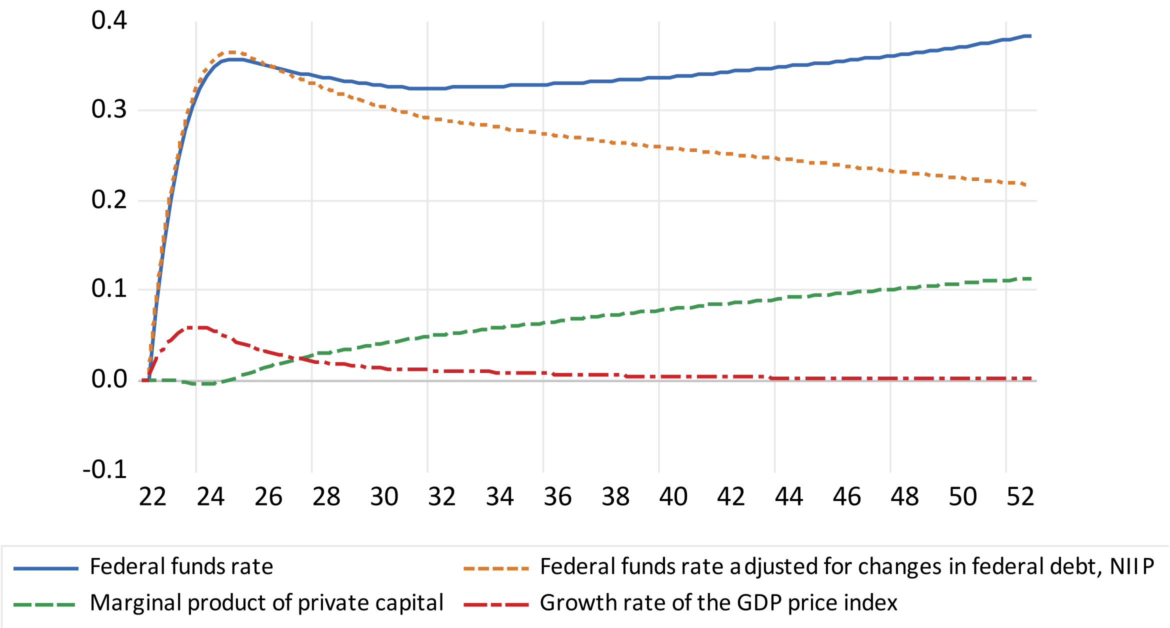
The policy experiment is a "permanent" increase in real federal government consumption and investment above baseline of $100 billion per year beginning in the third quarter of 2022. A truly permanent increase in government spending financed with deficits introduces some theoretical difficulties, so permanent means "through the end of the forecast horizon." Monetary policy is set using a Taylor rule with *r** endogenous.

GDP = gross domestic product.

Figure 5. [Return to Text 1 | 2 | 3]

Higher Federal Spending's Effects on Interest Rates and Inflation

Change from baseline, percentage points; Taylor rule with endogenous *r**



Source: Congressional Budget Office.

The policy experiment is a permanent increase in real federal government consumption and investment above baseline of $100 billion per year beginning in the third quarter of 2022. A truly permanent increase in government spending financed with deficits introduces some theoretical difficulties, so permanent means "through the end of the forecast horizon."

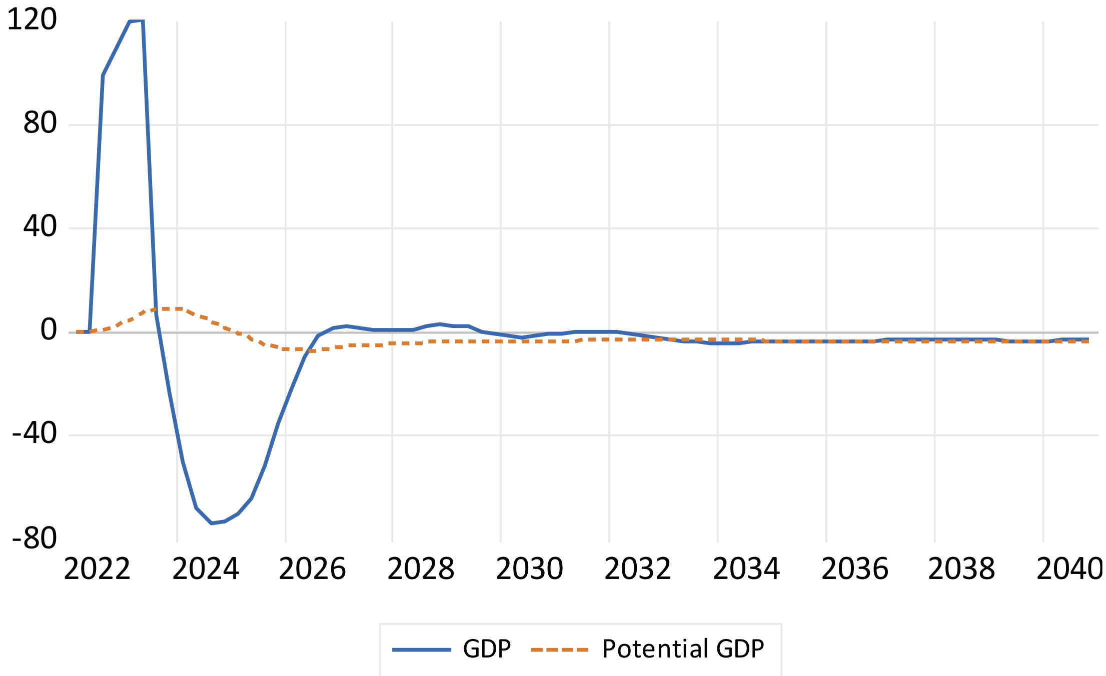
The marginal product of capital is $100\ \alpha Q^{*}/K$, where α is private capital's coefficient in production, Q^* is potential GDP, and K is the private stock of capital.

GDP = gross domestic product; NIIP = net international investment position, the United States' net overseas assets.

Figure 6. [Return to Text]

Effect on GDP and Potential GDP of Temporarily Increased Federal Spending

Change from baseline, billions of 2012 dollars; Taylor rule with endogenous *r**



Source: Congressional Budget Office.

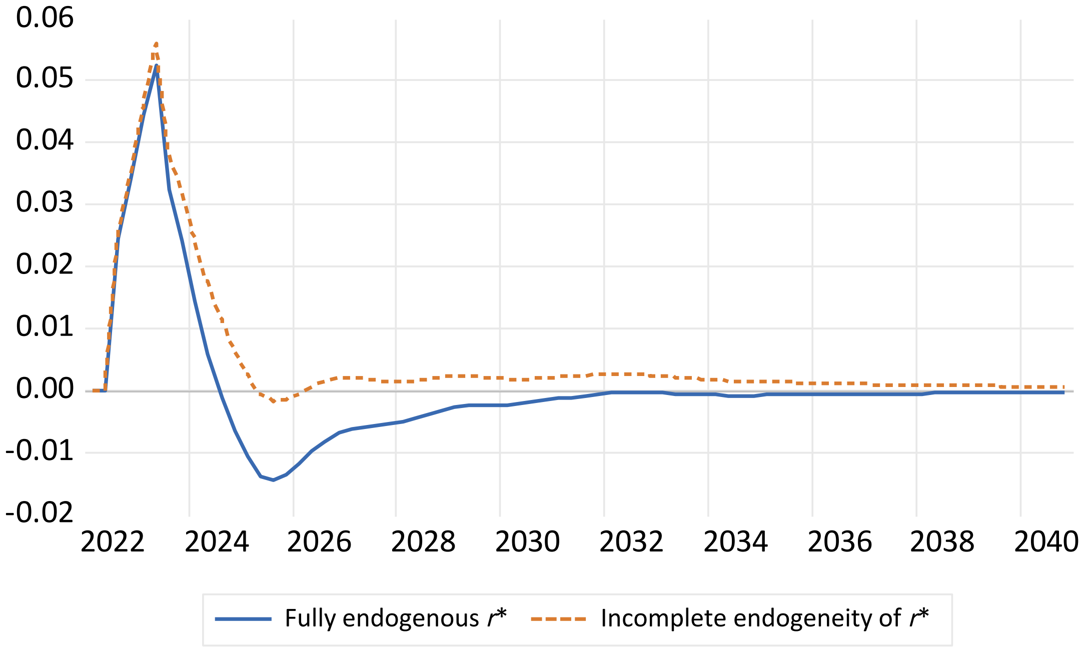
The policy experiment is an increase in real federal government consumption and investment above baseline of $100 billion per year from the third quarter of 2022 through the second quarter of 2023.

GDP = gross domestic product.

Figure 7. [Return to Text 1 | 2]

Effect on Inflation of Temporarily Increased Federal Spending

Percentage-point difference from baseline, annual rate



Source: Congressional Budget Office.

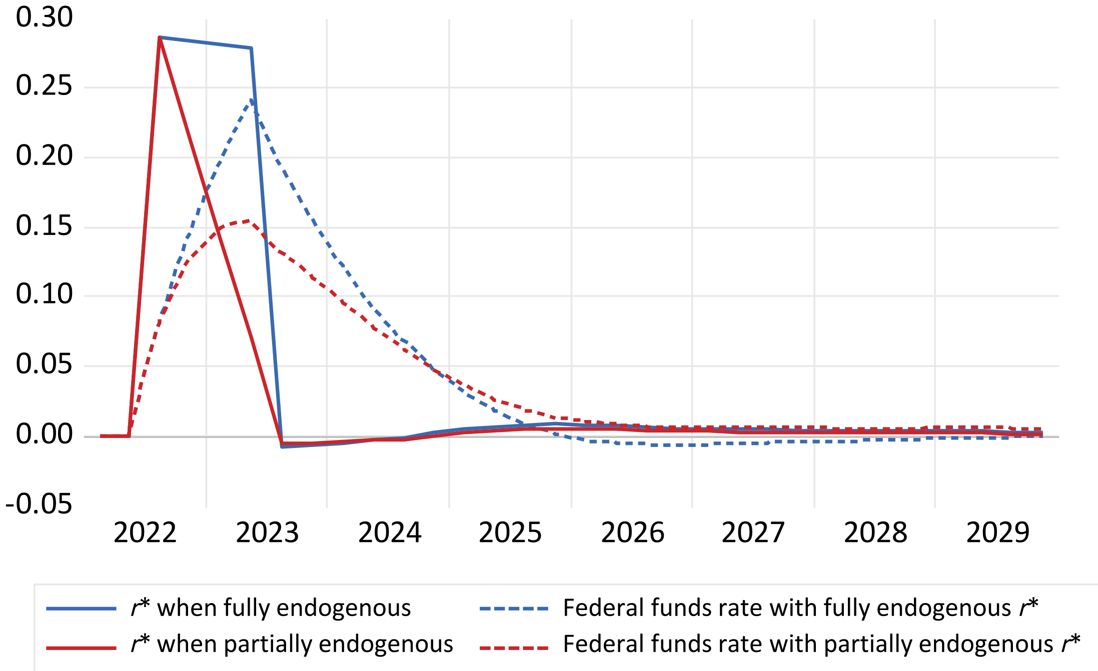
The policy experiment is an increase in real federal government consumption and investment above baseline of $100 billion per year from the third quarter of 2022 through the second quarter of 2023.

In the simulation with incomplete endogeneity of *r**, the adjustment of *r** is reduced by 25 percent in the fourth quarter of 2022, by 50 percent in the first quarter of 2023, and by 75 percent in the second quarter of 2023.

Figure 8. [Return to Text]

Effect on Interest Rates of Incomplete Endogeneity of *r**

Difference from baseline, percentage points



Source: Congressional Budget Office.

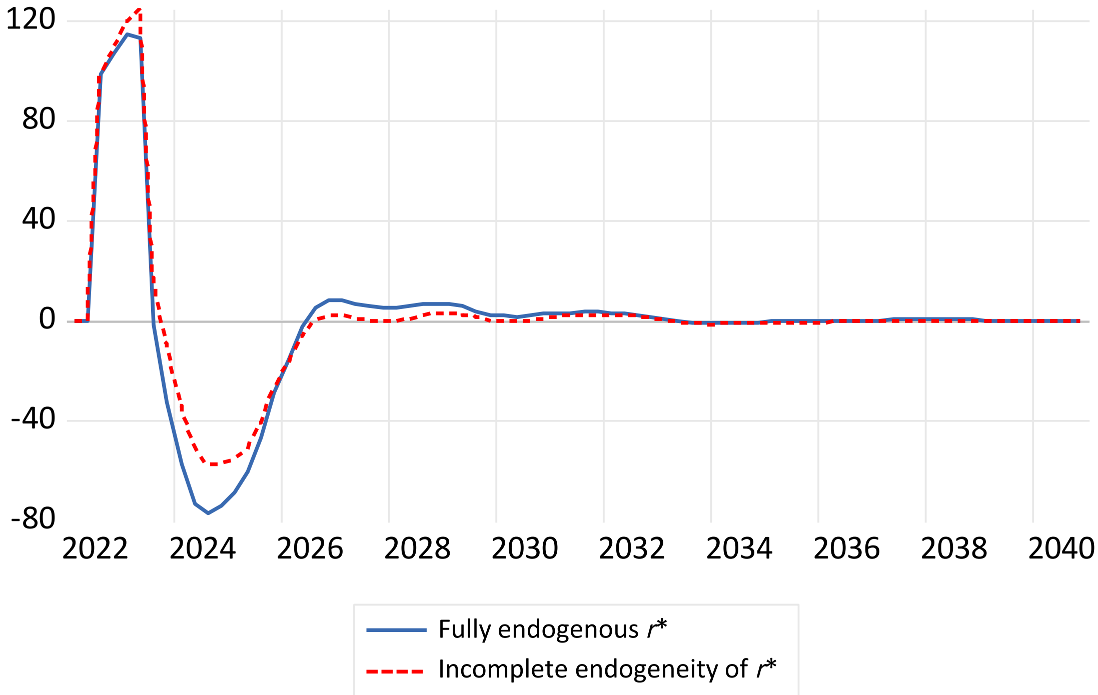
The policy experiment is an increase in real federal government consumption and investment above baseline of $100 billion per year from the third quarter of 2022 through the second quarter of 2023.

In the simulation with incomplete (partial) endogeneity of *r**, the adjustment of *r** is reduced by 25 percent in the fourth quarter of 2022, by 50 percent in the first quarter of 2023, and by 75 percent in the second quarter of 2023.

Figure 9. [Return to Text]

Effect on the GDP Gap of Incomplete Endogeneity of *r**

Difference of GDP minus potential GDP from baseline, billions of 2012 dollars



Source: Congressional Budget Office.

The policy experiment is an increase in real federal government consumption and investment above baseline of $100 billion per year from the third quarter of 2022 through the second quarter of 2023.

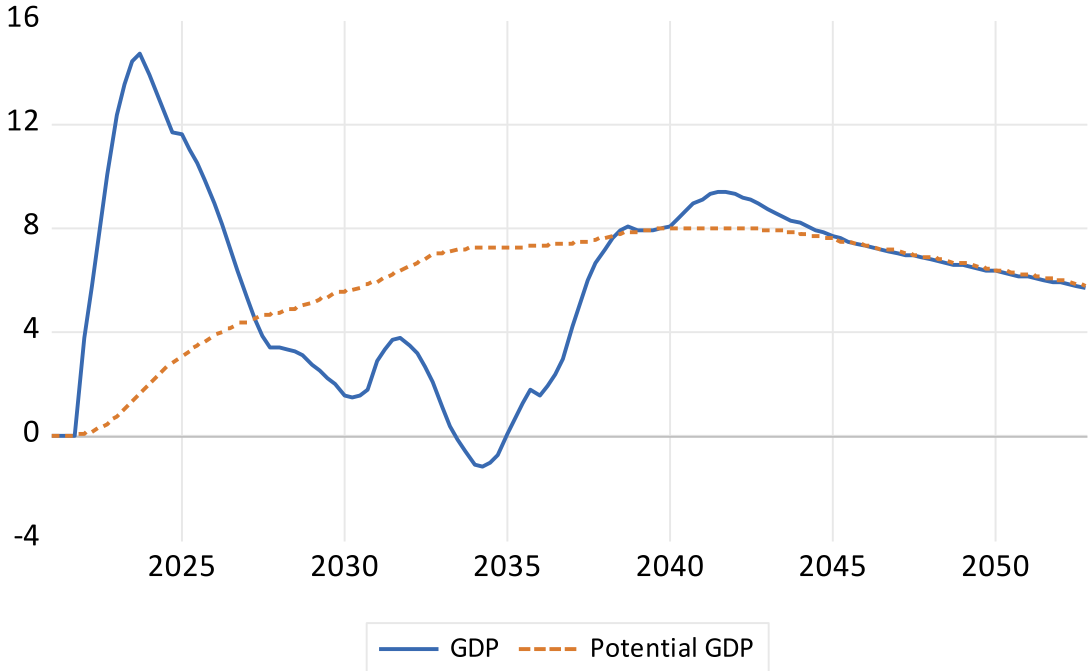
In the simulation with incomplete endogeneity of *r**, the adjustment of *r** is reduced by 25 percent in the fourth quarter of 2022, by 50 percent in the first quarter of 2023, and by 75 percent in the second quarter of 2023.

GDP = gross domestic product.

Figure 10. [Return to Text]

Higher Infrastructure Spending's Effect on GDP

Change from baseline, billions of 2012 dollars; Taylor rule with endogenous *r**



Source: Congressional Budget Office.

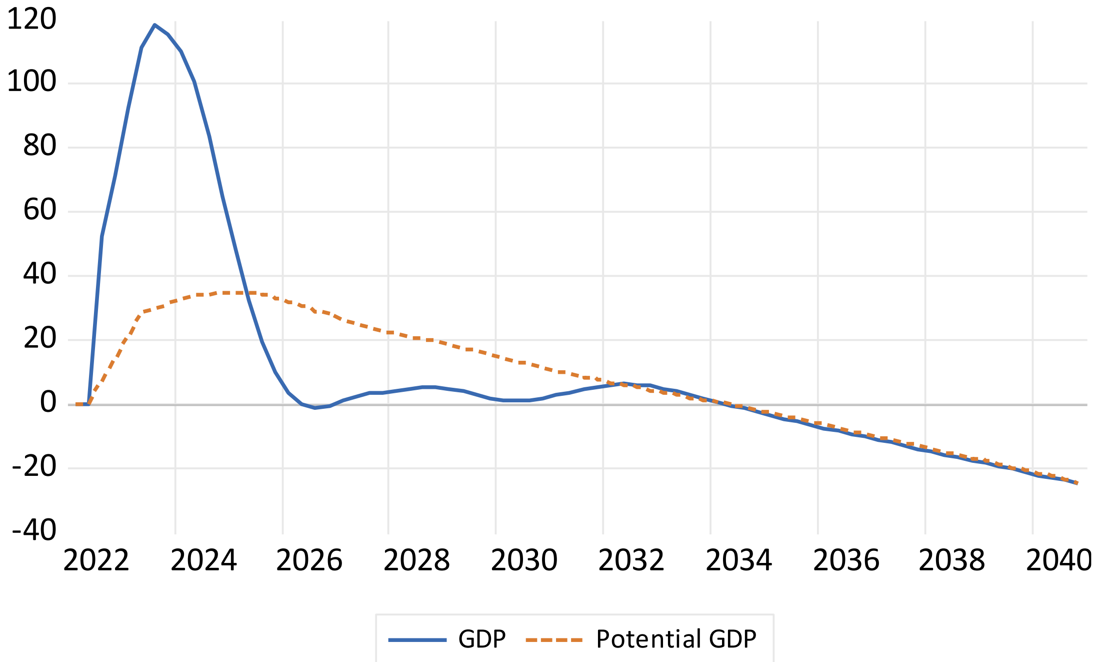
The policy experiment is an increase in nominal federal grants-in-aid for infrastructure spending of $50 billion per year from 2022 to 2031.

GDP = gross domestic product.

Figure 11. [Return to Text]

Effect of Permanently Reduced Marginal Tax Rates for Labor Income on GDP

Change from baseline, billions of 2012 dollars; Taylor rule with endogenous *r**



Source: Congressional Budget Office.

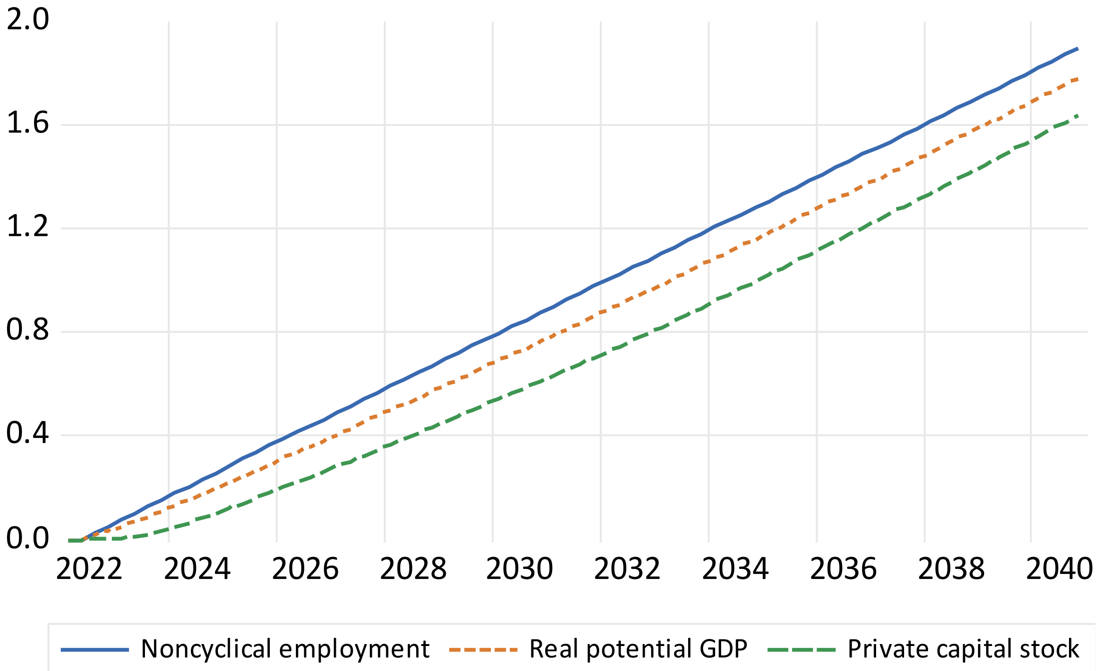
The policy experiment is a permanent reduction in federal marginal tax rates on labor income with a static cost of $100 billion per year in 2012 dollars beginning in the third quarter of 2022. A truly permanent reduction in federal revenues financed with deficits introduces some theoretical difficulties, so permanent means "through the end of the forecast horizon."

GDP = gross domestic product.

Figure 12. [Return to Text]

Effect on Real Potential GDP and Private Capital Stock of Faster Labor Force Growth

Percentage change from baseline; Taylor rule with endogenous *r**



Source: Congressional Budget Office.

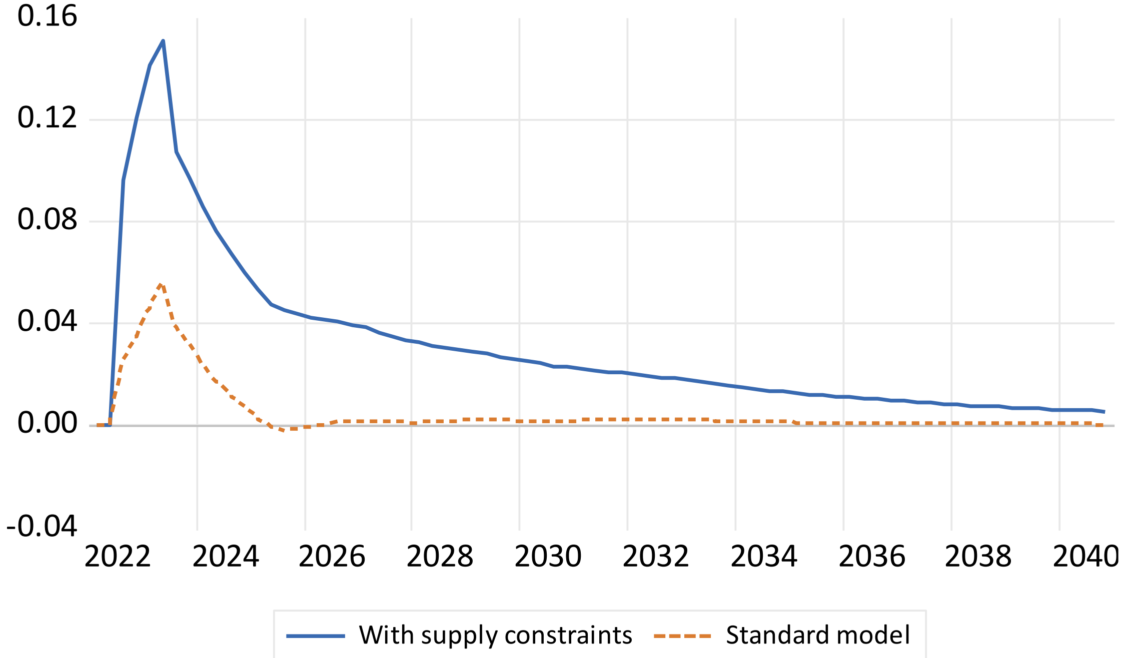
Annualized growth of noncyclical employment is increased by 0.1 percentage point per year relative to baseline beginning in the third quarter of 2022.

GDP = gross domestic product.

Figure 13. [Return to Text]

Effect on Inflation of Increased Federal Spending When Supply Is Constrained

Percentage-point difference from baseline, annual rate; Taylor rule with partially endogenous *r**



Source: Congressional Budget Office.

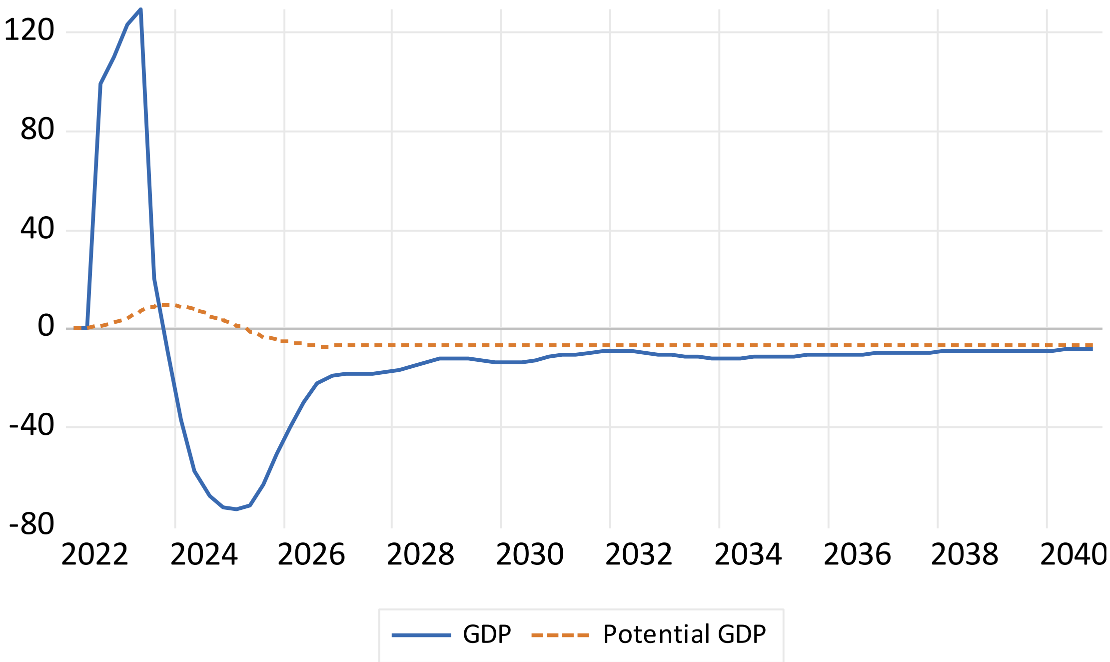
The policy experiment is an increase in real federal government consumption and investment above baseline of $100 billion per year from the third quarter of 2022 through the second quarter of 2023.

The adjustment of *r** is reduced by 25 percent in the fourth quarter of 2022, by 50 percent in the first quarter of 2023, and by 75 percent in the second quarter of 2023.

Figure 14. [Return to Text]

Effect on GDP of Increased Federal Spending When Supply Is Constrained

Change from baseline, billions of 2012 dollars; Taylor rule with partially endogenous *r**



Source: Congressional Budget Office.

The policy experiment is an increase in real federal government consumption and investment above baseline of $100 billion per year from the third quarter of 2022 through the second quarter of 2023.

The adjustment of *r** is reduced by 25 percent in the fourth quarter of 2022, by 50 percent in the first quarter of 2023, and by 75 percent in the second quarter of 2023.

GDP = gross domestic product.