Chapter 2: The New Keynesian Framework

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I. The Textbook NK Model

A. *Description of the model*

This section presents the textbook New Keynesian (NK) model (Galì (2015)). We will leverage this model to quantitatively study economic fluctuations and macroeconomic policies. The economy has an infinite horizon and admits a representative agent. In the economy, there is no aggregate risk. Markets are complete and households trade a real asset A_t subject to a natural borrowing limit ϕ. Given a real wage w_t, the real interest rate r_t and firms' profits D_t, decide how much to consume and work by solving

$$\max_{\{C_t, A_t, L_t\}} \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma}}{1-\gamma} - \varphi \frac{L_t^{1+\nu}}{1+\nu} \right)$$

$$\text{s.t.} \quad C_t + A_t = w_t L_t + (1+r_t)A_{t-1} + D_t, \qquad \forall t,$$

$$A_t \geq -\phi, \quad \forall t.$$

In the CRRA utility function, γ is the inverse of the intertemporal elasticity of substitution, and ν is the inverse of the Frisch elasticity of labor supply. The first order conditions with respect to the control variables $\{A_t, C_t, L_t\}$ yields

$$C_t^{-\gamma} = \beta(1+r_{t+1})C_{t+1}^{-\gamma}, \tag{1}$$

$$\varphi L_t^{\nu} = w_t C_t^{-\gamma}. \tag{2}$$

Equation (1) is the Euler equation. This condition sets the marginal utility of consumption today equal to the marginal utility of saving. Formally, is a first-order difference equation that determines the path of consumption given the real interest rate r_t and household time preferences via the discount factor β. Equation (2) is an intratemporal equilibrium condition that determines household labor supply decisions. This condition sets the marginal rate of substitution between labor and consumption $\varphi L_t^{\nu}/C_t^{-\gamma}$ equal to the real wage. Intuitively, household disutility from labor must be equal to the marginal gain of labor supply. The flow budget constraint determines the evolution of household assets given the optimal consumption and labor supply decisions. This is the household block of the model. Next, we turn to firms' decisions and the supply block of the model.

A representative firm produces a final good using a continuum of intermediate inputs indexed by $i \in [0, 1]$. The representative firm produces the final good in perfect competition to maximize profits given the production technology. The production function is a CES aggregator. Specifically, the firm's optimization problem is

$$\max_{Y_{it}} \quad P_t Y_t - \int_0^1 P_{it} Y_{it} di,$$

$$\text{s.t.} \quad Y_t = \left(\int_0^1 Y_{it}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}.$$

The first order condition and the zero profit condition imply the following demand system

$$Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} Y_t, \tag{3}$$

$$P_t = \left(\int_0^1 P_{it}^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}. \tag{4}$$

Intermediate producers demand labor N_{it} to minimize production costs $w_t N_{it}$ subject to the linear technology $Y_{it} = N_{it}$. The first-order condition implies that

$$mc_t = w_t.$$

The intermediate producers also maximize nominal profit subject to the market demand and quadratic cost of price adjustment. These firms use market real interest rate to discount profits. The discount factor is given by $Q_{t+1} := Q_t(1 + r_{t+1})^{-1}$ with $Q_0 = 1$ and total production costs are given by $\psi_{it}(Y_{it})$.

$$\max_{\{P_{it}\}} \quad \sum_{t=0}^{\infty} \left[Q_t \left(P_{it} \frac{Y_{it}}{P_t} - \frac{\psi_{it}(Y_{it})}{P_t} - \frac{\theta}{2} \left(\frac{P_{it}}{P_{it-1}} - 1 \right)^2 Y_t \right) \right]$$

$$\text{s.t.} \quad Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} Y_t, \forall t.$$

The first order condition and the symmetry conditions $P_t = P_{it}, Y_{it} = Y_t$ yields a New Keynesian Phillips Curve (NKPC) given by $(\varepsilon - 1) = \varepsilon mc_t - \theta(1+\pi_t)\pi_t + \theta[(1+r_{t+1})^{-1}(1+\pi_{t+1})\pi_{t+1} Y_{t+1} Y_t^{-1}]$. Let $\mu = \varepsilon/(\varepsilon - 1)$ and we can rewrite the NKPC as

$$(1 + \pi_t)\pi_t = \left(\pi_{t+1}(1 + \pi_{t+1}) \frac{1}{(1 + r_{t+1})} \frac{Y_{t+1}}{Y_t} \right) + \frac{\varepsilon}{\theta} \left(mc_t - \mu^{-1} \right). \tag{5}$$

We assume that households directly own the firms and earn real profits D_t. Moreover, we assume that the adjustment costs are "virtual", i.e. they only affect firms' behavior but do not imply a real waste of resources. Hence, the profits are given by $D_t = (1 - mc_t) Y_t$.

We close the model with the policy block. Monetary policy chooses the path of the nominal short-term interest rate $\{i_t\}$ following a simple Taylor rule (Taylor (1993))

$$i_t = i + \phi_\pi \pi_t + v_t, \tag{6}$$

where i is the nominal interest rate in the zero inflation steady state, $v_t \sim \text{AR}(1)$ is an unexpected monetary policy shock, and the Taylor principle $\phi_\pi > 1$ holds. We define the ex-post real interest rate as $1 + r_{t+1} := (1 + i_t)/(1 + \pi_{t+1})$ where $\pi_{t+1} := (P_{t+1} - P_t)/P_t$. This is the ex-post Fisher equation.

Equilibrium in the basic model. In the basic version of the model, we assume that bonds are in fixed net supply $B \geq 0$. In the basic NK model given prices $\{w_t, r_t, \pi_t\}$ households optimally decide $\{C_t, L_t, A_t\}$, firms choose $\{Y_t, N_t\}$ maximizing profits, and monetary policy sets the policy rate $\{i_t\}$ according to 6. Prices are such that the goods market, the financial market, and the labor market clear

$$C_t = Y_t, \quad \forall t$$

$$A_t = B, \quad \forall t$$

$$L_t = N_t, \quad \forall t.$$

By Walras's law one market-clearing equation or the household flow budget constraint is redundant. As a convention in this note I will simply use N_t everywhere implicitly assuming labor market clearing.

Equilibrium with fiscal policy. We can introduce fiscal policy in the basic model. To this end, the government budget constraint is given by

$$B_t = (1 + r_t)B_{t-1} + G_t - T_t - \tau_t w_t N_t, \tag{7}$$

where B_t is the real value of short-term government bonds, G_t is public expenditure, τ_t a distortionary linear labor income tax rate, and T_t lump-sum (non-distortionary) taxes. So, household net earnings now reads $(1 - \tau_t)w_t N_t - T_t$ and household labor supply is given by $\varphi N_t^\nu / C_t^{-\gamma} = (1 - \tau_t)w_t$. The government has three main fiscal instruments $\{G_t, \tau_t, B_t\}$. We assume that either taxes or government spending need to adjust to balance the intertemporal government budget constraint. Hence, either $\{\tau_t\}$ or $\{G_t\}$ is a function of the level of public debt B_t. Importantly, we also assume that government spending is a pure waste of resources, i.e. it only enters in Equation (7) and in the good market clearing condition $C_t + G_t = Y_t$. Now the asset market equilibrium is given by $A_t = B_t$. The other equilibrium conditions remain unchanged and the equilibrium definition closely follows the equilibrium definition of the basic model.

B. *A discussion of the model*

In the neoclassical growth model with TFP shocks Z_t. The Euler equation, the optimal labor supply condition, the first order conditions of the firm, and market clearing determine $\{C_t, N_t, A_t\}_{t=0}^{\infty}, \{w_t, r_t\}_{t=0}^{\infty}$ as a function of $\{Z_t, K_t\}_{t=0}^{\infty}$. In those models we can determine the equilibrium of the real variables without any reference to nominal variables. It turns out that this is the case also for neoclassical monetary models with nominal variables such as the price level P_t, and money or nominal currency M_t. For example, models with money in the utility function, and models with cash-in-advance constraints. In all these models money is almost always neutral and monetary policy has no real effects.[1] The key ingredient of the NK model is the introduction of nominal price rigidities. The NKPC links nominal variables to real variables breaking monetary neutralites in the short-run.

The Taylor principle is given by $\phi_\pi > 1$. This conditions implies that there is a unique local solution of the model or that the equilibrium is locally determinate, i.e. rules out multiple equilibria around the steady state of the model. To understand this point we need to revisit some of the history of the model. Sargent and Wallace (1975) using a simple linear model with rational expectations and argue that an exogenous path $\{i_t\}$ leads to multiple and stable solutions for $\{P_t\}$. Bullard and Mitra (2002), Woodford (2003), Galì (2015) show how interest rates policies $\{i_t\}$ with at least an endogenous component as in Equation (6) can solve the local multiplicity problem. To see this, consider first the case in which the central bank sets $\{i_t\}$ exogenously and the linearized ex-ante Fisher equation is $r_t = i_t - \pi_{t+1}$. Given the policy $\{i_t\}$ and $\{r_t\}$ from the equilibrium condition of the asset market, only future inflation (expected inflation) is pinned down π_{t+1} or $E_t\pi_{t+1}$ in an economy with aggregate risk. There are no other equilibrium equations to determine actual inflation π_t. This implies that there are multiple equilibria. Specifically, all the equilibria are indexed by an initial condition π_0 or in a model with aggregate risk by a prediction error u_t such that $\mathrm{E}_t u_{t+1} = 0, \forall t$ so that $E_t\pi_{t+1} = \pi_{t+1} + u_{t+1}$. Since this initial condition (random variable u_t) is unrelated to the economic fundamentals is also called sunspot shock. Allowing for an endogenous policy response is an appealing solution for two reasons. First, fits the data as central banks respond to inflation. Second, delivers a unique local solution. To see this point, suppose that instead the central bank sets $\{i_t\}$ endogenously according to $i_t = \phi_\pi \pi_t$ where $\phi_\pi \geq 0$. Using a linearized version of the Fisher equation $\phi\pi_t = \pi_{t+1} + r_t$. If $\phi > 1$ then we can solve the difference equation forward to obtain

$$\pi_t = \sum_{j=0}^{\infty} \phi^{-j-1} r_{t+j}.$$

Another important aspect of the NK model is how we model monetary and fiscal interactions. Consider the version of the model with both monetary and fiscal policy.

[1] Even in models with money in the utility function and nonseparable preferences money is quantitatively neutral.

If the government adjusts its policy to ensure intertemporal budget balance then monetary policy is free to set $\{i_t\}$. A second policy regime is one in which the government sets $\{G_t, \tau_t\}$ without any attention to intertemporal budget balance, as a consequence monetary policy must be adjusted to balance the budget of the public sector. Sargent (1982) defines the two regimes as Ricardian and non-Ricardian. Leeper (1991) as active monetary policy and active fiscal policy. If government sets the primary surplus to back a fraction $\psi \in [0, 1]$ of its debt that is $T_t - G_t = \psi((1 + r_t)B_{t-1} - B_t)$ or solving forward

$$\psi B_{t-1} = \sum_{j=0}^{\infty} R_{t,j}(T_{t+j} - G_{t+j})$$

where $R_{t,j} = \prod_{j=0}^{\infty}(1+r_{t+j})^{-1}$ under the stationarity condition $\lim_{j\to\infty} R_{t,j}\psi B_{t+j} = 0$, then $\psi = 1$ is the passive fiscal regime and $\psi < 1$ is the active fiscal regime. If $\psi < 1$ monetary policy should not react strongly to inflation $\phi_\pi < 1$ allowing inflation to reduce the real value of public debt, i.e. inflation is determined from the government budget constraint. Note that if $\psi = 1$ we cannot use this condition to pin down inflation because we need it to determine B_t given endogenous taxes $T_t = f(B_t)$ and an exogenous expenditure G_t. If $\psi < 1$ and $\{T_t, G_t\}$ are exogenous then the government budget provides an additional equilibrium condition to pin down $\{\pi_t\}$ without the Taylor Principle. These assumptions are not innocuous and affect the dynamics of the economy.

C. Numerical solution and calibration

We solve the model in sequence space and following the literature we focus on a linear approximation of the model around its steady state. First of all, note that we can reduce the basic NK model to a nonlinear dynamic system of equations given by

$$(1 + r_t)(1 + \pi_{t+1}) = 1 + i + \phi_\pi \pi_t + v_t,$$

$$Y_t = N_t,$$

$$(1 + \pi_t)\pi_t = \left(\pi_{t+1}(1 + \pi_{t+1})\frac{1}{(1 + r_{t+1})}\frac{Y_{t+1}}{Y_t}\right) + \frac{\varepsilon}{\theta}\left(mc_t - \mu^{-1}\right),$$

$$C_t^{-\gamma} = \beta(1 + r_{t+1})C_{t+1}^{-\gamma},$$

$$Y_t = C_t,$$

$$\varphi N_t^{\nu} = w_t C_t^{-\gamma}.$$

These are 6 equations with 6 endogenous variables $\{\pi, N, C, Y, w, r\}$ and bonds are in zero net supply $A_t = 0$. Figure 1 shows that given the unknowns $\{\pi, N\}$ and targets $H_1 := Y_t - C_t$ and $H_2 := \varphi N_t^{\nu} - w_t C_t^{-\gamma}$ we can revocer all the other variables.

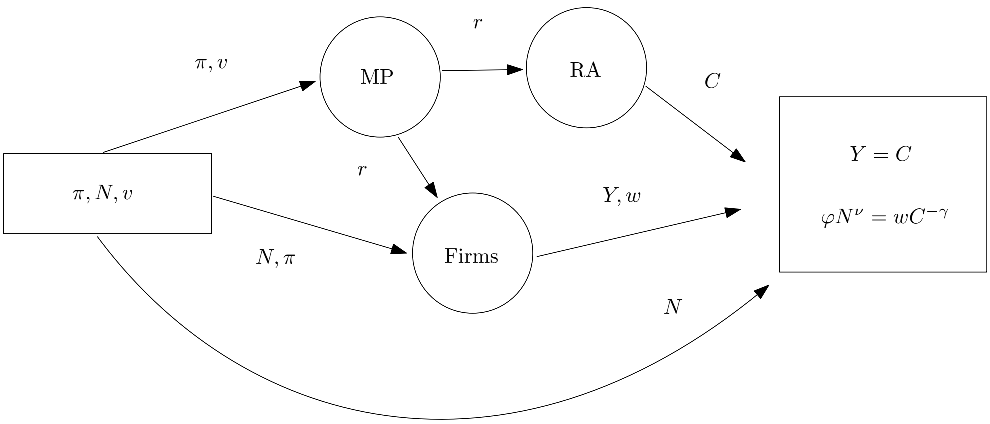

Figure 1: Graph of the basic New Keynesian model.

The structural parameters of the model are given by $\Theta = \{\gamma, \nu, \beta, \varphi, \varepsilon, \theta, \phi_\pi\}$. In the baseline calibration of the model I consider a zero inflation steady state $\pi = 0$. I set the discount factor β to 0.98, the coefficient of relative risk aversion γ to 1 (log-utility), and ν to 2 so that the Frisch elasticity of labor supply is 0.5. I do not rescale labor disutility. Thus, $\varphi = 1$. I also set the elasticity of substitution between intermediate goods ε to 10 so that the steady state profit share of aggregate income $1/\varepsilon$ is 10%. I choose the price adjustment cost parameter θ so that the slope of the price Phillips curve $\kappa := \varepsilon/\theta$ is equal to 0.1. Finally, ϕ_π is either 1.25 or 1.5. Table 1 summarizes this calibration. All these parameter choices correspond to standard values in the literature and are broadly consistent with empirical estimates. This type of calibration is often used in richer models to analyze the US economy at quarterly frequency.

Table 1: Parameters in the basic NK model

Parameter	Description	Value	Source
γ	CRRA/Inverse IES	1	External
ν	Inverse Frisch elasticity	2	External
ρ	Individual discount rate	0.02	External
θ	Adjustment costs	100	External
ε	Elasticity of substitution	10	External
ϕ_π	Taylor coeff.	1.25	External

II. Monetary Policy

Having calibrated the model we study the effects of monetary policy innovations. We assume that monetary policy shocks $\{v_t\}$ follow an AR(1) process with quarterly autocorrelation $\rho_v = 0.6$ as in the empirical VAR-based estimates. We consider an interest rate cut of 25 basis points, i.e. an exogenous reduction in the short-term nominal interest rate of 0.0025 or 1% annually. We leverage the basic NK model to compute structural impulse-response functions (IRFs) to this shock.[2]

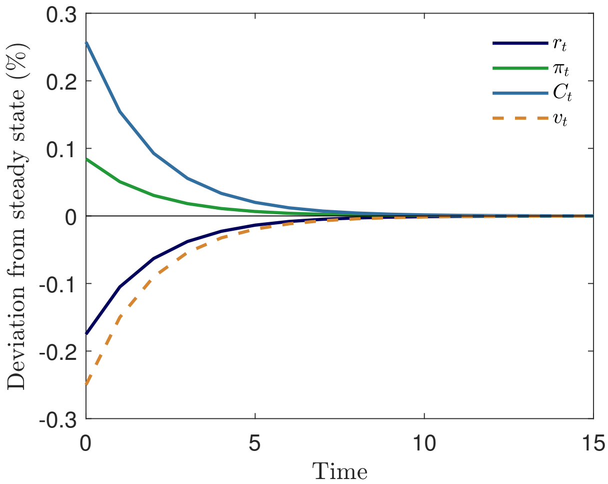

Figure 2: Monetary policy in the basic New Keynesian model.

Figure 2 plots the response of aggregate consumption (output), inflation, and the real interest rate, to the monetary policy innovation. In response to an expansionary monetary policy shock on impact the real interest rate falls, output increases via the Euler equation, and inflation rises via the Phillips curve. These results are qualitatively consistent with the empirical VAR literature on monetary policy shocks (Christiano, Eichenbaum, and Evans (2005)). Quantitatively the model matches the response of consumption but overstates the response of inflation. The endogenous or systematic component of the Taylor rule only partially offsets the reduction in the nominal interest rate, as a result the (ex-ante) real interest rate falls because of the lower nominal rate and higher future inflation (inflation expectations). In the simple NK model because of nominal rigidities the central bank can affect the real interest rate and via intertemporal substitution consumption and output. The Phillips curve is the key link between real and nominal variables in the model. For a detailed discussion on the mechanisms of the NK model see Rupert and Sustek (2019).

There are some limitations of the basic model that are important to highlight. In ad-

[2]For any outcome of interest Y_t we define the impulse response function as $IRF_t^Y := 100 * (Y_t - Y)/Y$ where Y is the steady state value. In the case of inflation and interest rates, I simply report percentage points deviations.

dition to the interest rate channel, monetary policy may affect the economy through other channels, e.g. money, credit, asset prices, and profits. All these channels are not present in the basic model in which intertemporal substitution is the main transmission mechanism of monetary policy to household expenditure and aggregate demand. Importantly, the response of profits in the model is at odds with the empirical evidence. In most of the calibrations, the model profits decline after an expansionary monetary policy shocks. On one hand, higher output increases firms' revenues and profits. On the other hand, the model features countercyclical markups $(1 - mc)$ because production costs increase more than prices reducing profits. Introducing sticky wages is a standard approach to solving or mitigating this problem.

III. Supply Shocks

The presence of sticky prices has also important implications for the response of profits and wages to productivity shocks and more broadly for the role of productivity shocks in driving economic fluctuations. In this section we revisit the effects of productivity shocks with a focus on aggregate employment and the distributional effects on wages and profits. To this end, we introduce a TFP shock Z_t following an AR(1) process in the basic NK model. Production is now given by $Y_t = Z_t N_t$ and marginal costs are $mc_t = w_t / Z_t$. Figure 3 shows the dynamics of the model after a 1% increase in productivity.

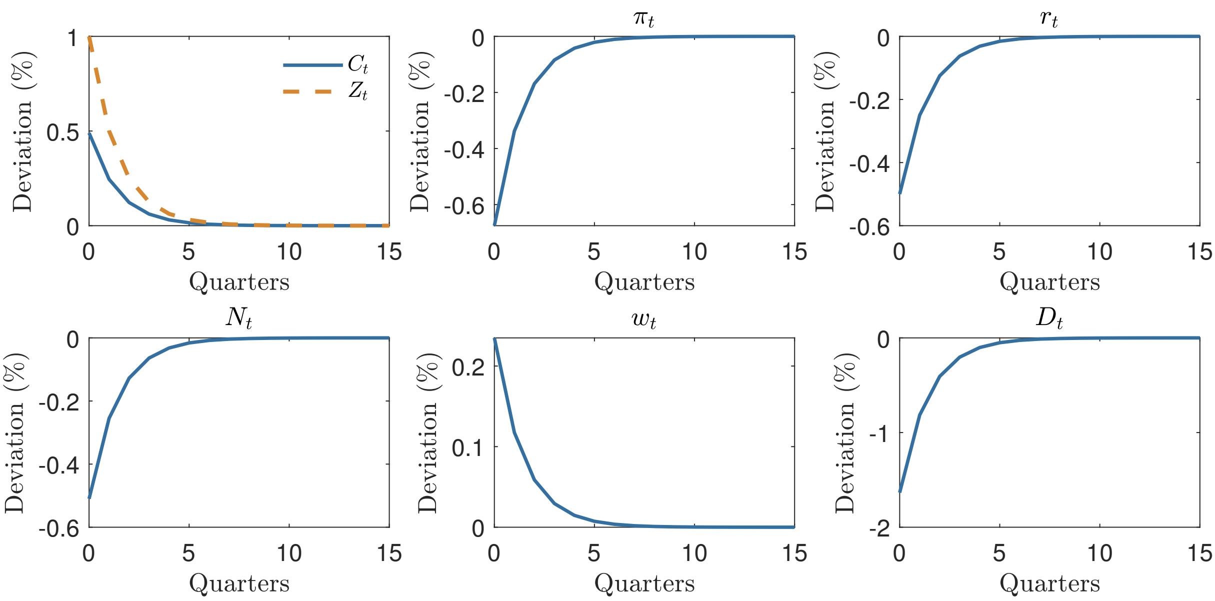

Figure 3: Productivity shock in the basic New Keynesian model with $\kappa = 0.5$.

In response to the productivity shock firms start reducing prices reflecting the lower production costs. However, since prices are sticky they also increase output. The central bank adjusts the nominal interest rate to the lower inflation rate, as a result the real interest rate declines increasing aggregate demand. The response of employment to productivity shocks is an important issue studied in the literature. Galì (1999) has argued that employment could fall in the short run in response to a positive productivity shock. The key implication is that productivity shocks cannot drive economic fluctuations. On one hand, firms need more labor services to increase output. On the other hand, higher labor productivity allows firms to produce the same output with fewer labor services. In the baseline calibration ($\kappa = 0.1$) and in a calibration with more flexible prices ($\kappa = 0.5$) the second effect dominates. In contrast with these results Christiano, Eichenbaum, and Vigfusson (2003) find that empirically productivity shocks increase employment. This suggests that other mechanisms or parametrizations are needed to generate an increase in employment. The sign of the response of real wages and profits depends on the degree of competition among firms and price rigidities. Under the baseline calibration ($\kappa = 0.1$) real wages fall after an increase in labor productivity, while if prices are flexible ($\kappa = 0.5$) real wages increase. In particular, there are two opposite effects. On one hand, higher labor productivity increases real wages lowering prices. On the other hand, higher productivity reduces production costs and firms can exploit their market power to increase profits rather than adjusting prices.

Another important supply shock studied in the literature is a "cost-push" shock. The idea is to capture in a reduced form supply bottlenecks and input shortages that increase production costs and inflation. To this end, we introduce a wedge s_t in the Phillips curve setting $mc_t = w_t + s_t$. Figure 4 shows the response of the economy to a 1% cost-push shock.

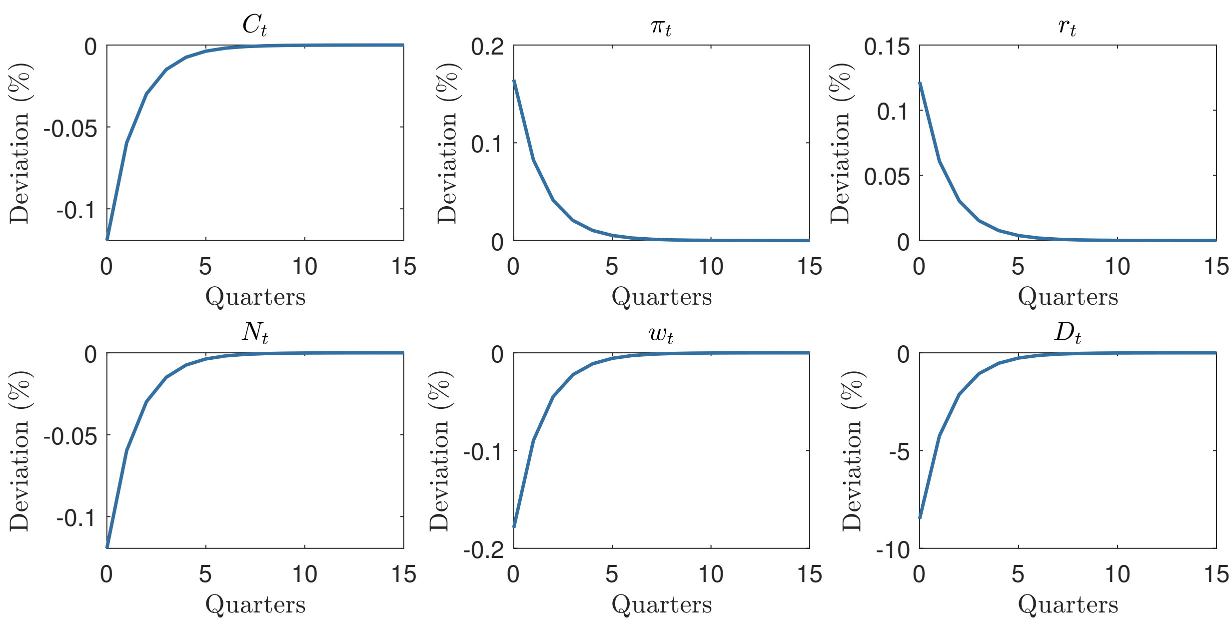

Figure 4: Cost-push shock in the basic New Keynesian model with $\kappa = 0.1$.

IV. Fiscal Policy

In this section we use the basic NK model to study the macroeconomic effects of fiscal policy on output and inflation. We begin following the simple analysis of the government spending multipliers in Woodford (2011). The government spending "multiplier" M_t is defined by the response of output to a government expenditure shock

$$dY_t = M_t dG_t.$$

Consider first the long-run multiplier with flexible prices. Note that the Phillips curve reduces to $mc_t = \mu^{-1}$ and we can determine $\{C, Y, N, w, r\}$ independently of the nominal block of the model $\{i, \pi\}$ (monetary neutrality). Moreover, if we pin down the real interest rate from the Euler equation we can further reduce the system of equilibrium conditions. Specifically, using $mc_t = w_t$, the production function, and the goods market clearing condition in the labor supply condition yields one nonlinear equation in Y_t given by

$$u'(Y_t - G_t) = \mu^{-1} v'(Y_t).$$

Totally differentiating this and using $u'(C_t) = \mu^{-1} v'(Y_t)$ delivers

$$\frac{dY_t}{dG_t} = \frac{u''(C_t)}{u''(C_t) - \mu^{-1} v''(Y_t)} = \frac{\eta_u}{\eta_u + \eta_v} \in (0,1),$$

where $\eta_u := -(u''(C_t)/u'(C_t))Y_t > 0, \eta_v >:= (v''(Y_t)/v'(Y_t))Y_t > 0$ are elasticities.

Intuitively government spending increases output and consumption levels. However, this increases the disutility from a higher labor supply. There is a crowding-out effect as private consumption partially offsets the increase in public consumption. Totally differentiating the above condition one can show that indeed $M_t \in (0,1)$. Now consider instead the opposite case, that is the short-run multiplier. In general, this multiplier depends on the reaction of monetary policy. So, to study the effects of government spending "keeping monetary policy unchanged" we can fix the real interest rate by setting $r_t = \rho$ this implies that $C_t = C_{t+1} = C$. Hence, $Y_t = C + G_t$ and the impact multiplier $M_t = 1$. In this case, we can solve for $\{Y, N, w, \pi\}$ holding the real rate and household consumption constant. Finally, we can add an exogenous endowment shock $\{G_t\}$ to the basic NK model without modeling how the government finance this shock. In this case the monetary policy reaction to higher inflation partially offsets the fiscal stimulus. Moreover, sticky prices imply a larger multiplier than the flexible price benchmark because of the higher real wages with countercyclical markups, but the impact multiplier is still less than one.

In the basic model we assumed that public expenditure is a pure waste of resources. If G_t also enters in the household utility function as complementary to private consumption C_t or takes the form of public investments in productive capital then the multiplier can be larger than in the basic model.

Next, we analyze the NK model with a fully-fledged fiscal policy as defined in Section A. In particular, the government can choose the path of public debt $\{B_t\}$, public expenditure $\{G_t\}$, lump-sum taxes $\{T_t\}$, and income taxes $\{\tau_t\}$. We study a set of four different fiscal policies. First, we study an increase in government spending G_t financed through public debt and assume that income taxes slowly adjust over the years to balance the government budget according to

$$\tau_t = \tau \left(\frac{B_t}{B} \right)^{\eta},$$

where η controls the speed of the tax adjustment. The second policy consists of the same increase in G_t financed by higher income taxes. In this case

$$\tau_t = (r_t B + G_t)/w_t N_t,$$

so that public debt remains fixed at the steady state level. A third policy uses public debt to finance the increase in G_t and lump-sum taxes T_t, instead of distortionary income taxes, to stabilize public debt. Finally, a fourth policy finances the increase in government spending by increasing lump-sum taxes without changing the level of public debt.

In all these cases I use the baseline calibration from Section C. Moreover, I set the steady state tax rate τ to 0.3, and calibrate B to match a public debt to annual output ratio equal to 100% at the steady state. I set steady state lump-sum taxes $T = 0$. All four fiscal policies have the same government spending shock. Specifically, G_t follows an AR(1) process with autoregressive coefficient $\rho_G = 0.6$. This value implies that the spending shocks last for 2 years assuming that on impact government spending increases by 1% of its steady state value. I choose the speed of fiscal adjustment γ_B so that the increase in public is fully repaid after 15 years, this yields a γ_B equal to 2.8. Table 2 summarizes this parametrization.

Table 2: Fiscal parameters in the NK model

Parameter	Description	Value	Source
γ_B	Tax adjustment	2.8	Internally calibrated
ρ_G	Autoregressive coefficeint	0.6	Internally calibrated
τ	Average labor income tax rate	0.3	External
B	Public debt	3.4	Internally calibrated

Figure 5 plots the responses of the economy to the first policy: an increase in government spending financed through public debt with income taxes gradually adjusting to repay the debt. The left panel shows the response of public debt as a percentage of steady state annual output b_t, the percentage points deviations of the real interest rate r_t and the inflation rate π_t from the steady state, the response of the primary surplus relative to steady state annual output s_t, and a counterfactual primary surplus without tax adjustment (dashed line). The right panel shows the responses of consumption and output relative to their steady state values and the government spending shock.

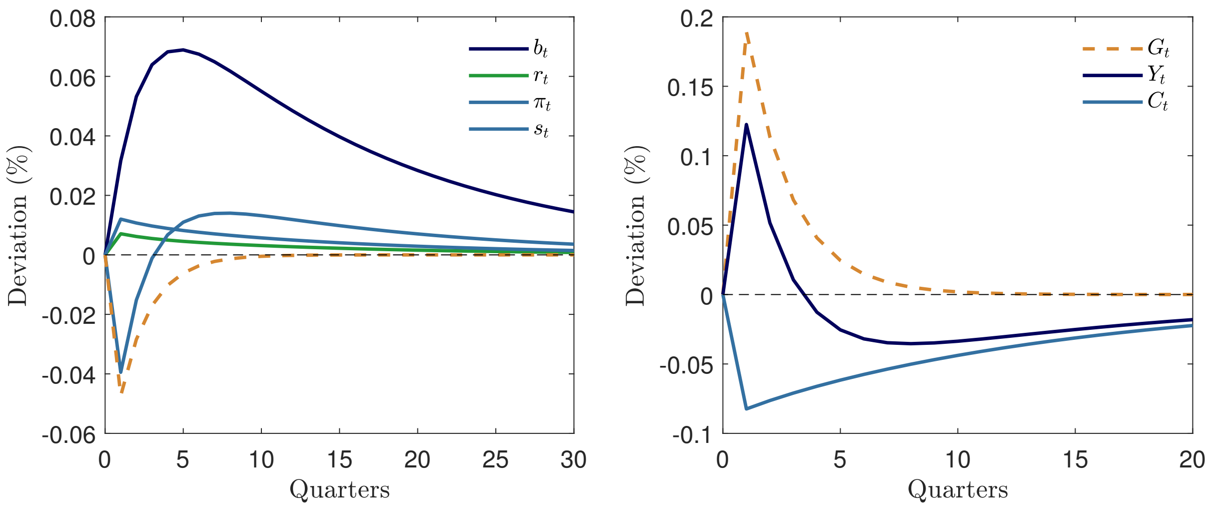

Figure 5: Fiscal stimulus in the New Keynesian model.

The increase in public debt is very persistent as the debt used to finance the increase in government spending is fully repaid after 15 years. The primary surplus s_t falls on impact and over time increases to stabilize the public debt. This policy increases output even though to a lesser extent than the increase in public expenditure ($M_t < 1$) because of the crowding out effect of public spending on private consumption. Importantly, this policy expands the tax base. Note that real wages and labor supply increase raising households' gross earnings $w_t N_t$ and government revenues this "self-financing" effect of the policy further contributes to the reduction of public debt. Moreover, inflation rises and monetary policy responds by increasing the real interest rate further reducing the expansionary effects of fiscal policy. In this model, the impact fiscal spending multiplier ($t = 1$) is 0.64. If monetary policy is constrained, e.g. because the nominal interest rates reach the zero lower bound (liquidity trap), the fiscal multipliers can be substantially higher (larger than 1). Similarly, in an active fiscal policy regime the central bank accommodates the spending shock and the government budget is stabilized through a combination of higher income taxes and inflation increasing the fiscal multiplier. This simple example shows how important are the monetary and fiscal interactions for the macroeconomy.

Figure 6 shows the response of output and taxes to a persistent shock in G_t when the government uses lump-sum taxes to finance the increase in spending. In one case the public debt is used to finance the deficit and lump-sum taxes gradually adjust to repay the debt (B adjusts). In the other case, lump-sum taxes adjust on impact keeping public debt constant (T adjusts). These are respectively policies 3 and 4.

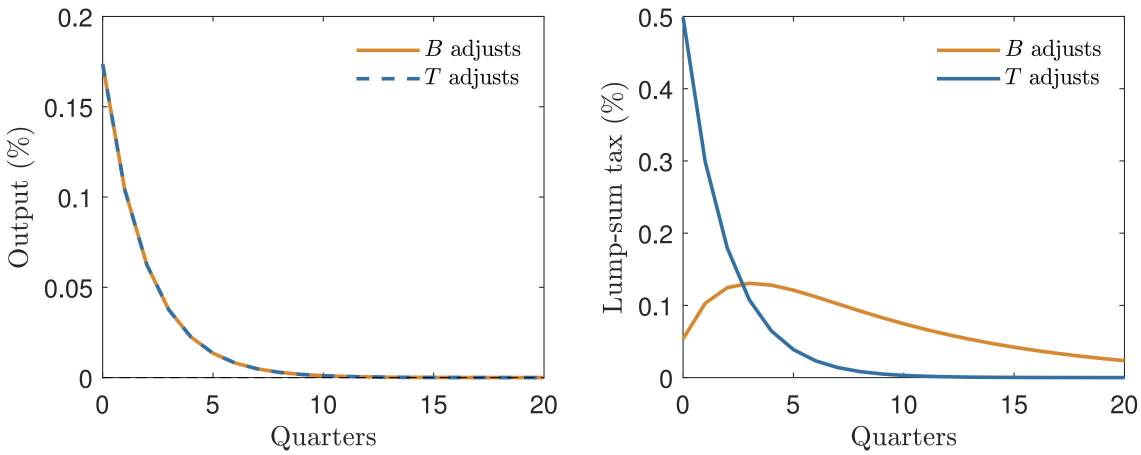

Figure 6: Ricardian equivalence in the New Keynesian model.

First of all, note that in the case of non-distortionary taxation the output response is the same regardless of how the deficit is financed, i.e. Ricardian equivalence holds. Intuitively, households are forward-looking and anticipate that the government will increase taxes in the future to repay the debt. Households fully internalize the government budget constraint and the bond market clearing condition in their budgets and adjust consumption-saving plans accordingly by reducing consumption and saving any income gain to repay taxes. Note that in the model there are no income effects on household consumption from temporary income fluctuations as consumption is determined by the Euler equation and the real interest rate. Therefore, the timing of taxes and the specific path $\{T_t\}$, i.e. whether taxes are frontloaded or smoothed over time, is irrelevant.

The Ricardian proposition breaks down easily. Suppose that households do not fully anticipate fiscal adjustments far in the future or that there are heterogeneous households and it is not obvious how the fiscal burden will be distributed. In the first case, households need to form expectations about fiscal policy and these expectations may not incorporate tax changes for 20 years in the future or it might require a learning process. In the second case, there could be liquidity constraints, different generations, or behavioral factors that make households adjust consumption expenditures when their income changes, and with such income effects the timing of taxes also matters. Moreover, if the government uses distortionary taxes the equivalence fails as the taxes shape labor supply decisions.

Figure 7 plots the response of output and taxes to the government spending shock under policies 1 and 2. In the former case, the government uses public debt to finance the fiscal deficit and income taxes to stabilize public debt (B adjusts). In the latter case, the government uses income taxes to finance the increase in spending keeping public debt constant (τ adjusts).

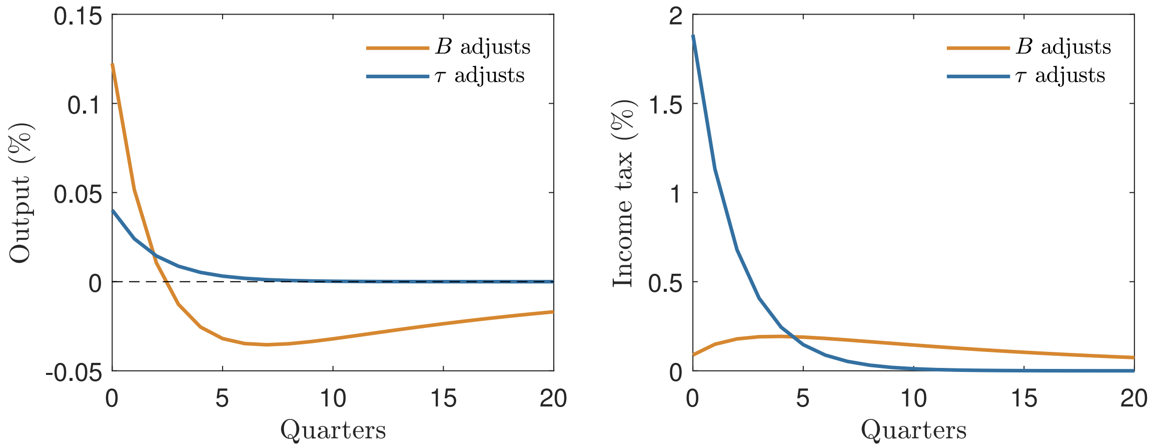

Figure 7: Income taxes in the New Keynesian model.

If the government uses distortionary taxes the timing of the fiscal adjustment matters. Adjusting public debt provides more stimulus in the short run than a fiscal expansion financed with frontloaded income taxes. In this model, a fiscal expansion financed with debt "borrows demand from the future" as the increase in output in the first years is offset by higher income taxes and lower labor supply in the following years. Note that this effect is not present with non-distortionary income taxes (Figure 6).

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