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Understanding Inflation Dynamics: The Role of Government Expenditures

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Abstract

This paper studies the impact government expenditure has on inflation by examining an augmented Phillips curve implied from a structural New Keynesian model. Our estimation results, based on external instruments, show that the augmented Phillips curve has a flatter slope than the canonical specification and that government expenditure has a negative coefficient. Changes in government expenditure account for a substantial portion of inflation variations and provide new insights into the "missing disinflation" puzzle. We also find that inflation and inflation expectations respond negatively to fiscal spending shocks, reaffirming the supply-side channel through which inflation responds to fiscal expansions.

Topics: Inflation and prices; Fiscal policy; Central bank research
JEL codes: E3, E62, E63

Résumé

Dans cette étude, nous examinons l'incidence des dépenses publiques sur l'inflation au moyen d'une courbe de Phillips augmentée issue d'un modèle structurel de type nouveau keynésien. Les résultats de notre estimation, basée sur des instruments externes, montrent que la courbe de Phillips augmentée est plus plate que la courbe classique et que les dépenses publiques ont un coefficient négatif. Les variations des dépenses publiques représentent une part importante des variations de l'inflation et fournissent un nouvel éclairage sur l'énigme de la « désinflation manquante ». Nous observons aussi que l'inflation et les attentes d'inflation baissent en réponse aux chocs de dépenses publiques, ce qui confirme de nouveau le canal tributaire de l'offre par lequel l'inflation réagit aux expansions budgétaires.

Sujets : Inflation et prix; Politique budgétaire; Recherches menées par les banques centrales
Codes JEL : E3, E62, E63

1 Introduction

Inflation has always been of keen interest to economists and policymakers, particularly with the recent spurt of inflation and concerns about post-pandemic stagflation. Whereas fiscal stimulus was widely implemented throughout the world during the pandemic and has become a more common tool since the Great Recession, the channel through which it affects inflation is still under debate. This paper aims to explore how government expenditure affects the Phillips curve, a fundamental relationship between economic slack and inflation, and its implication for inflation dynamics.

The literature has long debated whether the Phillips curve has flattened, disappeared, or is still alive but "hibernating."[1] In particular, recent experiences since the Great Recession have cast doubt on the traditional Phillips curve, as inflation did not drop much during high unemployment or rise much during low unemployment (see, e.g., Coibion and Gorodnichenko, 2015; Constâncio, 2016). A similar debate raged in the late 1990s when a low unemployment rate did not come with a rise in inflation. These decoupling observations between inflation and unemployment challenge our understanding of inflation dynamics, particularly to what extent the conventional Phillips curve can account for inflation dynamics.

This paper studies the Phillips curve and adds to the debate by incorporating fiscal policy—specifically, government expenditure—in determining the theoretical form of the Phillips curve and its empirical slope coefficient, which gauges the sensitivity of inflation to changes in unemployment. More importantly, we highlight the role of government expenditure in understanding inflation dynamics via the Phillips curve and provide an alternative explanation for the so-called "missing disinflation" puzzle following the Great Recession. We show that government expenditure contributes to a significant variation in inflation, nearly to the same extent to which the economic slack does. To further explore the effects of fiscal spending on inflation in general equilibrium, we conduct local projections to estimate the impulse responses of inflation and inflation expectations to government expenditure shocks.

In a standard New Keynesian model with government expenditure (e.g., Woodford, 2011), we

[1] Studies using various empirical strategies have obtained different estimates for the slope of the Phillips curve (i.e., the sensitivity of price inflation to changes in unemployment or the output gap). Among others, Mishkin (2007), Blanchard (2016), Hooper, Mishkin and Sufi (2020), Del Negro et al. (2020), and Stock and Watson (2020) have documented a flattening Phillips curve since the late 1970s. Jørgensen and Lansing (2019), by endogenizing inflation expectations, suggest a stable (and relatively large) slope for the Phillips curve since the 1960s, while Hazell et al. (2022), by exploiting US regional variations, find a stable (and relatively small) slope since the late 1970s. Despite many studies in recent years suggesting a flat Phillips curve, Barnichon and Mesters (2020) and McLeay and Tenreyro (2020), among others, recover a relatively steep Phillips curve, using different empirical approaches.

show the Phillips curve predicts that inflation not only responds to changes in economic slack and inflation expectations but also to changes in government expenditures. In particular, government expenditure enters the Phillips curve with a negative coefficient due to the wealth effect on labor supply. Furthermore, we show that whereas the response of output to a fiscal spending shock is always positive in general equilibrium, the response of inflation is not necessarily positive, depending on various factors such as the persistence of the fiscal shock and the monetary policy reaction function. For instance, when the spending shock is highly persistent, the response of inflation is more likely to be negative.[2]

The Phillips curve with government expenditure also implies that the canonical estimation of the slope of the Phillips curve is subject to the problem of missing variables by abstracting from fiscal spending. Figure 1 shows the unemployment rate in the United States against changes in total US government spending since the 1960s. Since the early 1980s, the period with an arguably flattening Phillips curve, unemployment has been positively correlated with changes in government expenditure, implying a biased estimate of the slope of the Phillips curve if one does not consider fiscal spending. In addition, the more recent development of Phillips curve estimation using demand-shock IVs, such as high-frequency identified monetary policy shocks, to address the endogeneity issue of economic slack with respect to supply shocks does not mitigate the endogeneity problem resulting from missing the variable of government expenditure.[3] Because government expenditures may endogenously respond to changes in monetary policy, such IVs violate the exogeneity condition when government expenditure is part of the error term.

Directed by a theoretically implied Phillips curve with government expenditure, we estimate the Phillips curve using aggregate US data including inflation, inflation expectations, the unemployment gap, and a measure of government expenditure. To address the potential endogeneity of the unemployment gap and government expenditure with respect to supply shocks, we instrument the explanatory variables with a vector of exogenously identified monetary policy shocks and various measures of defense spending shocks. We show that using monetary policy shocks alone is subject to the weak instrument problem, whereas using both sets of shocks passes the weak IV tests proposed in the literature.

We underscore two main results. First, our estimated slope of the augmented Phillips curve

[2]The estimated persistence of fiscal spending shocks for the US is indeed large with a value around 0.95 (see, e.g., Smets and Wouters, 2007; Jørgensen and Ravn, 2022).

[3]See Mavroeidis, Plagborg-Møller and Stock (2014) for a comprehensive survey of the early empirical studies of the Phillips curve using aggregate data.

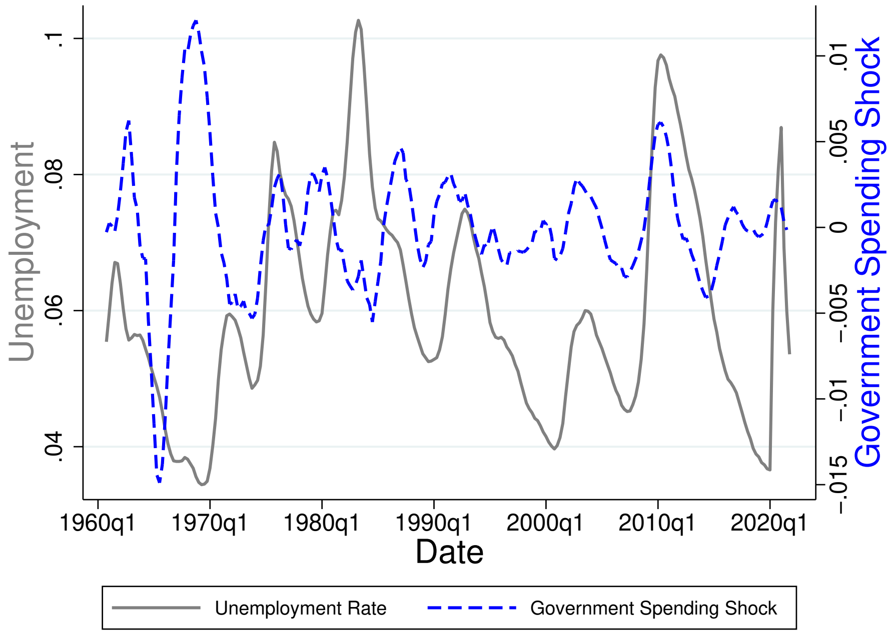

Figure 1: Unemployment Rate and Changes in Government Expenditure

Notes: This figure shows the four-quarter moving average of the unemployment rate against the fluctuation in total government spending, measured by the HP-filtered cyclical component of government expenditure over potential GDP. The unemployment rate comes from the BLS, and government expenditure is constructed using the BEA's "Real Government Consumption Expenditures and Gross Investment" data.

is significantly smaller than the slope found using traditional specifications without government expenditure, that is, omitting the fiscal expenditure variable significantly biases estimates of the Phillips curve coefficient. Second, the coefficient of government expenditure is significantly negative, consistent with the theoretical predictions for the supply curve. Our results are robust to alternative measures of inflation, government expenditure, and defense spending shocks, as well as alternative estimation specifications. In addition, we also estimate the Phillips curve by exploiting regional variations and discuss how it relates to the findings based on aggregate data.

These two results have strong implications for inflation dynamics. While a negative coefficient on government expenditure implies an even stronger decline in inflation during recessions because government expenditure tends to be strongly countercyclical, a smaller Phillips curve coefficient implies that inflation is tied much less to economic slack, measured by unemployment gaps, in a model with government expenditure. We proceed to show that taking government expenditure into account resolves the so-called "missing disinflation" puzzle in the literature, in which traditional estimations of the Phillips curve typically cannot explain the relatively high level of inflation right after the Great Recession when the unemployment rate was still high. Predicted inflation from our baseline model precisely captures the inflation in this period due to diminishing government expenditure. As such, the inclusion of government expenditure in the Phillips curve leads to more accurate predictions of inflation, especially since the Great Recession when standard models have been most disconnected from the data.

Our result is also particularly relevant for inflation dynamics following the onset of the COVID-19 pandemic, a period in which governments made extensive use of fiscal stimulus packages. We show that predicted inflation in 2020 using pre-2020 Phillips curve estimates is more accurate within the model featuring government expenditure in the Phillips curve. Overall, we highlight the important yet less-studied role of government expenditure in shaping inflation dynamics.[4]

In addition to the supply-side estimation, we further conduct local projections following Jordà (2005) and Ramey and Zubairy (2018) to estimate the impulse responses of inflation and inflation expectations to government expenditure shocks. Methodologically, this local projection exercise should deliver a result consistent with studies that estimate the effect of fiscal spending on inflation through VARs in a DSGE model. We find a persistent negative response of inflation and inflation expectations to fiscal spending shocks. We show this seemingly counter-intuitive result can be rationalized by a simple New Keynesian framework with government expenditure à la Woodford (2011) and Christiano, Eichenbaum and Rebelo (2011), as long as the monetary policy reaction function responds not only to inflation but also to economic slack. By further differentiating between periods in which the nominal interest rate was binding at the zero lower bound (ZLB) and when it was not, we show that this negative response is mainly driven by the non-binding ZLB periods.[5]

Literature. Our paper contributes to the large body of literature studying the New Keynesian Phillips curve (NKPC). The literature has generally developed three strategies for estimating the slope of a Phillips curve: (i) reduced-form estimation using aggregate data, either controlling for supply shocks or estimating via instrumental variables (e.g., Gordon, 2013; Mavroeidis, Plagborg-Møller and Stock, 2014; Barnichon and Mesters, 2020), (ii) reduced-form estimation by exploiting regional variations (e.g., Fitzgerald and Nicolini, 2014; Hooper, Mishkin and Sufi, 2020; McLeay and Tenreyro, 2020; Hazell et al., 2022), and (iii) estimating the slope of the Phillips curve in a fully

[4]The US government also implemented large-scale fiscal transfers to households during the Great Recession and the COVID-19 pandemic. These transfer policies may have had a positive impact on inflation by stimulating aggregate demand (e.g., Pennings, 2021; Woodford and Xie, 2022). However, since our focus here is not specific to the crisis episodes, we leave the effect of fiscal transfers on inflation for future study.

[5]Our findings are consistent with Miyamoto, Nguyen and Sergeyev (2018) in which the response of inflation to a fiscal spending shock is larger in ZLB periods than otherwise.

specified New Keynesian DSGE model through VARs (e.g., Del Negro, Giannoni and Schorfheide, 2015; Del Negro et al., 2020). McLeay and Tenreyro (2020) have summarized the existing literature and compared these three approaches. Our paper directly contributes to the reduced-form estimation strategy by emphasizing the endogeneity issue resulting from ignoring fiscal spending and finds that the Phillips curve flattens after controlling for government expenditure. Whereas the literature has paid special attention to inflation expectations in the Phillips curve,[6] our findings highlight the importance of government expenditure as a new element in studying the Phillips curve.

Our findings also suggest that estimating the Phillips curve using demand-shock IVs, such as high-frequency identified monetary policy shocks, as recently emphasized in Barnichon and Mesters (2020), does not solve the endogeneity problem resulting from missing the variable of government expenditure. We show that using identified monetary and fiscal policy shocks as IV for the unemployment gap, together with adding government expenditure as an explanatory variable, can yield an unbiased estimate. In particular, to address the concern of endogenous fiscal spending, we use exogenous defense spending shocks as an instrument, following Nakamura and Steinsson (2014) and Ramey and Zubairy (2018), or the alternative fiscal shocks constructed in Ramey (2011).

This paper emphasizes the role of government expenditure in augmenting the Phillips curve's ability to account for inflation dynamics. Recent literature has proposed several alternative explanations for the "missing disinflation" puzzles such as anchored inflation expectations (e.g., Carvalho et al., 2023),[7] financial frictions (Del Negro, Giannoni and Schorfheide, 2015), nonlinearities (Harding, Lindé and Trabandt, 2022), and downward nominal wage rigidity (Mineyama, 2021). Our work is complementary to the literature, showing that these puzzles can be resolved within the standard New Keynesian framework by accounting for fiscal spending.

Our work is also closely related to the literature investigating the overall effect of government expenditure on inflation. As summarized in Ferrara et al. (2021) and Jørgensen and Ravn (2022), the empirical findings in the literature are ambiguous—some papers suggest fiscal spending has a positive effect on inflation while others find negative or insignificant effects. We contribute to the discussion by illustrating the role of government expenditure in shaping inflation dynamics through the lens of the Phillips curve. Furthermore, to link to the structural estimates in the literature,

[6] See Mavroeidis, Plagborg-Møller and Stock (2014) for a survey of early work. More recent studies include Coibion and Gorodnichenko (2015) and Hazell et al. (2022), and others.

[7] Among others, also see Ball and Mazumder (2011), Coibion and Gorodnichenko (2015), and Jørgensen and Lansing (2019).

we also conduct local projections to estimate the impulse responses of inflation to changes in government expenditure and add evidence to those studies that find negative responses in inflation.

The rest of the paper proceeds as follows. Section 2 introduces a general form of the New Keynesian Phillips curve with government expenditure and discusses its implication for empirical estimation. Section 3 discusses our empirical strategy and presents the empirical results of estimating the Phillips curve using aggregate US data. We also link the aggregate result to the estimates using regional data. Section 4 compares the fit of the estimated Phillips curves with and without government expenditure to the data and shows that fiscal spending provides a natural explanation for the inflation puzzle since the Great Recession. Section 5 shows the impulse responses of inflation and inflation expectations to spending shocks estimated by local projections. Section 6 concludes the paper.

2 The Phillips Curve with Government Expenditure

We study the role of government expenditure in driving inflation dynamics through the New Keynesian Phillips curve, building upon the approach developed in Woodford (2011). In this section, we first briefly lay out the derivation of the NKPC with government expenditure in a closed economy and then discuss how the empirical estimation of the Phillips curve will be biased if one abstracts from fiscal spending. We further show that an (exogenous) increase in government expenditure downward shifts the Phillips curve, whereas its effect on inflation in general equilibrium is ambiguous, depending on many factors including the persistence of the fiscal spending shocks and the rule of monetary policy.

2.1 The Augmented New Keynesian Phillips Curve

In a standard New Keynesian model with Dixit-Stiglitz monopolistic competition among firms and subject to sticky prices in terms of the Calvo pricing (see Galí 2015, chap. 3), the optimal pricing problem of firms yields a log-linearized form of the NKPC given by

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \lambda \widehat{mc}_t + \mu_t, \tag{2.1}$$

where $\pi_t \equiv \log(P_t/P_{t-1})$ denotes aggregate inflation, $\widehat{mc}_t$ denotes the log-deviation of the economy's average real marginal cost of production from the steady state, and μ_t denotes cost-push shocks. The parameter λ is a constant measuring the degree to which inflation responds to the changes in the real marginal cost.[8] The Phillips curve (2.1) holds regardless of whether government expenditure is abstracted or not.

We now elaborate on the expression for the average real marginal cost of production in the Phillips curve (2.1) by taking government expenditure into account. Consider an infinite-lived representative household that maximizes the objective function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [u(C_t) - v(H_t)], \tag{2.2}$$

where C_t represents the quantity of composite consumption goods in period t and H_t represents the hours of labor supplied in period t. The budget constraint of the household is given by

$$P_t C_t + Q_t B_t = B_{t-1} + W_t H_t + \Phi_t,$$

where P_t is the price of the composite consumption good in period t, B_t is the quantity of one-period riskless nominal bonds with price Q_t in period t that mature in period $t+1$, W_t is the nominal wage, and Φ_t denotes the lump-sum dividends from firms (owned by the household) minus the lump-sum taxation imposed by the government. Note that each riskless bond pays one unit of money at maturity, and thus the short-term nominal interest rate is given by $i_t \equiv -\log Q_t$.

The first-order conditions of the household's problem yield the labor supply optimality condition

$$\frac{v'(H_t)}{u'(C_t)} = \frac{W_t}{P_t}. \tag{2.3}$$

Assume a continuum of firms indexed by $j \in [0, 1]$, which are subject to the same production function:

$$Y(j) = f(H(j)),$$

where $f' > 0$ and $f'' < 0$.[9] Then the average real marginal cost is given by

$$MC_t \equiv \frac{W_t}{P_t f'(H_t)}. \tag{2.4}$$

Since output is either consumed by the household or the government, we also have the goods market

[8] Here, the parameter $\lambda \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta} \frac{1-\alpha}{1-\alpha+\alpha\epsilon}$, where $1-\theta$ is the probability each firm can reset their prices in a given period, as in Calvo (1983), α measures the degree of decreasing returns in production, and ϵ is the demand elasticity. See Galí (2015, chap. 3) for the details of these parameters. Without losing generality, we assume zero inflation in the steady state.

[9] The final good supplied for consumption or government purchases satisfies $Y \equiv (\int_0^1 Y(j)^{\frac{\epsilon-1}{\epsilon}} dj)^{\frac{\epsilon}{\epsilon-1}}$.

clearing condition $C_t + G_t = Y_t$, where G_t denotes government expenditure.[10]

By further combining the labor supply condition (2.3) and labor demand condition (2.4), the average real marginal cost can be rewritten as

$$MC_t = \frac{\tilde{v}'(Y_t)}{u'(Y_t - G_t)},$$

where $\tilde{v}(Y) \equiv v(f^{-1}(Y))$ denotes the household disutility of supplying output Y. After log-linearization around the steady state, we can express the average real marginal cost in terms of the output gap and government expenditure, that is,

$$\widehat{mc}_t = \frac{\kappa}{\lambda}(\hat{y}_t - \Gamma \hat{g}_t), \tag{2.5}$$

where $\hat{y}_t \equiv (Y_t - \bar{Y})/\bar{Y}$ and $\hat{g}_t \equiv (G_t - \bar{G})/\bar{Y}$. Parameter $\kappa \equiv \lambda(\eta_u + \eta_v) > 0$ is the constant that is commonly referred to as the slope of the Phillips curve, and $0 < \Gamma \equiv \eta_u/(\eta_u + \eta_v) < 1$ is a constant measuring the flexible-price fiscal multiplier. Here $\eta_u \equiv -\bar{Y}u''/u' > 0$ is the inverse of the inter-temporal elasticity of substitution of private consumption and $\eta_v \equiv \bar{Y}\tilde{v}''/\tilde{v}' > 0$ denotes the elasticity of $\tilde{v}'$ with respect to output Y.[11] For the sake of parsimony, we abstract from the productivity shock in (2.5).

Thus, by plugging (2.5) into (2.1), the NKPC with government expenditure is given by

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa(\hat{y}_t - \Gamma \hat{g}_t) + \mu_t. \tag{2.6}$$

Equation (2.6) implies government expenditure enters negatively into the Phillips curve. The intuition comes from the wealth effect on labor supply. Consider the labor supply curve. Conditional on a given level of labor and, hence, output, an increase in government spending crowds out private consumption. The labor supply condition (2.3) then indicates that households are willing to accept a lower real wage due to a higher marginal benefit of consumption, implying a rightward shift of the labor supply curve. Thus, an increase in government expenditure decreases the real marginal cost of production and leads to less inflation for any given output gap.

The aforementioned wealth effect on labor supply is a consequence of the assumption of the

[10] The government collects lump-sum taxes from the household to finance its spending. Since Ricardian equivalence holds, the exact timing of the lump-sum taxation is irrelevant.

[11] When $u(C) = \frac{C^{1-\sigma}-1}{1-\sigma}$ and $v(H) = \frac{H^{1+\psi}}{1+\psi}$ with the assumption of a linear production function $Y_t(j) = A_t H_t(j)$, we have $\eta_u = \frac{\bar{Y}}{\bar{C}}\sigma$ and $\eta_v = \psi$.

household separable utility function (2.2). While the separable utility is a common assumption in the New Keynesian literature, one could alternatively shut down the wealth effect on labor supply by assuming the Greenwood-Hercowitz–Huffman (GHH) preference. In the latter case, government expenditure does not enter the Phillips curve. However, our empirical estimation of the Phillips curve in Section 3 estimates the general form of the Phillips curve (2.6) and suggests a non-negligible wealth effect on labor supply.

Comparing equations (2.1) and (2.6), the term representing government expenditure enters the Phillips curve via real marginal costs. The real marginal cost is a sufficient statistic in summarizing the roles of the output gap and government expenditure in the Phillips curve. Thus, if a perfect measure of the real marginal cost existed, there would be no need to consider government expenditure in estimating the Phillips curve. However, such a perfect measure is not available in the data. Equation (2.6) suggests a better measurement of the real marginal cost by including both output and fiscal spending.

In estimating the standard Phillips curve, a common practice is to use the output gap (or the corresponding unemployment gap) to represent the real marginal cost, where the output gap is the difference between output and its natural rate. If a perfect measure of the natural rate of output (i.e., the model-implied flexible-price output) was empirically available, then the term of government spending would not show up in the Phillips curve by expressing the Phillips curve in terms of deviation from the natural rate. However, empirical measures of the natural rate of unemployment or potential output typically only capture the natural rate from productive capacity but do not consider any short-term fiscal variations.[12] Therefore, such exercises using the empirical measure of output gap would still miss the role of government expenditure in the Phillips curve.

The large body of literature that estimates the slope of the Phillips curve and approaches inflation dynamics through this relationship has generally ignored the effect of government spending.[13] The canonical specification used to estimate the slope is subject to the problem of missing variables when government expenditure is included in the error term. As shown in Figure 1, from at least the early 1980s, the unemployment rate has a clear positive relationship with fluctuations in government expenditure, implying a steeper and biased estimate of the slope of the Phillips curve κ.

[12]For instance, one can refer to the manual for constructing the measure of potential output at the Congress Budget Office, as described in Shackleton (2018).

[13]Among others, McLeay and Tenreyro (2020) provide a comprehensive survey of the existing literature. The few papers that incorporate fiscal spending use spending shocks as an IV for demand shocks instead of considering their direct effect on the Phillips curve.

Furthermore, the recent development of using demand-shock IVs for the output gap (or unemployment gap) such as identified monetary policy shocks in estimating the aggregate Phillips curve does not solve the problem of missing variables and still yields a biased estimate of the slope. The reason is that such IVs violate the exogeneity condition when government expenditure endogenously responds to changes in monetary policy. Indeed, in Appendix B, we show that the correlations between the changes in government expenditure and monetary policy shock and its lags are not necessarily zero in the data. In addition, the use of identified monetary policy shocks as IVs also leads to the problem of weak instruments. We discuss this in more detail in Section 3.2.

Abstracting from fiscal spending not only yields a biased estimate of the slope of the Phillips curve, but also results in bad fits to the data and poor forecasts. We show in Section 4 that government expenditure is an important source of variations in inflation. Together with correctly estimating the slope of the Phillips curve by incorporating government spending, this provides an alternative explanation for the "missing disinflation" puzzle in the literature.

2.2 General-Equilibrium Effects of Government Expenditure

We now further illustrate the effects of government expenditure on aggregate output and inflation in general equilibrium. Assume monetary policy follows a standard Taylor rule, $\hat{\imath}_t = \phi_\pi \pi_t + \phi_y \hat{y}_t$ with $\phi_\pi > 1$ and $\phi_y > 0$.[14] Then the equilibrium of the New Keynesian model with government expenditure (see Woodford, 2011) is fully characterized by

$$\hat{y}_t - \hat{g}_t = \mathbb{E}_t[\hat{y}_{t+1} - \hat{g}_{t+1}] - \sigma(\hat{\imath}_t - \mathbb{E}_t \pi_{t+1}) \tag{2.7}$$

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa(\hat{y}_t - \Gamma \hat{g}_t) \tag{2.8}$$

$$\hat{\imath}_t = \phi_\pi \pi_t + \phi_y \hat{y}_t, \tag{2.9}$$

where, for the sake of parsimony, we abstract from other types of shocks except the fiscal expenditure shock. $\hat{g}_t$ can be determined by an endogenous reaction function or follow an exogenous process. To facilitate closed-form analyses, we assume government expenditure $\hat{g}_t$ follows an exogenous AR(1) process, that is,

$$\hat{g}_{t+1} = \rho_g \hat{g}_t + \epsilon^g_{t+1},$$

where $0 < \rho_g < 1$ and ϵ^g_{t+1} are i.i.d. shocks with mean zero.

[14] The equilibrium determinacy requires $\kappa(\phi_\pi - 1) + (1 - \beta)\phi_y > 0$.

Conjecturing a solution of the equilibrium of the form

$$\hat{y}_t = \eta_y \hat{g}_t, \qquad \pi_t = \eta_\pi \hat{g}_t, \qquad \hat{\imath}_t = \eta_i \hat{g}_t,$$

we can substitute these expressions into (2.7)-(2.9) and solve for the undetermined coefficients $\{\eta_y, \eta_\pi, \eta_i\}$. This yields a unique solution: $\{\eta_y, \eta_\pi\}$ are given by

$$\eta_y = \frac{1-\rho_g + (\psi - \sigma\phi_y)\Gamma}{1-\rho_g+\psi}, \qquad \eta_\pi = \frac{\kappa}{1-\beta\rho_g}\frac{(1-\rho_g)(1-\Gamma) - \sigma\phi_y\Gamma}{1-\rho_g+\psi}, \tag{2.10}$$

where ψ is a constant defined as

$$\psi \equiv \sigma[\phi_y + \frac{\kappa(\phi_\pi - \rho_g)}{1-\beta\rho_g}] > \sigma\phi_y > 0.$$

Equation (2.10) implies that the fiscal multiplier is always positive, that is, $\eta_y > 0$ (conditional on $\phi_\pi > 1$ and $\phi_y > 0$). An increase in government expenditure raises aggregate output in equilibrium by stimulating aggregate demand. This is consistent with the literature on estimating fiscal multipliers with respect to output in which the empirically estimated spending multiplier ranges from 0.6 to 1 (see the survey by Ramey, 2019).[15]

However, the effect of government expenditure on inflation is ambiguous—whether it is positive or negative depends on the persistence of the spending shock ρ_g, the flexible-price fiscal multiplier Γ, the inter-temporal elasticity of substitution of private consumption σ, and to what extent the nominal interest rate responds to the output gap, that is, ϕ_y, in the policy rule. When the spending shock is less persistent and the flexible-price fiscal multiplier Γ is small, or the elasticity of inter-temporal substitution σ is close to zero, or the nominal interest rate does not respond to the output gap (i.e., $\phi_y = 0$), we have $\eta_\pi > 0$, indicating a positive effect of government expenditure on inflation in equilibrium. Otherwise, the general-equilibrium effect of a spending shock on inflation is negative.

Our theory also provides a rationale for the ambiguous empirical findings regarding the general-equilibrium effect of fiscal spending on inflation—some studies suggest spending is inflationary whereas others suggest the opposite or find no effect.[16] Furthermore, if one borrows the cali-

[15] At the zero lower bound, the fiscal multiplier can be larger than one (e.g., Christiano, Eichenbaum and Rebelo, 2011; Woodford, 2011; Woodford and Xie, 2019). Some recent studies further suggest state-dependent fiscal multipliers (e.g., Shen and Yang, 2018; Barnichon, Debortoli and Matthes, 2022).

[16] See, for instance, Jørgensen and Ravn (2022) for a summary of the existing literature. In their paper, the reason why the standard New Keynesian model with government expenditure predicts a positive response of inflation to

brated/estimated parameters from the literature studying fiscal multipliers, for example, Eggertsson (2011) and Christiano, Eichenbaum and Rebelo (2011) in which the estimated fiscal multiplier on output is positive, the response of inflation to fiscal spending η_π as shown in (2.10) is calculated to be negative.[17] That is, fiscal spending that stimulates output does not necessarily increase inflation. To further explore the empirical effect of government expenditure on inflation in general equilibrium, we conduct local projections of inflation on fiscal spending shocks in Section 5 and find a persistent and negative impulse response of inflation to spending shocks.

The expression of η_π in (2.10) sheds further light on the interaction between fiscal and monetary policy. It shows that the effect of fiscal spending on inflation is strongly driven by how the monetary policy reacts to inflation and the output gap. In particular, it is the response of the nominal interest rate to the output gap ϕ_y that determines the sign of inflation response to a government expenditure shock, whereas the response of the nominal interest rate to inflation ϕ_π drives its size. In contrast to the typical discussion of monetary policy in the literature, which mostly focuses on the reaction of monetary policy to inflation, this observation underscores that how monetary policy reacts to economic slack also plays a crucial role in understanding the effects of fiscal spending.

Lastly, one should also recognize that the sign of inflation response to fiscal spending shocks relies on whether the supply channel of government expenditure or its demand channel dominates. While the demand channel always stimulates inflation, the supply channel exerts downward pressure on inflation through the wealth effect on labor supply, as discussed in Section 2.1. In this section, we employ the standard New Keynesian model, where the wealth effect on labor supply cannot be overlooked due to the assumption of household separable utility. Though one might question this assumption or, generally, the degree of the wealth effect, our empirical estimation of the Phillips curve in Section 3 affirms that the form of the Phillips curve adheres to (2.6), wherein the coefficient of government expenditure is significantly negative. Therefore, the supply channel plays an important role in determining how inflation responds to fiscal shocks.[18]

fiscal spending shocks is due to the assumption of $\phi_y = 0$ in the Taylor rule. Once one relaxes that assumption with a general form of the Taylor rule, the response of inflation is not always positive.

[17] Eggertsson (2011) chooses parameter values $\phi_\pi = 1.5$, $\phi_y = 0.25$, $\sigma = 2$, $\beta = 0.99$, $\kappa = 0.00859$, and $\Gamma = 0.425$ in a quarterly model to fit the US economy during the Great Depression, and Christiano, Eichenbaum and Rebelo (2011) set the persistence of the fiscal spending shock as $\rho_g = 0.8$ in their set of baseline parameter values. Taking these together, η_π in (2.10) is calculated to be -0.0053. η_π could be even more negative if the spending shock is more persistent, as estimated in Smets and Wouters (2007) and Jørgensen and Ravn (2022).

[18] The simple New Keynesian model also implies a negative response of consumption to fiscal spending shocks, against some existing VAR evidence (e.g., Monacelli and Perotti, 2008; Pappa, 2009; Lewis and Winkler, 2017; Jørgensen and Ravn, 2022). To address this issue, the literature introduces various complications. For instance, Monacelli and Perotti (2008) consider GHH preferences to shut down the wealth effect on labor supply, while alternatively, Jørgensen and Ravn (2022) introduce variable technology utilization in a standard New Keynesian framework

3 Phillips Curve Estimation

In this section, we begin with estimating the reduced-form New Keynesian Phillips curve using US aggregate data and highlighting the importance of including government expenditure in these estimations. We find that the estimated slope of the Phillips curve changes significantly after controlling for fiscal spending even when one uses identified policy shocks as IVs in the regressions, and the coefficient on fiscal spending is significantly negative as the theory predicts. In Section 3.5, we also discuss the results of estimating the regional Phillips curve by exploiting US state-level variations.

3.1 Data Description

Aggregate inflation is measured by the annualized quarter-over-quarter (QoQ) changes in aggregate price indices. Regarding the measure of the price level, we focus on the Constant Methodology Research Series for Core CPI, published by the US Bureau of Labor Statistics.[19] Our baseline estimation uses the research series data because the historical inflation in this series is calculated using current methods, yielding a better measure in terms of time consistency for research purposes. As a robustness check, we also present results using the published core CPI data and the inflation measures of Personal Consumption Expenditures (PCE), as shown in Appendix C. For the expectation term on the right-hand side of the Phillips curve, we use the Survey of Professional Forecasters (SPF) one- and ten-year-ahead inflation expectations as alternative proxies. In our baseline empirical analyses, the sample period starts at 1989Q4 because of the availability of SPF long-run inflation expectations data and stops at 2019Q4 to exclude the COVID-19 era. We discuss the COVID-19 period in more detail in Section 4.2.

Consistent with many studies, we estimate the Phillips curve in terms of the unemployment gap. Following McLeay and Tenreyro (2020), the unemployment gap is measured by the difference between the aggregate unemployment rate and the Congressional Budget Office's (CBO) estimate of the natural rate of unemployment.

Monetary policy shocks are measured as the sum of the three-month-ahead monthly Fed Funds futures (as in Gertler and Karadi, 2015) to capture the variation in Fed Funds futures prior to the

with separable utility. Nevertheless, since this paper mainly focuses on inflation dynamics and aims to illustrate to what extent the simple benchmark New Keynesian model can help us understand inflation dynamics after taking fiscal spending into account, we abstract from those complications that deal with the consumption response to fiscal shocks.

[19]The BLS homepage for the CPI research series is https://www.bls.gov/cpi/research-series/r-cpi-u-rs-home.htm.

ZLB period and surprises to the ten-year yield to capture interest rate variations in the post-2007 period.[20] These shocks are available from 1990Q1 to 2020Q1.

We use two government expenditure series to construct our measure of fiscal spending. The first expenditure variable is Real Government Consumption Expenditures and Gross Investment, which we refer to as aggregate expenditure. The second is the real federal defense component of aggregate expenditure, which we refer to as defense expenditure, and we use it to construct defense expenditure shocks. To construct the relative changes in expenditure variables, we also obtain real potential GDP data from the CBO's estimate of potential output. In addition, we also consider the fiscal news shocks constructed by the forecast errors on real federal expenditures based on the SPF, as in Ramey (2011). Appendix A gives summary statistics for all data used in the empirical analyses.

3.2 Phillips Curve Estimation Using Aggregate Data

To begin, we estimate a standard New Keynesian Phillips curve (without government expenditure) specified as follows:

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa(\hat{u}_t - u_t^n) + \nu_t, \tag{3.11}$$

where $\hat{u}_t$ is the aggregate unemployment rate and u_t^n is the natural rate of unemployment. Here ν_t is the error term capturing all supply shocks. In the baseline regressions, we use the research series core CPI inflation as the dependent variable, ten-year-ahead SPF inflation expectations as a proxy for the expectation term $\mathbb{E}_t \pi_{t+1}$ (the same measure as in McLeay and Tenreyro, 2020), and the unemployment gap described in Section 3.1. We convert all variables to quarterly frequency.

Motivated by the New Keynesian Phillips curve with government expenditure in equation (2.6), we next empirically explore the role of government expenditure by estimating the equation

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa(\hat{u}_t - u_t^n) + \gamma \hat{g}_t + \nu_t, \tag{3.12}$$

where the changes in government expenditure represented by $\hat{g}_t$, in theory, are equal to $(G_t - \bar{G})/\bar{Y}$ and, in practice, are measured by two methods: (i) HP-filtered total government expenditure over potential GDP, $G^{\text{def, cyclical}}/Y^{\text{potential}}$, and (ii) the change in government expenditure over the last four quarters divided by the output four quarters ago, $(G_t - G_{t-4})/Y_{t-4}$. The latter is the

[20] Here we follow the practice of Barnichon and Mesters (2020) in constructing high-frequency identified monetary policy shocks, but our results are also robust when we measure monetary policy shocks using only high-frequency changes in Fed Funds futures, as in Gertler and Karadi (2015).

benchmark measure of fiscal spending in Nakamura and Steinsson (2014). As shown in Section 2.1, the model implies that the estimates of $\hat{\kappa}$ and $\hat{\gamma}$ should both be negative.

Addressing Endogeneity. The estimation of the reduced-form Phillips curve needs to address endogeneity issues. In particular, the supply shock ν_t could be correlated with the unemployment gap. For instance, the size of any cost-push shock may endogenously affect the degree of economic slack, causing a non-zero correlation. McLeay and Tenreyro (2020) also highlight a simultaneity bias issue—the presence of cost-push shocks in the Phillips curve and the partial accommodation of these by optimal monetary policies would pose a challenge to identification where it can lead to estimating a wrongly signed slope for the Phillips curve. Further, the size of the simultaneity bias is magnified because monetary policy seeks to offset any demand shocks that, in practice, might otherwise help identify the curve.

Similarly, changes in government expenditure, $\hat{g}_t$, may also be endogenous. As Figure 1 suggests, government expenditure displays a strong cyclical pattern: it tends to rise with unemployment rates, especially after the 1990s. This would pose a challenge for the correct identification of γ in (3.12).

Our approach to identifying (β, κ, γ) is to find instruments for the unemployment gap $\hat{u}_t - u_t^n$ and government expenditure $\hat{g}_t$. One typical instrument for $\hat{u}_t - u_t^n$ used in recent literature is the exogenously identified monetary policy shocks using high-frequency identified monetary surprises. As argued in Barnichon and Mesters (2020), this instrument is valid in the context of estimating the Phillips curve because monetary policy shocks are uncorrelated with the supply shock ν_t (thus satisfying the exogeneity condition) and they affect inflation and the unemployment gap (thus satisfying the relevance condition).

To deal with the endogeneity of the government expenditure term $\hat{g}_t$, our baseline set of instruments also includes defense expenditure shocks. Defense expenditure shocks have arguably been exogenous to the economic situation and, thus, can be considered exogenous to total government expenditure. Similar to constructing the total expenditure shocks, we construct defense expenditure shocks by taking either the filtered defense expenditure divided by the potential output or its four-quarter change divided by the output four quarters prior.

The inflation expectation term in the specification (3.12) may also be endogenous and requires an instrument, using either the identified monetary policy shock or the defense spending shock or both. Taken together, the endogenous variables are the inflation expectation, the unemployment gap, and government expenditure. To summarize, the vector of instruments is composed of monetary policy and defense expenditure shocks as well as their lags because the impact of a macro shock usually persists for several quarters following the initial hit.

Putting this rigorously, we estimate (3.11) and (3.12) using instruments

$$Z_t = (\varepsilon_t^m, ..., \varepsilon_{t-H_m}^m, \varepsilon_t^d, ..., \varepsilon_{t-H_d}^d)',$$

where $(\varepsilon^m, \varepsilon^d)$ denote the high-frequency identified monetary policy shock and the defense expenditure shock, respectively, and (H_m, H_d) are the numbers of their lags. We further denote the endogenous variables in equation (3.11) by $X_t^1 = (\mathbb{E}_t\pi_{t+1}, \hat{u}_t - u_t^n)$ and those in equation (3.12) by $X_t^2 = (\mathbb{E}_t\pi_{t+1}, \hat{u}_t - u_t^n, \hat{g}_t)$. To be valid instruments, both the exogeneity condition (i.e., $\mathbb{E}[Z_t\nu_t] = 0$) and the relevance condition (i.e., $\mathbb{E}[Z_tX_t]$ has full column rank) need to be satisfied. In estimating (3.12), Z_t may satisfy both because (i) identified monetary policy shocks are by construction orthogonal to any cost-push factors and defense spending shocks are arguably not correlated with these shocks either,[21] and (ii) monetary and defense spending shocks do affect inflation (hence inflation expectations), the unemployment gap, and government expenditure through some unspecified channels including the demand channel through the IS curve.[22]

However, as noted in Section 2.1, this approach might lead to a biased estimate of the slope of the Phillips curve (3.11) because Z_t may be correlated with $\hat{g}_t$, which makes the exogeneity condition invalid in practice because $\hat{g}_t$ is implicitly included in ν_t in (3.11). Using only monetary policy shocks does not resolve this omitted variable bias; in fact, it will also lead to another issue, the weak instrument, which is explained in detail later.

Many-Instrument Issue. Due to the fact that the impulse responses of macro variables to monetary policy or fiscal spending shocks are usually persistent, the literature typically considers the structural shocks of 12 to 20 periods as instrument variables. However, when there are many instruments, estimators like the 2SLS may be inconsistent. Our solution to this potential bias in estimation is to reduce the number of instruments to six with the Almon parameterization used in Barnichon and Mesters (2020). Specifically, the vector of instruments used in our empirical

[21] We also investigate other identified government spending shocks in our robustness tests.

[22] In estimating (3.12), using monetary policy shocks alone would likely violate the relevance condition, leading to a weak instrument problem, as shown in Section 3.3. Here we add defense shocks to the vector of instruments in our baseline specification to guarantee that both conditions are satisfied.

analyses is

$$Z_t^A = \left(\sum_{h=0}^{H_m} \varepsilon_{t-h}^m, \sum_{h=0}^{H_m} h\varepsilon_{t-h}^m, \sum_{h=0}^{H_m} h^2 \varepsilon_{t-h}^m, \sum_{h=0}^{H_d} \varepsilon_{t-h}^d, \sum_{h=0}^{H_d} h\varepsilon_{t-h}^d, \sum_{h=0}^{H_d} h^2 \varepsilon_{t-h}^d \right)' . \tag{3.13}$$

Our baseline estimation takes $H_m = H_d = 16$. In the robustness tests in Appendix C.1, we show results using 8, 12, and 20 periods of lags for monetary and defense spending shocks.

Hansen (2022) points out that when the number of instruments is large relative to the sample size, the Limited Information Maximum Likelihood (LIML) estimators are more robust than 2SLS. As such, we also present results using the LIML estimator, besides the more commonly used 2SLS and GMM estimators.

Alternative Specifications. In addition to federal defense expenditure shocks, we also consider one alternative as the instrumental variable for government expenditure. We construct a measure for the forecast errors of four-quarter-ahead real federal expenditures based on the Survey of Professional Forecasters, that is, the "news shock" advocated in Ramey (2011). Specifically, we take as the shock the difference between the actual federal expenditure growth in the past four quarters and the forecast of it made four quarters earlier. This shock series is available since 1981Q3.

In addition, we take an alternative estimation approach by directly replacing the endogenous changes in total expenditure with the exogenous defense expenditure shock, leaving inflation expectations and the unemployment gap as the only endogenous variables. Ramey (2011) argues that fluctuations in defense spending account for almost all of the fluctuations in total government spending relative to its trend and that non-defense spending accounts for most of the trend in government spending, thus advocating for the use of defense spending data to identify fiscal shocks.

3.3 Estimation Results

In our baseline exercise, we assume β as a fixed parameter that is equal to one, following the literature of the NKPC estimation such as Coibion and Gorodnichenko (2015), and also consistent with typical calibrations in macro models. In Appendix C.1, we report results that jointly estimate (β, κ, γ) and show that our conclusions in the baseline are robust.

Table 1 presents the estimates of (κ, γ) under alternative specifications and estimation approaches, with the dependent variable being the inflation gap that is measured by the research series core CPI inflation less SPF ten-year-ahead inflation expectations. Columns (1) and (2) show

Table 1: Phillips Curve Estimation: Baseline Result

	OLS		GMM		2SLS		LIML	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unemployment Gap	-0.180***	-0.171***	-0.233***	-0.117***	-0.208***	-0.133**	-0.218**	-0.134**
	(0.044)	(0.063)	(0.054)	(0.019)	(0.076)	(0.058)	(0.085)	(0.062)
Government Expenditure		-0.120		-0.809***		-0.791***		-0.825***
		(0.351)		(0.234)		(0.219)		(0.223)
Constant	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***	-0.004***	-0.003***	-0.004***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
N	121	121	104	104	104	104	104	104

Notes: This table reports the baseline parameter estimates and their standard errors (in parentheses) in the Phillips curve. The dependent variable is the inflation gap that is measured by the research series core CPI inflation less SPF ten-year-ahead inflation expectations. Sample period: 1989Q4–2019Q4. For the OLS estimations, standard errors are calculated as Newey-West standard errors with a maximum lag of 16 quarters. For the IV estimations, Phillips curve parameters are estimated using three methods: (i) GMM, with an HAC weighting matrix using the quadratic spectral kernel where the lag order is selected using the Newey and West (1994) optimal lag-selection algorithm, (ii) 2SLS, and (iii) LIML. All use the same IVs, which include both the high-frequency identified monetary policy shocks and the defense expenditure shocks. The number of lags for these structural shocks as instruments is $H = 16$. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the standard OLS estimations in line with most of the literature. The Phillips curve coefficient κ estimates are both significantly negative and not significantly different from each other. Moreover, the estimate of the coefficient of government expenditure in Column (2) is negative but not significantly different from zero.

Columns (3)–(8) show the results of our baseline estimations using IV estimation strategies. These results, using different estimators, deliver three major observations. First, comparing estimations with and without government expenditure, we find that adding $\hat{g}_t$ to the estimation makes the Phillips curve coefficient significantly smaller. For example, in the GMM estimations, adding government expenditure reduces the Phillips curve coefficient by half. Second, the coefficient on $\hat{g}_t$ is significantly negative, consistent with the augmented New Keynesian Phillips Curve, as shown in Section 2.1. Third, our estimates are robust across the three IV estimators.

Table 2 examines how sensitive our baseline results are to alternative measures of government expenditure or its instrument, and an alternative estimation approach. Columns (1) and (2) repeat Columns (3) and (4) in Table 1 for easier comparisons. Column (3), using the four-quarter growth measure of government expenditure instead of the filtered measure, shows a similar result to Column (2), except that the coefficient on $\hat{g}_t$ shrinks because the two measures of $\hat{g}_t$ are not

Table 2: Alternative Measures of Government Expenditure Variables

	(1)	(2)	(3)	(4)	(5)	(6)
Unemployment Gap	-0.233***	-0.117***	-0.237***	-0.111***	-0.012	-0.101***
	(0.054)	(0.019)	(0.048)	(0.038)	(0.177)	(0.030)
Government Expenditure		-0.809***	-0.369***	-0.103	-1.412***	-1.598***
		(0.234)	(0.124)	(0.137)	(0.388)	(0.231)
Constant	-0.003***	-0.003***	-0.002***	-0.004***	-0.004***	-0.004***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
N	104	104	104	104	104	104

Notes: This table reports the Phillips curve estimates and their standard errors (in parentheses) with alternative measures of government expenditure variables and one alternative empirical specification. The dependent variable is the inflation gap, which is measured by the research series core CPI inflation less SPF ten-year-ahead inflation expectations. Columns (1) and (2) repeat our baseline IV estimation results in Table C.4, where Column (2) uses $G^{\text{cyclical}}/Y^{\text{potential}}$ as the measure of government expenditure and the defense expenditure shock $G^{\text{def, cyclical}}/Y^{\text{potential}}$ as one of the two types of instruments. Column (3) uses total government expenditure growth $(G_t - G_{t-4})/Y_{t-4}$ as the expenditure ($\hat{g}_t$) measure. Column (4) uses defense expenditure growth $(G_t^{\text{def}} - G_{t-4}^{\text{def}})/Y_{t-4}$ as the instrument for government expenditure. In Column (5), the instrumental variable for government expenditure is a news shock based on forecast errors of professional forecasters about real federal spending within a four-quarter horizon. Column (6) uses the defense expenditure shock as a proxy for government expenditure, rather than as an instrument. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

exactly comparable. By replacing the filtered measure of defense shocks with a growth measure, the results shown in Column (4) are qualitatively the same, with a significantly negative Phillips curve slope and government expenditure coefficient, although the former is estimated to be significantly smaller under this specification. Column (5) replaces the IVs of the defense spending shock with the forecast errors of federal expenditures made by professional forecasters, and Column (6) presents the result of a specification in which we use defense expenditure shocks (taken as exogenous) to directly proxy for government expenditure. Again, the results are qualitatively the same, with smaller estimates of the Phillips curve slope and larger estimates of the government expenditure coefficient.[23]

Weak-Instrument Tests. IV estimators can be biased when instruments are weak. In our setting with multiple endogenous regressors and multiple instruments, we provide the Cragg-Donald statistics against the critical values tabulated by Stock and Yogo (2005) and the generalized test statistic proposed by Lewis and Mertens (2022), which is robust to heteroskedastic and autocorrelated errors. Table 3 shows that only including monetary shocks would lead to serious weak

[23] One may also consider the alternative defense spending growth shocks constructed by Berndt, Lustig and Yeltekin (2012). However, the sample period in this exercise is relatively short (from 1990Q1 to 2008Q2) due to the data availability of this defense growth shock series.

Table 3: Weak IV Tests

	Stock-Yogo		Lewis-Mertens	
	Without G	With G	Without G	With G
Monetary Shocks	1.27 (8.53)	0.25 (N/A)	2.52 (15.67)	0.44 (25.34)
Both Shocks	29.82 (11.52)	24.32 (9.40)	33.54 (16.00)	25.34 (16.01)

Notes: This table presents the first-stage weak IV tests using the Cragg-Donald statistic proposed by Stock and Yogo (2005) and the generalized test statistic proposed by Lewis and Mertens (2022). Their corresponding critical values at the 95% confidence level are presented in parentheses. The Stock-Yogo critical value is unavailable when the number of endogenous variables is two and that of the IVs is three (hence, the "N/A" in the table).

instrument problems, with the test statistics significantly below the critical values at the 95% level. In contrast, the combination of monetary and defense spending shocks safely passes both weak IV tests. Therefore, we take this mixture of shocks as our IVs and do not have to resort to the weak-IV-robust techniques in our main analysis.

Robustness Check. In Appendix C.1, we provide more robustness checks by considering: (i) alternative variables in estimation, namely published core CPI inflation instead of the research series (Table C.6), PCE inflation (core and headline) instead of CPI inflation (Table C.7), output gap instead of unemployment gap (Table C.8), one-year ahead inflation expectation instead of ten-year-ahead (Table C.9); (ii) alternative numbers of lags of monetary shocks and defense expenditure shocks in the vector of instruments (Table C.10); and (iii) a hybrid version of the NKPC including lagged inflation or lagged government expenditure as another explanatory variable (Table C.11).

Whereas the point estimates and standard errors of each coefficient might be different across alternative specifications of the Phillips curve, our main findings remain robust across all IV estimations: augmenting the Phillips curve by including government expenditure flattens its slope, and the coefficient on government expenditure is significantly negative.

3.4 The Contribution of Government Expenditure

We decompose the augmented Phillips curve estimated using the GMM estimator (Column (4) of Table 1) and explore to what extent government expenditure shock contributes to the observed inflation dynamics relative to the well-studied economic slack term. Figure 2 shows that throughout our sample period, 1989Q4–2019Q4, government expenditure played a non-negligible role in shaping inflation dynamics—for the majority of the time, it enhanced the impact of the unemployment gap

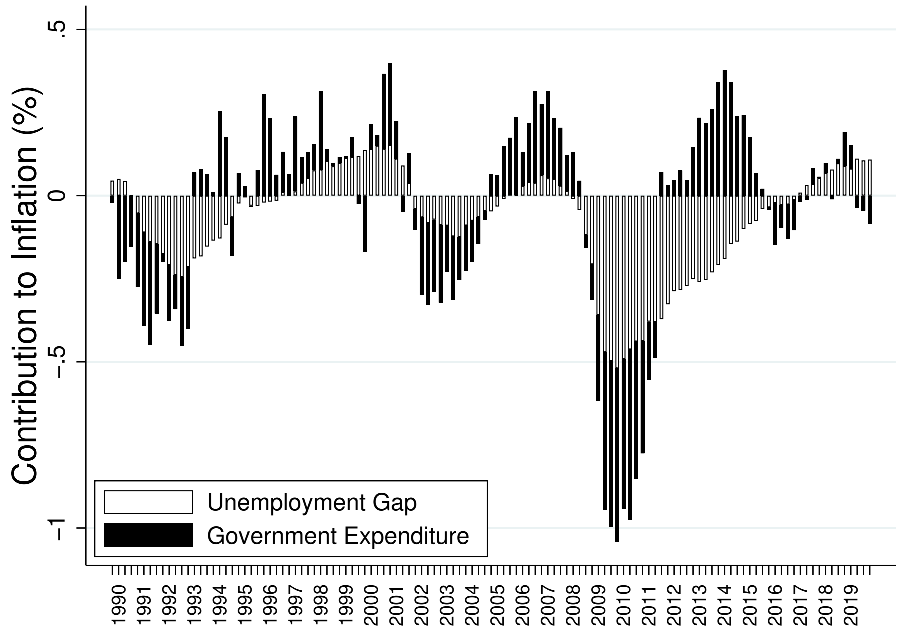

Figure 2: Decomposition of the Phillips Curve

Notes: This figure plots the contributions of the unemployment gap and government expenditure in driving inflation, based on our baseline estimates in Column (4) of Table 1, in which the inflation gap $\pi_t - \mathbb{E}_t \pi_{t+1}$ can be decomposed into a constant, unemployment gap, government expenditure, and a residual representing a cost-push shock.

on inflation, and in some periods, such as the recovery from the Great Recession, the two effects were able to cancel each other out. This result indicates notable deficiencies in the conventional NKPC, which ascribes inflation exclusively to economic slack (besides inflation expectations and supply shocks).

3.5 Regional Phillips Curve with Government Expenditure

Following a recent stream of literature that estimates the slope of the Phillips curve using regional variations, we also estimate a regional version of our baseline equations in Section 3.2. On the regional side, most of our data are the same as those used in Hazell et al. (2022): a state-level price index constructed from the BLS micro-price data and state-level unemployment rate data from Local Area Unemployment Statistics (LAUS). Data of state-level spending includes state government expenditure and is available from the Census Annual Survey of State Government Finances; data on federal spending in the states is available from the Consolidated Federal Funds Report (until 2010) and the Pew Charitable Trusts' Federal Spending in the States dataset (available

Table 4: State-Level OLS Estimates of the New Keynesian Phillips Curve

	(1)	(2)	(3)	(4)	(5)	(6)
Lagged Unemployment Rate	-0.117**	-0.107**	-0.121**	-0.112**	-0.112**	-0.104**
	(0.051)	(0.046)	(0.056)	(0.054)	(0.050)	(0.048)
Lagged Inflation		0.127***			0.131***	0.131***
		(0.033)			(0.036)	(0.034)
Total Spending			0.000		0.001	
			(0.018)		(0.017)	
Defense Spending				-0.025		-0.018
				(0.060)		(0.054)
Constant	2.952***	2.596***	3.148***	2.928***	2.759***	2.572***
	(0.301)	(0.280)	(0.307)	(0.315)	(0.288)	(0.287)
State- & Year-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	952	952	825	924	825	924
R^2	0.598	0.604	0.565	0.593	0.572	0.600

Notes: This table reports the parameter estimates and their standard errors (in parentheses, clustered by state) from state-level estimations. We use lagged unemployment rates following the specification in Hazell et al. (2022). "Total Spending" refers to the sum of state government spending and federal spending within each state. "Defense Spending" refers to federal defense spending within each state. In line with Nakamura and Steinsson (2014), we transform both spending variables as $(G_t - G_{t-2})/Y_{t-2}$, where G refers to either spending category and Y refers to state GDP. All specifications include both state- and year-fixed effects. Our sample consists of annual data for 33 states from 1989 to 2017. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

from 2005 to 2014).[24] State-level defense spending (prime military contract) data are available from the US National Archives and the Department of Defense. All data in the regional regressions are at a yearly frequency.

In the state-level estimation, we use US state-level data on inflation and unemployment rates, state government expenditure, federal government expenditure in each state, and defense spending by state. We include time-fixed effects in addition to state-fixed effects—as in the baseline specification in McLeay and Tenreyro (2020) and Hazell et al. (2022)—to control for time-varying factors that are uniform across regions (e.g., long-run inflation expectations) and to remove the bias from the endogenous monetary policy response to aggregate supply shocks. Table 4 presents the results of various specifications of the state-level OLS estimation. Compared with the benchmark estimation

[24]The Pew Charitable Trusts' Federal Spending in the States dataset is available at https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2016/03/federal-spending-in-the-states-2005-to-2014.

Table 5: State-Level Estimates of the New Keynesian Phillips Curve, Using IVs

	IV: Sensitivity of State Military Spending		Bartik Instrument	
	(1)	(2)	(3)	(4)
Lagged Unemployment Rate	-0.105*	-0.116**	-0.104*	-0.115**
	(0.058)	(0.056)	(0.058)	(0.055)
Total Spending		0.085		0.073
		(0.075)		(0.095)
Defense Spending	0.203		0.187	
	(0.168)		(0.243)	
Constant	2.149***	2.599***	2.153***	2.617***
	(0.317)	(0.411)	(0.325)	(0.423)
State- & Year-Fixed Effects	Yes	Yes	Yes	Yes
N	891	792	891	792
R^2	0.557	0.514	0.559	0.520

Notes: This table reports the parameter estimates and their standard errors (in parentheses, clustered by state) in state-level estimations, using a 2SLS instrumental variable approach. We use lagged unemployment rates following the specification in Hazell et al. (2022). "Total Spending" refers to the sum of state government spending and federal spending within each state. "Defense Spending" refers to federal defense spending within each state. In line with Nakamura and Steinsson (2014), we transform both spending variables as $(G_t - G_{t-2})/Y_{t-2}$, where G refers to either spending category and Y refers to state GDP. The instrument used in Columns (1) and (2) is total national military spending interacted with a state dummy. Columns (3) and (4) use Bartik-type instruments by scaling aggregate spending (defense or total) by the average of state spending shares in the aggregate over the first five years of our sample. All specifications include both state- and year-fixed effects. Our sample consists of annual data for 33 states from 1989 to 2017. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

without government expenditure (Columns (1) and (2)), the estimated slope of the Phillips curve augmented with government expenditure in Column (3) is slightly bigger, whereas the estimates in Columns (4), (5), and (6) are lower although only slightly so. The coefficients on government expenditure are negative, but not significantly different from zero.

Whereas national supply shocks are absorbed in the time-fixed effects, state-level supply shocks may still bias the regional Phillips curve estimation. We construct two sets of instrumental variables that capture the variations in demand across states and over time, following Nakamura and Steinsson (2014). The first instrument (used in Columns (1) and (2) of Table 5) is the product of the change in total national defense spending over the past two years with a state dummy. The identification assumption is that state-level defense spending is sensitive to aggregate defense spending, but the latter does not correlate with state-specific economic shocks. The second set of instruments is constructed following a Bartik approach (Bartik, 1991) by scaling aggregate spending (defense or total) by the average of state spending shares in the aggregate over the first five years of our sample. To be consistent with how we construct the independent spending variable, we take the data series' two-year differences divided by the two-year lagged state GDP to be included as instruments in Columns (3) and (4).

The estimates of the unemployment rate coefficient are consistently negative and significant, with similar magnitudes between -0.1 and -0.12. As with the result of the OLS estimation, the coefficient on fiscal spending is not significant at the 10% level in any of the four specifications, which may be due to its impact on inflation already having been captured by the fixed effects. Another possibility is that the effects of government expenditure are heterogeneous across states, thus resulting in misleading estimates if one assumes homogeneous treatment effects. Recent research in applied micro/econometrics literature has acknowledged the bias in linear regression coefficients with two-way (period and group) fixed effects when the treatment effects are heterogeneous (e.g., De Chaisemartin and d'Haultfoeuille, 2020, 2022). Our findings in Appendix D indicate that the effects of government expenditure on inflation in the Phillips curve differ significantly across states, with some states exhibiting negative coefficients and others showing positive ones.

Nevertheless, regional regressions are in sharp contrast with those using aggregate data, where leaving out the aggregate expenditure term would lead to a strong bias of the slope estimate and a poor fit of the Phillips curve to the actual inflation dynamics. However, though employing regional variations can possibly yield an unbiased estimate of the slope of the regional Phillips curve, it does not help quantify the effects of government expenditure on inflation if they are captured by fixed effects. Furthermore, regional regression estimates may also be biased if the effects of government expenditure are not the same across states.[25] Also, as discussed in Ramey (2019), translating estimates from regional regressions to their aggregate counterparts relies on extra structural assumptions.

4 Understanding Inflation Dynamics with Fiscal Expansion

4.1 Revisiting the "Missing Disinflation" Puzzle

The standard NKPC predicts a strong relationship between inflation and economic slack. However, many studies have pointed out the irrelevance of the latter in predicting the former (e.g., Coibion

[25] The unbiased estimates of government expenditure in regional regressions rely on the assumption that all the states are symmetric, i.e., the treatment effect is constant across states (and over time). Although the assumption of symmetry is generally assumed in macro studies using regional regressions, it is rarely empirically tested.

and Gorodnichenko, 2015; Constâncio, 2016). During the Great Recession, inflation did not drop as much as predicted by theory—in fact, many had even inaccurately predicted deflation during the worst period of the crisis—making for a "missing disinflation" puzzle. This discrepancy between inflation and economic slack has led many to argue that the Phillips curve flattened over the past two decades or that it simply disappeared.

We revisit this puzzle and provide a different explanation for the "flat" dynamics of inflation. Before comparing the model against the data, we present the predicted inflation from the standard Phillips curve (red dashed) and from a Phillips curve augmented with government expenditure (gray solid), in Figure 3.[26] By comparing these two lines, we can see that although there wasn't a significant difference between the two estimation approaches for a long time, their trajectories have diverged considerably since the Great Recession. Our baseline model with $\hat{g}$ predicts much higher inflation than the conventional estimation does for the years just after the Great Recession when the unemployment rate remained very high. This observation indicates that what was believed to be a "puzzle" may simply come from the failure of traditional NKPC in accounting for the role of fiscal spending changes.

Two forces are behind this result. First, the estimated slope of the Phillips curve is smaller compared to the standard estimation without $\hat{g}$, which, because of a large unemployment gap, contributes to a smaller decline in inflation. Second, in the immediate aftermath of the recession, government expenditure shocks at the peak of the recession gradually faded away. Coupled with the negative coefficient on $\hat{g}$, government expenditure turned out to contribute positively to inflation, a point shown in Figure 2. These two factors lead to much larger predictions of inflation than those of the standard NKPC.

To see how much these two effects contribute to the divergence, we plot the predicted inflation coming from the non-expenditure components using the augmented estimated Phillips curve, in Figure 3 (dotted line). Comparing the dotted and solid lines suggests that the government expenditure term plays an important role—without it, predicted inflation would have been much higher during the Great Recession and lower post-recession.

We proceed to explore whether our empirical model can generate an inflation series matching the data. Because of the cost-push shock term, any deviation between predicted inflation and the actual data can be simply explained by the supply shock. To deal with this problem, we take

[26] The red dashed line in Figure 3 is calculated using the estimates in Column (3) of Table 1, and the gray solid line is based on Column (4) in the same table.

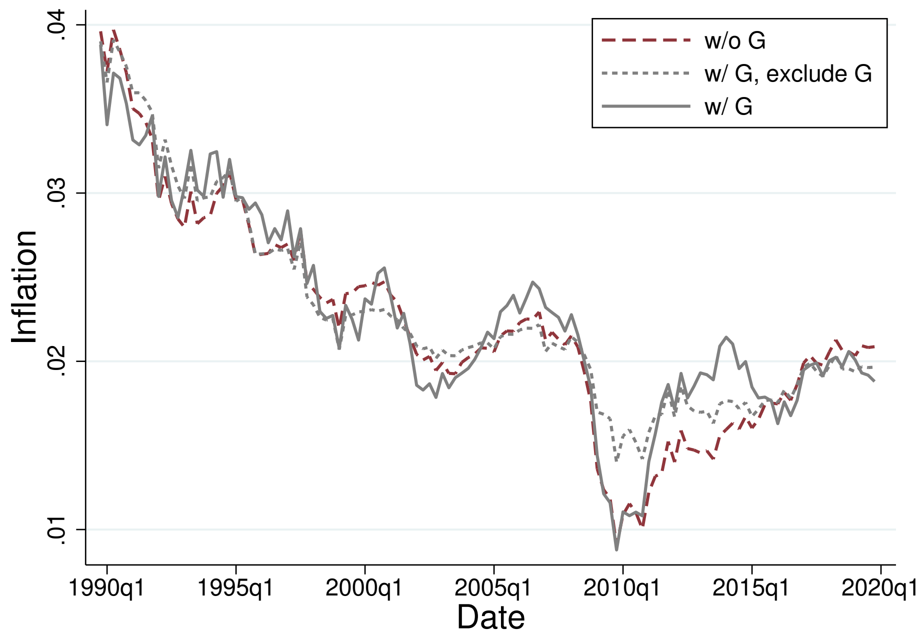

Figure 3: Baseline Predicted Inflation

Notes: This figure exhibits predicted inflation from the baseline Phillips curve IV estimations, from 1990Q1 to 2019Q4. The dashed line (with the label "w/o G") shows the fitted value of inflation without government expenditure as an explanatory variable. The dotted line (with the label "w/ G, exclude G") shows the predicted inflation coming from the non-expenditure components in the estimation specification that incorporates the fiscal spending. The solid line (with the label "w/ G") shows the fitted value of inflation with the fiscal spending variable included.

moving averages of the data and model predictions over the past four and eight quarters—the former shown here and the latter shown in Appendix C—with the assumption that cost-push shocks will average out as long as the averaging period is long enough. Figure 4 shows the 4-quarter moving averaged predicted inflation included in Figure 3 versus the realized core CPI data (represented by the circles). By comparing the gray solid line with the red dashed line, one can observe that the model incorporating government expenditure matches the data much better, particularly for the years immediately after the recession. The model without government expenditure (red dashed line) tends to under-predict inflation, that is, the "missing disinflation" puzzle as argued in Coibion and Gorodnichenko (2015). If we remove government expenditure from the baseline model (gray dotted line), the predicted inflation is counterfactually smooth. In a nutshell, the augmented NKPC yields an improved fit of the data, and it provides an alternative perspective in understanding inflation dynamics around the recent recession as well as the associated "puzzle."

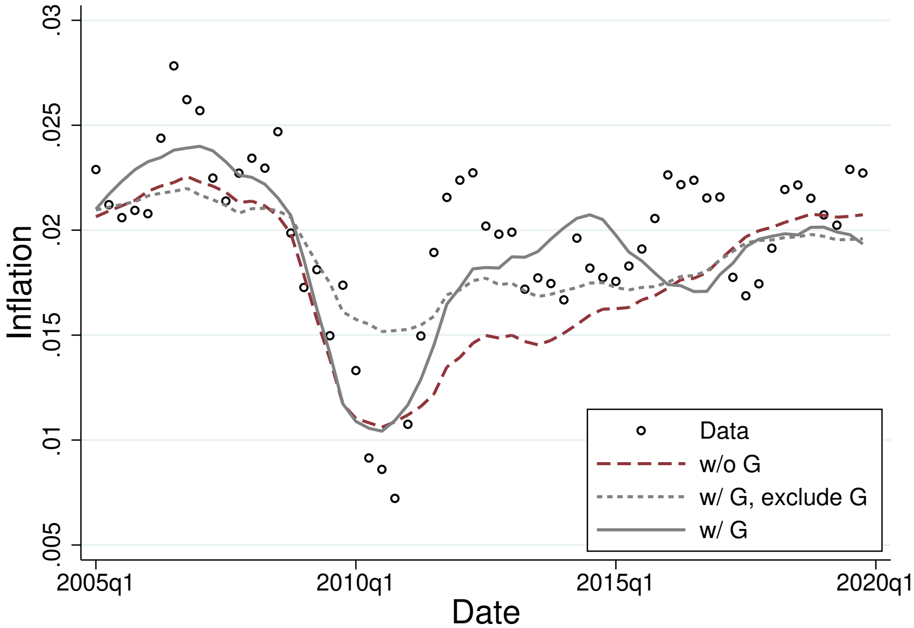

Figure 4: Model Predicted Inflation vs. Data

Notes: This figure shows the model fit of different Phillips curves against the data, from 1990Q1 to 2019Q4. All the series are displayed as their moving averages over the past four quarters. The "Data" label (circles) represents the realized research series of core CPI data, while the other three series are labeled as in Figure 3.

4.2 Inflation during the COVID-19 Recession

Can we also use our estimated NKPC to explain inflation dynamics during the COVID-19 recession? Figure 5 extends Figure 4 post-2020 using the Phillips curve estimated from the period before 2020, with four-quarter moving averages. The gray vertical line in Figure 5 represents the timing of 2020Q1, and the inflation dynamics on the right of this line are the predictions implied by the NKPC using pre-2020 estimates. A salient feature of this COVID-19 period is the strong fiscal expansions due to the fear of a deep recession. Comparing the inflation predicted by Phillips curves with and without government expenditure, the former predicts a much smaller decline in inflation for 2020, consistent with the data—despite the high unemployment rates during this period, inflation did not fall by much. This finding is analogous to the Great Recession episode that we extensively studied above: while a standard Phillips curve predicts a dramatic fall in inflation because of the surge in unemployment during the COVID-19 recession, our augmented NKPC predicts only a modest decline primarily due to the smaller Phillips curve slope estimate, consistent with the data.[27]

[27]One can observe a sharp increase in realized inflation since 2021Q2, which is not predicted by either estimated Phillips curve. The explanations for this inflation spike remain under debate, and one explanation is the supply chain disruption. However, in this paper, we focus on the role of government expenditure and leave this period for future

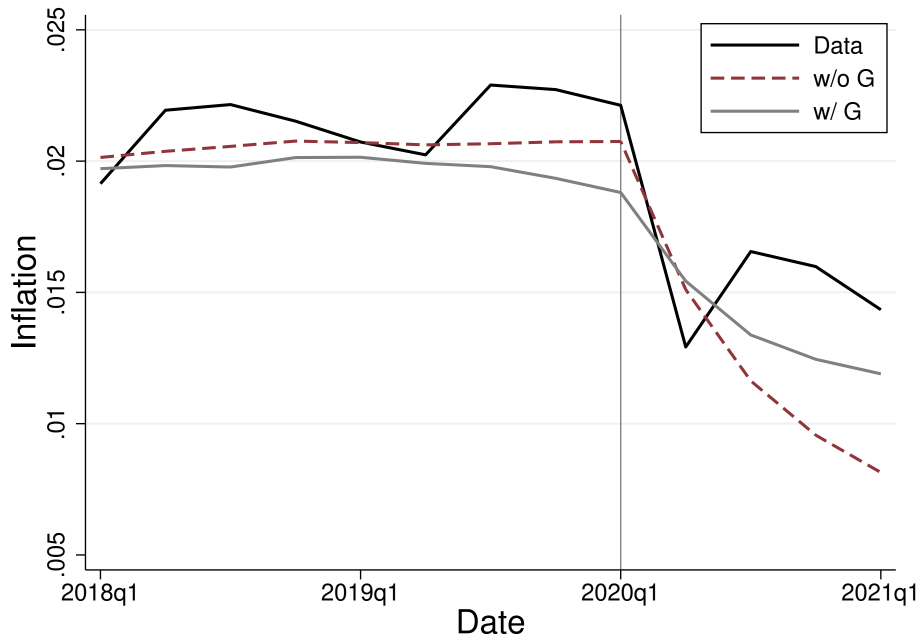

Figure 5: Inflation during the COVID-19 Recession

Notes: This figure shows the model fit of different Phillips curves against the data. Model coefficients are estimated from the 1989Q4–2019Q4 sample. All series are displayed as their moving averages over the past four quarters and are defined the same as in Figure 4.

5 Are Fiscal Expansions Inflationary?

So far we have focused on estimating a single-equation Phillips curve. Consistent with the theory, the negative coefficient of government expenditure implies a negative response of inflation to an increase in government expenditure through the *supply* channel. In this section, we proceed to explore the *overall* impact of fiscal expansions on inflation, as discussed in Section 2.2.

To explore the persistent effect of fiscal spending on inflation, we conduct local projections (LP) following Jordà (2005) and Ramey and Zubairy (2018) to estimate the impulse responses of inflation and inflation expectations to government expenditure shocks in general equilibrium. Methodologically, this exercise of LP should deliver consistent results with those from VAR exercises. Moreover, since a standard New Keynesian model with government expenditure predicts a stronger stimulative effect of fiscal spending when the nominal interest rate is binding at the ZLB, we also define the binding ZLB period as 2009Q1–2015Q3 and further explore the impulse responses of inflation under the two scenarios.

research.

5.1 Dynamic Responses of Inflation and Inflation Expectations

We estimate a dynamic version of the Phillips curve with expenditure shocks using local projection methods to further explore the dynamic impact of government expenditure shocks on inflation. Consider the following specification:

$$x_{t+h} = \beta_{0,h} + \beta_{u,h}(\hat{u}_t - u_t^n) + \beta_{g,h}\hat{g}_t^s + \varepsilon_{t+h}, \tag{5.14}$$

where x_{t+h} denotes any variable x h-period ahead, $\hat{u}_t - u_t^n$ is the unemployment gap at time t, and $\hat{g}_t^s$ is the government expenditure shock measured by the one-year change in defense spending over GDP, that is, $(G_t^{\text{def}} - G_{t-4}^{\text{def}})/Y_{t-4}$.[28] Then $\beta_{g,h}$ captures the impact of a one-percentage point change in government expenditure on variable x_{t+h}. In the following empirical analyses, we choose the maximum length of h to be 20 quarters.

Figure 6 shows the impulse responses of inflation and inflation expectations to a government expenditure shock, using the full sample. The left panel shows that the inflation response is initially negative and stays negative for a few quarters, before becoming indistinguishable from zero.[29] This result indicates that the impact of government expenditure on inflation is persistent for around six quarters and gradually dissipates over time. The right panel shows the response of ten-year-ahead inflation expectations, yielding a similar shape to that of the inflation response. The impulse response of SPF one-year-ahead inflation expectations is relegated to Figure E.4 in Appendix E. The responses of shorter-run inflation expectations share a similar shape to that of long-run inflation expectations but are slightly more persistent.

Our results run counter to the conventional wisdom that fiscal expansions are inflationary. Instead, we show that in response to an identified government spending shock, inflation and inflation expectations both fall before gradually returning to the pre-shock level. This empirical finding through local projection is consistent with studies looking at the effects of fiscal spending on inflation by estimating a VAR model (e.g., Jørgensen and Ravn, 2022). Our empirical finding, however, is not necessarily inconsistent with the New Keynesian theory. The discussion in Section 2.2 provides an explanation for this finding: even in the simplest New Keynesian framework, the

[28] The specification (5.14) does not need to include other control variables because changes in defense spending are exogenous shocks (see the discussion of LP method in Plagborg-Møller and Wolf (2021)). Our results are robust by adding other control variables.

[29] Appendix E shows the local projection result of an alternative specification in which lagged inflation is included as an additional control variable. The negative response of inflation to a government expenditure shock still holds, but its magnitude is smaller.

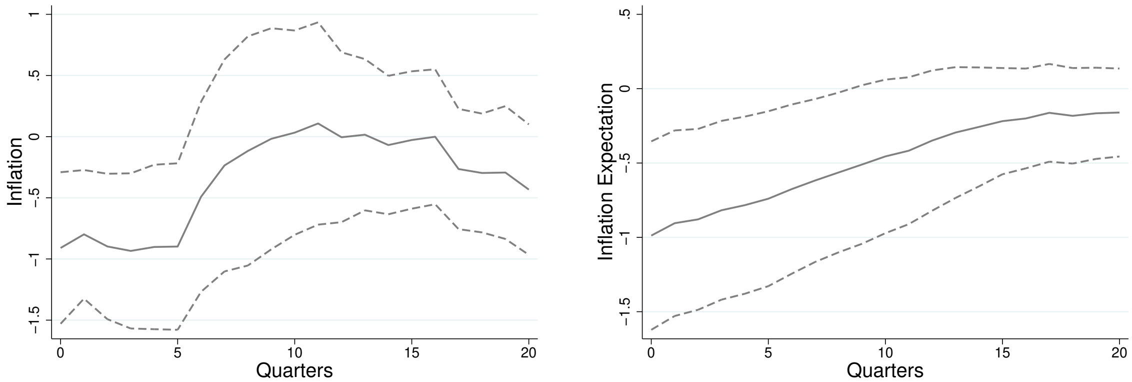

Figure 6: Impulse Responses of Inflation and Inflation Expectations to a Government Expenditure Shock

Notes: The figure on the left plots the impulse response of inflation (core research series) to a one-percentage point government expenditure shock, measured by the one-year change in defense spending over GDP. The right figure plots the impulse response of the SPF ten-year-ahead inflation expectation to the same shock. Dashed lines represent 95% confidence intervals for the impulse response estimates, constructed with Newey-West standard errors with a maximum lag of four quarters. The impulse responses are reported in percentage points.

general equilibrium effect of government expenditure on inflation depends on many parameters and is thus not necessarily positive. The negative response of inflation and inflation expectations, therefore, challenges the commonly held intuition that inflation and inflation expectations must rise with fiscal spending.

5.2 Effects of Fiscal Expansion on Inflation: Binding ZLB Period versus Non-Binding ZLB Period

Our theory in Section 2.2 implies that the inflation response to a fiscal expansion might depend on whether the ZLB binds. While few studies have investigated this specific context, many find that the fiscal multiplier on output is larger when the ZLB is binding (e.g., Eggertsson, 2011; Christiano, Eichenbaum and Rebelo, 2011; Ramey and Zubairy, 2018). In this section, we empirically explore whether ZLB matters for inflation responses, through LP.

More specifically, we estimate the following equation:

$$x_{t+h} = \mathbb{I}_t \left[\beta^z_{0,h} + \beta^z_{u,h}(\hat{u}_t - u^n_t) + \beta^z_{g,h}\hat{g}^s_t\right] + (1 - \mathbb{I}_t)\left[\beta^{n^*}_{0,h} + \beta^{n^*}_{u,h}(\hat{u}_t - u^n_t) + \beta^{n^*}_{g,h}\hat{g}^s_t\right] + \varepsilon_{t+h}, \quad (5.15)$$

where $\mathbb{I}_t$ is an indicator for a binding ZLB in period t, coefficients with superscripts of z indicate a binding ZLB, while n^* indicates a non-binding ZLB. We define the binding ZLB period as 2009Q1–2015Q3.

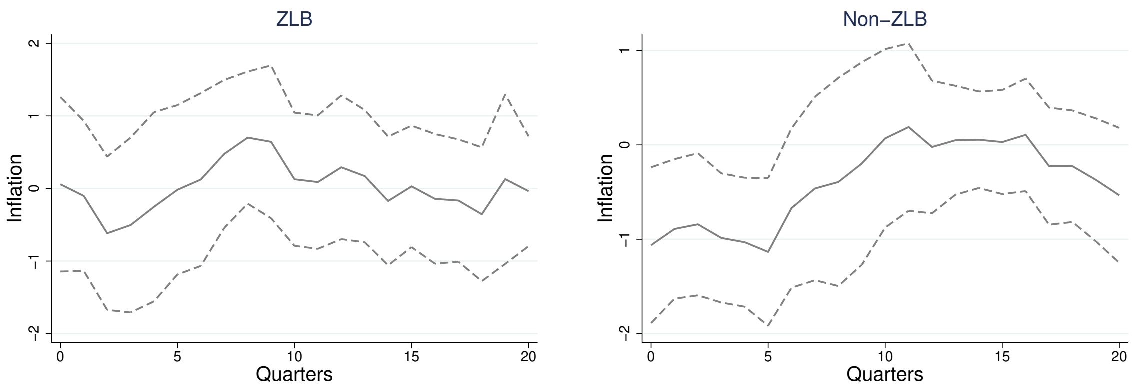

Figure 7: The Impulse Response of Inflation: Binding ZLB vs. Non-Binding ZLB

Notes: This figure shows the impulse responses of inflation (core research series) to a one-percentage point government expenditure shock, measured by the one-year change in defense spending over GDP, during binding ZLB (left) and non-binding ZLB (right) periods. Dashed lines represent 95% confidence intervals for the impulse response estimates, constructed with Newey-West standard errors with a maximum lag of four quarters. The impulse responses are reported in percentage points.

Figure 7 shows the impulse responses of inflation to a positive government expenditure shock. The left panel illustrates the impulse responses of inflation when the ZLB binds, while the right panel illustrates the impulse responses for non-binding ZLB periods. We find that the negative response of inflation, as shown in Figure 6, is mostly driven by non-binding ZLB periods (see the right panel of Figure 7), while during the binding ZLB periods, the inflation response is both small in magnitude and insignificantly different from zero, as shown in the left panel. This result is generally consistent with the theoretical prediction: the general equilibrium effect of fiscal expansion on inflation is typically more stimulative if the interest rate is constrained at the ZLB than if it can respond to the economic conditions à la the Taylor rule. It is also consistent with the findings in Miyamoto, Nguyen and Sergeyev (2018), which looks at the general equilibrium effects of fiscal spending on inflation, albeit in Japan rather than the US.

6 Conclusion

How are inflation dynamics shaped by fiscal policies, in particular those about government expenditure? We answer this question through the estimation of an augmented Phillips curve that incorporates government expenditure. Directed by a New Keynesian model with fiscal spending, we estimate the Phillips curve using aggregate US data and incorporate government expenditure as an explanatory variable. We find that the estimated slope of the Phillips curve is flatter than that in the canonical specification without government expenditure. Furthermore, variation in government expenditure is a significant driver of inflation dynamics. The inclusion of government expenditure in the Phillips curve provides a better fit of the actual inflation dynamics, including the first year of the COVID-19 pandemic when various fiscal packages were introduced. It also provides an alternative explanation for the "missing disinflation" puzzle associated with a standard New Keynesian framework.

In addition to exploring inflation dynamics through a standalone Phillips curve, we also estimate the impulse responses of inflation to fiscal spending shocks in general equilibrium using a local projection approach. We find that inflation falls following an increase in government expenditure and that the effect is relatively persistent, lasting for about one and a half years. This negative response of inflation can be justified in a simple three-equation New Keynesian model allowing for shocks to the government expenditure, a simple result, but often neglected. Moreover, this negative response is mostly driven by periods when the ZLB did not bind, while the response of inflation is muted when the ZLB was binding. Taken together, our results highlight the importance of the oft-neglected supply-side channel through which inflation responds to fiscal expansions.

While we focus on the effects of government expenditure in this paper, it would also be fruitful to study the impact of fiscal transfers, another commonly used fiscal tool during crisis episodes in recent years, on inflation. We leave that for future research.

References

Ball, Laurence M., and Sandeep Mazumder. 2011. "Inflation Dynamics and the Great Recession." *Brookings Papers on Economic Activity*, (Spring): 337–381.

Barnichon, Regis, and Geert Mesters. 2020. "Identifying Modern Macro Equations with Old Shocks." *The Quarterly Journal of Economics*, 135(4): 2255–2298.

Barnichon, Regis, Davide Debortoli, and Christian Matthes. 2022. "Understanding the Size of the Government Spending Multiplier: It's in the Sign." *The Review of Economic Studies*, 89(1): 87–117.

Bartik, Timothy J. 1991. "Who Benefits from State and Local Economic Development Policies?" Kalamazoo, MI: W. E. Upjohn Institute for Employment Research.

Berndt, Antje, Hanno Lustig, and Şevin Yeltekin. 2012. "How Does the US Government Finance Fiscal Shocks?" *American Economic Journal: Macroeconomics*, 4(1): 69–104.

Blanchard, Olivier. 2016. "The Phillips Curve: Back to the '60s?" *American Economic Review: Papers and Proceedings*, 106(5): 31–34.

Calvo, Guillermo A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics*, 12(3): 383–398.

Carvalho, Carlos, Stefano Eusepi, Emanuel Moench, and Bruce Preston. 2023. "Anchored Inflation Expectations." *American Economic Journal: Macroeconomics*, 15(1): 1–47.

Christiano, Lawrence, Martin Eichenbaum, and Sergio Rebelo. 2011. "When is the Government Spending Multiplier Large?" *Journal of Political Economy*, 119(1): 78–121.

Coibion, Olivier, and Yuriy Gorodnichenko. 2015. "Is the Phillips Curve Alive and Well after All? Inflation Expectations and the Missing Disinflation." *American Economic Journal: Macroeconomics*, 7(1): 197–232.

Constâncio, Vitor. 2016. "Understanding Inflation Dynamics and Monetary Policy." In: *Inflation Dynamics and Monetary Policy*, Proceedings of the Jackson Hole Economic Policy Symposium, Federal Reserve Bank of Kansas City.

De Chaisemartin, Clément, and Xavier d'Haultfoeuille. 2020. "Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects." *American Economic Review*, 110(9): 2964–2996.

De Chaisemartin, Clément, and Xavier d'Haultfoeuille. 2022. "Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects: A Survey." National Bureau of Economic Research No. w29691.

Del Negro, Marco, Marc P. Giannoni, and Frank Schorfheide. 2015. "Inflation in the Great Recession and New Keynesian Models." *American Economic Journal: Macroeconomics*, 7(1): 168–196.

Del Negro, Marco, Michele Lenza, Giorgio E. Primiceri, and Andrea Tambalotti. 2020. "What's up with the Phillips Curve?" *Brookings Papers on Economic Activity*, (Spring): 301–373.

Eggertsson, Gauti B. 2011. "What Fiscal Policy is Effective at Zero Interest Rates?" *NBER Macroeconomics Annual*, 25(1): 59–112.

Ferrara, Laurent, Luca Metelli, Filippo Natoli, and Daniele Siena. 2021. "Questioning the Puzzle: Fiscal Policy, Real Exchange Rate and Inflation." *Journal of International Economics*, 133: 103524.

Fitzgerald, Terry J., and Juan Pablo Nicolini. 2014. "Is There a Stable Relationship between Unemployment and Future Inflation? Evidence from US Cities." Working Paper no.713, Federal Reserve Bank of Minneapolis.

Galí, Jordi. 2015. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications.* Princeton, New Jersey, USA:Princeton University Press.

Gertler, Mark, and Peter Karadi. 2015. "Monetary Policy Surprises, Credit Costs, and Economic Activity." *American Economic Journal: Macroeconomics*, 7(1): 44–76.

Gordon, Robert J. 2013. "The Phillips Curve Is Alive and Well: Inflation and the NAIRU during the Slow Recovery." National Bureau of Economic Research No. w19390.

Hansen, Bruce. 2022. *Econometrics.* Princeton, New Jersey, USA:Princeton University Press.

Harding, Martín, Jesper Lindé, and Mathias Trabandt. 2022. "Resolving the Missing Deflation Puzzle." *Journal of Monetary Economics*, 126: 15–34.

Hazell, Jonathon, Juan Herreno, Emi Nakamura, and Jón Steinsson. 2022. "The Slope of the Phillips Curve: Evidence from US States." *The Quarterly Journal of Economics*, 137(3): 1299–1344.

Hooper, Peter, Frederic S. Mishkin, and Amir Sufi. 2020. "Prospects for Inflation in a High Pressure Economy: Is the Phillips Curve Dead or Is It Just Hibernating?" *Research in Economics*, 74(1): 26–62.

Jordà, Òscar. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review*, 95(1): 161–182.

Jørgensen, Peter L., and Kevin J. Lansing. 2019. "Anchored Inflation Expectations and the Slope of the Phillips Curve." Federal Reserve Bank of San Francisco Working Paper(27).

Jørgensen, Peter L., and Søren H. Ravn. 2022. "The Inflation Response to Government Spending Shocks: A Fiscal Price Puzzle?" *European Economic Review*, 141: 103982.

Lewis, Daniel J, and Karel Mertens. 2022. "A Robust Test for Weak Instruments with Multiple Endogenous Regressors." *Available at SSRN 4144103.*

Lewis, Vivien, and Roland Winkler. 2017. "Government Spending, Entry, and the Consumption Crowding-In Puzzle." *International Economic Review*, 58(3): 943–972.

Mavroeidis, Sophocles, Mikkel Plagborg-Møller, and James H. Stock. 2014. "Empirical Evidence on Inflation Expectations in the New Keynesian Phillips Curve." *Journal of Economic Literature*, 52(1): 124–88.

McLeay, Michael, and Silvana Tenreyro. 2020. "Optimal Inflation and the Identification of the Phillips Curve." *NBER Macroeconomics Annual*, 34(1): 199–255.

Mineyama, Tomohide. 2021. "Downward Nominal Wage Rigidity and Inflation Dynamics during and after the Great Recession." *Journal of Money, Credit, and Banking*, forthcoming.

Mishkin, Frederic S. 2007. "Inflation Dynamics." *International Finance*, 10(3): 317–334.

Miyamoto, Wataru, Thuy Lan Nguyen, and Dmitriy Sergeyev. 2018. "Government Spending Multipliers under the Zero Lower Bound: Evidence from Japan." *American Economic Journal: Macroeconomics*, 10(3): 247–277.

Monacelli, Tommaso, and Roberto Perotti. 2008. "Fiscal Policy, Wealth Effects, and Markups." National Bureau of Economic Research No. w14584.

Nakamura, Emi, and Jón Steinsson. 2014. "Fiscal Stimulus in a Monetary Union: Evidence from US Regions." *American Economic Review*, 104(3): 753–792.

Newey, Whitney K., and Kenneth D. West. 1994. "Automatic Lag Selection in Covariance Matrix Estimation." *The Review of Economic Studies*, 61(4): 631–653.

Pappa, Evi. 2009. "The Effects of Fiscal Shocks on Employment and the Real Wage." *International Economic Review*, 50(1): 217–244.

Pennings, Steven. 2021. "Cross-Region Transfer Multipliers in a Monetary Union: Evidence from Social Security and Stimulus Payments." *American Economic Review*, 111(5): 1689–1719.

Plagborg-Møller, Mikkel, and Christian K. Wolf. 2021. "Local Projections and VARs Estimate the Same Impulse Responses." *Econometrica*, 89(2): 955–980.

Ramey, Valerie A. 2011. "Identifying Government Spending Shocks: It's all in the Timing." *The Quarterly Journal of Economics*, 126(1): 1–50.

Ramey, Valerie A. 2019. "Ten Years after the Financial Crisis: What Have We Learned from the Renaissance in Fiscal Research?" *Journal of Economic Perspectives*, 33(2): 89–114.

Ramey, Valerie A., and Sarah Zubairy. 2018. "Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data." *Journal of Political Economy*, 126(2): 850–901.

Shackleton, Robert. 2018. "Estimating and Projecting Potential Output Using CBO's Forecasting Growth Model." Congressional Budget Office Working Paper 2018-03.

Shen, Wenyi, and Shu-Chun S. Yang. 2018. "Downward Nominal Wage Rigidity and State-Dependent Government Spending Multipliers." *Journal of Monetary Economics*, 98: 11–26.

Smets, Frank, and Rafael Wouters. 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review*, 97(3): 586–606.

Stock, James, and Motohiro Yogo. 2005. "Testing for Weak Instruments in Linear IV Regression." In *Identification and Inference for Econometric Models.* , ed. Donald W.K. Andrews, 80–108. New York:Cambridge University Press.

Stock, James H., and Mark W. Watson. 2020. "Slack and Cyclically Sensitive Inflation." *Journal of Money, Credit and Banking*, 52(S2): 393–428.

Woodford, Michael. 2011. "Simple Analytics of the Government Expenditure Multiplier." *American Economic Journal: Macroeconomics*, 3(1): 1–35.

Woodford, Michael, and Yinxi Xie. 2019. "Policy Options at the Zero Lower Bound When Foresight is Limited." *AEA Papers and Proceedings*, 109: 433–437.

Woodford, Michael, and Yinxi Xie. 2022. "Fiscal and Monetary Stabilization Policy at the Zero Lower Bound: Consequences of Limited Foresight." *Journal of Monetary Economics*, 125: 18–35.

Online Appendix

A Data

A.1 Summary Statistics

Table A.1 provides the mean, median, standard deviation, and sample period of the key variables in the empirical analyses.

Table A.1: Summary Statistics

	(1)	(2)	(3)	(4)
VARIABLES	Mean	Median	S.D.	Sample Period in the Analysis
Core Inflation (research series)	0.032	0.027	0.021	1989Q4–2020Q4
Core Inflation	0.036	0.027	0.026	1989Q4–2021Q4
Unemployment Gap	0.005	0.001	0.016	1989Q4–2021Q4
SPF Ten-Year Inflation Expectation	0.030	0.025	0.012	1989Q4–2021Q4
Cyclical Total Government Expenditure	-0.000	-0.000	0.004	1989Q4–2021Q3
Defense Expenditure Growth	0.001	0.001	0.003	1989Q4–2020Q4
Defense Expenditure Shock	0.000	-0.000	0.001	1989Q4–2020Q4
Monetary Policy Shock	-0.037	-0.007	0.131	1990Q1–2020Q1

A.2 Plots of Raw Data

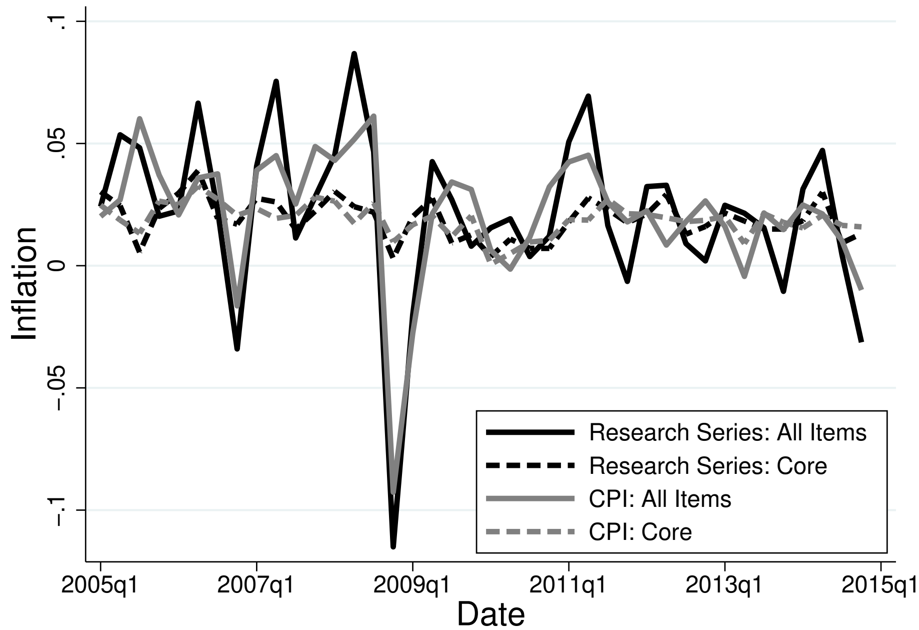

Figure A.1: Different Measures of Quarter-over-Quarter Inflation

B Monetary Policy Shock and Government Expenditure

This section provides empirical evidence on the relationship between the high-frequency identified monetary policy shocks and the government expenditure $\hat{g}$ (measured by two approaches: the cyclical part of total government expenditure over potential GDP and the four-quarter difference over GDP). Table B.2 presents the correlation between $\hat{g}$ and the monetary policy shock as well as its lags. We find that the contemporaneous correlation tends to be relatively small but that $\hat{g}$ has stronger correlations with lagged monetary policy shocks.

Table B.3 presents the regression results of $\hat{g}$ projected onto the monetary policy shock as well as its lags. Using the first measure of $\hat{g}$ (shown in Column 1), coefficients on the second, third, and fourth lags are significantly negative. In the second measure (shown in Column 2), none of the coefficients are significant at the 10% level. However, the t-statistics are relatively large for all but the coefficient on the contemporaneous monetary shock.

Table B.2: Correlation of Monetary Policy Shock and Government Expenditure

	Lag of Monetary Policy Shock				
	0	1	2	3	4
$\hat{g} = G^{\text{cyclical}}/Y^{\text{potential}}$	-0.071	-0.195	-0.214	-0.297	-0.320
$\hat{g} = (G_t - G_{t-4})/Y_{t-4}$	-0.078	-0.191	-0.154	-0.179	-0.174

Table B.3: Government Expenditure Projected onto Monetary Policy Shocks

	(1) $\hat{g} = G^{\text{cyclical}}/Y^{\text{potential}}$	(2) $\hat{g} = (G_t - G_{t-4})/Y_{t-4}$
Monetary Policy Shock	-0.000	-0.001
	(0.001)	(0.003)
Monetary Policy Shock (lag=1)	-0.002	-0.004
	(0.001)	(0.003)
Monetary Policy Shock (lag=2)	-0.003**	-0.004
	(0.001)	(0.003)
Monetary Policy Shock (lag=3)	-0.005***	-0.004
	(0.001)	(0.003)
Monetary Policy Shock (lag=4)	-0.005***	-0.004
	(0.001)	(0.003)
Constant	-0.001***	0.002***
	(0.000)	(0.001)
N	117	117

Notes: Newey-West standard errors with four lags are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

C More Empirical Results Using Aggregate Data

C.1 Robustness Tests of Phillips Curve Estimation

Joint Estimates of (β, κ, γ)**.** In the baseline, we hold $\beta = 1$. To investigate the robustness of our main result to this assumption, we first present the joint estimates of (β, κ, γ) under alternative specifications and estimation approaches, similar to Tables 1 and 2.

Table C.4: Phillips Curve Estimation

	OLS		GMM		2SLS		LIML	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unemployment Gap	-0.180***	-0.172***	-0.244***	-0.126***	-0.229***	-0.153***	-0.235***	-0.153***
	(0.049)	(0.057)	(0.035)	(0.026)	(0.075)	(0.040)	(0.077)	(0.041)
Inflation Expectations	0.954***	0.961***	0.337***	0.251***	0.256*	0.244***	0.246	0.243***
	(0.189)	(0.189)	(0.082)	(0.071)	(0.149)	(0.088)	(0.164)	(0.091)
Government Expenditure		-0.099		-0.823***		-0.809***		-0.815***
		(0.305)		(0.203)		(0.219)		(0.221)
Constant	-0.002	-0.002	0.013***	0.015***	0.015***	0.015***	0.016***	0.015***
	(0.005)	(0.005)	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)	(0.003)
N	121	121	104	104	104	104	104	104
R^2			0.117	0.149	0.124	0.144	0.121	0.144

Notes: This table reports the parameter estimates and their standard errors (in parentheses) when (β, κ, γ) are jointly estimated. Sample period: 1989Q4–2019Q4. For the OLS estimations, standard errors are calculated as Newey-West standard errors with a maximum lag of 16 quarters. For the IV estimations, the Phillips curve parameters are estimated using three methods: (i) GMM, with an HAC weighting matrix using the quadratic spectral kernel while the lag order is selected using the Newey and West (1994) optimal lag-selection algorithm, (ii) 2SLS, and (iii) LIML. The IVs include both the high-frequency identified monetary policy shocks and the defense expenditure shocks. The number of lags for these structural shocks as instruments is $H = 16$. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.5: Alternative Measures of Government Expenditure Variables

	(1)	(2)	(3)	(4)	(5)	(6)
Unemployment Gap	-0.244***	-0.126***	-0.256***	-0.166***	0.055	-0.113***
	(0.035)	(0.026)	(0.058)	(0.020)	(0.080)	(0.035)
Inflation Expectations	0.337***	0.251***	0.217*	0.345***	0.347***	0.275***
	(0.082)	(0.071)	(0.121)	(0.115)	(0.047)	(0.056)
Government Expenditure		-0.823***	-0.414***	-0.227**	-1.318***	-1.574***
		(0.203)	(0.055)	(0.108)	(0.322)	(0.176)
Constant	0.013***	0.015***	0.018***	0.013***	0.011***	0.014***
	(0.002)	(0.002)	(0.004)	(0.003)	(0.001)	(0.002)
N	104	104	104	104	104	104

Notes: This table reports the Phillips curve estimates and their standard errors (in parentheses) with alternative measures of government expenditure variables and one alternative empirical specification. Columns (1) and (2) repeat our baseline IV estimation results in Table C.4, where Column (2) uses $G^{\text{cyclical}}/Y^{\text{potential}}$ as the measure of government expenditure and the defense expenditure shock $G^{\text{def, cyclical}}/Y^{\text{potential}}$ as one of the two types of instruments. Column (3) uses total government expenditure growth $(G_t - G_{t-4})/Y_{t-4}$ as the expenditure ($\hat{g}_t$) measure. Column (4) uses defense expenditure growth $(G_t^{\text{def}} - G_{t-4}^{\text{def}})/Y_{t-4}$ as the instrument for government expenditure. In Column (5), the instrumental variable for government expenditure is a news shock based on forecast errors of professional forecasters about real federal spending within a four-quarter horizon. Column (6) uses the defense expenditure shock as a proxy for government expenditure, rather than as an instrument. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Other Robustness Tests. We provide additional empirical results from estimating the augmented Phillips curve using alternative measures of inflation and economic slack and consider different empirical specifications as robustness checks. Table C.6 presents the findings using the published core CPI series (instead of the research series used in our benchmark). Table C.7 uses PCE instead of CPI inflation. Table C.8 measures economic slack with the output gap instead of the unemployment gap. Table C.9 presents the results where the inflation expectations term is proxied by SPF one-year-ahead inflation expectations instead of the ten-year-ahead used in our baseline exercise. Table C.10 shows the results when we vary the number of structural shocks (in the baseline, $H = 16$) included as instrumental variables. Table C.11 shows the results of estimating a hybrid New Keynesian Phillips curve, in which we add lagged inflation as an additional explanatory variable. Our results show that the conclusions drawn from the baseline estimation are robust to most of these alternative choices, except when using PCE inflation where the coefficient estimates are not significant.

Table C.6: Robustness Check: Published Core CPI Data

	OLS		IV	
	(1)	(2)	(3)	(4)
Unemployment Gap	-0.181***	-0.191***	-0.181***	-0.132***
	(0.036)	(0.058)	(0.053)	(0.010)
Government Expenditure		0.136		-0.695***
		(0.530)		(0.247)
Constant	-0.002**	-0.002*	-0.003***	-0.003***
	(0.001)	(0.001)	(0.000)	(0.000)
N	121	121	104	104

Notes: This table reports the parameter estimates and their standard errors (in parentheses) using published core CPI data instead of the research series. Everything else is the same as in Table 1.

Table C.7: Robustness Check: PCE Inflation

	PCE Core Inflation				PCE Headline Inflation			
	OLS		IV		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Unemployment Gap	-0.066	-0.067	-0.085	-0.069	-0.110	-0.130	-0.144	-0.098
	(0.057)	(0.062)	(0.061)	(0.084)	(0.109)	(0.104)	(0.132)	(0.128)
Government Expenditure		0.012		-0.348		0.264		-0.425
		(0.341)		(0.363)		(0.489)		(0.718)
Constant	-0.007***	-0.007***	-0.007***	-0.008***	-0.006***	-0.006***	-0.008***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
N	121	121	104	104	121	121	104	104

Notes: This table reports the parameter estimates and their standard errors (in parentheses) using PCE inflation (including core and headline) instead of CPI inflation. Everything else is the same as in Table 1.

Table C.8: Robustness Check: Output Gap

	OLS		IV	
	(1)	(2)	(3)	(4)
Output Gap y_gap	0.108***	0.092**	0.201***	0.106***
	(0.037)	(0.038)	(0.017)	(0.023)
Government Expenditure		-0.272		-0.704***
		(0.356)		(0.161)
Constant	-0.003***	-0.003***	-0.002***	-0.003***
	(0.001)	(0.001)	(0.000)	(0.001)
N	121	121	104	104

Notes: This table reports the parameter estimates and their standard errors (in parentheses) using the output gap instead of the unemployment gap as the measure of economic slack. Everything else is the same as in Table 1.

Table C.9: Robustness Check: One-Year-Ahead Inflation Expectations

	OLS		IV	
	(1)	(2)	(3)	(4)
Unemployment Gap	-0.050	-0.050	-0.086**	-0.007
	(0.035)	(0.050)	(0.043)	(0.022)
Government Expenditure		-0.004		-0.530***
		(0.284)		(0.087)
Constant	-0.002**	-0.002**	-0.002***	-0.002***
	(0.001)	(0.001)	(0.000)	(0.000)
N	121	121	104	104

Notes: This table reports the parameter estimates and their standard errors (in parentheses) using the SPF one-year-ahead inflation expectations as a proxy for the inflation expectations term in the Phillips curve. Everything else is the same as in Table 1.

Table C.10: Robustness Check: Varying the Number of Structural Shocks

	$H = 8$		$H = 12$		$H = 20$	
	(1)	(2)	(3)	(4)	(5)	(6)
Unemployment Gap	-0.241***	-0.144**	-0.224***	-0.137***	-0.217***	-0.140***
	(0.007)	(0.063)	(0.053)	(0.049)	(0.028)	(0.014)
Government Expenditure		-0.720***		-0.741***		-0.690***
		(0.195)		(0.254)		(0.181)
Constant	-0.003***	-0.004***	-0.003***	-0.004***	-0.003***	-0.003***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
N	112	112	108	108	100	100

Notes: This table reports the parameter estimates using the GMM estimator and their standard errors (in parentheses) when we vary the number of structural shocks used as instruments: $H = 8$, 12, and 20. Everything else is the same as in Table 1.

Table C.11: Robustness Check: Estimates of a Hybrid New Keynesian Phillips Curve

	OLS with Lagged π		IV with Lagged π	
	(1)	(2)	(3)	(4)
Unemployment Gap	-0.144***	-0.121*	-0.135*	-0.100***
	(0.055)	(0.070)	(0.071)	(0.032)
Lagged Inflation	0.253***	0.268***	0.504***	0.329
	(0.087)	(0.090)	(0.195)	(0.308)
Government Expenditure		-0.277		-0.598**
		(0.246)		(0.253)
Constant	-0.009***	-0.010***	-0.014***	-0.010
	(0.002)	(0.002)	(0.004)	(0.006)
N	121	121	104	104

Notes: This table reports the parameter estimates and their standard errors (in parentheses) of a hybrid New Keynesian Phillips curve using a GMM estimator. Everything else is the same as in Table 1.

C.2 Model vs. Data

In Section 4.1, we present the inflation dynamics predicted by our empirical model against the actual inflation data using a four-quarter moving average. Here we present the same comparison using an eight-quarter moving average.

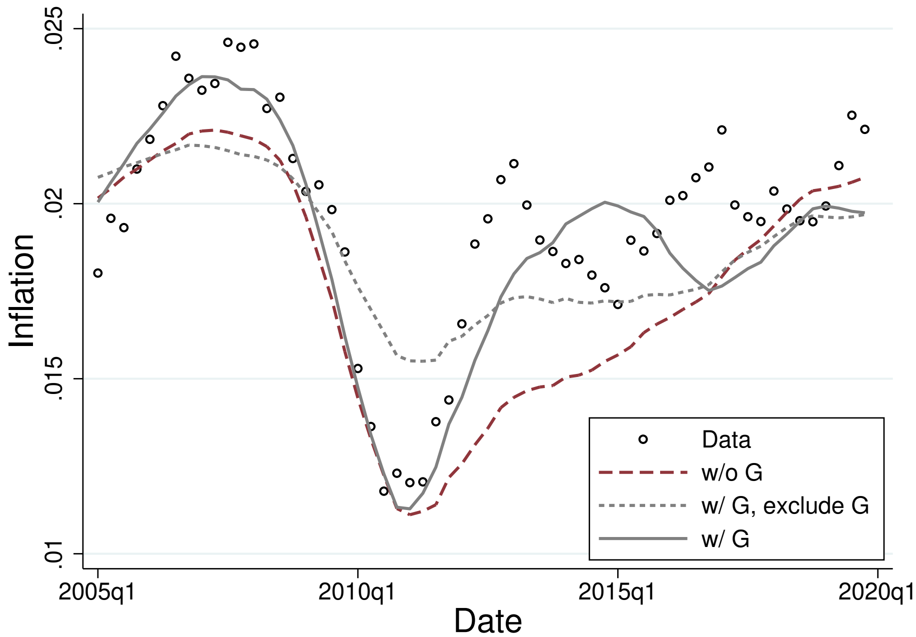

Figure C.2: Model Predicted Inflation vs. Data: Eight-Quarter Moving Average

Notes: This figure shows the model fit of different Phillips curves against the data, from 1990Q1 to 2019Q4. All the series are displayed as their moving averages over the past eight quarters. The "Data" label (circle) represents the realized research series of core CPI data, while the other three series are labeled as in Figure 3.

D State-Specific Regression for the Regional Phillips Curve

The empirical regressions in Section 3.5 rely on the assumption that the effects of government expenditure are homogeneous across states, that is, all states are symmetric. In this section, we look at a similar regression but assume that the Phillips curve can be state-specific.

Using the same data as in Section 3.5, we conduct a panel regression with the following specification:

$$\pi_{i,t} = \kappa_i \hat{u}_{i,t-4} + \gamma_i \hat{g}_{i,t} + \alpha_i + \beta_t + \nu_{i,t}, \tag{D.16}$$

where κ_i and γ_i are state-dependent and $\hat{g}_{i,t}$ is measured by the total government spending in state i constructed with the same approach as in Table 4. In the regression, we use dummy variables

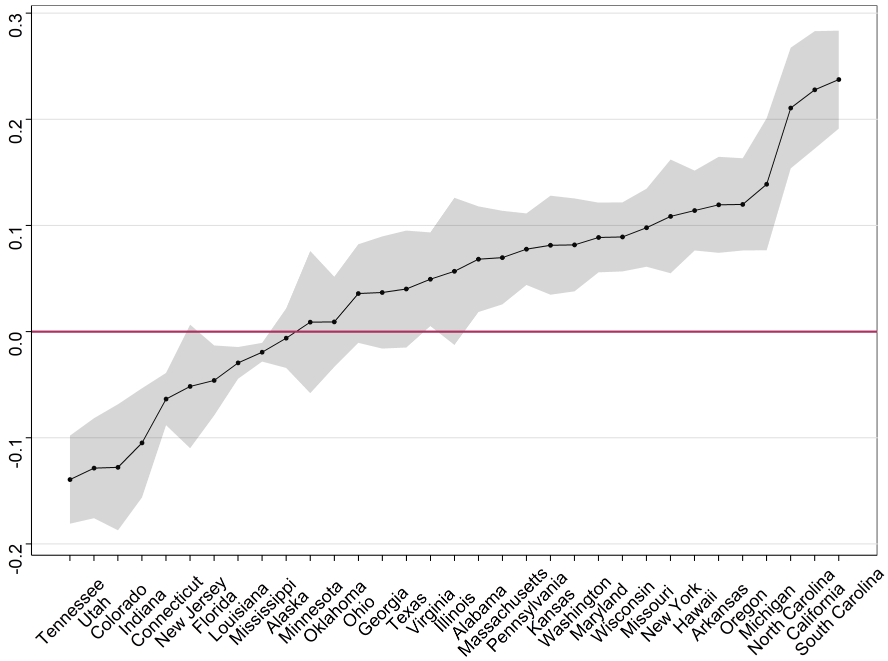

Figure D.3: The State-Specific (Marginal) Coefficients of Government Expenditure in the Regional Phillips Curve

Notes: This figure shows the state-specific coefficients of government expenditure in the regional Phillips curve. The black bullet points present point estimates of the coefficients, while the gray area represents the 95% confidence intervals.

indicating state i to interact with the independent variables.

Figure D.3 displays the estimated γ_i for each state with available data. The black bullet points present point estimates of the coefficients, while the gray area represents the 95% confidence intervals. Figure D.3 shows that the effects of government expenditure on inflation embedded in the regional Phillips curve vary significantly across states. For instance, some states such as Tennessee, Utah, and Colorado, exhibit negative coefficients, whereas others display positive ones. This finding poses challenges to the current approach of utilizing regional variations in macro studies by assuming homogeneous treatment effects. Moreover, it complicates the interpretation of micro evidence in the context of macro implications.

E Robustness of Local Projection

Figure E.4 displays the impulse response of one-year-ahead inflation expectations to a one-percentage point increase in government expenditure. The response is similar to that of ten-year-ahead inflation expectations. In Figure E.5, we present the local projection result of an alternative specification in which lagged inflation is included as an additional control variable. The negative response of inflation to a government expenditure shock still holds, but its magnitude is smaller.

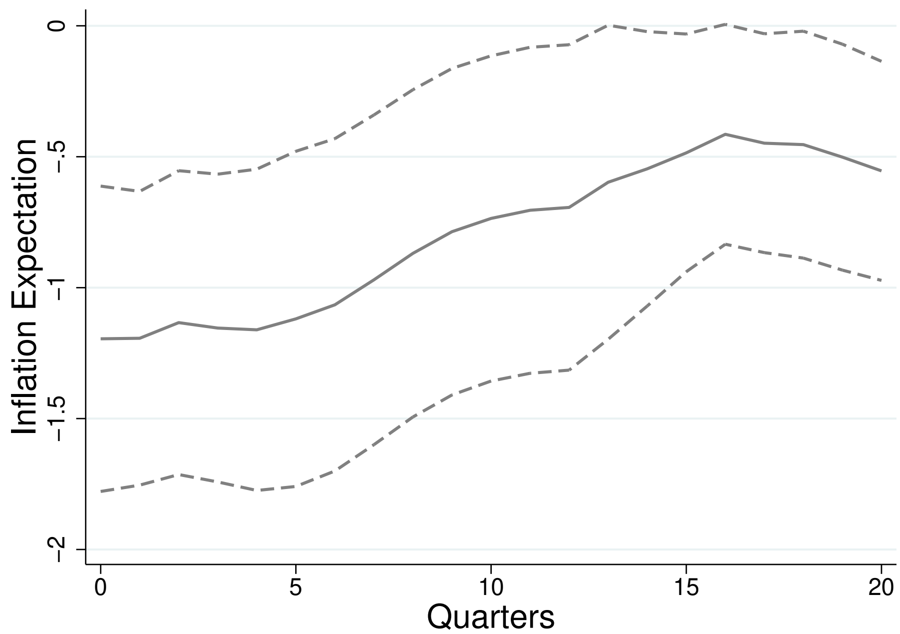

Figure E.4: Impulse Responses of One-Year-Ahead Inflation Expectations to Government Expenditure Shocks

Notes: This figure shows the impulse response of the SPF one-year-ahead inflation expectation to a one-percentage point government expenditure shock, measured by the one-year change in defense spending over potential GDP. Dashed lines represent 95% confidence intervals for the impulse response estimates, constructed with Newey-West standard errors with a maximum lag of four quarters. The impulse responses are reported in percentage points.

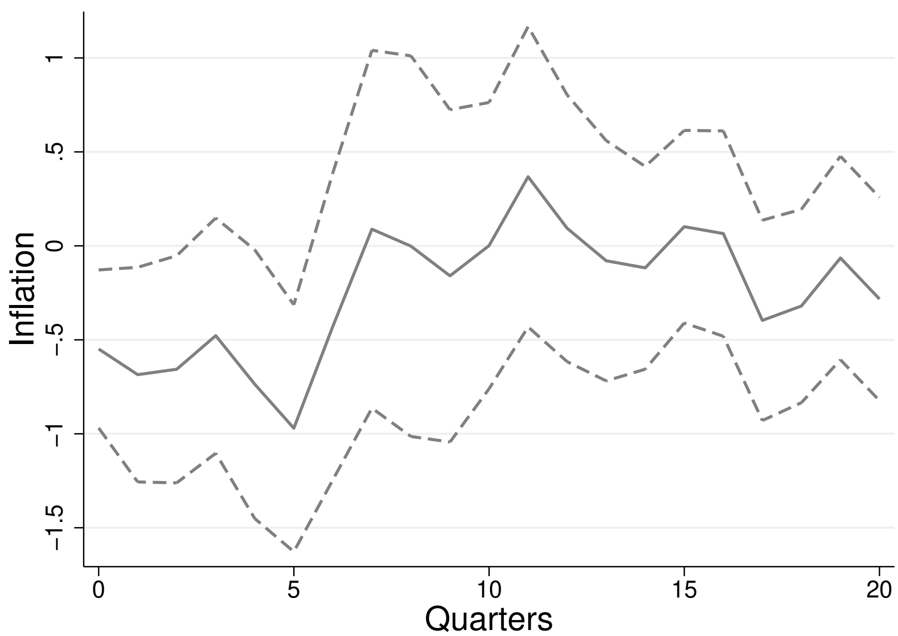

Figure E.5: Impulse Responses of Inflation to Government Expenditure Shocks

Notes: This figure shows the same estimation as the left panel of Figure 6 except that lagged inflation is added as an additional control variable in the local projection. The impulse responses are reported in percentage points.