FISCAL INFLATION IN THE UK*

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Abstract

We employ a model that allows for unfunded fiscal shocks to study inflation and real activity in the United Kingdom. Unfunded fiscal shocks are not backed by future fiscal adjustments and are instead stabilized with inflation. In an estimated quantitative model, we find that fiscal inflation was high in the 1960s and 1970s, but came down in the early 1980s. Following the pandemic, fiscal inflation has risen steadily due to rapidly growing government spending, which has contributed to greater persistence in inflation. Monetary and fiscal policy coordination has been instrumental in achieving both a soft landing and bringing inflation to target for the UK economy in the post-pandemic period.

JEL Codes: E50, E62, E30.

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1 Introduction

We study inflation dynamics in the United Kingdom, using a model in which policymakers stabilize fiscal imbalances through a combination of fiscal adjustments and inflation (Bianchi et al, 2023). Specifically, unfunded fiscal shocks are not backed by future fiscal adjustments and are instead stabilized with inflation. In response to business cycle shocks and funded fiscal shocks, the monetary authority controls inflation and the fiscal authority stabilizes debt. Instead, the subdued response of monetary and fiscal policy to the effects of unfunded fiscal shocks results in persistent changes in both inflation and real interest rates.

We first illustrate the distinction between funded and unfunded fiscal shocks in the context of a Fisherian model. Funded and unfunded shocks coexist in the model. The difference between the two types of shocks is that funded fiscal shocks are backed by future fiscal adjustments, while unfunded fiscal shocks are not. As a result, funded fiscal shocks are irrelevant for inflation, while unfunded fiscal shocks lead to an increase in inflation accommodated by the central bank. We then move to consider the effects of unfunded fiscal shocks in production economies. Absent nominal rigidities, unfunded fiscal shocks cause large and temporary jumps in inflation and do not have real effects, as in the Fisherian model. Allowing the central bank to partially respond to fiscal inflation delivers a more persistent inflation response, while introducing a maturity structure tempers the size of the initial jump. However, these extensions leave real activity and real interest rates unaffected and create a counterfactually tight link between inflation persistence and the monetary policy rule. Instead, with nominal rigidities, unfunded fiscal shocks have real effects and cause persistent movements in inflation and real interests rates, which leads us to a fiscal theory of persistent inflation.

We then augment a quantitative New Keynesian (NK) model with unfunded fiscal shocks to assess their importance for the dynamics of inflation in the UK. The model features all the ingredients that have been proven successful in matching business cycle dynamics in advanced economies, including a large set of business cycle shocks. With regard to these shocks, monetary policy satisfies the Taylor principle and the fiscal authority is in control of debt stabilization. Thus, in this respect, the model behaves as its counterparts extensively studied in the literature. However, the model also features unfunded fiscal shocks. We model these as shocks to transfers that are not backed by future fiscal adjustments, implying that a share of the overall government debt is unfunded. The central bank accommodates the increase in inflation necessary to stabilize the unfunded amount of debt. As in the textbook version of the New Keynesian model described above, these shocks trigger persistent movements in inflation, output, and real interest rates.

The model is endowed with a rich set of shocks, including a persistent shifter to the New

Keynesian Phillips Curve (NKPC) that is meant to capture autonomous factors, such as globalization and demographic changes, that can affect inflation in the long run. The model also features hand-to-mouth agents to allow for the possibility that funded fiscal shocks can influence macroeconomic dynamics.

We find that fiscal inflation was high in the 1960s and 1970s, but came down in the early 1980s. In this respect, the UK experience is similar to what documented for the United States in Bianchi et al. (2023). Both countries experienced a large acceleration in fiscal spending in the mid-1960s that generated inflationary pressure accommodated by the central banks. Similarly, both countries experienced a drastic change in the political environment in the 1980s. The United States with the election of President Reagan, the United Kingdom with the Premiership of Margaret Thatcher.

Between the 1980s and early 2000s, fiscal inflation in the UK remained remarkably low and even declined, in contrast to trends in the US. This diminished contribution of coordinated monetary and fiscal policies to inflation in the UK likely reflects the strengthened monetary framework established with the adoption of inflation targeting in 1992. Fiscal inflation declined further in the aftermath of the Great Financial Crisis in the US, contributing negatively to overall inflation in the post-crisis years. Consequently, our model suggests that both monetary and fiscal policies acted as a drag on the UK's recovery in the early 2010s. This finding highlights a notable disconnect from what Bianchi et al. (2023) find for the US over the same period and is consistent with the fiscal austerity program launched by the Conservative and Liberal Democrat coalition government in 2010. Although fiscal inflation saw a modest rise in the second half of the past decade as the government relaxed austerity measures to focus on growth, the overall contribution of coordinated monetary and fiscal policy to fiscal inflation remained limited during these years.

The pandemic crisis, however, triggered unprecedented coordination between monetary and fiscal policy to combat the severe economic impact of the health crisis. This coordination led to a substantial, albeit gradual, increase in the fiscal component of inflation. It, however, emerges from the model that this joint intervention played a critical role in stabilizing the economy and accelerating the UK's recovery after one of the most severe recessions in the postwar history of the country.

Importantly, while the model attributes the rapid rise and fall in UK post-pandemic inflation primarily to short-term supply shocks, the substantial monetary and fiscal stimulus –alongside rising government spending in recent years – has been a major contributor to increased inflation persistence. As of 2024, fiscal inflation remains elevated despite a decline in headline inflation, suggesting a continued risk of inflation resurgence, given that fiscal inflation often tracks low-frequency movements in broader inflation trends. This result aligns with the hypothesis proposed by Barro and Bianchi (2023), which posits that countries with longer debt maturities may aim to smooth inflation increases over an extended period.

The model enables counterfactual analysis that highlights the critical role of coordinated monetary and fiscal policies in the UK's economic recovery and in bringing inflation back to the Bank of England's 2% target. While inflation is expected to remain somewhat more persistent than in the pre-pandemic period due to accelerated fiscal spending, our model suggests that the combined objectives of the soft landing of the UK economy and the return to 2% inflation would not have been achieved without this policy coordination.

From a methodological perspective, this paper follows closely Bianchi et al. (2023) that introduces a novel class of models that allow policymakers to respond differently to various shocks. While the primary focus is on the impacts of unfunded fiscal shocks, these models can also be applied to explore other types of heterogeneity in policy responses. Smets and Wouters (2024) generalize this framework to allow policymakers to coordinate their monetary and fiscal policies differently in response to demand, fiscal, and supply shocks. Bianchi et al. (2023), in turn, builds on Bianchi and Melosi (2019), that propose shock-specific rules to address conflicts between monetary and fiscal authorities under high fiscal burdens. Here, both monetary and fiscal authorities adopt state-dependent targets, providing a fiscal theory of persistent inflation that operates continuously, not just during exceptional events

This paper contributes to the extensive body of work on monetary-fiscal policy interaction, including notable studies by Sargent and Wallace (1981), Leeper (1991), Sims (1994), Woodford (1994, 1995, 2001), Cochrane (1998, 2001), Schmitt-Grohe and Uribe (2000, 2002), Bassetto (2002a), and Bassetto and Sargent (2020). Barro (1974) demonstrates that non-Ricardian effects can arise if agents mistakenly view bonds as net wealth. Sargent and Hall (2010) show that US debt stabilization has historically been achieved through growth, revaluation effects, and low real interest rates. Bianchi and Melosi (2017, 2022) estimate a model with regime changes in the monetary/fiscal policy mix, linking the high inflation of the 1960s and 1970s to a fiscally-led regime. Bianchi and Melosi argue that the potential return to such a regime explains the absence of deflation after the Great Recession and the post-pandemic inflation.

2 Persistent Fiscal Inflation

In this section, we revisit the distinction between funded and unfunded shocks introduced by Bianchi et al. (2023). Bianchi et al. (2023) present a novel class of models that integrate both Monetary-led and Fiscally-led policy mixes simultaneously. The impact of shocks varies based on the specific policy response to each shock. This framework enables the inclusion of unfunded fiscal shocks into a standard model. We demonstrate the mechanism of these models, which feature shock-specific policy rules, using a simple Fisherian model as outlined by Leeper (1991) and Sims (1994, 2016). While our main focus is on fiscal inflation, this methodology can be applied to other contexts where researchers aim to model shock-specific policy responses. We then expand the analysis to a production economy, examining the effects of introducing nominal rigidities. In this extended model, we show that unfunded fiscal shocks lead to persistent inflation dynamics and have tangible economic impacts.

2.1 Funded and Unfunded Fiscal Shocks

Stylized Model. The economy consists of a continuum of infinitely many households and a government. The representative household has concave and twice continuously differentiable preferences over non-storable consumption goods and is endowed with a constant quantity Y of these goods each period. The government issues one-period bonds, B_t, which households can trade for consumption goods. The representative household chooses consumption and government bonds to maximize:

$$\max \sum_{t=0}^{\infty} \beta^t U\left(C_t\right),$$

subject to the flow budget constraint $P_t C_t + Q_t B_t + P_t T_t = P_t Y + B_{t-1}$, where $\beta < 1$ is the household's discount factor, P_t is the price of consumption goods, T_t represents real lump-sum net taxes, and $Q_t = 1/R_{n,t}$ is the price of the one-period government bond, equal to the inverse of the gross nominal interest rate $R_{n,t}$.

The government's budget constraint is given by $Q_t B_t + P_t T_t = B_{t-1}$, where net taxes T_t correspond to the real primary surplus. The fiscal authority follows a fiscal rule of the form:

$$\tau_t/\tau = \left(s_{b,t-1}/s_b\right)^{\gamma} e^{\zeta_{z,t}},$$

where $\tau = T_t/Y$ denotes the surplus-to-output ratio, $s_{b,t} = Q_t B_t/(P_t Y)$ is the real market value of debt as a share of output, τ and s_b represent their respective steady-state values, $\zeta_{z,t}$ is an autoregressive (AR(1)) shock to lump-sum taxes, and γ governs the fiscal authority's responsiveness to fluctuations in debt.

The central bank follows the monetary rule:

$$R_{n,t}/R_n = \left(\Pi_t/\Pi\right)^{\phi},$$

where $\Pi_t = P_t/P_{t-1}$ is the gross inflation rate at time t, variables without time subscripts denote steady-state values, and ϕ controls the central bank's response to inflation deviations from target.

Combining the household's Euler equation with the market clearing condition $C_t = Y$ in every period yields the Fisher equation: $Q_t = \beta\left(\mathbb{E}_t \Pi_{t+1}\right)^{-1}$.

Linearized System of Equations. We linearize the model around the deterministic steady state, where hatted variables represent log deviations from their steady-state values. The system of linearized equations is as follows:

$$
\begin{aligned}
\hat{r}_{n,t} &= \mathbb{E}_t\hat{\pi}_{t+1}, && (1)\\
\hat{s}_{b,t} &= \beta^{-1}[\hat{s}_{b,t-1} + \hat{r}_{n,t-1} - \hat{\pi}_t - (1-\beta)\hat{\tau}_t], && (2)\\
\hat{r}_{n,t} &= \phi\hat{\pi}_t, && (3)\\
\hat{\tau}_t &= \gamma\hat{s}_{b,t-1} + \zeta_{z,t}. && (4)
\end{aligned}
$$

Substituting the monetary rule (3) into the Fisher equation (1) gives the *monetary block*:

$$\mathbb{E}_t\hat{\pi}_{t+1} = \phi\hat{\pi}_t. \tag{5}$$

Combining the debt law of motion (2) with the fiscal rule (4) yields the *fiscal block*:

$$\hat{s}_{b,t} = \beta^{-1}[1-(1-\beta)\gamma]\hat{s}_{b,t-1} + \beta^{-1}[\hat{r}_{n,t-1} - \hat{\pi}_t - (1-\beta)\zeta_{z,t}]. \tag{6}$$

Existence and Uniqueness of a REE equilibrium. In this class of models, two distinct regions of the parameter space ensure the existence and uniqueness of a stationary solution (Leeper 1991). In the first region, monetary policy is active, meaning it responds more than proportionally to deviations of inflation from its target ($\phi > 1$). The fiscal authority, in turn, implements the necessary adjustments to ensure debt remains on a stable path ($\gamma > 1$). This is referred to as passive fiscal policy, as it accommodates the actions of the monetary authority. We term this policy configuration the *Monetary-led policy mix.* The defining characteristic of the Monetary-led policy mix is that the macroeconomy is fully insulated from fiscal dynamics, rendering fiscal imbalances irrelevant for inflation determination in equilibrium (a condition referred to as *Monetary and Fiscal Dichotomy*). This insulation is achieved through fiscal adjustments that ensure debt stability.[1] The first panel of Figure I illustrates this by showing that inflation remains unaffected by a negative shock to primary surpluses.

In the second region of the parameter space, characterized by the Fiscally-led policy mix, the fiscal authority does not commit to implementing the necessary fiscal adjustments. Monetary policy is now passive ($\phi \leq 1$), effectively accommodating the behavior of the active fiscal authority ($\gamma \leq 1$). Under this regime, the macroeconomy is not insulated from fiscal imbalances. Instead, inflation is driven by the need to stabilize government debt, making fiscal imbalances a determinant of inflation. The second panel of Figure I illustrates this outcome, showing that a negative shock to primary surpluses leads to an increase in inflation. This inflationary pressure is fully accommodated by the central bank ($\phi = 0$),

[1] In richer models featuring distortionary taxation and government expenditures, fiscal variables do influence the macroeconomy, albeit through a different channel than the one examined here.

ensuring that debt stability is preserved.

Shock-Specific Rules and Partially Unfunded Debt. We now extend the model to allow for the coexistence of Monetary-led and Fiscally-led policy mixes. In this new framework, the dynamics characteristic of a Monetary-led policy mix operate alongside those typical of a Fiscally-led policy mix. While our primary focus is on fiscal shocks, the same logic applies to any shocks that shift the fiscal burden of the economy, as shown in the more comprehensive model used in our empirical analysis. For clarity, we use the superscripts M and F to distinguish policy parameters associated with a Monetary-led and Fiscally-led policy mix, respectively.

We consider the following fiscal rule:

$$\tau_t/\tau = \left(s_{b,t-1}/s_{b,t-1}^F\right)^{\gamma^M} \left(s_{b,t-1}^F/s\right)^{\gamma^F} e^{\zeta_{z,t}^M+\zeta_{z,t}^F}, \tag{7}$$

where $\zeta_{z,t}^M$ and $\zeta_{z,t}^F$ represent funded and unfunded fiscal shocks, respectively. The unfunded component of debt, $s_{b,t}^F$, arises from unfunded fiscal shocks, for which the fiscal authority is not committed to making large fiscal adjustments ($\gamma^F \leq 1$). However, the fiscal authority actively stabilizes deviations from the funded component of debt ($\gamma^M > 1$). In other words, fiscal policy is passive with respect to the funded component of debt ($s_{b,t-1}/s_{b,t-1}^F$) and active with respect to the unfunded component ($s_{b,t-1}^F$).

The corresponding monetary rule is:

$$R_{n,t}/R_n = (\Pi_t/\Pi_t^F)^{\phi^M} (\Pi_t^F/\Pi)^{\phi^F}, \tag{8}$$

where Π_t^F refers to fiscal inflation, which represents the inflation tolerated by the central bank because needed to stabilize the share of unfunded debt. For fiscal inflation, monetary policy is passive, reacting less than one-to-one ($\phi^F \leq 1$). However, the central bank remains active in stabilizing inflation deviations from fiscal inflation, with $\phi^M > 1$.

By linearizing the fiscal rule presented in equation (7), we derive:

$$\hat{\tau}_t = \gamma^M \left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F\right) + \gamma^F \hat{s}_{b,t-1}^F + \zeta_{z,t}^M + \zeta_{z,t}^F. \tag{9}$$

Given that $\gamma^F \leq 1$, this expression clearly indicates that the fiscal adjustments are insufficient to fully address the fiscal burden.

Next, we linearize the monetary rule, which yields:

$$\hat{r}_{n,t} = \phi^M \left(\hat{\pi}_t - \hat{\pi}_t^F\right) + \phi^F \hat{\pi}_t^F. \tag{10}$$

Assuming further that $\phi^F = 0$, we arrive at a Taylor rule that is isomorphic to one featuring a time-varying target: $\hat{r}_{n,t} = \phi^M \left(\hat{\pi}_t - \hat{\pi}_t^F\right)$. Importantly, the time-varying target $\hat{\pi}_t^F$ does not represent an additional shock; rather, it is intricately linked to the inflation level that the central bank is willing to tolerate in order to manage a portion of the overall fiscal burden, leading to a fiscal theory of persistent inflation.

In Appendix A, we exploit the linearity of the model to demonstrate that the deviations in debt and inflation from their respective targets, $\hat{s}^M_{b,t} = \hat{s}_{b,t} - \hat{s}^F_{b,t}$ and $\hat{\pi}^M_t = \hat{\pi}_t - \hat{\pi}^F_t$, are *exactly* the amounts of debt and inflation that would occur if the Monetary-led policy mix were perpetually in effect and only funded shocks were present. Therefore, $\hat{s}^M_{b,t}$ can be interpreted as the amount of funded debt that the fiscal authority is dedicated to stabilizing through fiscal adjustments. Similarly, $\hat{\pi}^M_t$ reflects changes in inflation arising from shocks that the central bank does not accommodate and are instead the responsibility of the fiscal authority. The superscript M emphasizes that the Monetary-led policy mix applies to these variables.

Given that in the linearized model the total debt comprises two components, funded and unfunded debt, i.e., $\hat{s}_{b,t} = \hat{s}^M_{b,t} + \hat{s}^F_{b,t}$, we can reformulate the fiscal rule as:

$$\hat{\tau}_t = \gamma^M \hat{s}^M_{b,t-1} + \gamma^F \hat{s}^F_{b,t-1} + \zeta^M_{z,t} + \zeta^F_{z,t}.$$

In a similar vein, utilizing the fact that in the linearized model $\hat{\pi}_t = \hat{\pi}^M_t + \hat{\pi}^F_t$, we can restate the monetary rule as:

$$\hat{r}_{n,t} = \phi^M \hat{\pi}^M_t + \phi^F \hat{\pi}^F_t.$$

Consequently, the linearized model permits two equivalent interpretations of the policy rules. First, the rules can be viewed as characterizing a situation where policymakers respond to time-varying targets driven by the necessity to stabilize the unfunded debt. Alternatively, these rules can be understood as shock-specific reaction functions wherein policymakers react differently to distinct components of the endogenous target variables based on the shocks that induce the fluctuations.

By substituting the monetary rule (10) into the Fisherian equation (1), we obtain the monetary block of the model with partially unfunded debt:

$$\mathbb{E}_t \hat{\pi}_{t+1} = \phi^M \left(\hat{\pi}_t - \hat{\pi}^F_t\right) + \phi^F \hat{\pi}^F_t. \tag{11}$$

Inserting the policy rules into the law of motion of debt (2) leads to the fiscal block:

$$\hat{s}_{b,t} = \beta^{-1}[1 - (1-\beta)\gamma^M]\hat{s}_{b,t-1} + \beta^{-1}[(1-\beta)\hat{s}^F_{b,t-1} + \hat{r}_{n,t-1} - \hat{\pi}_t - (1-\beta)(\zeta^M_{z,t} + \zeta^F_{z,t})], \tag{12}$$

where, for simplicity, we assume that the fiscal authority completely ignores the amount of unfunded debt: $\gamma^F = 0$.

To close the model, we have to characterize the dynamics of fiscal inflation, $\hat{\pi}^F_t$, and the corresponding amount of unfunded debt, $\hat{s}^F_{b,t}$. To achieve this, we construct a shadow economy where the Fiscally-led policy mix is always in place, and only shocks to unfunded spending $\zeta^F_{z,t}$ occur. The shadow economy allows us to track fiscal inflation and the amount of unfunded debt. The monetary and fiscal blocks for this shadow economy are then given

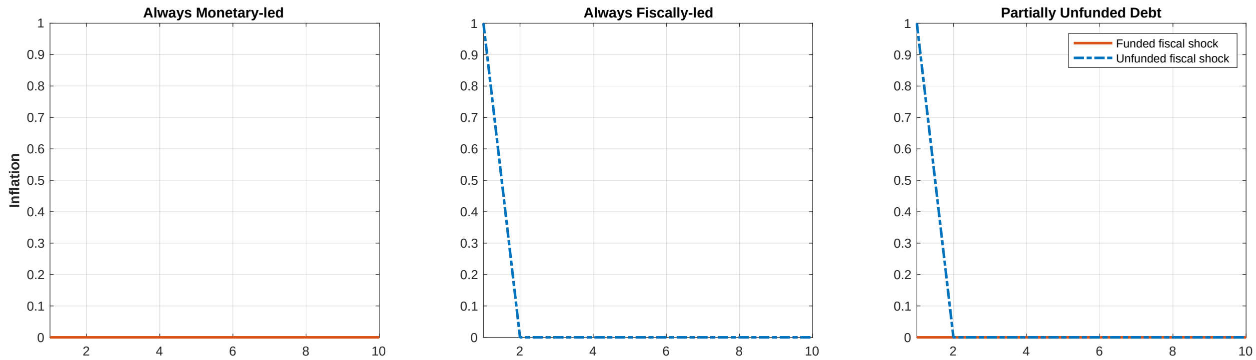

Figure I – Impulse Response of Inflation to a Fiscal Shock. The discount factor β is set to 0.99 and the steady-state value of debt-to-GDP ratio s_b is set to 1. In the model with partially unfunded debt, the monetary policy parameters are $\phi^M = 2$ and $\phi^F = 0$ and the fiscal policy parameters are $\gamma^M = 20$ and $\gamma^F = 0$. The Always Monetary-led model is parameterized as follows: $\phi = \phi^M$ and $\gamma = \gamma^M$. The Always Fiscally-led model is parameterized as follows: $\phi = \phi^F$ and $\gamma = \gamma^F$. Fiscal shocks have autocorrelation coefficient of 0.5 and their variance is scaled to produce a unit response of inflation on impact of an unfunded shock.

by:

$$\begin{aligned} \mathbb{E}_t \hat{\pi}^F_{t+1} &= \phi^F \hat{\pi}^F_t, && (13) \\ \hat{s}^F_{b,t} &= \beta^{-1} \hat{s}^F_{b,t-1} + \beta^{-1}(\hat{r}^F_{n,t-1} - \hat{\pi}^F_t) - \beta^{-1}(1-\beta)\zeta^F_{z,t}. && (14) \end{aligned}$$

It is noteworthy that the monetary and fiscal blocks for the shadow economy are isomorphic to those in equations (5) and (6) once the parameter restrictions for the Fiscally-led policy mix are enforced and only unfunded shocks are permitted.

The equations (11), (12), (13), and (14) together delineate the model with partially unfunded debt. Since there are two non-predetermined variables ($\hat{\pi}_t$ and $\hat{\pi}^F_t$) and two eigenvalues outside the unit circle associated with equations (11) and (14), the model meets the Blanchard and Khan conditions and is therefore determinate, implying the existence of a unique stable Rational Expectations equilibrium.

The third panel of Figure I illustrates the impulse responses within the model featuring partially unfunded debt. As before, we consider that the monetary authority fully accommodates the rise in fiscal inflation: $\phi^F = 0$. In reaction to a funded spending shock (represented by the solid blue line), the economy with partially unfunded debt behaves identically to the scenario depicted in the left panel, where policymakers consistently adhere to the Monetary-led policy mix, resulting in no impact on inflation from the shock. Conversely, in response to an unfunded spending shock, inflation rises. The behavior of the economy with partially unfunded debt mirrors that in the middle panel, where policymakers always implement the Fiscally-led policy mix. The policy rules within the model characterized by partially unfunded debt are shock-specific, leading policymakers to react differently based on the type of fiscal shocks encountered. Thus, the characteristics of both the Monetary-led and Fiscally-led policy mixes coexist within the framework of partially unfunded debt.

Our modeling framework aligns with a fundamental concept of the fiscal theory of the price level, which posits that debt stability can be attained through a combination of fiscal adjustments and inflationary movements that the central bank accommodates. In this context, the shadow economy serves to track the progression of the portion of debt that is not anticipated to be addressed through fiscal adjustments, while the remaining share, deemed funded, is expected to be backed by future fiscal adjustments. Therefore, the division between funded and unfunded spending resembles an accounting exercise, based on the conventional assumption of perfect and symmetric information among both agents and policymakers.

Lastly, it is noteworthy that we could have approached solving the model by constructing an alternative (Monetary-led) shadow economy where all public debt is funded, and the central bank consistently adheres to the Taylor principle, although only funded fiscal shocks are considered. This duality in solving models with shock-specific rules arises from the linearity of the model. Linearity indicates that the two shadow economies are, in fact, additive subeconomies of the actual economy. This implies that the aggregate inflation rates and total debts in the two parallel economies correspond to those in the actual economy (refer to Appendix A).

2.2 Unfunded fiscal shocks and nominal rigidities

We now extend the model presented in the previous section to include a production side. This enhanced model will be used to explore the impact of price rigidity on the transmission of funded and unfunded fiscal shocks to inflation, output, debt, and the real interest rate.

We modify the previous setup by assuming the period utility function is given by $U(C_t, N_t) = \ln C_t + \phi \ln(1 - N_t)$, where N_t denotes hours worked. Households earn real wage income $W_t N_t$ in exchange for providing labor services to firms, while the production function is defined as $Y_t = N_t^{1-\alpha}$. All other assumptions remain as described in the previous section, including the specification of the fiscal rules in equation (7). In the scenario of flexible prices, which serves as the benchmark for a classical economy, we assume perfect competition exists in both goods and labor markets. This stylized model is calibrated to align with the parameters of the quantitative model that we will estimated in Section 4. The linearized equations and the calibrated parameter values are documented in Appendix B.

The graphs in the first row of Figure II depict the impulse responses to funded and unfunded fiscal shocks (represented by the blue solid and red dashed lines, respectively) in the context of flexible prices. Two key observations arise from these graphs. First, expansionary fiscal shocks result in an increase in inflation solely when they are unfunded;

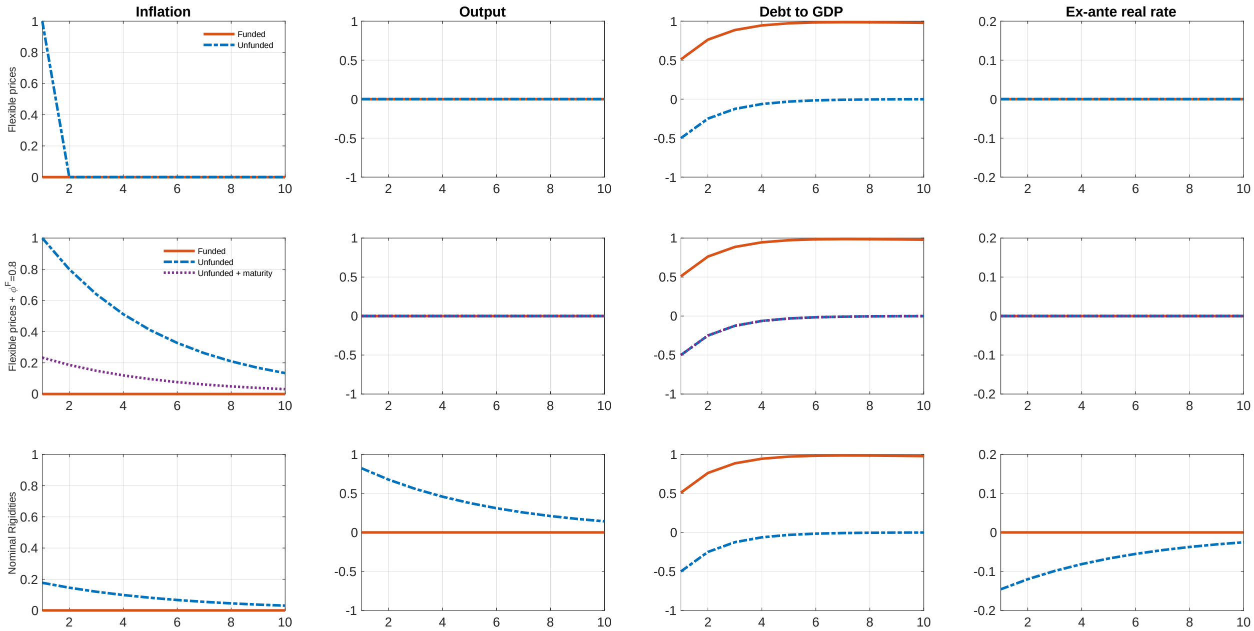

Figure II – Funded and unfunded fiscal shocks in production economies. Impulse responses of inflation, real output, debt-to-GDP ratio, the ex-ante real interest rate to funded (red solid line) and unfunded shocks (blue dash-dotted line) to primary surpluses. The first row shows the propagation in a model with perfectly flexible prices and $\phi^F = 0$. The second row shows the propagation in a model with perfectly flexible prices and $\phi^F = .8$. For unfunded shocks, we also consider the case with a maturity structure (purple dotted line). The last row reports the propagation in a prototypical New Keynesian model.

that is, only if they are not supported by future fiscal adjustments. Second, regardless of whether the expansionary fiscal shock is funded or unfunded, the real economy remains perfectly insulated from fiscal shocks. Similar to the standard model with flexible prices, the real economy is unaffected by changes in inflation. Additionally, it is noteworthy that the debt-to-output ratio declines following an unfunded fiscal shock because the increase in inflation boosts nominal output (although not real output). Consequently, incorporating a production economy with flexible prices does not alter the inflation dynamics as per the Fisherian model. This outcome is expected since, in this class of models, real activity and real interest rates are exogenous concerning inflation.

In the second row of Figure II, we explore two extensions of the model with flexible prices. Firstly, we allow for a positive central bank response to fiscal inflation, ($\phi^F > 0$), albeit still less than one-to-one ($\phi^F < 1$). For simplicity, we select $\phi^F = 0.8$. This positive response to fiscal inflation does not alter the response to funded shocks, but it induces a persistent inflation response to unfunded fiscal shocks. To clarify this, we can rewrite the monetary block (13) as:

$$\hat{\pi}^F_{t+1} \quad = \quad \phi^F \hat{\pi}^F_t + \eta^{\pi^F}_{t+1}. \tag{15}$$

Here, $\eta^{\pi^F}_{t+1} \equiv \hat{\pi}^F_{t+1} - \mathbb{E}_t \hat{\pi}^F_{t+1}$ represents the inflation surprise resulting from the unfunded fiscal shock.

This expression demonstrates that the persistence of fiscal inflation is governed by the Taylor rule coefficient ϕ^F. By adjusting the nominal interest rate, the central bank influences expected inflation. If the central bank alters the nominal interest rate in response to current inflation, it produces a lasting impact on inflation. The change in expected inflation does not affect the magnitude of the initial inflation jump $\eta_{t+1}^{\pi^F}$ because anticipated inflation cannot be used to devalue bonds that have yet to be issued.

Next, we introduce a maturity structure for government debt while maintaining $\phi^F = 0.8$ and choosing an average maturity of six years. The dotted magenta line in the second row of Figure II illustrates how this maturity structure influences the propagation of an unfunded fiscal shock. While the persistence of inflation remains controlled by the parameter ϕ^F, the introduction of a maturity structure reduces the initial inflation spike. This reduction occurs because a persistent inflation movement combined with a maturity structure results in increased long-term interest rates, which devalues outstanding long-term bonds. One can prove that the initial jump relies solely on the change in the present discounted value of future real surpluses. It diminishes if if ϕ^F increases or if the maturity lengthens.

In summary, for a fixed maturity, a larger ϕ^F leads to a greater rise in long-term interest rates for a given inflation trajectory, resulting in the devaluation of outstanding long-term bonds. For any given $\phi^F > 0$, an extended maturity entails a more significant devaluation of outstanding debt. If $\phi^F = 0$ or if the debt consists solely of one-period bonds, the initial response aligns with that obtained in the absence of a maturity structure. If bonds possess a long maturity but $\phi^F = 0$, neither inflation nor short-term rates exhibit persistence, preventing any devaluation of currently outstanding long-term bonds. Conversely, if $\phi^F > 0$ but the debt comprises only short-term instruments, there are no outstanding long-term bonds to devalue in the first place.

In all scenarios considered thus far, ex-ante real interest rates and output remain unaffected by unfunded fiscal shocks. This suggests that all debt stabilization must be achieved through an inflation surprise (whether present or future). We now modify the model further by incorporating monopolistically competitive firms that face price rigidities. These modifications render the linearized model akin to the stylized New Keynesian frameworks examined in the textbooks by Galí (2008) and Woodford (2003). The linearized equations for this model are presented in Appendix B. To isolate the effects of nominal rigidities, we revert to the case of $\phi^F = 0$ and no maturity structure.

In the third row of Figure II, we depict the propagation of funded (blue solid lines) and unfunded shocks (red dashed lines) in the model with nominal rigidities. A comparison of these responses to those illustrated in the first row highlights the impact of nominal rigidities on the propagation of these two types of fiscal shocks. Notably, the introduction of nominal rigidities does not alter the response to funded shocks, which remain irrelevant for output and inflation. However, nominal rigidities significantly affect the response to unfunded fiscal shocks. Unlike the model with fully flexible prices, the change in inflation following an unfunded fiscal shock unfolds over time, even in the absence of a maturity structure. Moreover, unfunded fiscal shocks now influence the trajectory of real interest rates and consequently output. As a result, the increase in inflation is considerably more moderated since debt stabilization is partly achieved through heightened output and a sustained decline in the cost of financing debt.

In conclusion, persistent movements in inflation can emerge in a frictionless environment by permitting a positive response of interest rates to fiscal inflation. Additionally, a maturity structure can substantially reduce the initial effect of an unfunded fiscal shock. However, variations in real interest rates and output arise only when nominal rigidities are introduced. The lower cost of financing debt and the elevated level of real activity contribute to stabilizing debt and attenuating the magnitude of the initial inflation spike.

In our quantitative assessment, we choose a model with nominal rigidities for several reasons. First, real interest rates and output exhibit significant low-frequency variations in the data and play a crucial role in the evolution of the government debt-to-GDP ratio. A model with flexible prices fails to account for these phenomena. Second, the lower panels of Figure II highlight essential empirical cross-correlations, which are critical for identifying unfunded fiscal shocks in the large-scale model estimated in Section 4. Specifically, unfunded shocks lead to increased inflation while simultaneously decreasing both the real interest rate and the debt-to-GDP ratio. Finally, a model featuring flexible prices can only produce persistence in fiscal inflation if the central bank partially responds to fiscal inflation ($\phi^F > 0$). This establishes a very tight relationship between nominal interest rates and expected inflation, which appears inconsistent with the data. For instance, in the post-pandemic period, inflation persistently increased despite nominal interest rates not initially responding to inflation ($\phi^F = 0$). A model incorporating nominal rigidities, where the central bank accommodates the surge in fiscal inflation, seems more suitable for explaining this stylized fact.

3 A Quantitative Model

In this section, we develop and estimate a state-of-the-art Two-Agent New Keynesian (TANK) model that includes a comprehensive fiscal framework and accounts for partially unfunded debt. The model incorporates key features that have been effective in capturing business cycle dynamics in advanced economies, such as a wide range of business cycle shocks. In terms of these shocks, monetary policy adheres to the Taylor principle, while the fiscal authority ensures debt stabilization. In this sense, the model behaves similarly to those widely studied in the literature (see, for example, Christiano et al. (2005) and Leeper et al. (2017)). However, a distinctive aspect of this model is the inclusion of unfunded fiscal shocks. These shocks affect transfers and government purchases and are not accompanied by future fiscal adjustments, meaning that part of the government debt remains unfunded. The following section provides a detailed outline of the model.

3.1 The Economy

The economy is populated by a unit measure of households, of which a fraction μ are hand-to-mouth consumers. The remaining fraction of households, $1-\mu$, are savers, denoted with an S superscript. The existence of hand-to-mouth households, along with distortionary taxation, breaks Ricardian equivalence and makes funded fiscal shocks relevant for part of the population even under a monetary-led policy mix.

Savers. Each household of optimizing saving agents, indexed by j, derives utility from the consumption of a composite good, $C_t^{*S}(j)$, which consists of private consumption, $C_t^S(j)$, and government purchases, G_t, such that $C_t^{*S}(j) = C_t^S(j) + \alpha_G G_t$. The parameter α_G governs the substitutability between private and government consumption: when negative, the goods are complements; when positive, they are substitutes. External habits in consumption imply that utility is derived relative to the previous period's aggregate savers' consumption of the composite good, θC_{t-1}^{*S}, where $\theta \in [0,1]$ is the habit parameter. Saver households also experience disutility from supplying differentiated labor services from all members, indexed by l, $L_t^S(j) = \int_0^1 L_t^S(j,l)dl$. The period utility function is given by

$$U_t^S(j) = u_t^b \left(\ln \left(C_t^{*S}(j) - \theta C_{t-1}^{*S} \right) - \frac{L_t^S(j)^{1+\xi}}{1+\xi} \right), \tag{16}$$

where u_t^b represents a discount factor shock and ξ is the Frisch elasticity of labor supply.

Households accumulate wealth in the form of physical capital $\bar{K}_t^S$. The stock of capital depreciates at rate δ and grows with investment I_t^S, net of adjustment costs. The law of motion for physical capital is:

$$\bar{K}_t^S(j) = (1-\delta)\bar{K}_{t-1}^S(j) + u_t^i \left[1 - s\left(\frac{I_t^S(j)}{I_{t-1}^S(j)} \right) \right] I_t^S(j),$$

where u_t^i is a shock to the marginal efficiency of investment, and s denotes an investment adjustment cost function that satisfies the properties $s(e^{\varkappa}) = s'(e^{\varkappa}) = 0$ and $s''(e^{\varkappa}) \equiv s > 0$, with $\varkappa$ as a drift parameter capturing the logarithm of the gross rate of steady-state technology growth.

Households earn income by renting effective capital $K_t^S(j)$ to intermediate firms. Effective capital is related to physical capital by $K_t^S(j) = \nu_t(j)\bar{K}_{t-1}^S(j)$, where $\nu_t(j)$ is the capital utilization rate. The cost of utilizing one unit of physical capital is governed by the function $\Psi(\nu_t(j))$. For the steady-state utilization rate $\nu(j) = 1$, the function Ψ satisfies $\Psi(1) = 0$, and $\frac{\Psi''(1)}{\Psi'(1)} = \frac{\psi}{1-\psi}$, where $\psi \in [0, 1)$. The gross rental rate of capital is denoted by $R_{K,t}$, and the tax rate on capital rental income is represented by $\tau_{K,t}$.

The household can also save by purchasing one-period government bonds in zero net supply and a more general portfolio of long-term government bonds in non-zero net supply. The one-period bonds, which promise a nominal payoff of B_t at time $t+1$, can be purchased at the present discounted value $R_{n,t}^{-1}B_t$, where the gross nominal interest rate $R_{n,t}$ is set by the central bank. The long-term bond B_t^m mimics a portfolio of bonds with an average maturity of m and a duration of $(1 - \beta\rho)^{-1}$, where $\rho \in [0, 1]$ is a constant rate of decay. This bond can be purchased at the price P_t^m, which is determined by the arbitrage condition $R_{n,t} = \mathbb{E}_t\left[(1 + P_{t+1}^m)/P_t^m\right] e^{-u_t^{rp}}$, where the wedge u_t^{rp} can be interpreted as a risk premium shock.

Each period, the household receives after-tax nominal labor income, after-tax revenues from renting capital to firms, lump-sum transfers from the government, Z_t^S, and dividends from the firms, D_t. These resources can be used for consumption, physical capital investment, and bond purchases. Omitting the index j for simplicity, the nominal budget constraint for the saver household can be written as:

$$
\begin{aligned}
P_t\left(1-\tau_{C,t}\right)C_t^S + P_tI_t^S + P_t^mB_t^m + R_{n,t}^{-1}B_t \\
= \left(1+\rho P_t^m\right)B_{t-1}^m + B_{t-1} + \left(1-\tau_{L,t}\right)\int_0^1 W_t(l)L_t^S dl \\
+ \left(1-\tau_{K,t}\right)R_{K,t}\nu_t\bar{K}_{t-1}^S - \psi\left(\nu_t\right)\bar{K}_{t-1}^S + P_tZ_t^S + D_t,
\end{aligned}
\tag{17}
$$

where $W_t(l)$ denotes the wage rate faced by all household members, and $\tau_{C,t}$ and $\tau_{L,t}$ are the tax rates on consumption and labor income, respectively. The household maximizes discounted utility $\sum_{t=0}^{\infty}\beta^tU_t^S$ subject to the sequence of budget constraints in equation (17).

Hand-to-Mouth Households. Each period, hand-to-mouth households consume all of their disposable, after-tax income, which consists of revenues from labor supply and government transfers. Hand-to-mouth households supply differentiated labor services, setting their wage equal to the average wage optimally chosen by the savers, as described below. Both savers and non-savers face the same tax rates on consumption and labor income. Using the superscript N to denote non-saving, hand-to-mouth households, their budget constraint can be written as:

$$\left(1+\tau_{C,t}\right)P_tC_t^N = \left(1-\tau_{L,t}\right)\int_0^1 W_t(l)L_t^N(l)dl + P_tZ_t^N.$$

Final Good Producers. A perfectly competitive sector of final good firms produces the homogeneous good Y_t at time t by combining a unit measure of intermediate differentiated inputs using the technology

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{1}{1+\eta_t^p + u_t^{NKPC}}} di \right)^{1+\eta_t^p + u_t^{NKPC}},$$

where η_t^p denotes exogenous independent and identically ditributed (i.i.d.) changes in the elasticity of substitution among good varieties. In the linearized version of the model, these shocks shift the New Keynesian Phillips curve (NKPC) and are often dubbed cost-push shocks. The variable u_t^{NKPC} is also a cost-push shock, but it is assumed to follow a near-unit-root process. This highly persistent cost-push shock is meant to capture other external forces, such as international trade, that can generate low-frequency movements of inflation. Profit maximization yields the demand function for intermediate goods

$$Y_t(i) = Y_t \left(P_t(i) / P_t \right)^{-\left(1+\eta_t^p + u_t^{NKPC}\right)/\left(\eta_t^p + u_t^{NKPC}\right)},$$

where $P_t(i)$ is the price of the differentiated good i and where P_t is the price of the final good.

Intermediate Good Producers. Intermediate firms produce using the technology

$$Y_t(i) = K_t(i)^{\alpha} \left(A_t L_t(i) \right)^{1-\alpha} - A_t \Omega,$$

where Ω is a fixed cost of production that grows with the rate of labor-augmenting technological progress A_t and $\alpha \in [0,1]$ is a parameter. Technological progress, denoted by A_t, follows an exogenous process that is stationary in its growth rate. Specifically, we assume the process $\hat{u}_t^a = \rho_{ea} \hat{u}_{t-1}^a + \varepsilon_t^a$, where $\hat{u}_t^a = \ln(A_t/A_{t-1}) - \varkappa$. Intermediate firms rent capital and labor in perfectly competitive factor markets. The labor input, L_t, is an aggregation of all differentiated labor services supplied in the economy, which are consolidated into a homogeneous input by a labor agency, as described later. Cost minimization implies that all firms face the same nominal marginal cost, given by:

$$MC_t = (1-\alpha)^{\alpha-1} \alpha^{-\alpha} \left(R_{K,t} \right)^{\alpha} W_t^{1-\alpha} A_t^{-1+\alpha}.$$

When setting prices, intermediate producers encounter price frictions à la Calvo, meaning that at any time t, a firm i can optimally reset its price with probability ω_p. Otherwise, it adjusts its price through partial indexation to the previous period's inflation rate according to the rule:

$$P_t(i) = \left(\Pi_{t-1} \right)^{\chi_p} (\Pi)^{1-\chi_p} P_{t-1}(i),$$

where $\chi_p \in [0,1]$ is a parameter, $\Pi_{t-1} = \frac{P_{t-1}}{P_{t-2}}$, and Π denotes the steady-state inflation rate.

Firms that can reset their prices maximize the expected discounted stream of nominal profits:

$$\max \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\omega_p)^s \frac{\Lambda^S_{t+s}}{\Lambda^S_t} \left[\left(\prod_{k=1}^{s} \Pi^{\chi_p}_{t+k-1} \Pi^{1-\chi_p} \right) P_t(i) Y_{t+s}(i) - MC_{t+s} Y_{t+s}(i) \right],$$

subject to the demand function of the final goods sector, with Λ^S representing the marginal utility of the savers.

Wages. Both savers and hand-to-mouth households supply differentiated labor services, indexed by l, in units. In each period, a saver household has a chance to optimally readjust the wage rate $W_t(l)$ with probability ω_w. If not, the wage increases at the geometric average of the steady-state inflation rate Π and the previous period's inflation rate Π_{t-1}, according to the rule:

$$W_t(l) = W_{t-1}(l) \left(\Pi_{t-1} e^{\varkappa}\right)^{\chi_w} \left(\Pi e^{\varkappa}\right)^{1-\chi_w},$$

where $\chi_w \in [0,1]$ governs the degree of nominal wage indexation. All households, both savers and non-savers, sell their labor services to a representative, competitive agency that aggregates them into a homogeneous input according to the technology:

$$L_t = \left(\int_0^1 L_t(l)^{\frac{1}{1+\eta^w_t}} dl \right)^{1+\eta^w_t},$$

where η^w_t represents an exogenous wage mark-up shock. The agency rents differentiated labor $L_t(l)$ at price $W_t(l)$ and sells a homogeneous labor input to intermediate producers at the wage rate W_t. The static profit maximization problem yields the labor demand function:

$$L_t(l) = L_t \left(\frac{W_t(l)}{W_t} \right)^{-\frac{1+\eta^w_t}{\eta^w_t}}.$$

Monetary and Fiscal Policy. Assuming that one-period government bonds are in zero net supply and that households receive the same level of transfers, regardless of being hand-to-mouth or savers, the government's nominal budget constraint is given by:

$$P^m_t B^m_t + \tau_{K,t} R_{K,t} K_t + \tau_{L,t} W_t L_t + \tau_{C,t} P_t C_t = \left(1 + \rho P^m_t\right) B^m_{t-1} + P_t G_t + P_t Z_t,$$

where $C_t = \mu C^N_t + (1-\mu) C^S_t$ and $Z_t = \int_0^1 Z_t(j) dj$ represent aggregate consumption and total transfers, respectively. This budget constraint implies that the fiscal authority finances government expenditures, transfers, and debt rollover by raising taxes on consumption, labor, and capital, as well as by issuing new long-term debt obligations.

We rescale fiscal variables as $g_t = G_t/A_t$ and $z_t = Z_t/A_t$. For any variable x_t, $\widehat{x}_t$ denotes the percentage deviation from its steady state. The debt-to-GDP ratio $s_{b,t} = \frac{P^m_t B^m_t}{P_t Y_t}$, in deviations from the steady state, $\hat{s}_{b,t}$, can be split into two components: funded debt $\hat{s}^M_{b,t}$ and unfunded debt $\hat{s}^F_{b,t}$. As in the models from Section 2, the monetary-led policy mix applies to funded debt, while the fiscally-led policy mix governs unfunded debt. Shocks are identified using superscripts, with transfer shocks affecting both types of debt, and all other shocks impacting only the funded portion.

The fiscal authority adjusts government purchases $\hat{g}_t$, transfers $\hat{z}_t$, and tax rates on capital income, labor income, and consumption $\hat{\tau}_J,\ J \in \{K, L, C\}$ as follows:

$$\hat{g}_t^b = \rho_G \hat{g}_{t-1}^b - (1-\rho_G)\left[\gamma_G\left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F\right) + \phi_{gy}\hat{y}_t\right] + \hat{\zeta}_{g,t} \tag{18}$$

$$\hat{z}_t^b = \rho_Z \hat{z}_{t-1}^b - (1-\rho_Z)\left[\gamma_Z\left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F\right) + \phi_{zy}\hat{y}_t\right] + \hat{\zeta}_{z,t} \tag{19}$$

$$\hat{\tau}_{J,t} = \rho_J \hat{\tau}_{J,t-1} + (1-\rho_J)\gamma_J\left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F,\right) \tag{20}$$

where $(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F)$ denotes the portion of the debt-to-GDP ratio that the fiscal authority is committed to stabilize with fiscal adjustments. This commitment is captured by the values for the reaction parameters γ_G, γ_Z, and $\gamma_J > 0$ that are large enough to guarantee that this portion of debt remains on a stable path. The fiscal authority does not make fiscal adjustments in response to the remaining portion of debt, which is unfunded, $\hat{s}_{b,t-1}^F$. The total amount of transfers is given by $\hat{z}_t \equiv \hat{z}_t^b + \zeta_{z,t}^M + \zeta_{z,t}^F$. The shocks $\zeta_{z,t}^M$ and $\zeta_{z,t}^F$ influence the funded and unfunded share of total transfers and are assumed to follow persistent AR(1) processes to capture the historical evolution of transfers in the United Kingdom. The term $\hat{z}_t^b$ captures transitory movements in funded transfers and possible adjustments in response to debt and the business cycle. Analogously, the total amount of government purchases is given by $\hat{g}_t \equiv \hat{g}_t^b + \zeta_{g,t}^M + \zeta_{g,t}^F$. The short-term fiscal shocks $\hat{\zeta}_{g,t}$ and $\hat{\zeta}_{z,t}$ follow AR(1) processes with Gaussian shocks.

The short-term interest rate $\hat{R}_{n,t}$ is set by the central bank in response to fluctuations of inflation originating from the typical business cycle shocks and the funded fiscal shocks, while it fully accommodates the movements in inflation necessary to stabilize the unfunded portion of debt. As explained in Section 2, this shock-specific monetary policy rule can be captured by a standard Taylor rule in which the central bank reacts to deviations of inflation from the level of inflation needed to stabilize the unfunded share of debt. We call this level of inflation tolerated by the central bank, fiscal inflation, $\hat{\pi}_t^F$. It follows that the linearized monetary policy rule with an effective lower bound constraint (ELB) can be written as

$$\hat{r}_{n,t} = \max\left[-\ln \underline{R_n}, \rho_r \hat{r}_{n,t-1} + (1-\rho_r)\left[\phi_\pi\left(\hat{\pi}_t - \hat{\pi}_t^F\right) + \phi_y \hat{y}_t\right] + u_t^m\right], \tag{21}$$

where u_t^m is a monetary policy shock.

The parameter $\phi_\pi > 1$ implies that the Taylor principle is satisfied and monetary policy is active when responding to deviations of inflation, $\hat{\pi}_t$, from fiscal inflation, $\hat{\pi}_t^F$. The variable $\hat{\pi}_t^F$ measures the increase in inflation, relative to the central bank's long-term target (and steady-state rate), that the central bank accommodates to stabilize the amount of unfunded debt $\hat{s}_{b,t-1}^F$. The policy mix characterized by equations (18)-(21) therefore implies that monetary policy is active in response to deviations of inflation from fiscal inflation and passive (no response) with respect to the inflation needed to stabilize the share of unfunded debt in deviations from its long-term target. Concurrently, fiscal policy is passive with respect to its commitment in stabilizing the share of funded government debt $\hat{s}_{b,t-1} - \hat{s}^F_{b,t-1}$, and active (no response) with respect to the unfunded share of debt. Thus, a monetary-led policy mix with respect to the typical business cycle shocks coexists with a fiscally-led policy mix with respect to the unfunded fiscal shocks.

The way fiscal inflation $\hat{\pi}^F_t$ enters the Taylor rule is similar to a time-varying target or an inflation drift that is typically added to estimated medium-scale Dynamic Stochastic General Equilibrium (DSGE) models to explain persistent inflation in the data (e.g., Smets and Wouters 2007). However, while the inflation drift in these other models evolves exogenously according to a close-to-random-walk process, fiscal inflation in our model varies in response to the need to stabilize the share of unfunded debt, which is endogenous. Changes in fiscal inflation $\hat{\pi}^F_t$ result from the coordination between monetary and fiscal authorities regarding the stabilization of the existing public debt.

3.2 Solving the Model

To solve the model, we begin by detrending the non-stationary variables to account for the unit root present in the labor-augmenting technology, A_t. Following this, we log-linearize the model equations around the deterministic steady-state equilibrium. The complete list of log-linearized equations is provided in Appendix C.

In a manner consistent with Section 2, we construct a shadow economy that monitors the unfunded portion of debt alongside the evolution of the associated endogenous variables. The shadow economy differs from the actual economy in that it only incorporates unfunded fiscal shocks ($\zeta^F_{z,t}$ and $\zeta^F_{g,t}$), with policymakers adhering to the fiscally-led policy mix. All other model equations remain identical between the actual and shadow economies. The model can be solved using standard techniques applicable to linear rational expectations models.

4 Empirical analysis

The model is estimated using Bayesian techniques. The posterior distribution is obtained combining the priors for the model parameters with the model's likelihood function. The likelihood is evaluated with the Kalman filter.

4.1 Data

The data set we use for estimation comprises 10 variables for the UK economy observed at quarterly frequency over the period 1960:Q1 - 2024:Q1 (T = 257): real per capita GDP growth, real per capita consumption growth, real per capita investment growth, a measure of the hours gap, nominal interest rate (measured by the Bank Rate), the growth of average weekly real earnings, price inflation based on household consumption, the growth of real per capita government transfers, the growth of real per capita government consumption and investment, and the government debt-to-GDP ratio[2]. Appendix D shows how these series are constructed.

Figure III illustrates the dynamics of a subset of observable variables used in our estimation. Prior to the 1980s, the UK economy experienced high volatility, marked by severe inflationary episodes that reached a peak near 25% in the mid-1970s, accompanied by negative real interest rates. The post-1980s were characterized by sustained lower inflation and more stable positive real interest rates. This period of relative stability was dramatically interrupted by the 2008 Financial Crisis, which triggered a significant monetary policy response, bringing the Bank Rate close to zero for an extended period. The fiscal variables reveal an evolving role of the UK government in the economy. The transfers-to-GDP ratio shows a secular upward trend from around 10% in the 1960s to above 20% by 2020, with sharp spikes during the Financial Crisis and an unprecedented surge during the COVID-19 pandemic. Government purchases have remained relatively stable at around 15 - 20% throughout the period, although with notable increases during major crises. The debt-to-GDP ratio, which had been declining from its post-WWII levels through the 1970s, began a sharp ascent following the 2008 crisis and accelerated dramatically during the COVID-19 pandemic, reaching its historic peak of around 140% in 2020:Q2. A detailed structural analysis of the main drivers of these observables according to our model will be presented later in the paper.

To account for the Bank Rate being stuck at the effective lower bound (ELB) for most of the 2008:Q1 - 2024:Q1 period, we estimate the model over two subsamples: from 1960:Q1 through 2007:Q4 and then from 2008:Q1 through 2024:Q1. When estimating the model on the second subsample, we incorporate market expectations of the Bank Rate 1 through 10 quarters ahead. These expected policy rates are based on the Bank of England daily overnight index swap (OIS) forward curve, available from January 1, 2009. For each day t, we take the average of instantaneous forward rates at $3j-2$, $3j-1$, and $3j$ months as the expected policy rate for the j-th quarter ($j = 1, 2, \ldots, 10$). Then we construct the quarterly series by taking the average of the daily series within each quarter of our sample.

Figure IV shows the evolution of the short-term interest rate along with its market expected paths in the second subsample (2008:Q1 - 2024:Q1). Notably, during the extended

[2] We allow for measurement errors in the real per capita GDP growth and the debt-to-GDP ratio in our estimation.

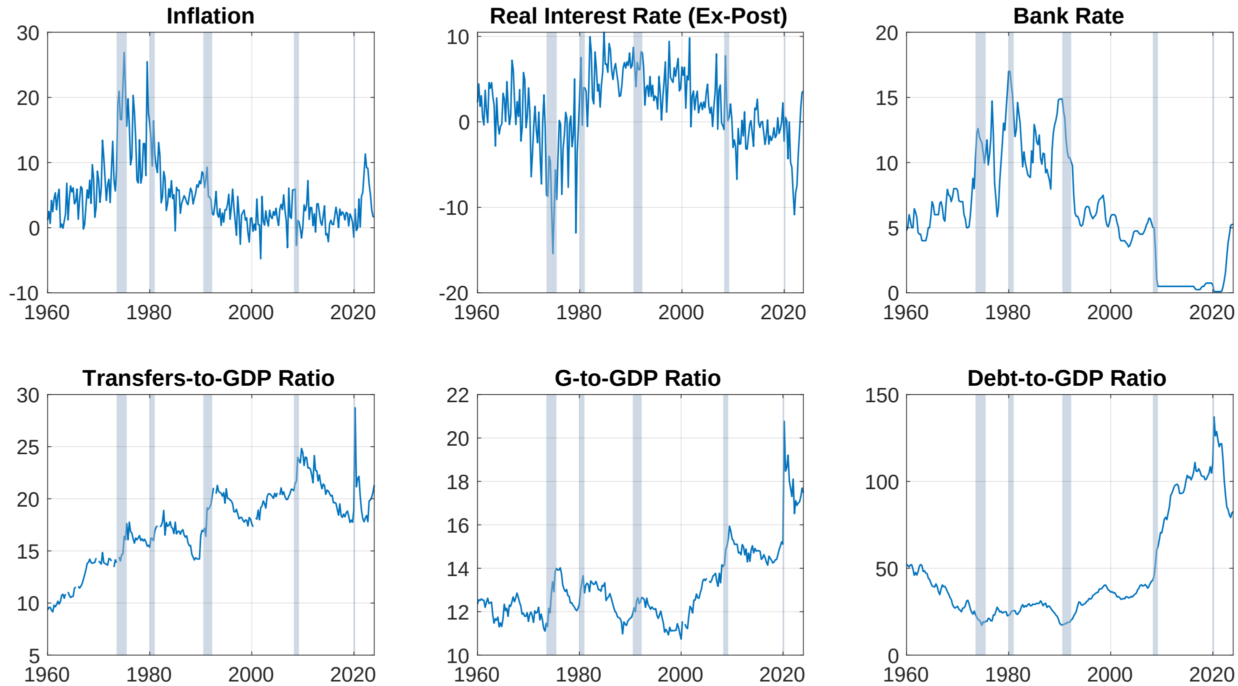

Figure III – **Time series of Macro and Fiscal Variables in the UK.** The sample period is 1960:Q1 to 2024:Q1. Macro variables include inflation, the ex-post real interest rate, and the Bank Rate, all expressed as annualized percentage points. Fiscal variables consist of the government transfers-to-GDP ratio, the government consumption and investment (denoted as "G") to GDP ratio, and the debt-to-GDP ratio, expressed in percentage points. Shaded areas highlight periods of economic recessions according to Office for National Statistics.

period when the policy rate was constrained at the ELB, observing the market's expected path of interest rates provides crucial insights into the anticipated timing for liftoff in our empirical analysis. This path also enhances our ability to evaluate the monetary policy's stance on inflation stabilization, which is crucial for assessing the extent of monetary and fiscal policies coordination, even during periods when we do not see movements in the policy rate due to the binding ELB constraint.

4.2 Priors

Some parameters are fixed in the estimation or determined by steady-state restrictions. We set the discount factor β to 0.99, ensuring that the steady-state real interest rate broadly aligns with its sample average. The quarterly capital depreciation rate, δ, is chosen to achieve an investment rate of 2.5%. The parameters related to steady-state markups on wages and prices cannot be distinctly identified in the estimation process, so they are fixed at 0.12 as per Harrison and Oomen (2010). The elasticity of output to capital in the production function α is set at 0.3 to broadly correspond to the observed share of labor income in the sample. The parameter s_{gc}, representing government purchases-to-GDP ratio, is assigned

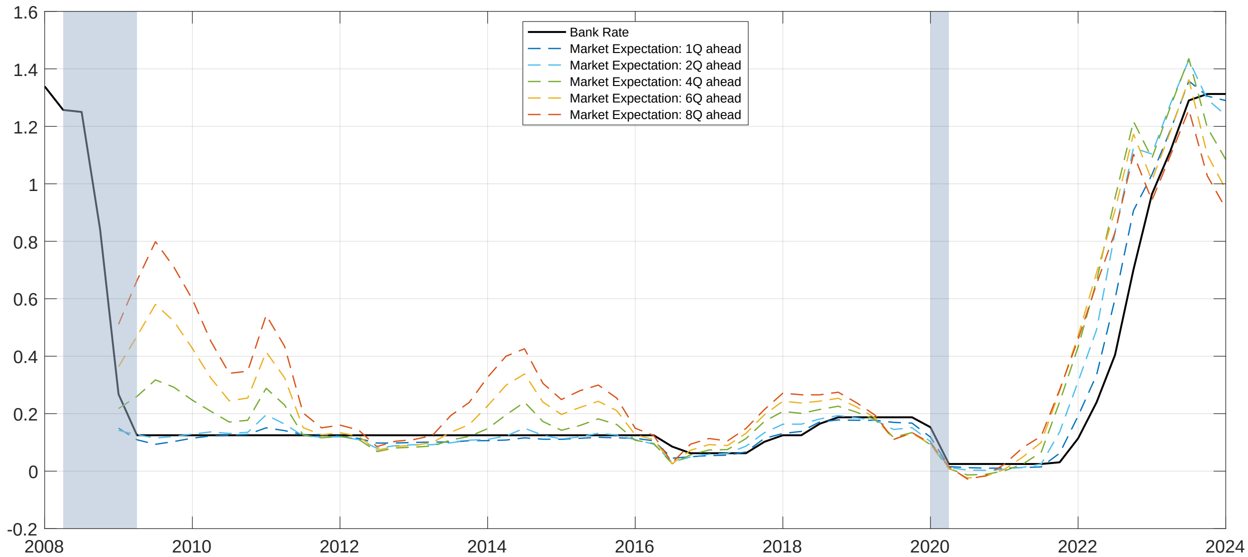

Figure IV – **Bank rate and its market expectations in the UK**. The sample period is 2008:Q1-2024:Q1. The Bank Rate (solid black line) is the policy rate set by the Bank of England. The market expectations of the Bank Rate (dashed lines) are derived from the instantaneous nominal forward curve, which is based on overnight index swaps.

a value of 0.12 to reflect the sample mean. Steady-state tax rates on labor, capital, and consumption, denoted by the parameters τ_L, τ_K, and τ_C, are set at 0.29, 0.29, and 0.2, respectively, following Bhattarai and Trzeciakiewicz (2017).

Figure V reports the number of outstanding UK government bonds of different maturities (in years). Darker areas imply that a larger number of securities of the corresponding maturity is outstanding. The green dashed line corresponds to the average maturity based on the number of bonds outstanding, and the red solid line reports the value-weighted average maturity. Both average maturity measures exhibit a U-shaped pattern over the sample period, decreasing from over 20 years in the early 1960s to approximately 10 years in the early 2000s. Subsequently, they rose gradually, leveling off at roughly 17.5 and 15 years, respectively, by the end of the sample. The sample mean for these measures is 14.1 and 14.0, respectively, which leads us to set the average maturity of government debt at 14 years.

The right panels in Tables I and II report the priors for the structural parameters and for the exogenous processes, respectively. In order to determine the prior distributions for the model parameters, we employ the methodology proposed by Negro and Schorfheide (2008).

Generally, priors for macroeconomic and fiscal variables are fairly diffuse. The prior for the proportion of hand-to-mouth households μ is set at 0.1 to match the share of poor hand-to-mouth consumers, following Kaplan et al. (2014). The debt parameter s_b is centered at 1.21 to target the sample mean of the debt-to-GDP ratio. The priors for the monetary policy parameters (ϕ_y, ϕ_π) are based on Harrison and Oomen (2010), while those for fiscal policy parameters $(\gamma_Z, \gamma_G, \gamma_K, \gamma_L, \gamma_C)$ follow Bhattarai and Trzeciakiewicz (2017). The priors for

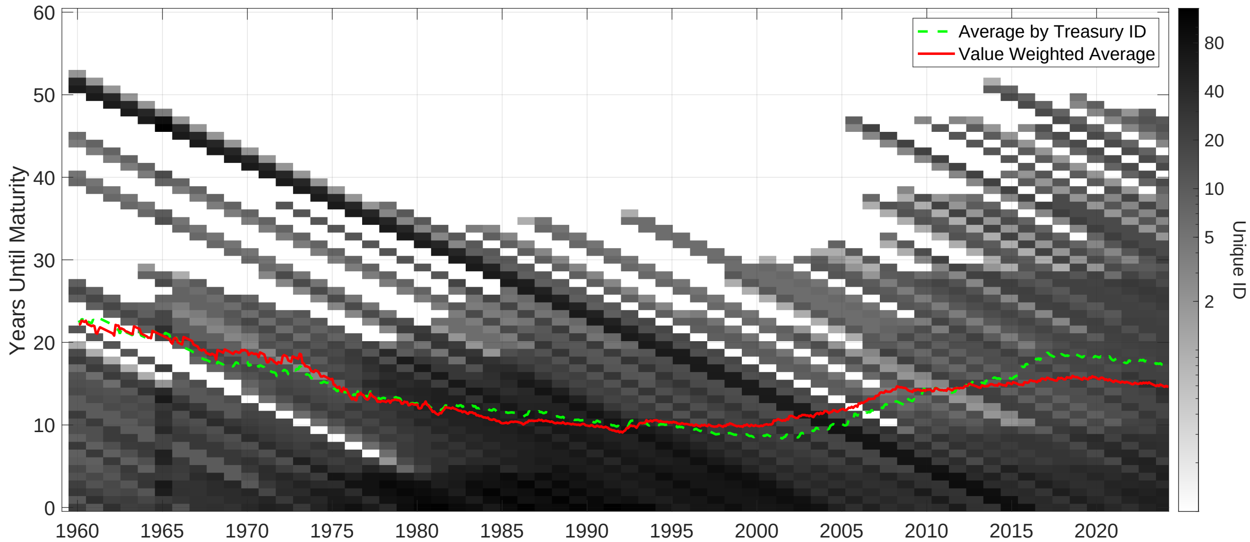

Figure V – **Maturity Structure of Outstanding UK Government Debt.** The figure reports the number of outstanding UK government bonds of different maturities (in years) over the sample 1960–2024. Darker areas imply that a larger number of securities of the corresponding maturity is outstanding. The green dashed line corresponds to the average maturity based on the number of bonds outstanding, and the red solid line reports the value-weighted average maturity.

the autocorrelation coefficients of the funded and unfunded fiscal shocks are tightly centered around a very persistent mean, reflecting the econometrician's beliefs in the persistence of changes in these transfers and purchases, and capturing their tendency to orbit around a stable trend as shown in the data. In contrast, cyclical increases in government transfers and purchases are expected to be backed by the increase in tax revenues and the decline in spending that ensue during the next economic recovery. We also set the prior on the autocorrelation coefficient of the persistent cost-push shock ($\rho_{\mu^{NKPC}}$) to provide the model with a competing mechanism to explain persistent inflation. Thus, the model allows, but does not require, persistent inflation to be generated by unfunded fiscal shocks. Finally, the prior for the standard deviation of the shocks is the same across different shocks.

4.3 Posterior Distributions

The left panels of Tables I and II report the posterior distributions for the structural parameters and the exogenous processes, respectively, obtained over the sample period 1960:Q1–2007:Q4. The estimates obtained over the second subsample, 2008:Q1 – 2024:Q1, are reported in Appendix E. Our estimated price rigidities, wage rigidities, and habit parameter are on the upper side relative to the literature. The output and inflation coefficient in the Taylor rule are consistent with other studies that rely on estimated monetary DSGE models using UK data (Harrison and Oomen, 2010; Chen and Macdonald, 2012; Bhattarai

Prior and Posterior Distributions for the Structural Parameters								
		Posterior Distribution				Prior Distribution		
Param	Description	Mode	Median	5%	95%	Type	Mean	Std
s_b	Debt to GDP annualized	1.3425	1.3446	1.2748	1.4168	N	1.21	0.05
$100\varkappa$	Steady state growth rate	0.3875	0.3657	0.2935	0.4375	N	0.50	0.05
$100\ln\Pi$	Steady state inflation	0.4892	0.4988	0.4143	0.5481	N	0.50	0.05
ξ	Inverse Frisch elasticity	1.9419	1.8870	1.8366	1.9319	G	2.00	0.25
μ	Share of hand-to-mouth	0.0147	0.0111	0.0052	0.0203	B	0.1	0.05
ω_w	Wage Calvo param	0.6845	0.6765	0.6424	0.7131	B	0.50	0.10
ω_p	Price Calvo param	0.8089	0.8233	0.7924	0.8508	B	0.50	0.10
ψ	Capital utilization cost	0.4300	0.3676	0.3276	0.4413	B	0.50	0.10
s	Investment adjust. cost	4.7373	4.6815	4.5973	4.7368	N	4.00	1.50
χ_w	Wage infl. indexation	0.2592	0.2628	0.2296	0.2965	B	0.30	0.15
χ_p	Price infl. indexation	0.2067	0.1442	0.1048	0.1855	B	0.30	0.15
θ	Habits in consumption	0.8439	0.8421	0.8278	0.8554	B	0.70	0.10
α_G	Subs. private/gov. cons.	−0.0089	0.0229	−0.0702	0.0822	N	0.00	0.10
ϕ_y	Interest response to GDP	0.2674	0.2543	0.2223	0.2872	N	0.11	0.05
ϕ_π	Interest response to infl.	1.7874	1.6919	1.6124	1.7789	N	1.87	0.10
ϕ_{zy}	Transfers response to GDP	0.0021	0.0027	0.0003	0.0095	G	0.50	0.50
ϕ_{gy}	G response to GDP	0.0016	0.0020	0.0002	0.0084	G	0.50	0.50
γ_Z	Transfers response to debt	0.2316	0.2469	0.2220	0.2995	N	0.20	0.10
γ_G	G response to debt	0.0008	0.0014	0.0002	0.0051	N	0.20	0.10
γ_K	Capital tax response to debt	0.0007	0.0015	0.0002	0.0052	N	0.20	0.10
γ_L	Labor tax response to debt	0.1100	0.1137	0.1040	0.1258	N	0.20	0.10
γ_C	Cons. tax response to debt	−0.0243	−0.0219	−0.1018	0.0364	N	0.20	0.10
ρ_r	AR coeff. monetary rule	0.9092	0.9013	0.8850	0.9166	B	0.50	0.10
ρ_G	AR coeff. gov. cons. rule	0.3898	0.4288	0.3864	0.5090	B	0.50	0.10
ρ_Z	AR coeff. transfers rule	0.5017	0.5269	0.4840	0.5840	B	0.50	0.10

Table I – Posterior modes, medians, 90% posterior credible sets, and prior moments for the structural parameters. The letters in the column with the heading "Prior Type" indicate the prior density function: N, G, and B stand for Normal, Gamma, and Beta, respectively.

and Trzeciakiewicz, 2017).

The proportion of hand-to-mouth households is significantly lower than we initially conjectured, suggesting that traditional funded fiscal shocks may be less effective for fitting the data. Transfers and labor taxes exhibit the strongest response to debt, implying a leading role of these fiscal tools in debt stabilization in the UK. The steady-state debt-to-GDP ratio aligns well with prior expectations. The degrees of wage and price inflation indexation are slightly below their prior mean, positioning them on the lower end of the estimated spectrum. Long-term growth of the UK economy, largely informed by the sample average growth rate of real variables (GDP, consumption, real wages, etc.), is about 1.5% annually –a bit below the prior mean. The long-run inflation rate, which in the model serves as the central bank's inflation target, is approximately 2%, in line with our priors.

Prior and Posterior Distributions for the Exogenous Processes								
		Posterior Distribution				Prior Distribution		
Param	Description	Mode	Median	5%	95%	Type	Mean	Std
ρ_{eG}^M	AR coeff. funded G	0.9951	0.9949	0.9932	0.9964	B	0.995	0.001
ρ_{eG}^F	AR coeff. unfunded G	0.9953	0.9951	0.9933	0.9965	B	0.995	0.001
ρ_g	AR coeff. short-term G	0.4899	0.5068	0.4195	0.6079	B	0.500	0.100
ρ_{eZ}^M	AR coeff. funded trans.	0.9950	0.9948	0.9929	0.9964	B	0.995	0.001
ρ_{eZ}^F	AR coeff. unfunded trans.	0.9949	0.9946	0.9930	0.9960	B	0.995	0.001
ρ_z	AR coeff. short-term trans.	0.4958	0.5060	0.4663	0.5663	B	0.500	0.100
ρ_a	AR coeff. technology	0.6537	0.6487	0.6034	0.7098	B	0.500	0.100
ρ_b	AR coeff. preference	0.3163	0.3408	0.2868	0.4174	B	0.500	0.100
ρ_m	AR coeff. mon. policy	0.3615	0.3442	0.2827	0.4141	B	0.500	0.100
ρ_i	AR coeff. investment	0.2923	0.3306	0.2675	0.4477	B	0.500	0.100
ρ_{rp}	AR coeff. risk premium	0.8986	0.9010	0.8751	0.9272	B	0.500	0.100
$\rho_{\mu^{NKPC}}$	AR coeff. pers. cost push	0.9955	0.9954	0.9936	0.9967	B	0.995	0.001
σ_G^M	St.dev. funded G	2.0509	2.1676	1.9866	2.3428	IG	0.500	0.200
σ_G^F	St.dev. unfunded G	0.4919	0.4745	0.4499	0.5029	IG	0.500	0.200
σ_g	St.dev. short-term G	0.3793	0.3968	0.3650	0.4348	IG	0.500	0.200
σ_Z^M	St.dev. funded transfers	3.6981	3.7122	3.5927	3.8053	IG	0.500	0.200
σ_Z^F	St.dev. unfunded transfers	0.4536	0.4618	0.4239	0.5172	IG	0.500	0.200
σ_z	St.dev. short-term trans.	0.3920	0.4527	0.3886	0.5231	IG	0.500	0.200
σ_a	St.dev. technology	1.9050	1.9671	1.8086	2.0547	IG	0.500	0.200
σ_b	St.dev. preference	4.9845	4.9841	4.9626	4.9976	IG	0.500	0.200
σ_m	St.dev. mon. policy	0.2572	0.2588	0.2359	0.2843	IG	0.500	0.200
σ_i	St.dev. investment	1.4014	1.3206	1.1878	1.4281	IG	0.500	0.200
σ_w	St.dev. wage markup	0.6416	0.6469	0.5842	0.7192	IG	0.500	0.200
σ_p	St.dev. price markup	0.5958	0.6271	0.5794	0.6875	IG	0.500	0.200
σ_{rp}	St.dev. risk premium	0.4426	0.4165	0.3501	0.4722	IG	0.500	0.200
$\sigma_{\mu^{NKPC}}$	St.dev. persistent cost push	0.4164	0.4444	0.4010	0.4863	IG	0.500	0.200
σ_{GDP}^m	Measur. error GDP	0.9447	0.9492	0.8872	1.0197	IG	0.500	0.200
σ_{by}^m	Measur. error Debt/GDP	0.3777	0.2644	0.2378	0.3607	IG	0.500	0.200

Table II – Posterior modes, medians, 90% posterior credible sets, and prior moments for the exogenous processes. The letters in the column with the heading "Prior Type" indicate the prior density function: B and IG stand for Beta and Inverse Gamma, respectively.

5 Quantitative analysis

In this section, we are interested in assessing the role of unfunded fiscal shocks for movements in inflation and real activity. We first review the historical evidence and we then move to analyze the post pandemic period in more detail.

5.1 Impulse Responses

In this subsection, we examine the propagation of unfunded fiscal shocks to transfers, $\zeta_{z,t}^F$, and government purchases, $\zeta_{g,t}^F$, relative to their funded counterparts, $\zeta_{z,t}^M$ and $\zeta_{g,t}^M$. We also consider long-run cost-push shocks, u_t^{NKPC}, which can similarly generate persistent movements in inflation. This analysis highlights how these different types of shocks can be identified during the estimation process.

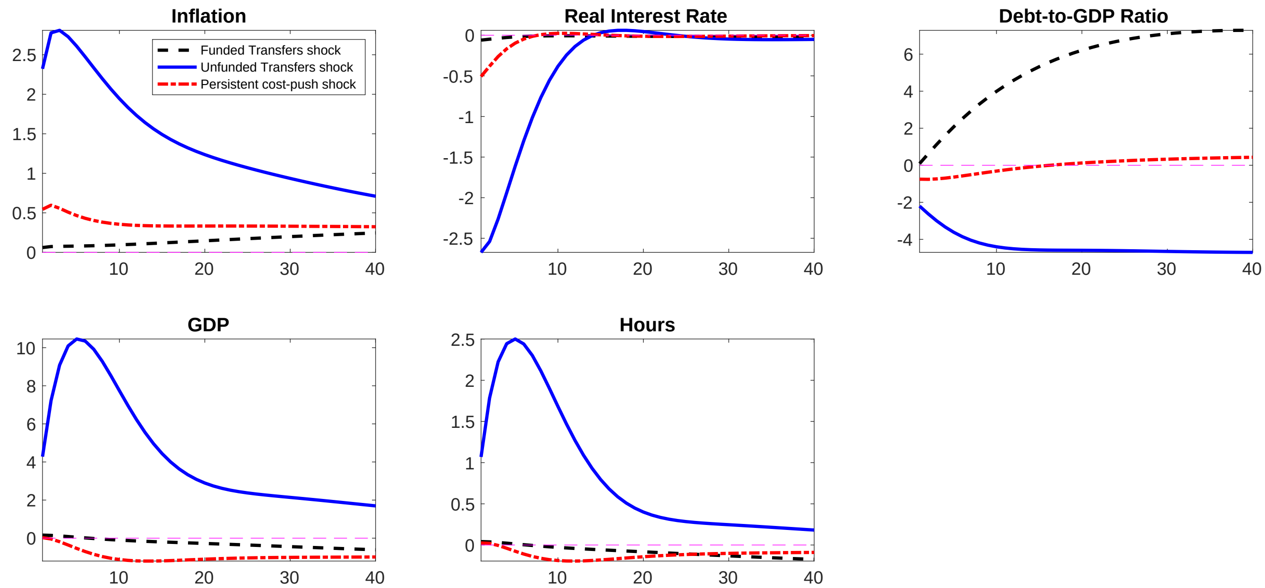

Figure VI – **Impulse Responses to Government Transfer Shocks.** Impulse responses for inflation, real interest rate, debt-to-GDP ratio, GDP and hours to a shock to funded transfers (black dashed line), to unfunded transfers (blue solid line), and to the persistent cost-push shock (red dash-dotted line). Units: percentage deviations from steady-state values. The magnitude of the initial shocks is set to be equal to one-standard deviation as estimated in the second sample (2008:Q1-2024:Q1).

Figure VI examines the effects of shocks to transfers and persistent mark-up shocks, illustrating how each shock generates distinct impulse responses of key macroeconomic variables, including the inflation rate, real interest rate, and debt-to-GDP ratio. Despite the presence of hand-to-mouth households, the macroeconomic impact of a funded transfer shock (dashed black line) is quite modest. These small effects arise because funded transfer shocks raise expectations of higher future taxes and/or reduced government purchases. The response of these expectations is also the major culprit for output to slowly decline after a funded transfer shock.

Inflation rises as a result of the positive funded stimulus to aggregate demand and real marginal costs. Meanwhile, the debt-to-GDP ratio increases to finance the rise in transfers, with this increase proving persistent due to the slow adjustment of tax revenues and government purchases to the higher debt. Nonetheless, the debt remains on a sustainable path, as future fiscal adjustments are anticipated.

In contrast, unfunded transfer shocks (solid blue line) have a much stronger expansionary effect on the macroeconomy. Unlike funded transfer shocks, unfunded transfers lead to a decrease in the real interest rate, as the monetary authority allows inflation to rise to accommodate the increase in transfers. This coordinated policy increases both inflation and inflation expectations, with inflation staying above its long-run level even a decade after the shock. The lower real interest rate stimulates aggregate production, and the combination of

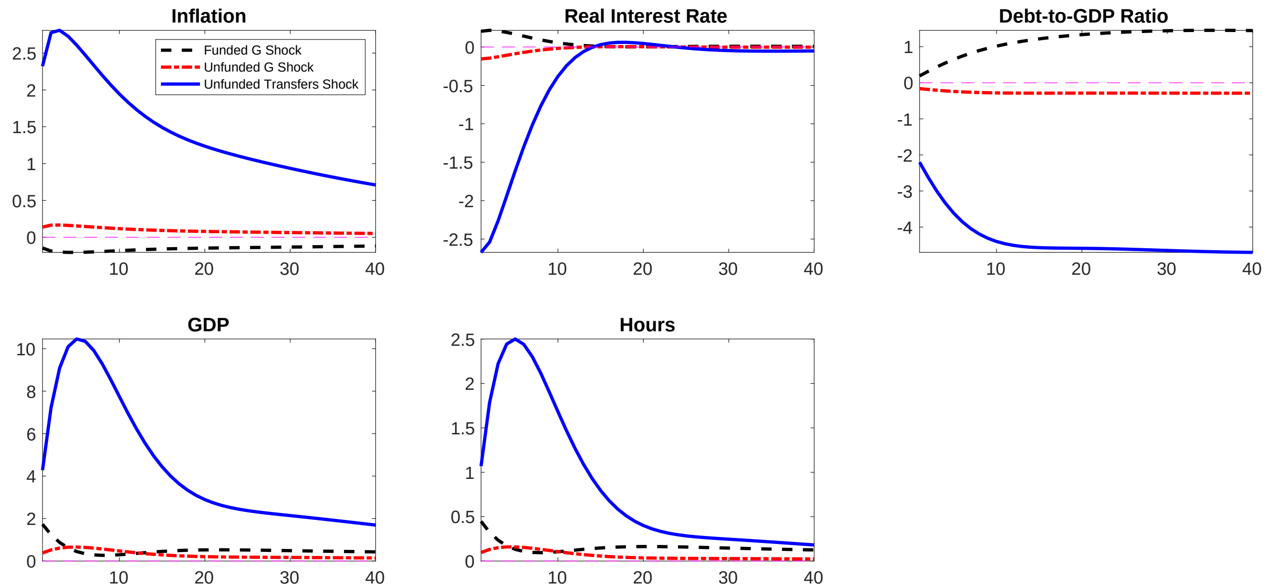

Figure VII – Impulse Responses to G Shocks. Impulse responses for inflation, real interest rate, debt-to-GDP ratio, GDP and hours to a shock to funded G (black dashed line), to unfunded G (red dash-dotted line), and to unfunded transfers shock (blue solid line). Units: percentage deviations from steady-state values. The magnitude of the initial shocks is set to be equal to one-standard deviation as estimated in the second sample (2008:Q1-2024:Q1).

reduced financing costs and higher GDP leads to a decline in the debt-to-GDP ratio, despite the increased spending.

A shock to firms' long-run cost-push factors (dash-dotted red line) causes a modest but persistent rise in inflation. However, unlike unfunded transfer shocks, real activity declines rather than increases. The real interest rate initially falls but then rises persistently, remaining near zero, as the central bank balances inflationary pressure against the need to support economic activity. These small changes in real interest rates and output cause a brief drop in the debt-to-GDP ratio, which quickly reverses. The differential responses in real interest rates, real activity, and the debt-to-GDP ratio after unfunded transfer shocks and long-run cost-push shocks facilitate the identification between the unfunded transfers shock and the persistent cost-push shock.

Figure VII focuses on shocks to government purchases (denoted as "G"). It distinguishes between funded and unfunded G shocks and also includes unfunded transfer shocks. Notably, the solid blue line in Figures VI and VII is the same. As with G shocks, the responses of inflation and real interest rates differ between funded and unfunded shocks. Interestingly, output initially responds more strongly to a funded G shock, though the difference diminishes after a few quarters. However, the overall effects of an unfunded G shock on macroeconomic variables and the debt-to-GDP ratio are much smaller than those triggered by an unfunded transfer shock.

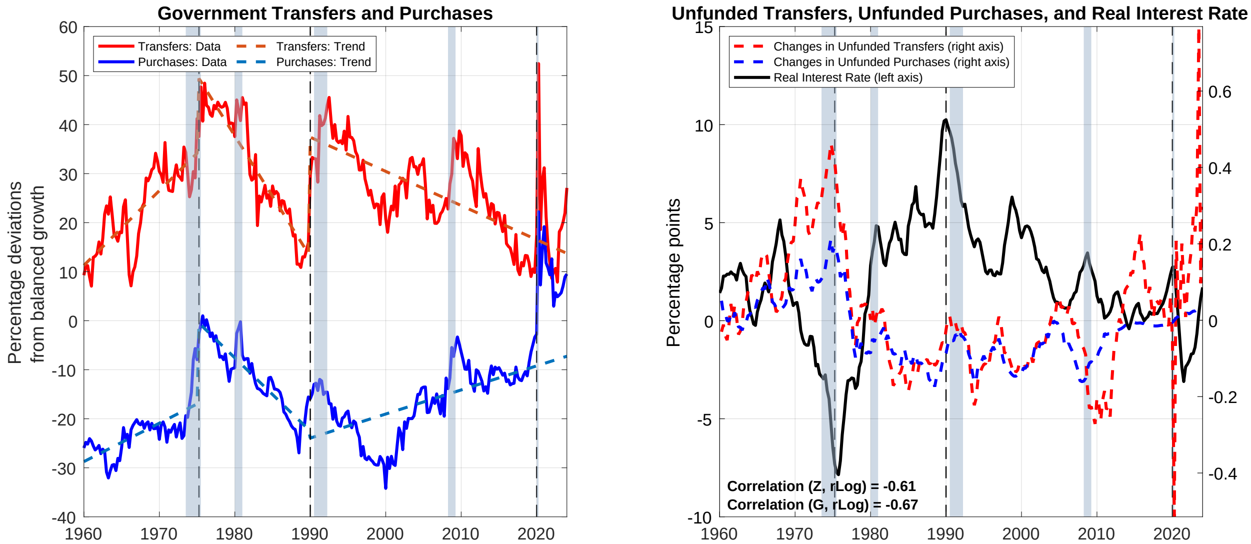

Figure VIII – **Government Transfers, Purchases, and Real Interest Rate.** Left panel: Government transfers (red solid line) and government purchases (blue solid line) in percentage deviations from balanced growth. Both series have linear trends fitted for each of the first three sub-sample periods: 1960:Q1–1974:Q4, 1975:Q1–1989:Q4, and 1990:Q1–2019:Q4 – marked by the vertical black lines. The trend computed over the third period is projected onto the last subsample, 2020:Q1-2024:Q1. Right panel: Changes in the amount of unfunded transfers (red dashed line), changes in the amount of unfunded purchases (blue dashed line), and ex-ante real interest rate (black solid line). The first two series are computed by taking the one-year moving average of the quarter-over-quarter percentage changes in the amount of unfunded transfers (purchases) predicted by the model (smoothed estimates). The last series is computed by taking the three-year moving average of the annualized ex-ante real interest rate predicted by the model (smoothed estimates). The sample period is 1960:Q1-2024:Q1.

5.2 Funded and Unfunded Transfers

Before using the model to analyze the historical behavior of funded and unfunded fiscal shocks, it is helpful to review the evolution of government transfers and government purchases in the data.

The left panel of Figure VIII shows the changes in real government transfers and real government purchases from 1960:Q1 to 2024:Q1. The variables are reported in deviations from their detrended steady state. The dashed lines represent linear trends fitted over three key periods, marked by vertical lines. The trend of the third period is extended to the pandemic period, from the first quarter of 2020 to the first quarter of 2024. The first period, from the 1960s to the mid-1970s, saw a significant rise in both transfers and government purchases. This steady upward trend has a sudden acceleration in the mid-1970s, following the 1974 oil crisis.

After this jump, both measures of spending start drifting down, except for a short-lived resurgence in the early 1980s. These joint downward trends last until the early 1990s, corresponding with a turbulent period for the UK, culminating in the Exchange Rate Mechanism (ERM) crisis. The United Kingdom adopted the European Exchange Rate Mechanism in October 1990, but was forced out by speculative attacks in September 1992.

After this turbulent period, transfers start declining steadily with respect to their detrended steady state, while the opposite occurs to government purchases. Finally, during the pandemic, both variables jump by an unprecedented level. Interestingly, even at the end of the sample, 2024:Q1, both variables remain visibly above their prepandemic trend.

To understand the contributions of funded and unfunded fiscal shocks to these changes, the right panel of Figure VIII shows the model estimates of changes in unfunded transfers and government purchases and their relationship with the real interest rate. This plot demonstrates how the structural estimation attributes changes in total spending to funded and unfunded components. The real interest rate decreases as unfunded transfers or unfunded purchases increase. The correlation of changes in real interest rates with unfunded transfer and purchases shocks is -0.61 and -0.67, respectively. This aligns with the impulse response functions in Figure VI and Figure VII, showing a large negative response of the real interest rate to increases in unfunded transfers, and a more modest response to unfunded purchase shocks. Changes in unfunded spending require coordination between monetary and fiscal policies, with monetary policy accommodating inflation changes resulting from unfunded transfers, leading to fluctuations in the real interest rate.

The panels in the left column of Figure IX show the historical evolution of unfunded transfers and purchases as percentage deviations from the balanced growth path, with a zoomed-in view of the pandemic period in the northeast corner. The eight panels on the right side of the same figure illustrate the contributions of funded and unfunded transfers to the overall increase in transfers over the sample period, corresponding to the same four periods highlighted in Figure VIII. The red line represents total transfers or total purchases.

Changes in unfunded transfers reflect revisions in expectations about the monetary and fiscal commitment to using fiscal instruments to repay the persistent flow of total transfers. For example, total transfers may decrease while the share of unfunded transfers rises. These changes are informed by the joint dynamics of inflation, real interest rate, and debt-to-GDP ratio, as shown in the top panel of Figure VI. Historical events like major recessions, the creation of large welfare programs, and changes in the operational agreements of the Bank of England can be linked to movements in unfunded transfers.

The large increase in spending from the mid-1960s to the mid-1970s was partially funded and partially unfunded (Panel B and Panel G). The rise in unfunded spending during this period was substantial. This is especially true for unfunded transfers. While unfunded government purchases started declining in the mid-1970s, unfunded transfers remain elevated until the early 1980s, when the UK started its own process of disinflation. Similar to findings for the United States, the model interprets the UK's disinflation as a joint monetary and fiscal policy phenomenon, potentially linked to the shift in the political environment that

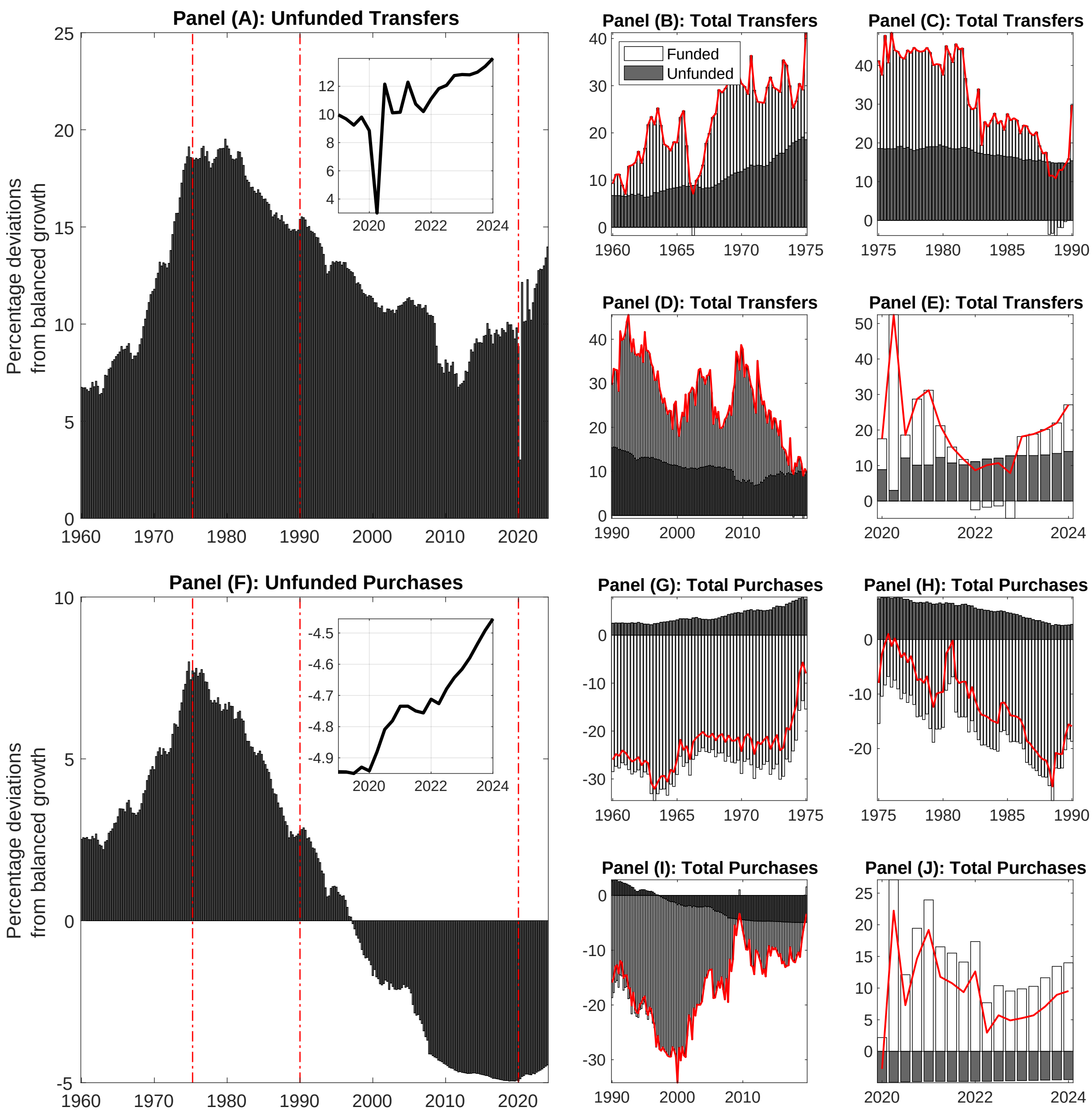

Figure IX – Estimated Decomposition of Total Government Transfers and Purchases into Their Funded and Unfunded Components. In Panel A, we show the historical evolution of unfunded transfers in percentage deviations from the balanced growth path. The display in the north-east corner of the panel zooms into the pandemic period. In Panel B, C, D, and E, we show the contribution of changes in unfunded and funded transfers to the overall increase in transfers over the sample in each of the four sub-sample periods (1960:Q1-1974:Q4; 1975:Q1-1989:Q4; 1990:Q1-2019:Q4; 2020:Q1-2024:Q1). The red line in these panels corresponds to total transfers. The unfunded component is the amount of transfers in the shadow economy – i.e., a counterfactual economy where the monetary and fiscal authorities follow the fiscally-led policy mix and the unfunded fiscal shocks ($\zeta_{z,t}^F$ and $\zeta_{g,t}^F$) are the only exogenous disturbances. Panel F shows the historical evolution of unfunded government purchases in percentage deviations from balanced growth. Panel G to Panel J conduct the decomposition of government purchases into its funded and unfunded components. Parameters are set at their posterior mode and shocks are estimated using the Kalman smoother. The sample is 1960:Q1-2024:Q1.

coincided with Margaret Thatcher's premiership (4 May 1979 – 28 November 1990).

After that, both measures of unfunded spending decline steadily, with an acceleration in the mid-2000s. However, the 2008 financial crisis triggers a large acceleration in unfunded transfers (but not in unfunded purchases). A second, larger increase of unfunded transfers occurs during the pandemic. Unfunded government purchases also increase, but by a less visible amount.

5.3 Unfunded Fiscal Shocks, Inflation, and Real Activity

We now turn our attention to the relationship between unfunded spending and the historical trends of inflation and real activity. The first panel of Figure X illustrates the historical contribution of unfunded spending shocks to inflation, while the second panel presents a similar analysis for hours worked, a commonly used metric for real activity in estimated DSGE models.

Let us first consider the role unfunded spending for inflation dynamics. The black dashed line reports actual inflation, while the solid blue line describes what inflation would have been if only unfunded fiscal shocks had occurred. This series is obtained by filtering the shocks based on the posterior mode parameters and then simulating an economy that was at the same starting point in the early 1960s, but it was then hit exclusively by unfunded fiscal shocks. The red dash-dotted line also adds markup shocks to this simulation. For the gap in hours, we produce a similar exercise, but focusing on the role of unfunded spending *vis-à-vis* the contribution of the typical business cycle shocks.

Starting from the early 1980s and until the post-Millennial period, the role of unfunded spending shocks is largely reduced. This is consistent with a much more stable inflation environment and the Great Moderation in real activity. Similar to findings for the United States, the model interprets the UK's disinflation as a joint monetary and fiscal policy phenomenon, potentially linked to the shift in the political environment that coincided with Margaret Thatcher's premiership (4 May 1979 – 28 November 1990). We still observe some more contained increases in fiscal inflation, like in the aftermath of the ERM crisis, but these fluctuations are modest compared to what observed in the 1960s and 1970s. Accordingly, the second panel of Figure X shows that the business cycle is largely driven by the business cycle shocks with respect to which a Monetary-led policy mix holds.

From the 1980s through the early 2000s, fiscal inflation in the UK stayed remarkably low and even trended downward, contrasting with the US. This reduced inflationary impact from coordinated monetary and fiscal policies might reflect the adoption of inflation targeting in 1992. Our model suggests that, in the UK, both monetary and fiscal policies similarly restrained economic recovery in the aftermath of the economic slowdown ensuing the Great Financial Crisis in the US. This finding points to a notable divergence from the results in

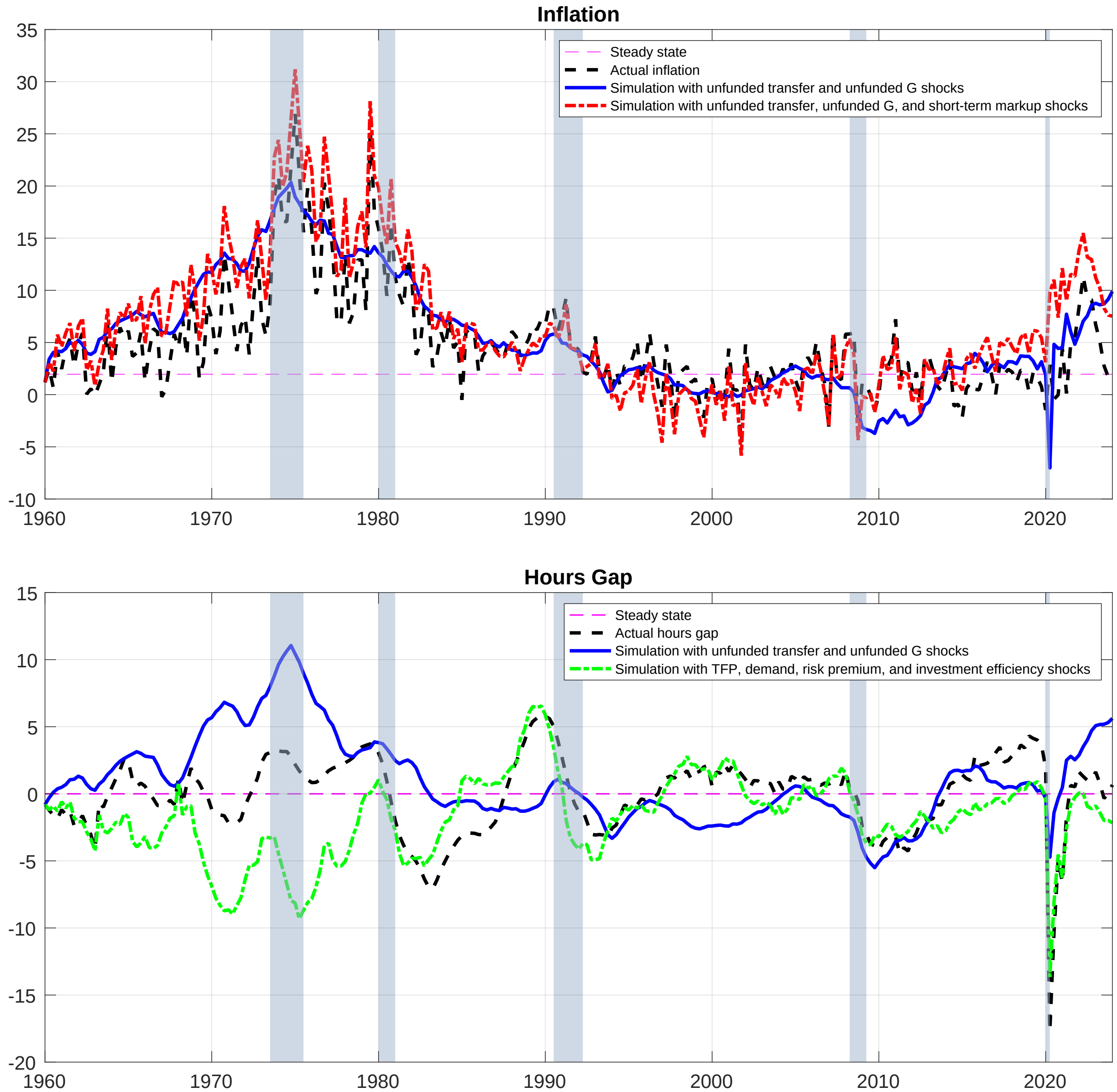

Figure X – Drivers of Inflation and Hours Gap. Top panel: comparison of actual inflation (black dashed line) against simulated inflation under scenarios: i) with only unfunded fiscal shocks (blue solid line), and ii) with both unfunded fiscal shocks and short-term markup shocks (red dash-dotted line). Bottom panel: comparison of actual hours gap (black dashed line) with simulated hours gap under scenarios: i) with only unfunded fiscal shocks (blue solid line), and ii) with only TFP, demand, risk premium, and investment efficiency shocks (green dash-dotted line).

Bianchi et al. (2023), who observed a different dynamic in the US over the same period, and could be explained by the fiscal austerity program introduced by the Conservative-Liberal Democrat coalition government in 2010. Although fiscal inflation rose modestly in the latter half of the past decade as the government eased austerity measures to support growth, the overall inflationary impact from coordinated policy remained relatively limited during this period.

Finally, the pandemic brings a new wave of fiscal inflation. Inflation reaches record high levels and fiscal inflation fuels large part of this increase. This massive monetary and fiscal coordination also sustains a quick rebound in real activity above the pre-pandemic level. Here is interesting to notice that the large increase of fiscal inflation coincides with the shift in monetary policy in the UK. The policy rate was 0.75 between 2018:Q4 - 2019:Q4, 0.612 in 2020:Q1, and then cut quickly to 0.1 in 2020Q2 – 2021Q4. it is only when inflation has caused a large drop in the debt-to-GDP ratio that policy rates start increasing: 0.456 in 2022:Q1.

These are overall very turbulent times, with the announcement of Premier Truss's Mini budget on September 23, 2022, to add fuel to concerns that the fiscal policy stance is not consistent with low and stable inflation. Interestingly, our results suggest that fiscal inflation is still elevated, consistently with the fact that fiscal spending has not declined after the pandemic. Given that historical evidence shows fiscal inflation has induced low-frequency movements in inflation, this result suggests that some fiscal adjustments could be necessary to cement recent gains in inflation.

5.4 Unfunded Fiscal Shocks in the Post-Pandemic Period

Figure XI shows the hours gap (left), the inflation rate (center), and the real interest rate (right) under different assumptions.[3] The solid black line represents the actual data, which the estimated model is calibrated to match exactly. The dotted-dashed red line illustrates the dynamics of these three variables under the assumption that all shocks to government purchases and transfers are funded. This counterfactual analysis suggests that coordinated monetary and fiscal policies were critical in helping the UK economy recover from the pandemic recession whose effects on the real economy was large and persistent. According to our model, without this policy coordination, the UK would still be facing a significant hours gap, with only half of the pandemic-induced gap reabsorbed.

Additionally, inflation would have remained subdued without these concerted policy interventions. Although inflation has initially risen due to short-term cost-push shocks –likely capturing inflationary pressures from the 2021-2022 energy price surge – these shocks were not strong enough to push inflation above the Bank of England's 2% target. As supply pressures subsided, inflation would have quickly dropped to extremely negative levels due to weak aggregate demand lacking the support of coordinated monetary and fiscal policies. Without coordination, the massive pandemic fiscal stimulus would have led to expectations of significant budget cuts, which would have considerably slowed down the recovery. On the

[3]The hours gap serves as a key proxy for the output gap, as it measures the degree of slack in the labor market.

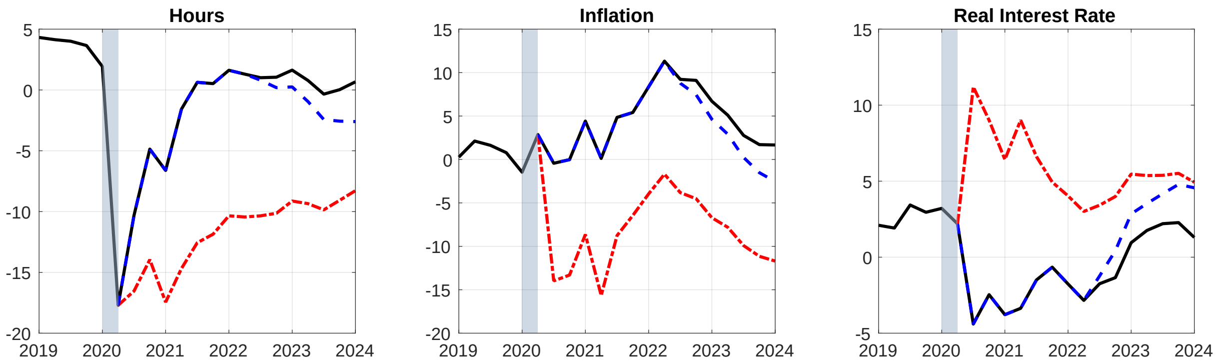

Figure XI – **Unfunded Fiscal Shocks and the Post-pandemic Rise in Inflation** The figure compares the data (black solid line) for hours gap, inflation and the real interest rate, with two counterfactual scenarios. In the first counterfactual simulation, all fiscal shocks to government transfers and purchases estimated starting from post-pandemic expansion (i.e., 2020:Q3) are assumed to be funded (red dash-dotted line). In the second counterfactual simulation, only all fiscal shocks estimated starting from the announcement of Premier Truss' Mini budget (i.e., 2022:Q3) are assumed to be funded (blue dashed line). All other shock are left unchanged. Shocks are estimated using the Kalman smoother. Model parameters are set at their posterior mode. The estimation sample is 1960:Q1-2024:Q1.

monetary policy side, the combination of a binding effective lower bound (ELB) and deflationary pressures would have sharply increased the real interest rate (right panel), further weakening aggregate demand. This contractionary outcome was averted by coordinated monetary and fiscal policies that mitigated the anticipated size of fiscal adjustments and allowed inflation to rise, thus softening the contractionary effects of the ELB constraint.

The dashed blue line illustrates a counterfactual scenario in which all fiscal shocks from the announcement of Prime Minister Liz Truss' "mini-budget" in September 2022 are funded. This scenario is notable as it would have led to a steeper path of real interest rates, indicating a faster pace of monetary tightening (see the right panel). The combination of this rapid tightening and the increased share of debt funded through future fiscal adjustments would have constrained the UK's ability to achieve the soft landing observed in the data (represented by the solid black line in the left panel). The model not only forecasts a recession under these conditions but also anticipates inflation declining less persistently than actually observed. However, this tighter policy trajectory, combined with more fiscal spending backed by future taxation, would have led policymakers to undershoot the 2% inflation target.

6 Conclusions

In this paper, we adopted the class of models introduced by Bianchi et al. (2023) to study the role of unfunded fiscal shocks in explaining inflation dynamics in the United Kingdom. Unfunded fiscal shocks are not backed by future fiscal adjustments and cause a decline in real interest rates as the central bank accommodates the resulting inflationary pressure. We incorporated unfunded fiscal shocks in a quantitative TANK model. Our empirical results show that fiscal inflation plays a major role in explaining low-frequency movements in inflation.

We then focus on the pandemic period and find that fiscal inflation helped the recovery, but it still remains elevated even if actual inflation declined. Given that fiscal inflation is typically associated with persistent movements in inflation, this suggests that more is needed to bring inflation safely under control.

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Appendices

A Solving Economies with Partially Unfunded Debt

To prove that the system of equations (11), (12), (13), and (14) in the main text are the correct policy functions of the model with partially unfunded debt, we have to show that the two following claims are true. First, the difference between the overall stock of debt and its unfunded share is funded, that is, $\hat{s}_{b,t} - \hat{s}^F_{b,t} = \hat{s}^M_{b,t}$. Second, the inflation rate the central bank strives to stabilize with active monetary policy in the actual economy is precisely the actual rate of inflation net of the inflation needed to stabilize the unfunded debt (i.e., $\hat{\pi}^M_t = \hat{\pi}_t - \hat{\pi}^F_t$).

Both claims can be proved by constructing yet another parallel economy to pin down (i) the share of inflation the monetary authority has to control with active monetary policy, $\hat{\pi}^M_t$, and (ii) the share of funded debt, $\hat{s}^M_{b,t}$, which is the share of debt the fiscal authority is responsible to repay by raising future surpluses. This parallel economy is as follows:

$$
\begin{aligned}
\mathbb{E}_t \hat{\pi}^M_{t+1} &= \hat{r}^M_{n,t}, && (22)\\
\hat{s}^M_{b,t} &= \beta^{-1}(\hat{s}^M_{b,t-1} - \hat{r}^M_{n,t-1} - \hat{\pi}^M_t - (1-\beta)\hat{\tau}^M_t), && (23)\\
\hat{r}^M_{n,t} &= \phi^M \hat{\pi}^M_t, && (24)\\
\hat{\tau}^M_t &= \gamma^M \hat{s}^M_{b,t} + \zeta^M_t. && (25)
\end{aligned}
$$

In this parallel economy, all fiscal shocks are funded, $\zeta^M_{z,t}$, and the policy mix is monetary led ($\phi^M > 1$ and $\gamma^M > 1$). The monetary and fiscal blocks are obtained as done for the other economies we studied in the main text:

$$
\begin{aligned}
\mathbb{E}_t \hat{\pi}^M_{t+1} &= \phi^M \hat{\pi}^M_t, && (26)\\
\hat{s}^M_{b,t} &= \beta^{-1}\left[1-(1-\beta)\gamma^M\right]\hat{s}^M_{b,t-1} + \beta^{-1}[\hat{r}^M_{n,t-1} - \hat{\pi}^M_t - (1-\beta)\zeta^M_{z,t}]. && (27)
\end{aligned}
$$

To prove the first claim, we need to show that $\hat{\pi}^M_t = \hat{\pi}_t - \hat{\pi}^F_t$. This can be done by subtracting equations (26) and (13) from equation (12). This yields:

$$
\mathbb{E}_t(\hat{\pi}_{t+1} - \hat{\pi}^F_{t+1} - \hat{\pi}^M_{t+1}) = \phi^M(\hat{\pi}_t - \hat{\pi}^F_t - \hat{\pi}^M_t). \qquad (28)
$$

Because $\phi^M > 0$, the above expression implies $\hat{\pi}_t - \hat{\pi}^F_t - \hat{\pi}^M_t = 0$, i.e., $\hat{\pi}^M_t = \hat{\pi}_t - \hat{\pi}^F_t$.

Let us now turn to the second claim. This claim requires us to show that $\hat{s}^M_{b,t} = \hat{s}_{b,t} - \hat{s}^F_{b,t}$. Substituting the fiscal rule in equation (9) (with $\gamma^F = 0$) and the monetary rule in equation (10) into the law of motion of debt in equation (2), we obtain:[4]

$$
\begin{aligned}
\beta\hat{s}_{b,t} = (1-(1-\beta)\gamma^M)\hat{s}_{b,t-1} + (1-\beta)\gamma^M\hat{s}^F_{b,t-1} + \phi^M(\hat{\pi}_{t-1} - \hat{\pi}^F_{t-1}) && (29)\\
+\phi^F\pi^F_{t-1} - \pi_t + (1-\beta)(\zeta^M_{z,t} + \zeta^F_{z,t}). && (30)
\end{aligned}
$$

[4]The fiscal rule could be equivalently expressed as $\tau_t/\tau = \left(b_{t-1}/b^M_{t-1}\right)^{\gamma^F}\left(b^M_{t-1}/b\right)^{\gamma^M} e^{\zeta^M_{z,t}+\zeta^F_{z,t}}$.

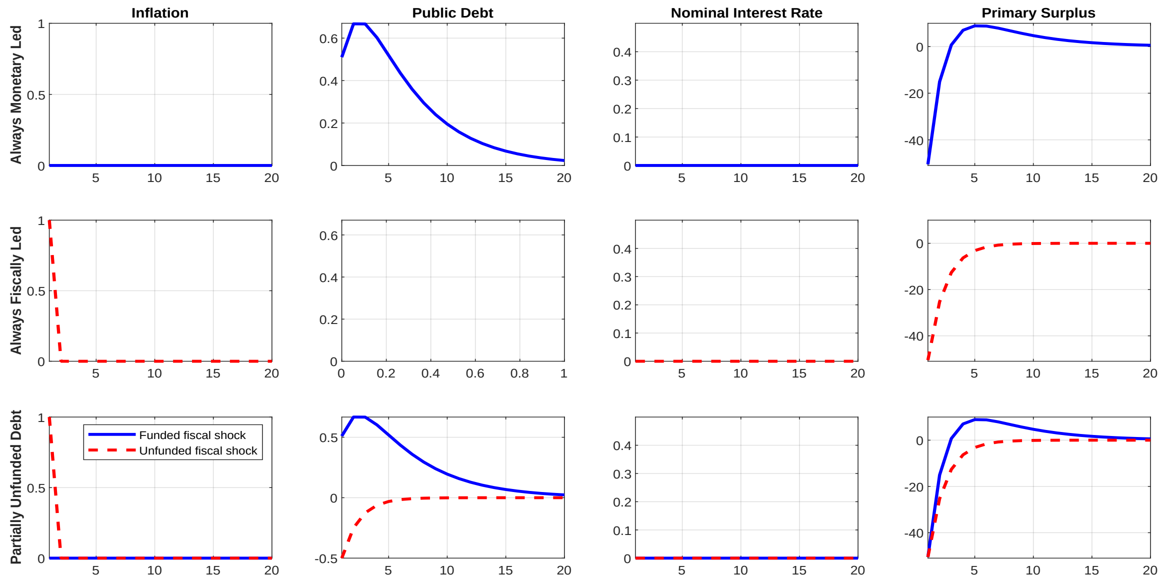

Figure A.1: Response of Model Variables to a Fiscal Shock

Substituting (25) and (24) into (23) implies:

$$\beta \hat{s}^M_{b,t} = (1-(1-\beta)\gamma^M))\hat{s}^M_{b,t-1} + \phi^M \hat{\pi}_{t-1} - \hat{\pi}^M_t + (1-\beta)\zeta^M_{z,t}. \tag{31}$$

Repeating the same steps for the shadow economy with unfunded debt yields:

$$\beta \hat{s}^F_{b,t} = (1-(1-\beta)\gamma^F))\hat{s}^F_{b,t-1} + \phi^F \hat{\pi}_{t-1} - \hat{\pi}^F_t + (1-\beta)\zeta^F_{z,t}. \tag{32}$$

Subtracting $\beta \hat{s}^M_{b,t}$ and $\beta \hat{s}^F_{b,t}$ from $\beta \hat{s}_{b,t}$ yields:

$$\beta(\hat{s}_{b,t} - \hat{s}^M_{b,t} - \hat{s}^F_{b,t}) = (1-(1-\beta)\gamma^M)(\hat{s}_{b,t-1} - \hat{s}^M_{b,t-1} - \hat{s}^F_{b,t-1}) \tag{33}$$

$$+\phi^M(\hat{\pi}_{t-1} - \hat{\pi}^F_{t-1} - \hat{\pi}^M_{t-1}) - \hat{\pi}_t + \hat{\pi}^F_t + \hat{\pi}^M_t. \tag{34}$$

Using the first claim, $\hat{\pi}^M_t = \hat{\pi}_t - \hat{\pi}^F_t$, it follows that $\hat{s}^M_{b,t} = \hat{s}_{b,t} - \hat{s}^F_{b,t}$ for every period t.

Finally, Figure A.1 shows the complete plot of the response of all the variables of the toy model to funded and unfunded fiscal shocks.

B Production Economies: Linearized Equations

B.1 Flexible-Price Model

Euler equation

$$\mathbb{E}_t \hat{y}_{t+1} = \hat{y}_t + \hat{r}_t \tag{35}$$

Labor supply

$$\frac{n}{1-n}\hat{n}_t = \hat{y}_t + \widehat{w}^r_t \tag{36}$$

Labor demand

$$\hat{w}_t^r = -\alpha \hat{n}_t \tag{37}$$

Production function

$$\hat{y}_t = (1-\alpha)\hat{n}_t \tag{38}$$

Equations (35) to (38) denote an autonomous system that solves for the real block of the economy, $\hat{y}_t$, $\hat{n}_t$, $\hat{w}_t^r$, $\hat{r}_t$. However, inflation is not determined. We introduce the behavior of the monetary and fiscal authorithies to pin down the path of inflation.

Real rate definition

$$\hat{r}_t = \hat{r}_{n,t} - \mathbb{E}_t \hat{\pi}_{t+1} \tag{39}$$

Taylor rule

$$\hat{r}_{n,t} = \phi_\pi^M (\hat{\pi}_t - \hat{\pi}_t^F) + \phi_\pi^F \hat{\pi}_t^F \tag{40}$$

Evolution of debt-to-GDP

$$\hat{s}_{b,t} = \beta^{-1} \left(\hat{y}_{t-1} - \hat{y}_t + \hat{r}_{n,t-1} - \hat{\pi}_t + \hat{s}_{b,t-1} - (1-\beta)\hat{\tau}_t \right) \tag{41}$$

Fiscal rule

$$\hat{\tau}_t = \gamma^M (\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F) + \gamma^F \hat{s}_{b,t-1}^F + \zeta_t^F + \zeta_t^M \tag{42}$$

The system of equations above is supplemented with a block of equations that characterize the shadow economy. This block consists in an additional set of equations (35) to (42), where any variable that refers to the actual economy x_t is replaced by the same variable in the shadow economy x_t^F, funded shocks $\zeta_{z,t}^M$are shut down, and the central Bank only responds to deviations of inflation from its long-run target.

B.2 New Keynesian Model

Euler equation

$$\mathbb{E}_t \hat{y}_{t+1} = \hat{y}_t + \hat{r}_t \tag{43}$$

Labor supply

$$\frac{n}{1-n}\hat{n}_t = \hat{y}_t + \widehat{w}_t^r \tag{44}$$

New Keynesian Phillips Curve

$$\hat{\pi}_t = \kappa \hat{w}_t^r + \beta \mathbb{E}_t \hat{\pi}_{t+1} \tag{45}$$

Production function

$$\hat{y}_t = (1-\alpha)\hat{n}_t \tag{46}$$

Real rate definition

$$\hat{r}_t = \hat{r}_{n,t} - \mathbb{E}_t \hat{\pi}_{t+1} \tag{47}$$

Taylor rule

$$\hat{r}_{n,t} = \phi_\pi^M (\hat{\pi}_t - \hat{\pi}_t^F) + \phi_\pi^F \hat{\pi}_t^F \tag{48}$$

Evolution of debt-to-GDP

$$\hat{s}_{b,t} = \beta^{-1} \left(\hat{y}_{t-1} - \hat{y}_t + \hat{r}_{n,t-1} - \hat{\pi}_t + \hat{s}_{b,t-1} - (1-\beta)\hat{\tau}_t \right) \tag{49}$$

Fiscal rule

$$\hat{\tau}_t = \gamma^M (\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F) + \gamma^F \hat{s}_{b,t-1}^F + \zeta_t^F + \zeta_t^M \tag{50}$$

The block of equations that characterize the shadow economy consists in an additional set of equations (43) to (50), where any variable that refers to the actual economy x_t is replaced by the same variable in the shadow economy x_t^F, funded shocks $\zeta_{z,t}^M$are shut down, and the central Bank only responds to deviations of inflation from its long-run target.

Plugging eq.(47) into (43), and combining eq.(44) and (46) to substitute for $\hat{w}_t$ into eq.(45), it is possible to express the New-Keynesian block (eq.43) to (48)) as three equations:

$$\mathbb{E}_t \hat{y}_{t+1} = \hat{y}_t + \hat{r}_{n,t} - \mathbb{E}_t \hat{\pi}_{t+1}, \tag{51}$$

$$\hat{\pi}_t = \tilde{\kappa} \hat{y}_t + \beta \mathbb{E}_t \hat{\pi}_{t+1}, \tag{52}$$

where $\tilde{\kappa} = \left(\frac{\eta}{1-\alpha} - 1 \right) \kappa$ and $\eta = \frac{n}{1-n}$, and

$$\hat{r}_{n,t} = \phi_\pi^M (\hat{\pi}_t - \hat{\pi}_t^F) + \phi_\pi^F (\hat{\pi}_t^F) + \phi_y \hat{y}_t. \tag{53}$$

B.3 Parameter values

The parameter values are reported in Table B.1.

C The Log-Linearized Model

The quantitative model in Section 3 features a trend in the state of labor-augmenting technological progress. In order to introduce stationarity, we define the following variables: $y_t = \frac{Y_t}{A_t}$, $c_t^{*S} = \frac{C_t^{*S}}{A_t}, c_t^S = \frac{C_t^S}{A_t}, c_t^N = \frac{C_t^N}{A_t}, k_t = \frac{K_t}{A_t}, g_t = \frac{G_t}{A_t}, z_t = \frac{Z_t}{A_t}, b_t = \frac{P_t^m B_t^m}{P_t A_t}, s_{b,t} = \frac{P_t^m B_t^m}{P_t Y_t}, w_t = \frac{W_t}{P_t A_t}$, and $\lambda_t^S = \Lambda_t^S A_t$. We list below the equations of the log-linearized model.

Parameter	Value	Description
Preferences, technology and price frictions		
β	0.99	Discount factor
α	0.33	Elasticity production fn
N	0.4	Average hours worked
Π	1	Gross steady-state inflation
s_b	2.45	debt to output ratio
κ	0.02	Slope Phillips curve
Monetary and fiscal authorities		
ϕ_π^M	2	Taylor rule response to regular inflation $(\pi - \pi^F)$
γ^M	1.5	Debt response with surplus $(s_b - s_b^F)$
ϕ_π^F	0	Taylor rule response to unfunded inflation (π^F)
γ^F	0	Debt response with surplus (s_b^F)
Shocks		
ρ_τ	0.5	Autocorrel. fiscal shocks
STD_τ	1	St. dev. fiscal shocks

Table B.1: Calibrated parameter values in the simple model with price rigidities

C.1 Actual Economy

Production function

$$\hat{y}_t = \frac{y+\Omega}{y}\left[\alpha\hat{k}_t + (1-\alpha)\hat{L}_t\right] \tag{A.1}$$

Production factors

$$\hat{r}_{K,t} - \hat{w}_t = \hat{L}_t - \hat{k}_t. \tag{A.2}$$

Marginal cost

$$\widehat{mc_t} = \alpha\hat{r}_{K,t} + (1-\alpha)\hat{w}_t. \tag{A.3}$$

Price Phillips curve

$$\hat{\pi}_t = \frac{\beta}{1+\chi_p\beta}\mathbb{E}_t\hat{\pi}_{t+1} + \frac{\chi_p}{1+\chi_p\beta}\hat{\pi}_{t-1} + \kappa_p\widehat{mc_t} + \kappa_p\hat{\eta}_t^p + \kappa_p\hat{u}_t^{NKPC}, \tag{A.4}$$

where $\kappa_p = [(1-\beta\omega_p)(1-\omega_p)]/[\omega_p(1+\beta\chi_p)]$.

Saver's Lagrange Multiplier

$$\hat{\lambda}_t^S = \hat{u}_t^b - \frac{\theta}{e^{\varkappa}-\theta}\hat{u}_t^a - \frac{e^{\varkappa}}{e^{\varkappa}-\theta}c_t^{*S} + \frac{\theta}{e^{\varkappa}-\theta}c_{t-1}^{*S} - \frac{\tau^C}{1+\tau^C}\hat{\tau}_{C,t} \tag{A.5}$$

Long-run real interest rate

$$\hat{r}_t^L + \hat{P}_t^B = -\mathbb{E}_t\hat{\pi}_{t+1} + \frac{\beta}{R}\mathbb{E}_t\left[\hat{r}_{t+1}^L + \hat{P}_{t+1}^B\right] \tag{A.6}$$

Long-run inflation rate

$$\hat{\pi}_t^L = -\hat{r}_t^L - \hat{P}_t^B \tag{A.7}$$

Public/private consumption in utility

$$\hat{c}_t^* = \frac{c^S}{c^S + \alpha_G g}\hat{c}_t^S + \frac{\alpha_G g}{c^S + \alpha_G g}\hat{g}_t \tag{A.8}$$

Saver's Euler equation

$$\hat{\lambda}_t^S = \hat{r}_{n,t} + \mathbb{E}_t\hat{\lambda}_{t+1}^S - \mathbb{E}_t\hat{\pi}_{t+1} - \mathbb{E}_t\hat{u}_{t+1}^a + \hat{u}_t^{rp} \tag{A.9}$$

Saver's FOC for capacity utilization

$$\hat{r}_{K,t} - \frac{\tau_K}{1-\tau_K}\hat{\tau}_{K,t} = \frac{\psi}{1-\psi}\hat{\nu}_t \tag{A.10}$$

Saver's FOC for capital

$$\begin{aligned}\hat{q}_t = {} & \mathbb{E}_t\hat{\pi}_{t+1} - \hat{r}_{n,t} + \beta e^{-\varkappa}\left(1-\tau_K\right)r_K\mathbb{E}_t\hat{r}_{K,t+1} - \beta e^{-\varkappa}\tau_K r_K\mathbb{E}_t\hat{\tau}_{K,t+1} \\ & + \beta e^{-\varkappa}(1-\delta)\mathbb{E}_t\hat{q}_{t+1} - \hat{u}_t^{rp}\end{aligned} \tag{A.11}$$

Saver's FOC for investment

$$\hat{\imath}_t + \frac{1}{1+\beta}\hat{u}_t^a - \frac{1}{(1+\beta)se^{2\varkappa}}\hat{q}_t - \hat{u}_t^i - \frac{\beta}{1+\beta}\mathbb{E}_t\hat{\imath}_{t+1} - \frac{\beta}{1+\beta}\mathbb{E}_t\hat{u}_{t+1}^a = \frac{1}{1+\beta}\hat{\imath}_{t-1} \tag{A.12}$$

Effective capital

$$\hat{k}_t = \hat{\nu}_t + \hat{\bar{k}}_{t-1} - \hat{u}_t^a \tag{A.13}$$

Law of motion for capital

$$\hat{\bar{k}}_t = (1-\delta)e^{-\varkappa}\left(\hat{\bar{k}}_{t-1} - \hat{u}_t^a\right) + \left[1-(1-\delta)e^{-\varkappa}\right]\left[(1+\beta)se^{2\varkappa} + \hat{\imath}_t\right] \tag{A.14}$$

Wage equation

$$\begin{aligned}\hat{w}_t = {} & \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}\mathbb{E}_t\hat{w}_{t+1} - \kappa_w\left[\hat{w}_t - \xi\hat{L}_t + \hat{\lambda}_t^S - \frac{\tau_L}{1-\tau_L}\hat{\tau}_{L,t}\right] + \frac{\chi_w}{1+\beta}\hat{\pi}_{t-1} \\ & - \frac{1+\beta\chi_w}{1+\beta}\hat{\pi}_t + \frac{\beta}{1+\beta}\mathbb{E}_t\hat{\pi}_{t+1} + \frac{\chi}{1+\beta}\hat{u}_{t-1}^a - \frac{1+\beta\chi_w - \rho_{ea}\beta}{1+\beta}\hat{u}_t^a + \kappa_w\hat{\eta}_t^w,\end{aligned} \tag{A.15}$$

where $\kappa_w \equiv \left[\left(1-\beta\omega_w\right)\left(1-\omega_w\right)\right] / \left[\omega_w(1+\beta)\left(1+\frac{(1+\eta^w)\xi}{\eta^w}\right)\right]$.

Monetary policy rule

$$\hat{r}_{n,t} = \rho_r\hat{r}_{n,t-1} + \left(1-\rho_r\right)\left[\phi_\pi\left(\hat{\pi}_t - \hat{\pi}_t^F\right) + \phi_y\hat{y}_t\right] + \hat{u}_t^m + \sum_{f=1}^{12} FG_{t-f}^f, \tag{A.16}$$

where the last term is the summation of forward guidance shocks released in the previous 10 quarters.

Aggregate resource constraint

$$y\hat{y}_t = c\hat{c}_t + i\hat{\imath}_t + g\hat{g}_t + \psi'(1)k\hat{\nu}_t. \tag{A.17}$$

Hand-to-mouth household's budget constraint

$$\tau_C c^N \hat{\tau}_{C,t} + (1+\tau_C)\, c^N \hat{c}_t^N = (1-\tau_L)\, wL \left(\hat{w}_t + \hat{L}_t\right) - \tau_L w L \hat{\tau}_{L,t} + z\hat{z}_t \tag{A.18}$$

Consumption aggregation

$$c\hat{c}_t = c^S(1-\mu)\hat{c}_t^S + c^N \mu \hat{c}_t^N \tag{A.19}$$

Maturity structure of debt

$$\hat{r}_{n,t} + \hat{P}_t^m = \frac{\rho}{R}\mathbb{E}_t \hat{P}_{t+1}^m - \hat{u}_t^{rp} \tag{A.20}$$

Government budget constraint

$$\begin{aligned} &\frac{b}{y}\hat{b}_t + \tau_K r_K \frac{k}{y}\left[\hat{\tau}_{K,t} + \hat{r}_{K,t} + \hat{k}_t\right] + \tau_L w \frac{L}{y}\left[\hat{\tau}_{L,t} + \hat{w}_t + \hat{L}_t\right] + \tau_C \frac{c}{y}\left(\hat{\tau}_{C,t} + \hat{c}_t\right) \\ =&\frac{1}{\beta}\frac{b}{y}\left[\hat{b}_{t-1} - \hat{\pi}_t - \hat{P}_{t-1}^m - \hat{u}_t^a\right] + \frac{b}{y}\frac{\rho}{e^x}\hat{P}_t^m + \frac{g}{y}\hat{g}_t + \frac{z}{y}\hat{z}_t. \end{aligned} \tag{A.21}$$

Fiscal rules

$$\hat{g}_t^b = \rho_G \hat{g}_{t-1}^b - (1-\rho_G)\left[\gamma_G\left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F\right) + \phi_{gy}\hat{y}_t\right] + \hat{\zeta}_{g,t} \tag{A.22}$$

$$\hat{g}_t = \hat{g}_t^b + \hat{\zeta}_{g,t}^M + \hat{\zeta}_{g,t}^F \tag{A.23}$$

$$\hat{\tau}_{J,t} = \rho_J \hat{\tau}_{J,t-1} + (1-\rho_J)\,\gamma_J\left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F\right), \quad J \in \{K, L, C\} \tag{A.24,25,26}$$

$$\hat{z}_t^b = \rho_Z \hat{z}_{t-1}^b - (1-\rho_Z)\left[\gamma_Z\left(\hat{s}_{b,t-1} - \hat{s}_{b,t-1}^F\right) + \phi_{zy}\hat{y}_t\right] + \hat{\zeta}_{z,t} \tag{A.27}$$

$$\hat{z}_t = \hat{z}_t^b + \hat{\zeta}_{z,t}^M + \hat{\zeta}_{z,t}^F \tag{A.28}$$

Fisher Equation

$$\hat{r}_{r,t} = \hat{r}_{n,t} - \mathbb{E}_t \hat{\pi}_{t+1} \tag{A.29}$$

Debt-to-GDP ratio

$$\hat{s}_{b,t} = \hat{b}_t - \hat{y}_t \tag{A.30}$$

Consumption tax revenue

$$\hat{T}_{C,t} = \hat{\tau}_{C,t} + \hat{c}_t \tag{A.31}$$

Capital tax revenue

$$\hat{T}_{K,t} = \hat{\tau}_{K,t} + \hat{r}_{K,t} + \hat{k}_t \tag{A.32}$$

Return of long-term bond

$$\hat{r}_{t-1,t}^m = \frac{\rho}{R}\hat{P}_t^m - \hat{P}_{t-1}^m \tag{A.33}$$

Government primary surplus

$$\hat{S}_t = \tau_K r_K k\left[\hat{\tau}_{K,t} + \hat{r}_{K,t} + \hat{k}_t\right] + \tau_L w L\left[\hat{\tau}_{L,t} + \hat{w}_t + \hat{L}_t\right] + \tau_C c\left(\hat{\tau}_{C,t} + \hat{c}_t\right) - g\hat{g}_t - z\hat{z}_t \tag{A.34}$$

Labor tax revenue

$$\hat{T}_{L,t} = \hat{\tau}_{L,t} + \hat{w}_t + \hat{L}_t \tag{A.35}$$

C.2 Shadow Economy

Equation (A.1') to (A.35') characterize the shadow economy, where the fiscally led policy mix is always in place. For Equation (A.1) $\sim$ (A.15), (A.17) $\sim$ (A.21), and (A.29) $\sim$ (A.35), any variable that refers to the actual economy x_t is replaced by the same variable in the shadow economy x_t^F, and all the non-policy shocks are removed. For instance, the equation in the shadow economy block corresponding to Equation (A.4) is:

$$\hat{\pi}_t^F = \frac{\beta}{1+\chi_p\beta}\mathbb{E}_t\hat{\pi}_{t+1}^F + \frac{\chi_p}{1+\chi_p\beta}\hat{\pi}_{t-1}^F + \kappa_p\widehat{mc_t}^F \tag{A.4'}$$

Then, the shadow economy is augmented with its monetary and fiscal rules.

$$\hat{r}_{n,t}^F = \rho_r\hat{r}_{n,t-1}^F + (1-\rho_r)\,\phi_y\hat{y}_t^F + \sum_{f=1}^{12} FG_{t-f}^f \tag{A.16'}$$

$$\hat{g}_t^{b,F} = \rho_G\hat{g}_{t-1}^{b,F} - (1-\rho_G)\,\phi_{gy}\hat{y}_t^F \tag{A.22'}$$

$$\hat{g}_t^F = \hat{g}_t^b + \hat{\zeta}_{g,t}^F \tag{A.23'}$$

$$\hat{\tau}_{J,t}^F = \rho_J\hat{\tau}_{J,t-1}^F, \quad J \in \{K, L, C\} \tag{A.24',25',26'}$$

$$\hat{z}_t^{b,F} = \rho_Z\hat{z}_{t-1}^{b,F} - (1-\rho_Z)\,\phi_{zy}\hat{y}_t^F \tag{A.27'}$$

$$\hat{z}_t = \hat{z}_t^b + \hat{\zeta}_{z,t}^F \tag{A.28'}$$

C.3 Forward Guidance Shocks

The model features a two-factor structure of forward guidance shocks, following Campbell et al. (2012, 2017). At period t, the monetary authority releases information about future monetary policy 1 to 10 quarters ahead. For f from 1 to 10,

$$FG_t^f = Aload(f)\cdot FactorA_t + Bload(f)\cdot FactorB_t + \varepsilon_{FG,t}^f,$$

where $FactorA$ is the target factor, $FactorB$ is the path factor, and $\varepsilon_{FG,t}^f$ is a horizon-specific signal. The factors and signals are assumed to follow i.i.d. normal distribution. Their standard deviations, along with factor loadings, are estimated in the second sample (2008:Q1 - 2024:Q1).

D Data Sources and Construction

The data set we use for estimation comprises 10 variables for the UK economy observed quarterly from 1960:Q1 to 2024:Q1. Most of the time series come from the Office for National

Statistics (ONS). The ONS ID of these series are in square brackets. The Bank Rate is from the Bank of England. The equations below explain how we construct these variables[5].

1) Real per capita GDP growth $\equiv \Delta \log \frac{\text{real GDP}}{\text{WAP}} = \Delta \log \frac{[\text{ABMI}]}{\text{WAP}}$

2) Real per capita consumption growth $\equiv \Delta \log \frac{\text{HH \& NPISH final consumption expenditure}}{\text{WAP}}$

$$= \Delta \log \frac{[\text{ABJR}]+[\text{HAYO}]}{\text{WAP}}$$

3) Real per capita investment growth $\equiv \Delta \log \frac{\text{nominal private investment}}{\text{WAP} \times \text{investment price index}}$

$$= \Delta \log \frac{\text{nominal private investment}}{\text{WAP} \times [\text{YBFU}]}$$

4) Gap of hours per capita $\equiv \frac{\text{total weekly hours worked}}{\text{WAP}}$ − trend (5th-degree polynomial)

5) Nominal interst rate $\equiv$ Bank Rate

6) Real wage growth $\equiv \Delta \log \frac{\text{nominal compensation of employees and household mixed income}}{\text{total weekly hours worked} \times \text{price index}}$

$$= \Delta \log \frac{[\text{DTWM}] + [\text{ROYH}]}{\text{total weekly hours worked} \times \text{price index}}$$

7) Inflation $\equiv \Delta \log (\text{price index}) = \Delta \log \frac{[\text{ABJQ}] + [\text{HAYE}]}{[\text{ABJR}] + [\text{HAYO}]}$

8) Real per capita govt. cons. & inv. growth $\equiv \Delta \log \frac{\text{nominal CG consumption and investment}}{\text{WAP} \times \text{price index}}$

9) Real per capita govt. transfers growth $\equiv \Delta \log \frac{\text{nominal CG transfers}}{\text{WAP} \times \text{price index}}$

10) Debt-to-GDP ratio $\equiv \log \frac{\text{MV of UK national debt}}{\text{nominal GDP}} = \log \frac{\text{MV of UK national debt}}{[\text{YBHA}]}$

To construct the time series for the working-age population (defined as individuals aged 16+), we begin with the annual UK population dataset aged 15+ sourced from "ONS: Estimates of the population for the UK, England, Wales, Scotland, and Northern Ireland, UK population estimates, 1838 to 2020". The [MGSL] annual series starts from 1971; we project this data back to earlier years using a linear regression of [MGSL] on the population aged 15+ from 1971 to 2020 (with a sample size of 50 for the linear regression). Then, we splice the extrapolated [MGSL] annual series from 1955 to 1970 with the [MGSL] quarterly series (available from 1971:Q1), and perform linear interpolation to fill in missing values.

For total weekly hours worked, we use [YBUS] from 1971 Q1 onward. Prior to 1970 Q4, we construct annual measures of total hours by multiplying the series for "average

[5] Abbreviations: "WAP": working age population; "HH": households; "NPISH": Non-Profit Institutions Serving Household; "CG": central government; "MV": market value.

annual hours per person engaged, whole economy" and "number of persons engaged, whole economy" provided in O'Mahony and de Boer (2002).

The three variables presented in the following are derived based on the methodology described in "Bank of England: A millennium of macroeconomic data". We utilize the X-13ARIMA-SEATS program to convert them into seasonally adjusted series. We replace abnormal observations in these series with missing values.

- nominal CG consumption and investment = [NMBJ] + [ANPI] + [ANMY]
- nominal CG transfers = [ANLP] − [ANNS] + [NSRN] − [NMFX] − [NMCD]
  − nominal CG consumption and investment
- nominal private investment = [NPQX] − [ANPI]

We extend the monthly series of the market value of UK government debt from Ellison and Scott (2020) to March 2024 using the ESCoE British Government Securities Database. The Database consists of spreadsheets that capture monthly quantities (from 1964) and prices (from 1975) of every gilt issued by the British Government up to the present. See Ellison and Scott (2020) for more details.

Finally, since not all variables are observed at each period, the state-space estimation uses different measurement equations to include series when they are available, and exclude them when they are missing.

E Second Sample Estimates

Table E.1 shows the prior and the posterior moments for the parameters estimated in the second sample. In the second sample estimation, we add the market expectations of the Bank Rate as observables. The prior for the parameters that are estimated in the first sample is centered at their posterior mode in the first sample. We report only the posterior mode of the parameters estimated in the second sample. The prior and posterior moments of the parameters of the factor model governing the contemporaneous correlation of forward guidance shocks follow Campbell et al. (2017) closely and are not shown here.

Prior and Posterior Distributions for the Exogenous Processes									
		Posterior Distribution				Prior Distribution		
Param	Description	Mode	Median	5%	95%	Type	Mean	Std
σ_G^M	St.dev. funded G	4.2383	4.2439	4.2377	4.2493	IG	2.0509	0.500
σ_G^F	St.dev. unfunded G	0.2978	0.2991	0.2971	0.3009	IG	0.4919	0.500
σ_g	St.dev. short-term G	0.2004	0.1997	0.1987	0.2007	IG	0.3793	0.500
σ_Z^M	St.dev. funded transfers	7.5499	7.5556	7.5501	7.5604	IG	3.6981	0.500
σ_Z^F	St.dev. unfunded transfers	1.5653	1.5649	1.5632	1.5667	IG	0.4536	0.500
σ_z	St.dev. short-term trans.	0.2098	0.2097	0.2089	0.2112	IG	0.3920	0.500
σ_{GDP}^m	Measur. error GDP	0.7531	0.7538	0.7520	0.7561	IG	0.9447	0.200
σ_{by}^m	Measur. error Debt/GDP	0.2702	0.2697	0.2684	0.2706	IG	0.3777	0.200

Table E.1 - Posterior modes, medians, 90% posterior credible sets, and prior moments for the exogenous processes. The letters in the column with the heading "Prior Type" indicate the prior density function: IG stands for Inverse Gamma.