UNIVERSIDADE FEDERAL DE PERNAMBUCO
CENTRO DE CIÊNCIAS SOCIAIS APLICADA
DEPARTAMENTO DE ECONOMIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ECONOMIA

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Trend inflation and weak identification in the New Keynesian Phillips curve

Recife

2024

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Dissertação apresentada ao Programa de Pós-Graduação em Economia da Universidade Federal de Pernambuco, como requisito parcial para a obtenção do título de Mestre em Economia.

Orientador: Prof. Dr. Marcelo Eduardo Alves da Silva

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2024

Catalogação na Fonte
Bibliotecária Ângela de Fátima Correia Simões, CRB4-773

M538t Mendes, Igor Manoel Bezerra Roque
Trend inflation and weak identification in the New Keynesian Phillips curve / Igor Manoel Bezerra Roque Mendes. - 2024.
67 folhas: il. 30 cm.

Orientador: Prof. Dr. Marcelo Eduardo Alves da Silva.
Dissertação (Mestrado em Economia) – Universidade Federal de Pernambuco, CCSA, 2024.
Inclui referências e apêndices.

1. Phillips, curva de. 2. Inferência robusta. 3. Funções de impulso Respostas. I. Silva, Marcelo Eduardo Alves da (Orientador). II. Título.

336 CDD (22. ed.) UFPE (CSA 2024 – 031)

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Aprovado em: 23/02/2024.

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Dedico este trabalho à minha avó, *in memoriam*, Luíza Maria Bezerra da Silva.

AGRADECIMENTOS

O mestrado no PIMES foi marcado por muita dedicação e privações, mas também por desenvolver habilidades essenciais para minha vida como pesquisador, e este trabalho é um retrato de tudo isso. Aqui, vou agradecer a todos que contribuíram de maneira direta ou indireta para o progresso da minha jornada acadêmica até momento.

Primeiramente, agradeço à minha mãe, Walewiska, e à minha avó, Luíza. Afinal, para chegar aqui, precisei fazer muitas tarefas de casa desde o ensino infantil, que minha avó me ensinava com tanto zelo e paciência. Enquanto isso, minha mãe sempre se desdobrou para oferecer o melhor em todos os aspectos, sobretudo, o educacional. Considero-as as pedras fundamentais da minha vida, responsáveis por me educar, criar, dar amor e mais um tanto de coisas que me fazem ser quem eu sou hoje. Eu só tenho a agradecer a elas pelo amor, apoio incondicional, renúncias e por tudo que elas já fizeram por mim. Definitivamente, sem elas, nada seria possível.

Agradeço ao meu avô, José Bezerra, meus tios, Brawowisky e Camila, meus irmãos, Yasmin, Manuela e Marcio, e meu padrasto, Paulo. Obrigado por me darem apoio, amor, carinho, e por sempre me estenderem a mão quando eu precisei, cada um à sua forma. Tenho muita sorte em tê-los como minha família.

Também agradeço aos meus amigos que estiveram juntos a mim nessa (louca) caminhada do mestrado: Danilo, Rafaela, Izabelita, Lucas, Denis e Mattheus. Em especial, agradeço à minha amiga e namorada, Ricari, minha companheira de todas as horas. Com eles eu virei muitas noites estudando, dei risadas, desabafei, briguei e me diverti. Essa fase seria bem mais difícil sem eles.

Eu também não posso deixar de agradecer a todos os professores do PIMES, que me ensinaram para além de Economia, sobretudo, agradeço às contribuições de Paulo e Breno nessa fase. Ao Paulo por ter me dado a oportunidade de ser monitor da disciplina de Macroeconomia 1, por me aconselhar sobre os passos que eu deveria tomar na vida acadêmica e por me ajudar no meu processo de admissão no Doutorado. Ao Breno por ter mudado minha visão de como se pensar em pesquisa nas suas aulas e conversas informais e por ter me dado a oportunidade de ser seu assistente de pesquisa. Sobre esse último ponto, também agradeço ao Marco, Vitor e Dimitri, que, juntos ao Breno, foram meus supervisores no projeto. Essas experiências como monitor e assistente de pesquisa, sem dúvidas, engrandeceram minha trajetória.

Por fim, sou imensamente grato ao Edilean pela leitura cuidadosa e sugestões, que foram imprescindíveis para a elaboração destre trabalho, e por ter me ajudado no meu processo de admissão no Doutorado. Agradeço ao Rafael por ter me aconselhado sobre possíveis melhorias que poderiam ser feitas, ainda na banca de qualificação. Aproveito para agradecer a ambos por aceitarem participar da banca examinadora. Agradeço ao Professor Marcelo por me orientar e por ser compreensivo com as demandas que tive no meio do processo de orientação. Também agradeço à FACEPE pelo apoio financeiro dado para a elaboração deste trabalho.

ABSTRACT

In this work, we estimate the generalized New Keynesian Phillips curve (GNKPC) using monetary shocks as instruments. We employ an approach that is robust to weak instruments and is valid regardless of the shocks' variance contribution to construct confidence intervals. Our point estimates suggest that not considering trend inflation tends to overestimate the cost of disinflation. We also show that the effects of expectational terms are not stable. Finally, we show considerable uncertainty about the true values of the parameters of the GNKPC, as in some cases the confidence intervals are unbounded. These findings have important implications for monetary policy and indicate that caution should be exercised in the choices and calibrations of dynamic stochastic general equilibrium models.

Keywords: Generalized New Keynesian Phillips curve; Weak identification; Robust inference; Instrumental variables; Impulse responses.

RESUMO

Neste trabalho, estimamos a curva de Phillips novo-keynesiana generalizada (GNKPC) utilizando choques monetários como instrumentos. Empregamos uma abordagem robusta a instrumentos fracos e válida independentemente da contribuição da variância dos choques para construir intervalos de confiança. Nossas estimativas pontuais sugerem que não considerar a inflação tendencial tende a superestimar o custo da desinflação. Também mostramos que os efeitos dos termos expectacionais não são estáveis. Por fim, mostramos considerável incerteza sobre os valores reais dos parâmetros da GNKPC, uma vez que, em alguns casos, os intervalos de confiança são ilimitados. Essas descobertas têm importantes implicações para a política monetária, e indica que se deve ter cautela nas escolhas e calibrações de modelos dinâmicos estocáticos de equilíbrio geral.

Palavras-chaves: Curva de Phllips novo keynesiana genralizada; Identificação fraca; Inferência robusta; Variáveis instrumentais; Respostas ao impulso.

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1 Introduction

"The assumptions one makes about trend inflation have important implications for the cyclical of the economy, affecting the policy trade-offs and the conduct of monetary policy." - Ascari and Sbordone (2014).

The New Keynesian Phillips curve (NKPC) suggests that central banks can control inflation by managing inflation expectations and exploiting the trade-off between unemployment and inflation. In the workhorse New Keynesian model, the NKPC is constructed from the log-linearization of firms' optimal conditions around a zero inflation steady state (GALí; GERTLER, 1999). However, at least since Taylor (1993), it is known that the Fed, even if implicitly, pursues a positive inflation target, implying a positive inflation trend.[1] Recent analyses suggest that accounting for trend inflation has important monetary policy and welfare implications. For instance, Coibion and Gorodnichenko (2011) show that with positive trend inflation, the Taylor principle does not guarantee a determinate equilibrium.[2]

As both inflation and unemployment (or output gap) are endogenously determined, and given that the NKPC contains unobservable terms, this poses an important challenge for its estimation. To address this problem, some studies employ limited-information methods to estimate the NKPC parameters, such as the Generalized Method of Moments (GMM) and Instrumental Variables (IV), using lags of macroeconomic variables as instruments.[3] Others adhere to full-information methods, such as Bayesian estimation of Dynamic Stochastic General Equilibrium (DSGE) models.[4] However, despite the potential of the latter approach to enhance estimator precision, it introduces the risk of misspecification, leading to bias or inconsistency in the estimation of the parameters (MAVROEIDIS et al., 2014). On the other hand, while limited information methods are much less prone to this issue, they are susceptible to weak identification problems. This is particularly problematic when lags of macroeconomic variables are used as instruments

[1] Indeed, between 1990 and 2007, characterized as a period of inflation stability, the inflation rate measured by the Personal Consumption Expenditures Price Level excluding food and energy prices (Core PCE) had averaged 1.98%.

[2] Further implications can be found in Ascari (2004), Alves (2014), Ascari and Sbordone (2014), Kurozumi and Zandweghe (2016), Gemma et al. (2023), and Kurozumi and Zandweghe (2023).

[3] See, e.g., Roberts (1995), Galí and Gertler (1999), among others.

[4] See, e.g., Smets and Wouters (2007), among others.

(MAVROEIDIS et al., 2014).

In this work, we estimate the generalized NKPC (GNKPC) based on Cogley and Sbordone (2008), which accounts for trend inflation, employing the approach of Barnichon and Mesters (2020) (hereafter referred to as BM) to estimate prospective macroeconomic equations. Specifically, we use Romer and Romer (2004) narrative monetary shocks as instruments to identify the parameters of the NKPC. We do this because the traditional approach of using lags of macroeconomic variables empirically faces a trade-off between exogeneity and strength, two necessary conditions for instrumental variable estimation. As monetary shocks are not lagged variables, their utilization does not encounter this challenge. Besides monetary shocks theoretically have two necessary conditions to be considered instruments: exogeneity and relevance. Still, in line with the recommendation of Kleibergen and Mavroeidis (2009), Mavroeidis et al. (2014), and the literature discussing issues of weak identification of the Phillips curve[5], we employ an identification-robust procedure because, empirically, monetary shocks are not necessarily strong instruments.[6]

We estimate an unrestricted and restricted version of the GNKPC. In our preferred approach, the restricted one, we find that BM overestimates the slope (the coefficient of the forcing variable) of the Phillips curve by 18% when the forcing variable is unemployment and by 72% when it is the output gap. This means that by ignoring trend inflation, one would overestimate the cost of disinflation. We also indicate that the forward-looking parameter is underestimated by them and it is larger than the backward-looking parameter, regardless of the chosen specification. These results indicate that the Fed can decrease inflation with a lower cost of unemployment and that forward guidance plays a crucial role in determining inflation.

To ascertain the robustness of our findings, we estimate the NKPC and the GNKPC for various combinations of variables, different constructions of our instrument vector, a different measure of trend inflation, and a sub-period. Overall, the results only confirmed an overestimation of the forcing variable parameter when the trend is not considered. Regarding the expectation terms, there were disagreements arising from the new choices. However, considering our confidence intervals, in some cases, we find wide confidence

[5] See, e.g., Dufour et al. (2006), Dufour et al. (2010), Dufour et al. (2010), Nason and Smith (2008), Martins and Gabriel (2009), Magnusson and Mavroeidis (2010), Magnusson and Mavroeidis (2014), BM, and Aragón and Galvão (2023).

[6] See, e.g., Caldara and Herbst (2019), Gorodnichenko and Lee (2020) and Plagborg-Møller and Wolf (2022).

intervals for all parameters, suggesting high uncertainty about our inferences depending on the chosen specification. These results have relevant implications for the conducting of monetary policy and for calibrating DSGE models.

This work relates to two strands of the literature. First, we join the literature on the identification of forward-looking macro equations using structural shocks as instruments, such as BM, Doser et al. (2023), Aragón and Galvão (2023), and Beaudry et al. (2024). Second, we consider an NKPC specification that is often overlooked in the weak identification literature. In general, those analyses use a hybrid NKPC or some variation of the NKPC, such as the models by Ravenna and Walsh (2006), Blanchard and Galí (2007), and Blanchard and Galí (2010).[7] According to the chosen specification, this study is more closely related to Mavroeidis et al. (2014), as they consider the GNKPC as one of their estimated specifications. Methodologically, we align more with BM as they use monetary shocks to identify the NKPC. However, our work differs from theirs as we combine the estimation of the GNKPC with the use of monetary shocks as instruments.

This work is structured as follows: In the next section, we discuss the identification strategy, the empirical model, the use of monetary shocks as instruments, and the robust approach to weak identification that we employ in the study; In Section 3, we present the data; In Section 4, we present the baseline results, robustness, and policy implications of our findings; Finally, in Section 5, we present the conclusion.

2 Identification strategy

In this section, we introduce the empirical model of the GNKPC in Subsection 2.1. Subsection 2.2 addresses the issue of using monetary shocks to identify the GNKPC. In subsection 2.3, we address the robust methodology for weak instruments that we employ in this study.

[7] See, e.g., Dufour et al. (2006), Dufour et al. (2010), Dufour et al. (2010), Nason and Smith (2008), Kleibergen and Mavroeidis (2009), Martins and Gabriel (2009), Magnusson and Mavroeidis (2010), Magnusson and Mavroeidis (2014), BM, and Aragón and Galvão (2023).

2.1 Empirical model

To contextualize the use of the GNKPC, we first introduce the hybrid NKPC and its sources of endogeneity. This equation takes the following format:

$$\pi_t = \gamma_b \pi_{t-1}^4 + \gamma_f E_t(\pi_{t+1}^4) + \lambda x_t + \epsilon_t^s \tag{1}$$

where π_t (annualized) is the quarter-to-quarter inflation, $\pi_{t-1}^4 = \frac{1}{4}(\pi_{t-1}+\pi_{t-2}+\pi_{t-3}+\pi_{t-4})$ is average inflation over the past year, $E_t(\pi_{t+1}^4)$ is the (rational) expected inflation over the next year dependent upon the information available t, with $\pi_{t+1}^4 = \frac{1}{4}(\pi_{t+1} + \pi_{t+2} + \pi_{t+3} + \pi_{t+4})$, and x_t is some proxy for real marginal costs, such as output gap or unemployment gap.[8] If there is no misspecification or omitted variables, ϵ_t^s denotes cost-push factors.

Nevertheless, according to Kim and Kim (2008), the NKPC has two sources of endogeneity. First, the error term can affect the dependent and independent variables through a system of simultaneous equations. Second, the proxy variables for inflation expectations and the measure of economic activity are unobservable and, hence, measurement errors may occur. Assuming these measurement errors are not serially correlated, the NKPC in Eq. (1) can be expressed by:

$$\pi_t = \gamma_b \pi_{t-1}^4 + \gamma_f \pi_{t+1}^4 + \lambda \hat{x}_t + \varepsilon_t \tag{2}$$

where $\varepsilon_t = \epsilon_t^s - \gamma_f(\pi_{t+1}^4 - E_t(\pi_{t+1}^4)) - \lambda(\hat{x}_t - x_t)$. Since π_{t+1}^4 and x_t are included in ε_t, the NKPC includes all two sources of endogeneity, as $E_t(\pi_{t+1}^4 \varepsilon_t) \neq 0$ and $E_t(\hat{x}_t \varepsilon_t) \neq 0$.

The derivation of the model estimated in Eq. (2) follows from the log-linearized optimization of firms' conditions around a zero inflation steady state.[9] However, numerous papers demonstrate that allowing a non-zero steady state leads to different implications. For instance, Ascari (2004) illustrates that when trend inflation is considered, the long-term and short-term properties of models based on Calvo's staggered price model change dramatically. Cogley and Sbordone (2008) argue that considering trend inflation ensures the correct capture of inflation persistence, even in the absence of a backward-looking

[8] Empirically, studies adopt various arbitrary treatments for the choices of inflation lags. Some opt for only the lag of the last period (e.g., Galí and Gertler (1999), Sbordone (2005)). Others choose to consider the last quarter (e.g., Christiano et al. (2005)). Additionally, there is a range of works that consider the average of the last 4 quarters or 12 months, i.e., the last year, as specified in the present study (e.g., Atkeson and Ohanian (2001), Zhang and Clovis (2010), Barnichon and Mesters (2020)).

[9] For details about the derivation of the hybrid NKPC, see Galí and Gertler (1999).

term in the NKPC. According to Coibion and Gorodnichenko (2011), with positive trend inflation, the Taylor principle does not guarantee a determinate equilibrium. Alves (2014) demonstrates that the monetary authority is only able to simultaneously stabilize inflation and the output gap in response to preference and technological shocks when inflation stabilizes exactly at zero. Ascari and Sbordone (2014) concludes that the increase in trend inflation is associated with a more volatile economy and tends to destabilize inflation expectations. Kurozumi and Zandweghe (2023) demonstrate that a lower trend inflation reduces the persistence of inflation, and credible disinflation leads to a gradual decline in inflation and a fall in production. Gemma et al. (2023) shows that GNKPC outperforms NKPC in terms of estimation using the quasi-marginal likelihood and, when trend inflation fell after the period of the Great Inflation, the probability of price changes decreased, and the GNKPC stabilized.

Despite all those implications, Mavroeidis et al. (2014), as far as we are aware, is the only paper addressing weak identification and trend inflation in one of its estimations. They do not find significant differences between the estimation of the NKPC and the GNKPC using lags of macroeconomic variables as instruments.[10] They argue that this may be because the sum of the coefficients of the forward- and backward-looking terms equals 1, thereby mitigating the influence of considering trend inflation in the estimation of the NKPC. However, they show that using lags of macroeconomic variables results in weak instruments.

Therefore, considering the implications of using trend inflation and that non-zero steady-state inflation aligns more with reality, we estimate the GNKPC using monetary shocks as instruments. We follow Mavroeidis et al. (2014) and estimate the GNKPC, in line with the simplified version of Cogley and Sbordone (2008). Thus, we estimate the following GNKPC written in terms of the difference between inflation and trend inflation:

$$\hat{\pi}_t = \gamma_b \hat{\pi}^4_{t-1} + \gamma_f E_t(\hat{\pi}^4_{t+1}) + \lambda x_t + \epsilon^s_t \tag{3}$$

where $\hat{\pi}_t = \pi_t - \bar{\pi}_t$ is the inflation gap and $\bar{\pi}_t$ is inflation trend. However, under this specification, we may introduce another source of endogeneity, the potential for measurement error in trend inflation. Thus, we can express the GNKPC as follows:

[10] Despite addressing the GNKPC, Mavroeidis et al. (2014) do not extend into a detailed presentation and discussion of the estimation results.

$$\hat{\hat{\pi}}_t = \gamma_b \hat{\hat{\pi}}^4_{t-1} + \gamma_f \hat{\hat{\pi}}^4_{t+1} + \lambda \hat{x}_t + u_t \tag{4}$$

where $u_t = \epsilon^s_t - \gamma_f((\pi^4_{t+1} - E_t(\pi^4_{t+1})) + (\hat{\hat{\pi}}^4_{t+1} - (\hat{\pi}^4_{t+1}))) - \lambda(\hat{x}_t - x_t) - \gamma_b(\hat{\hat{\pi}}^4_{t-1} - \hat{\pi}^4_{t-1}) + (\hat{\hat{\pi}}_t - \hat{\pi}_t)$.

2.2 Using monetary shocks as instruments

To address the issue of endogenous regressors in forward-looking macro equations, the literature suggests using some methods that use instruments in the estimation, such as GMM and IV. Using Eq. (4) for a general explanation, from the standard approach, $\hat{\hat{\pi}}^4_{t+1}$ is treated as predetermined and lagged values of x_t are used as instruments. The objective is to ensure that x_{t-i}, where i=1,2,3,...,n, is correlated with x_t, but not with u_t. To eliminate the endogeneity bias, $z^l_t = (\hat{\hat{\pi}}^4_{t-2} \hat{x}_{t-1})$ is considered, and to address the bias, it is necessary that $E(u_t z^l_t) = 0$. Additionally, to satisfy the relevance condition, let $w_t = (\hat{\hat{\pi}}^4_{t+1}, \hat{x}_t)$', we need that $E(z^l_t w'_t)$ to be of full column rank.

However, despite Kleibergen and Mavroeidis (2009) arguing that theoretically the rank condition is easily verified under moderate assumptions for $\hat{x}_t$, they, along with Nason and Smith (2008), Mavroeidis (2010), and Mavroeidis et al. (2014) show that empirically lags of macroeconomic variables are weak instruments. The use of lagged macro variables as instruments requires that none of the components in the error term u_t be autocorrelated; otherwise, $E(u_t z^l_t) \neq 0$. To address this concern, it is generally preferred to increase the lags of the macroeconomic variables. However, by increasing the lags of the macroeconomic variables, the instrument loses strength, leading the choice of macro variables as instruments to a trade-off between strength and exogeneity. In other words, the choice of lagged variables as instruments tends to result in weak instruments, leading to inference on the point estimates, hypothesis tests, and confidence intervals lacking robustness (STOCK et al., 2002).

On the other hand, by using independently identified monetary shocks as instruments, we can allow autocorrelation in the equation's residual and avoid the trade-off problem between strength and exogeneity. Let ξ^m_{t-h} be a sequence of monetary shocks, then we need that $E(\xi^m_{t-h} u_t) = 0$ for $h \geq 0$. We consider this to be true because, similar to BM, we assume that monetary shocks are innovations in the systematic conduct of monetary policy and should therefore be orthogonal to cost-push factors that drive inflation. This holds as long as monetary policy does not impact aggregate supply, that is to say, assuming there is no cost channel of monetary policy.[11] Furthermore, we assume that money is neutral if there is price flexibility and if rational expectations hold or if accurate inflation expectation surveys are available, allowing for some additive measurement error term. To satisfy the relevance condition, we also need that $E(\xi^m_{t-h}(\hat{\hat{\pi}}^4_{t-1}, \hat{\hat{\pi}}^4_{t+1}, \hat{x}_t))$ to be of full column rank. Thus, we assume that if there exists an underlying IS curve such that the impulse response functions of $\hat{x}$ and $\hat{\hat{\pi}}$ are linearly independent, then $E(\xi^m_{t-h}(\hat{\hat{\pi}}^4_{t-1}, \hat{\hat{\pi}}^4_{t+1}, \hat{x}_t))$ is of full column rank. All these assumptions are valid in typical New Keynesian models.[12]

According to BM, we can interpret this methodology of employing independently identified shocks as instruments as a regression within the impulse response space. When we assume that all variables are stationary, monetary shocks exhibit no mutual correlation, and the macro variables ($\hat{\hat{\pi}}^4_{t-1}$, $\hat{\hat{\pi}}^4_{t+1}$,$\hat{x}_t$), in addition to u_t, can be written as a linear function of the monetary shocks. Thus, the conditions of exogeneity and relevance can be written $R^u_h = 0$ and $[R^{\hat{\hat{\pi}}}_{h-1}, R^{\hat{\hat{\pi}}}_{h+1}, R^{\hat{x}}_h]^H_{h=0}$ is of full column rank, respectively, where R^j_h is the impulse response function of j_t, for $j = u, \hat{\hat{\pi}}, \hat{x}$ to the monetary shocks ξ^m_{t-h}.

Therefore, post-multiplying Eq. (4) by ξ^m_{t-h} and take the expectation, we have:

$$E(\hat{\hat{\pi}}_t \xi^i_{t-h}) = \gamma_b E(\hat{\hat{\pi}}^4_{t-1} \xi^i_{t-h}) + \gamma_f E(\hat{\hat{\pi}}^4_{t+1} \xi^i_{t-h}) + \lambda E(\hat{x}_t \xi^i_{t-h}) + E(u_t \xi^i_{t-h}) \tag{5}$$

Taking into account the exogeneity and relevance conditions, the last term is zero and the other expectations are the impulse responses of $\hat{\hat{\pi}}^4_{t-1}$, $\hat{\hat{\pi}}^4_{t+1}$, and $\hat{x}_t$. Thus, we obtain:

$$R^{\hat{\hat{\pi}}}_h = \gamma_b R^{\hat{\hat{\pi}}}_{h-1} + \gamma_f R^{\hat{\hat{\pi}}}_{h+1} + \lambda R^{\hat{x}}_h \qquad \forall \quad h = 0, ..., H \tag{6}$$

With the result from Eq. (6), it can be verified that it is possible to estimate the parameters of Eq. (4) using a regression in the impulse response space. Intuitively, the exogeneity condition implies that Eq. (6) holds while the relevance condition implies that the dynamics of the impulse responses of $(\hat{\hat{\pi}}^4_{t-1}, \hat{\hat{\pi}}^4_{t+1}, \hat{x}_t)$ are rich enough to allow a unique parameter vector $(\lambda, \gamma_b, \gamma_f)$ that satisfies Eq. (6).

[11] However, we acknowledge the possibility of a cost channel (e.g., Barth III and Ramey (2001), Gaiotti and Secchi (2006), Ravenna and Walsh (2006), Tillmann (2008), Tillmann (2009), Castelnuovo (2012), and Beaudry et al. (2024).).

[12] For more details, see Galí (2015).

2.3 Inference with a robust method to weak instruments

We use the Almon-Restricted Anderson and Rubin (1949) (AR) statistic in order to estimate the GNKPC using validation tests of instruments that do not rely on strength. We invert the AR statistic used to test the null hypothesis $H_0 : \delta = \delta_0$, where δ is the parameter vector of Eq. (4) and δ_0 represents the true value of the parameters. According to Moreira (2009), the AR statistic is uniformly more accurate when the system is identified. Then, we follow BM in constructing our instrument vector[13] as follows:

$$z_t^m = (\sum_{h=0}^{H} \xi_{t-h}^m, \sum_{h=0}^{H} h\xi_{t-h}^m, \sum_{h=0}^{H} h^2\xi_{t-h}^m) \tag{7}$$

Since z_t^m is a deterministic linear function of the proxies of monetary shocks, exogeneity property is inherited. Thus, the number of instruments matches the number of endogenous variables. In this case, the AR statistic is given by:

$$AR_a[\delta_0] = \hat{\theta}_a' \hat{\sum}_{\theta_a}^{-1} \hat{\theta} \tag{8}$$

where

$$\hat{\theta}_a = (\sum_{t=H+1}^{n} z_t^m z_t^{m'})^{-1} \sum_{t=H+1}^{n} z_t^m (\hat{\hat{\pi}}_t - \mu_t' \delta_0), \qquad \hat{\sum}_{\theta_a} = (\sum_{t=H+1}^{n} z_t^m z_t^{m'})^{-1} \hat{S}_u^2$$

where $\hat{S}_u^2$ is a consistent estimate for the long-run variance of $\hat{\hat{\pi}}_t - \mu_t' \delta_0$.

When aiming for inference on each parameter of the equation, we partition the parameters in such a way that $\delta = (\beta', \alpha')'$, where the hypothesis of interest is $H_0 : \beta = \beta_0$, while α are parameters that are not identified under the null hypothesis. To test the null hypothesis without assuming strong identification, we use a subset version of the Almon-restricted AR statistic:

$$AR_{a,s}[\beta_0] = \min_{\alpha \in R^{dim(\alpha)}} AR_a[(\beta' \alpha')'] \tag{9}$$

Since the Almon-restricted AR statistic with converges to a χ^2 distribution with degrees of freedom equal to the dimension of β, the $AR_{a,s}[\beta_0]$ statistic is compared with the critical values of a $\chi^2(\dim(\beta))$. Therefore, if the test statistic is smaller than the critical value, β_0 is contained within the confidence interval.[14]

[13] BM relies on Almon (1965) to parameterize the elements of the impulse response of monetary shocks with respect to the error term of its regression as a polynomial function.

[14] For more details, see Moreira (2009), Chernozhukov et al. (2009), Andrews et al. (2019), and BM.

3 Data description

The Eq. (3) of the GNKPC is estimated using quarterly data for the period 1969Q2 to 2007Q4.[15,16] As a proxy for inflation, we use changes in the core PCE[17], and for the explanatory variables, we employ detrended unemployment and detrended real GDP gap. The unemployment variable is obtained from the Bureau of Labor Statistics with series ID: LNS14000000, and GDP is sourced from the FRED database of the St. Louis Fed. For unemployment and GDP, we remove trends by applying the HP filter with $\lambda_{hp} = 1600$. For inflation, we define trend inflation in terms of the infinite-horizon forecast, following Kamber et al. (2018) which correct the signal-to-noise ratio problem that causes the Beveridge and Nelson (1981) filter to produce estimates that are at odds with reality.[18]

We use as instruments Romer and Romer (2004) monetary shocks in Eq. (7). They are obtained using the residual of a regression between the intended Fed funds rate change during FOMC meetings and the Greenbook forecasts of output growth and inflation over the next two quarters. Since the Romer and Romer monetary shocks series ended in 1996, we use the extension provided by Tenreyro and Thwaites (2016) to cover the sample period until 2007. Still, in Eq. (7) we use H=20 because, according to BM, between 12 and 20 is the horizon for which macroeconomic impulse responses are typically found to be significantly different from zero for quarterly data.

To assess the robustness of our results, we implement a series of different choices in our estimations. We re-estimate our results using different values of H, with H=10, H=15, and H=30. Additionally, we employ the Beveridge-Nelson filter without correction to measure the inflation trend, following the approach of Ascari and Sbordone (2014). We

[15] We chose this period because, according to Mavroeidis (2010), with small sample sizes, there is a tendency to encounter difficulties in parameter identification. In fact, we estimated some specifications with high-frequency monetary shocks after 1990, and the results showed the impossibility of parameter identification using the monetary shocks from Jarociński and Karadi (2020) and Bauer and Swanson (2023) as instruments. Therefore, as we cannot be certain whether this relates to sample size or to the actual difficulty in parameter identification that the NKPC literature often faces (see Mavroeidis et al. (2014)), we chose not to include these results in this work. These findings corroborate with the results of BM for a sample period between 1990 and 2017. If necessary, these results can be requested from us.

[16] The sample period is similar to that analyzed by BM, which was 1969Q1–2007Q4.

[17] The annualized inflation rate is $400\triangle ln(P_t)$, where P_t is Core PCE.

[18] In particular, instead of focusing solely on the freely adjusted model by estimating a time series forecasting model, they develop a filter that compensates for model amplitude and fit, maximizing the signal-to-noise ratio, in order to determine a low signal-to-noise ratio imposed in the Bayesian estimation of a univariate AR model.

also verify the results for the Great Moderation period. Finally, we use different proxies for the inflation rate and the forcing variable. Thus, in some specifications, we use PCE, the CBO unemployment gap, and the CBO output gap, all extracted from the FRED database.

4 Empirical findings

In this section, we present our baseline results of Eq. (4) for the period 1969Q2-2007Q4 using Romer and Romer (2004) monetary shocks as instruments in Subsection 4.1. In Subsection 4.2, we assess the robustness of our results for a different measure of trend, different values of H, different proxies for the inflation rate and forcing variable, and for a period after 1984. In Subsection 4.3, we discuss the policy implications of our empirical findings.

4.1 Baseline results

The results for the parameters of Eq. (4) for the period 1969Q2-2007Q4 are presented in Table 1. We report the restricted Almon IV point estimates for the individual parameters and use the $AR_{a,s}$ statistic from the subset to obtain robust confidence intervals for weak identification. In column 2, we present the results for the unrestricted GNKPC estimation, and in column 3, the results are presented under the restriction that $\gamma_f + \gamma_b = 1$. Kleibergen and Mavroeidis (2009) argue that although this restriction can be grounded in the model, it is more motivated by empirical findings and can improve the identification of the NKPC.

Table 1 – The U.S. GNKPC – 1969Q2-2007Q4, RR id.

	IV unrestricted	IV restricted
γ_b	0.45 [-1.20, 0.82]	
γ_f	0.82 [0.31, 2.15]	0.69 [0.36, 2.07]
λ_U	-0.27 [-1.39,-0.07]	-0.38 [-1.26,-0.19]
γ_b	0.48 [-1.43, 0.87]	
γ_f	0.64 [-0.41, 1.69]	0.56 [0.17, 1.67]
λ_Y	0.16 [0.04, 1.01]	0.18 [0.09, 0.58]

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. GNKPC (1969Q2-2007Q4). We show the Almon-restricted IV point estimates based on the Romer and Romer (2004) monetary shocks as instruments (H = 20) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Kamber et al. (2018). The forcing variables is the unemployment gap λ_U or the output gap λ_Y.

Our findings indicate that the slope of the GNKPC is significantly different from zero, regardless of the chosen forcing variable and whether the estimation is restricted or not. Furthermore, our point estimates reveal that both forward- and backward-looking parameters are crucial in determining inflation dynamics. However, our confidence intervals indicate that the forward-looking parameter is not significantly different from zero when the forcing variable in unrestricted estimation is the output gap. Conversely, the confidence interval for the backward-looking parameter does not allow us to reject it, regardless of the forcing variable.

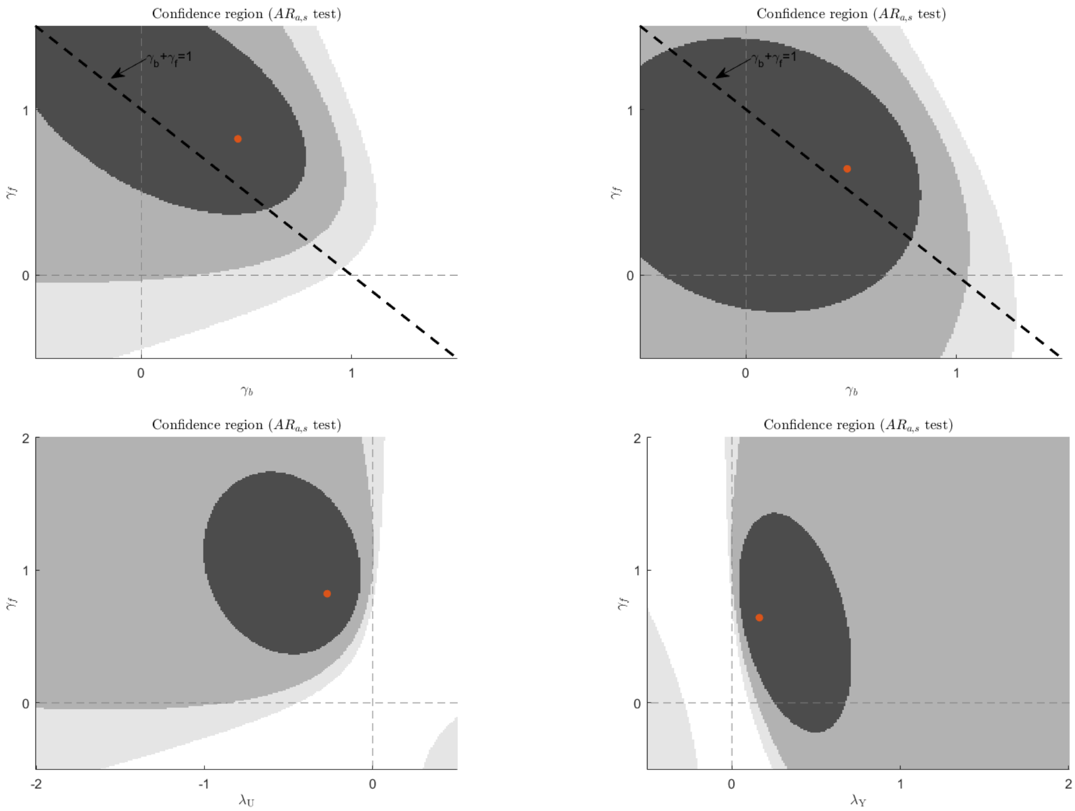
The results of BM are similar in terms of the direction of the parameters, but they find that the hybrid NKPC is significantly preferred to the forward-looking NKPC. Furthermore, our results differ in two more aspects regarding the values of the estimated coefficients. First, when the inflation trend is not considered, our findings indicate an overestimation of the NKPC slope. In the unrestricted estimation, there is an overestimation of 64% and 57% when the forcing variables are the unemployment gap and the output gap, respectively. In the preferred estimation we choose to compare, the restricted one, because Mavroeidis et al. (2014) argue that the restriction mitigates the effects of inflation trend on the NKPC parameters, the overestimation is 18% and 72%, respectively. Second, we show that forward-looking term are more crucial than the backward-looking term in determining inflation, similar to the arguments in the NKPC literature that use lags of macroeconomic variables as instruments, such as those put forth by Dufour et al.

(2006), Martins and Gabriel (2009), and Kleibergen and Mavroeidis (2009).

To analyze the interaction among variables, we plot the two-dimensional confidence intervals of both unrestricted specifications in Figure 1. Panel A displays the results when the forcing variable is the unemployment gap, and Panel B when it is the output gap. In the top row, we show that for both estimations, our restriction is supported by the data, as $\gamma_f + \gamma_b = 1$ falls within the confidence set. In the bottom row, if we consider the 90% confidence interval, we can reject that the slope of the GNKPC is equal to zero. However, we emphasize the caveat that this conclusion may change depending on the confidence level used for the analysis. In addition, we can find a wide range of combined values for γ_f and λ, including large values for both parameters.

Figure 1 – The U.S. GNKPC — 1969Q2-2007Q4, RR id.

(a) Unemployment gap (b) Output gap

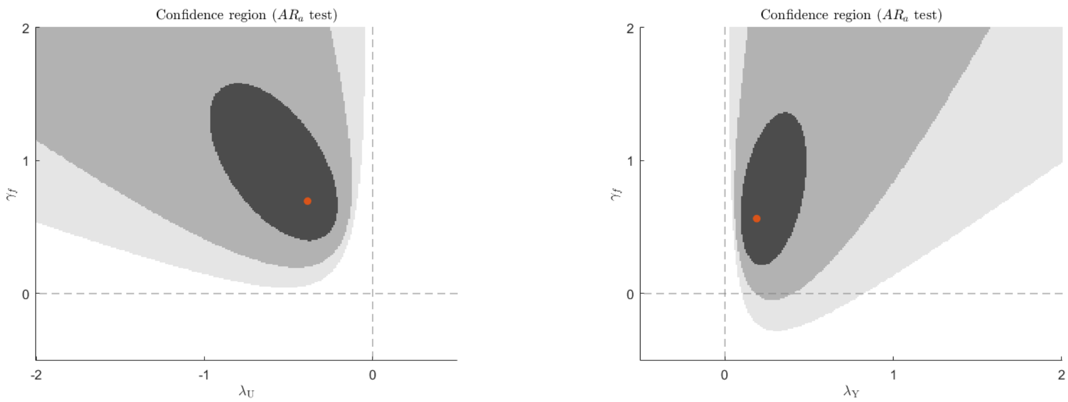


Notes: Robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

In Figure 2, we plot the two-dimensional confidence sets for both specifications of the restricted version. With this choice, we achieve a significant improvement in parameter identification in accordance with the suggestion of Kleibergen and Mavroeidis (2009). Thus, the joint behavior of these variables becomes much clearer, where the GNKPC is always different from zero and we are not able to reject combinations of large λ with large γ_f. This combination may raise a discussion about the conclusions of BM related to the NKPC, which find possible combinations of large values for λ and small values for γ_f both in the restricted and unrestricted estimation. If changes in long-term inflation expectations move negatively with unemployment (as occurs during an imperfectly credible shift in the long-term inflation target), the Phillips curve may appear steeper than it actually is (HAZELL et al., 2022).

Figure 2 – The U.S. GNKPC — 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

4.2 Robustness check

Our baseline results use trend inflation measured according to Kamber et al. (2018), with H=20, Core PCE as a proxy for inflation, and output gap or unemployment gap, both employing HP filter, as forcing variables. However, for robustness analysis, we implement a series of different choices within the estimations to verify whether our conclusions hold.

Thus, we use a different measure of trend inflation; then, we check our results for different values of H, and subsequently, we use different proxies for the inflation rate and forcing variable. Lastly, we assess whether our results hold using the Great Moderation period. The results are presented in Tables 2 to 8 of Appendix A and in Figures 3 to 26 of Appendix B.

Firstly, we employ the Beveridge-Nelson filter to obtain the inflation gap, following Ascari and Sbordone (2014).[19] The estimation results and confidence intervals for each parameter are presented in Table 2, and the two-dimensional confidence sets are depicted in Figures 3 and 4. From a point estimation perspective, when we do not consider trend inflation, we find a larger overestimation of the slope, regardless of the choice of forcing variable, as well as a larger underestimation of the forward-looking term. Furthermore, the forward-looking parameter is greater than the backward-looking one. However, the confidence sets are unbounded, hence we can not make precise inferences. Moreover, from the two-dimensional confidence intervals, we observe that our restriction, $\gamma_f + \gamma_b = 1$, remains supported. Additionally, we find that the forcing variable and the forward-looking term can be combined in various ways in the unrestricted estimation, whereas in the restricted estimation, again, combinations of large γ_f and large λ are possible.

Concerning the different values of H, we use H=10, H=15, and H=25. In this and the subsequent results of this section, we also estimate the GNKPC and the NKPC to ensure a comparison between both. The results are presented in Tables 3 to 5 and in Figures 5 to 16. In these estimations, according to our point estimates, the slope parameter is often smaller in the GNKPC than in the NKPC. Regarding the expectational terms, we find that the backward-looking term is more significant than the forward-looking one in some cases. We also find that with the least plausible values of H, i.e., H=10 and H=25, the estimation of the NKPC results in a higher γ_f than the estimation of the GNKPC in some cases.

Still regarding the estimations with H=10 and H=15, we encountered difficulties in identifying the parameters, resulting in unbounded confidence intervals. One possible explanation for this is that with these choices, we may be excluding quarters where the impulse responses to monetary shocks are significantly different from zero in the first case. In addition, in the second case, we may be including quarters where the impulse responses

[19] By obtaining the inflation gap from the Beveridge-Nelson filter, we lose three observations, and therefore, the analysis is conducted for the period 1969Q4-2007Q4.

to monetary shocks are equal to zero, as there are typically between 12 and 20 quarters where the impulse responses tend to be significantly different from zero.

Concerning the two-dimensional confidence sets, in all cases, our constraint is supported. Nevertheless, we obtained quite discrepant results among the different values of H, and therefore, also with our baseline regarding the relationship between the forward-looking component and the forcing variable. Yet, the results regarding the possible combinations between γ_f and λ for the NKPC and GNKPC when the same value of H is chosen depend on the choice of the forcing variable and whether the estimation is restricted or not.

To further modify the variable choices, in Table 6 and Figures 17 to 20, we present the results of the NKPC and GNKPC using PCE instead of Core PCE. Again, we find γ_f greater than γ_b, overestimation of the forward-looking parameter, and underestimation of the slope according to our point estimates. However, the confidence intervals of the GNKPC encompass the extended real number set, while the NKPC produces narrower intervals, with the two-dimensional confidence plots showing difficulty in rejecting small absolute values of γ_f with large absolute values of λ, similar to BM's baseline results. On the other hand, when keeping Core PCE as the dependent variable but using the CBO unemployment gap or CBO output gap as the forcing variable, as shown in Table 7 and Figures 21 to 24, we encountered difficulties in identifying the parameters of the NKPC, as well as the GNKPC in some cases. In addition, the point estimates and two-dimensional confidence sets also varied depending on whether the estimation was restricted or not and on whether the variable was the CBO output gap or the CBO unemployment gap.

Finally, we checked our results by keeping all baseline choices but changing the sample period to the Great Moderation, i.e., from 1984Q1 to 2007Q4 in Table 8 and Figures 25 and 26. This decision is made due to a mixture of different regimes observed in our complete sample, as existing literature suggests that the Phillips curve is flatter after 1984. Given the sample size, we estimate the NKPC and GNKPC only in the restricted version with $\gamma_f + \gamma_b = 1$. On this occasion, our point estimates show the NKPC as flat and the GNKPC with counterintuitive results for λ. Additionally, we obtained higher values of γ_f in the estimation of the NKPC. However, again, we were unable to identify the parameters of both the NKPC and the GNKPC. In addition, both two-dimensional confidence sets exhibited similar behavior, regardless of the choice of the forcing variable.

Theses results are in line with the identification issues of the Phillips curve because if inflation expectations do not vary, their effect on inflation will not be identified. In other words, effective monetary policy, as carried out after the Volcker disinflation, can lead to identification problems (MAVROEIDIS, 2004; MAVROEIDIS, 2010; COCHRANE, 2011). Another possible explanation for these results is that the smaller number of observations may also be related to difficulties in identifying the parameters (MAVROEIDIS, 2010).

In general, our robustness tests confirmed that estimating the NKPC instead of the GNKPC using monetary shocks as instruments tends to overestimate the point estimate of the slope, while the result of underestimation of γ_f and greater importance of the forward-looking term to the backward-looking term of inflation proved to be sensitive depending on our choices to estimate the GNKPC. Regarding the analysis of confidence intervals, the results are quite sensitive to changes in the measure of inflation trend, the value of H, different proxies for the inflation rate and forcing variable, and sample period. It is important to note that difficulty in identifying the parameters of the NKPC is also encountered by Dufour et al. (2006), Nason and Smith (2008), Martins and Gabriel (2009), Mavroeidis et al. (2014), BM for a post-1990 period, and Aragón and Galvão (2023). Still, the sensitivity to different estimation alternatives is common in the literature. According to Mavroeidis et al. (2014), small changes in the specification of the NKPC lead to large differences in results. In this manner, our conclusions warrant caveats, which will be discussed in the next subsection.

4.3 Policy implication

Our results bring implications for policy-making and the literature studying identification issues in the NKPC. Since the NKPC is used as a reference in the policy-making process, and given that DSGE models typically require reliable estimates for model calibration, it is important to identify possible flaws in NKPC estimations and, consequently, the impact on parameter estimation.[20]

When analyzing our point estimates in the baseline and robustness tests, in most

[20] However, we acknowledge that the existence of a positive inflation trend is not the sole shortcoming of NKPC estimations, and our results are subject to change as additional plausible channels of the NKPC are incorporated, such as, for instance, the cost channel. (e.g., Barth III and Ramey (2001), Gaiotti and Secchi (2006), Ravenna and Walsh (2006), Tillmann (2008), Tillmann (2009), Castelnuovo (2012), Aragón and Galvão (2023), and Beaudry et al. (2024)).

cases, the NKPC tends to have a higher λ compared to the GNKPC. From a policy perspective, this implies, on the one hand, that the Fed has less power to control inflation based on the activity-inflation trade-off, and on the other hand, that the cost of disinflation is lower. In other words, the Fed can reduce inflation with less sacrifice to the economy's unemployment rate. In our baseline, moreover, our results show that the confidence interval is often negative (positive) when the forcing variable is the unemployment gap (output gap). However, when making changes to the baseline estimation, this latter result proved to be sensitive, not providing us with great confidence in our conclusions, as in some cases our confidence intervals are wide. This uncertainty can also lead to implications of nonlinearity in the response of the interest rate to inflation. As shown by Tillmann (2011), if the central bank adopts a min-max strategy to formulate policy and is uncertain about the slope of the NKPC, the interest rate reacts more strongly to inflation when inflation is further away from the target.

We also find sensitivity in the point estimates of the forward-looking parameter regarding its importance relative to the backward-looking component in determining inflation dynamics and whether it is overestimated when estimating a GNKPC instead of the NKPC. We also demonstrate that the baseline identification result of this parameter with the confidence interval always positive in three out of four estimations did not remain robust in our robustness analysis. As argued by Aragón and Galvão (2023), this result raises doubts about the usefulness of managing inflation expectations as a monetary policy instrument because transparency and communication about future policy, which is fundamental to current forward guidance policies, may have limited effects on improving the effectiveness of monetary policy in controlling the inflation rate.

In addition, all these uncertainties regarding the parameters of the GNKPC suggest caveats to the calibrations of DSGE models for two reasons. Firstly, because we show that the GNKPC can produce different estimates from the NKPC, and we do not even have clarity on whether the inclusion of the backward-looking component is relevant. Second, because Mavroeidis et al. (2014) find a wide range of possible impulse responses to monetary shocks, with different short-term dynamics and steady-state returns, by calibrating a DSGE model for the U.S. economy with varied values for inflation expectation and economic activity parameters.

5 Conclusion

In this work, we estimate an extension of the NKPC model, considering a positive inflation trend, which is overlooked by the literature investigating identification issues. Specifically, we use monetary shocks as instruments to identify the parameters of the simplified version of the GNKPC proposed by Cogley and Sbordone (2008) in the reduced-form, using post-1969 U.S. data. Since monetary shocks are not necessarily strong instruments, we employ an identification-robust procedure for constructing our confidence intervals.

Our results point to substantial differences in estimation between the NKPC and GNKPC. Our baseline point estimate results show that when not considering the positive inflation trend, the slope of the NKPC is overestimated. This finding is confirmed in most of our robustness tests. In contrast, our baseline point estimate indicates an underestimation of the forward-looking parameter in the NKPC and that expectations for the future are more important in determining inflation dynamics than the backward-looking term. However, this result proved to be sensitive to our robustness tests.

Regarding the analysis of our confidence intervals, we find significant uncertainty for all parameters of the GNKPC, depending on the estimation choices we make. For example, in our baseline results, we can reject that the GNKPC is always different from zero, and although with the exception of one of the four estimations made, the forward-looking parameter is also different from zero. In contrast, for example, when using the PCE instead of the Core PCE, the confidence sets for all our parameters are unlimited, giving us uncertainty about the true value of the parameters. This is not the only case, as our results depend on how we measure the trend, how we construct our instrument matrices, the option we choose as the forcing variable, as well as depending on the period analyzed. According to Mavroeidis et al. (2014), this finding is common, as the estimation of the Phillips curve undergoes significant changes with small changes in specification.

Logically, considering that disregarding a positive inflation trend does not correspond to reality, these results bring important policy implications. First, if we were to consider only our point estimates, we show that the Fed's cost of disinflation is lower than when a GNKPC is preferred to a NKPC. However, the uncertainty about the true value of the slope of the GNKPC may imply a nonlinearity of the response of interest rates to inflation, and the uncertainty about the true value of the forward-looking parameter raises doubts about the utility of managing inflation expectations as a monetary policy tool. Additionally, these results suggest reservations about the choices and parameter calibrations of DSGE models.

We acknowledge, however, that there are further intricacies to be considered in the NKPC to enhance parameter estimations. Thus, depending on the context, we believe that future research may delve into incorporating factors, in addition to inflation trend, such as the cost channel (RAVENNA; WALSH, 2006; ARAGÓN; GALVÃO, 2023; BEAUDRY et al., 2024), supply shock (BLANCHARD; GALÍ, 2007), nonlinearity (BALL et al., 2022; DOSER et al., 2023), among others. Additionally, from a methodological perspective, one can exploit nonlinearities in the impulse responses to monetary shocks.

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APPENDIX A – ADDITIONAL TABLES

Table 2 – The U.S. GNKPC with Core PCE gap measured by Beveridge-Nelson filter as dependent variable – 1969Q4-2007Q4, RR id.

	IV unrestricted	IV restricted
γ_b	0.46 [-∞,+∞]	
γ_f	1.01 [-∞,+∞]	0.93 [-∞,+∞]
λ_U	-0.07 [-∞,+∞]	-0.12 [-∞,+∞]
γ_b	0.42 [-∞,+∞]	
γ_f	0.72 [-∞,+∞]	0.65 [-∞,+∞]
λ_Y	0.04 [-∞,+∞]	0.04 [-∞,+∞]

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. GNKPC (1969Q4-2007Q4). We show the Almon-restricted IV point estimates based on the Romer and Romer (2004) monetary shocks as instruments (H = 20) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Beveridge and Nelson (1981). The forcing variables is the unemployment gap λ_U or the output gap λ_Y.

Table 3 – The U.S. NKPC and GNKPC with H=10 – 1969Q2-2007Q4, RR id.

	IV unrestricted	IV restricted
	NKPC	
γ_b	1.38 $[-\infty, +\infty]$	
γ_f	0.21 $[-\infty, +\infty]$	0.38 [0.10, 0.60]
λ_U	-1.14 $[-\infty, +\infty]$	-0.84 [-1.56,-0.33]
γ_b	4.64 $[-\infty, +\infty]$	
γ_f	-1.27 $[-\infty, +\infty]$	0.43 [0.07, 0.79]
λ_Y	1.96 $[-\infty, +\infty]$	0.80 [0.49, 1.82]
	GNKPC	
γ_b	1.46 $[-\infty, +\infty]$	
γ_f	0.78 $[-\infty, +\infty]$	0.57 [0.18, 1.05]
λ_U	-0.20 $[-\infty, +\infty]$	-0.62 [-1.17,-0.41]
γ_b	1.65 $[-\infty, +\infty]$	
γ_f	0.68 $[-\infty, +\infty]$	0.11 [-0.82, 0.52]
λ_Y	0.10 $[-\infty, +\infty]$	0.37 [0.24, 0.81]

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. NKPC and GNKPC (1969Q2-2007Q4). We show the Almon-restricted IV point estimates based on the Romer and Romer (2004) monetary shocks as instruments (H = 10) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Kamber et al. (2018). The forcing variables is the unemployment gap λ_U or the output gap λ_Y.

Table 4 – The U.S. NKPC and GNKPC with H=15 – 1969Q2-2007Q4, RR id.

	IV unrestricted	IV restricted
	NKPC	
γ_b	0.67 [-0.19, 1.88]	
γ_f	0.38 [-0.08, 0.69]	0.39 [0.15, 0.58]
λ_U	-0.51 [-1.45,-0.11]	-0.55 [-1.32,-0.26]
γ_b	0.86 [0.36, 3.70]	
γ_f	0.22 [-1.41, 0.48]	0.22 [-0.72, 0.48]
λ_Y	0.35 [-0.03, 1.76]	0.39 [0.16, 1.58]
	GNKPC	
γ_b	0.40 [-0.62, 0.69]	
γ_f	0.60 [0.19, 1.02]	0.60 [0.40, 1.02]
λ_U	-0.32 [-1.33,-0.12]	-0.33 [-0.86,-0.16]
γ_b	0.44 [-0.76, 0.77]	
γ_f	0.41 [-0.88, 0.79]	0.48 [0.24, 0.78]
λ_Y	0.19 [0.07, 1.05]	0.16 [0.08, 0.36]

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. NKPC and GNKPC (1969Q2-2007Q4). We show the Almon-restricted IV point estimates based on the Romer and Romer (2004) monetary shocks as instruments (H = 15) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Kamber et al. (2018). The forcing variables is the unemployment gap λ_U or the output gap λ_Y.

Table 5 – The U.S. NKPC and GNKPC with H=25 – 1969Q2-2007Q4, RR id.

	IV unrestricted	IV restricted
	NKPC	
γ_b	0.58 [0.40, 0.79]	
γ_f	0.41 [0.21, 0.60]	0.41 [0.21, 0.06]
λ_U	-0.24 [-0.69, 0.03]	-0.24 [-0.69, 0.03]
γ_b	0.68 [0.49, 1.12]	
γ_f	0.32 [-0.11, 0.51]	0.31 [-0.11, 0.51]
λ_U	0.13 [-0.01, 0.45]	0.13 [-0.01, 0.44]
	GNKPC	
γ_b	0.68 [0.49, 1.12]	
γ_f	0.32 [-0.11, 0.51]	0.31 [-0.11, 0.51]
λ_U	0.13 [-0.01, 0.45]	0.13 [-0.01, 0.44]
γ_b	0.19 [-∞,+∞]	
γ_f	0.49 [-∞,+∞]	0.47 [-∞, 0.98]
λ_Y	0.10 [-∞,+∞]	0.00 [-∞, 0.12]

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. NKPC and GNKPC (1969Q2-2007Q4). We show the Almon-restricted IV point estimates based on the Romer and Romer (2004) monetary shocks as instruments (H = 25) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Kamber et al. (2018). The forcing variables is the unemployment gap λ_U or the output gap λ_Y.

Table 6 – The U.S. NKPC and GNKPC with PCE gap as dependent variable – 1969Q2-2007Q4, RR id.

	IV unrestricted	IV restricted
	NKPC	
γ_b	0.46 [0.08, 0.71]	
γ_f	0.57 [0.33, 0.96]	0.55 [0.33, 0.92]
λ_U	-0.62 [-1.56,-0.24]	-0.69 [-1.56,-0.33]
γ_b	0.56 [0.21, 0.94]	
γ_f	0.47 [0.07, 0.83]	0.43 [0.07, 0.79]
λ_Y	0.36 [0.14, 0.98]	0.40 [0.18, 0.97]
	GNKPC	
γ_b	0.59 [-∞,+∞]	
γ_f	0.78 [-∞,+∞]	0.80 [-∞,+∞]
λ_U	-0.28 [-∞,+∞]	-0.60 [-∞,+∞]
γ_b	0.47 [-∞,+∞]	
γ_f	0.67 [-∞,+∞]	0.63 [-∞,+∞]
λ_Y	0.17 [-∞,+∞]	0.23 [-∞,+∞]

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. NKPC and GNKPC (1969Q2-2007Q4). We show the Almon-restricted IV point estimates based on the Romer and Romer (2004) monetary shocks as instruments (H = 20) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Kamber et al. (2018). The forcing variables is the unemployment gap λ_U or the output gap λ_Y.

Table 7 – The U.S. NKPC and GNKPC with CBO unemployment gap or CBO output gap as forcing variable – 1969Q2-2007Q4, RR id.

	IV unrestricted	IV restricted
	NKPC	
γ_b	-0.06 [-∞,+∞]	
γ_f	0.48 [-∞,+∞]	0.65 [-∞,+∞]
λ_U	4.32 [-∞,+∞]	1.37 [-∞,+∞]
γ_b	0.84 [-∞,+∞]	
γ_f	0.28 [-∞,+∞]	0.21 [-∞,+∞]
λ_Y	0.35 [-∞,+∞]	0.43 [-∞,+∞]
	GNKPC	
γ_b	1.42 [-∞,+∞]	
γ_f	0.47 [-∞,+∞]	$10^{13} * -4.38[0.00, 0.00]$
λ_U	-0.99 [-∞,+∞]	$10^{13} * -6.68[0.00, 0.00]$
γ_b	0.64 [-0.68, 4.62]	
γ_f	0.47 [-∞, 1.36]	0.36 [-1.01, 1.13]
λ_Y	0.14 [0.03, 6.45]	0.16 [0.07, 0.91]

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. NKPC and GNKPC (1969Q2-2007Q4). We show the Almon-restricted IV point estimates based on the Romer and Romer (2004) monetary shocks as instruments (H = 20) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Kamber et al. (2018). The forcing variables is the CBO unemployment gap λ_U or the CBO output gap λ_Y.

Table 8 – The U.S. NKPC and GNKPC - 1984Q1-2007Q4, RR id.

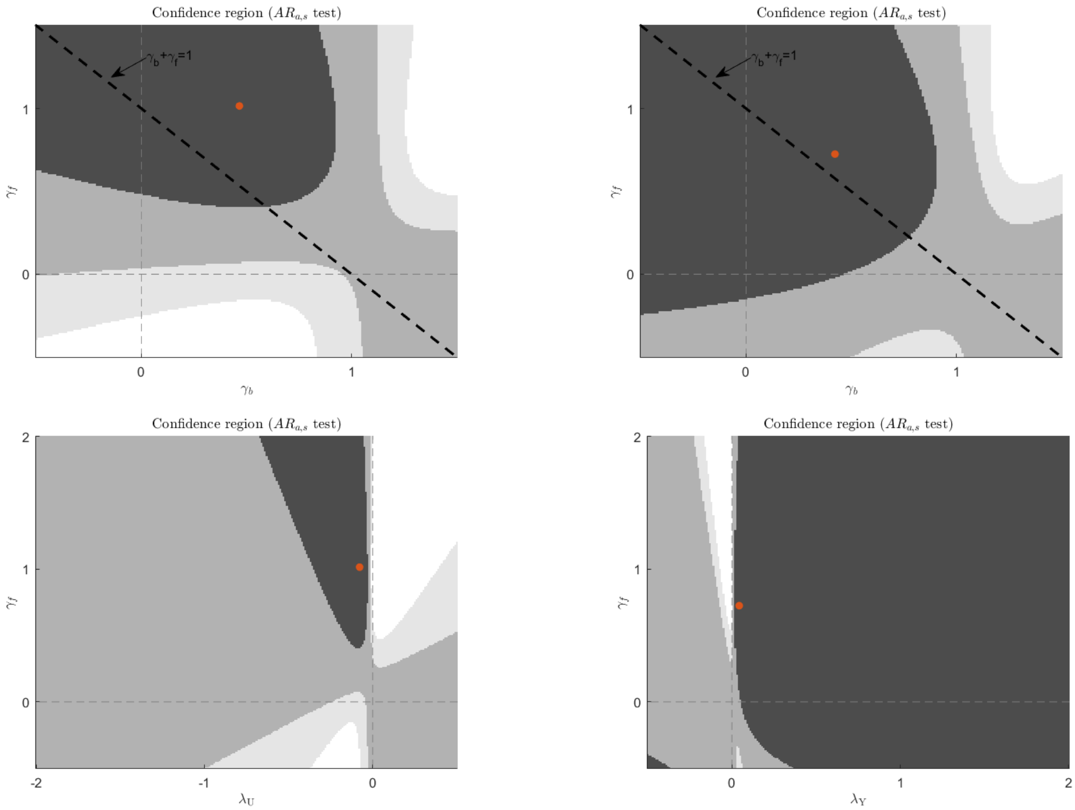
	NKPC	
γ_f	0.48	$[-\infty, +\infty]$
λ_U	-0.01	$[-\infty, +\infty]$
γ_f	0.47	$[-\infty, +\infty]$
λ_Y	0.00	$[-\infty, +\infty]$
	GNKPC	
γ_f	0.07	$[-\infty, +\infty]$
λ_U	0.09	$[-\infty, +\infty]$
γ_f	0.17	$[-\infty, +\infty]$
λ_Y	-0.05	$[-\infty, +\infty]$

Notes: The table reports the parameter estimates and weak-IV robust confidence intervals for the U.S. NKPC and GNKPC (1884Q2-2007Q4). We show the Almon-restricted IV point estimates based on the high frequency identified Romer and Romer (2004) monetary shocks as instruments (H=20) and the $AR_{a,s}$ based 90% confidence bounds. The inflation trend is measured following the approach of Kamber et al. (2018). The forcing variables is the unemployment gap λ_U or the output gap λ_Y.

APPENDIX B – ADDITIONAL FIGURES

Figure 3 – The U.S. GNKPC with Core PCE gap measured by Beveridge-Nelson filter as dependent variable – 1969Q4-2007Q4, RR id.

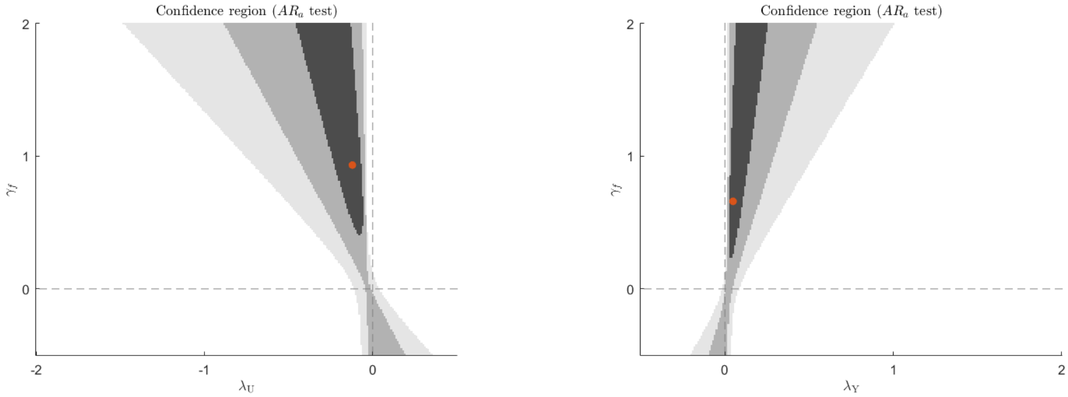
(a) Unemployment gap (b) Output gap



Notes: Robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q4–2007Q4. The inflation trend is measured following the approach of Beveridge and Nelson (1981). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 4 – The U.S. GNKPC with Core PCE gap measured by Beveridge-Nelson filter as dependent variable – 1969Q4-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

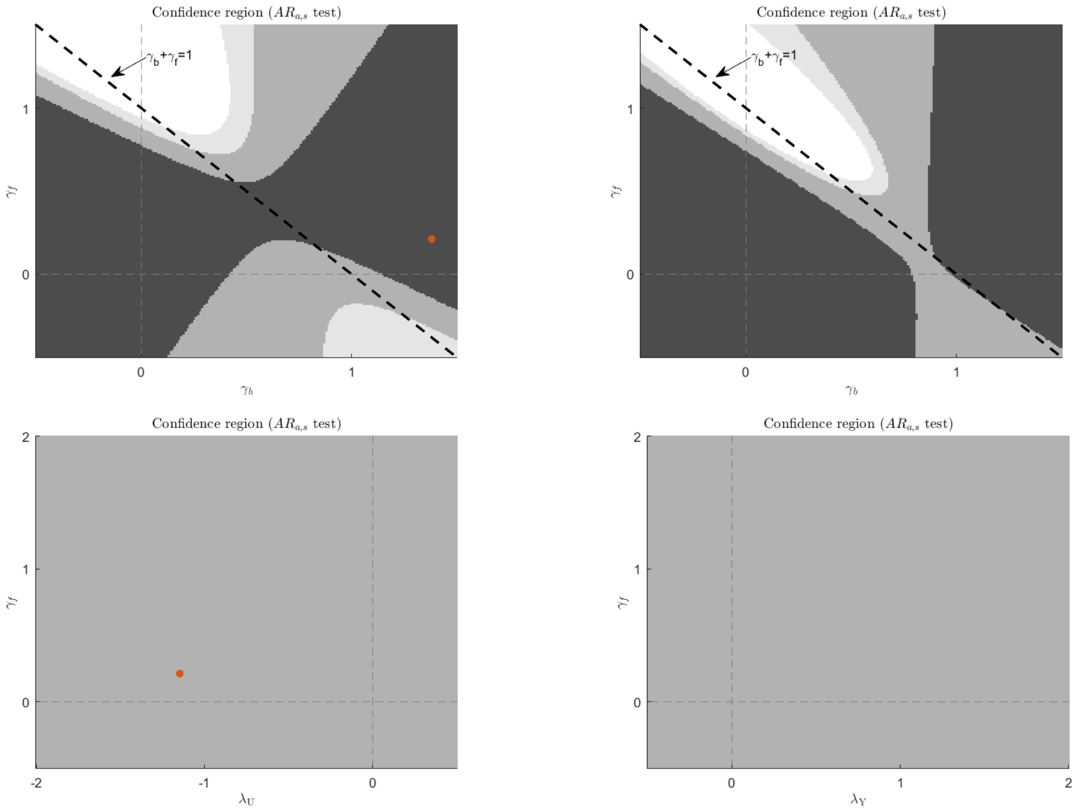
(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q4–2007Q4. The inflation trend is measured following the approach of Beveridge and Nelson (1981). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 5 – The U.S. NKPC with H=10 – 1969Q2-2007Q4, RR id.

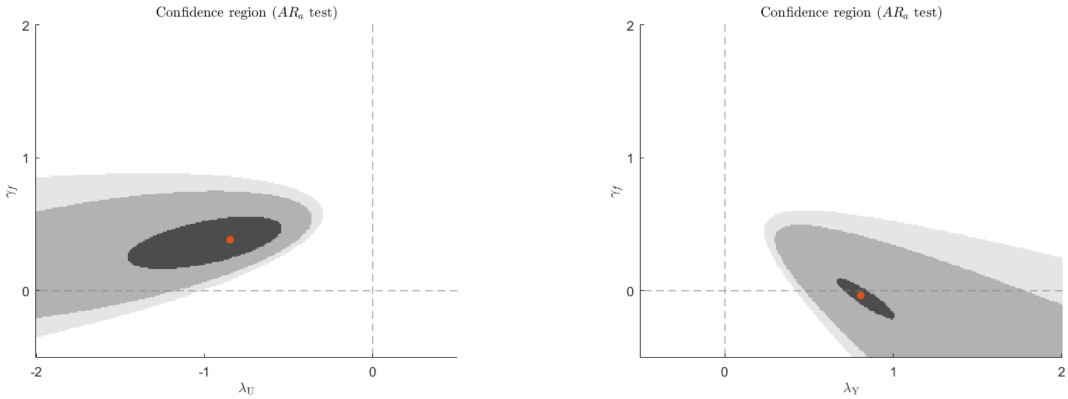
(a) Unemployment gap (b) Output gap



Notes: Robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f+\gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=10) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 6 – The U.S. NKPC with H=10 – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

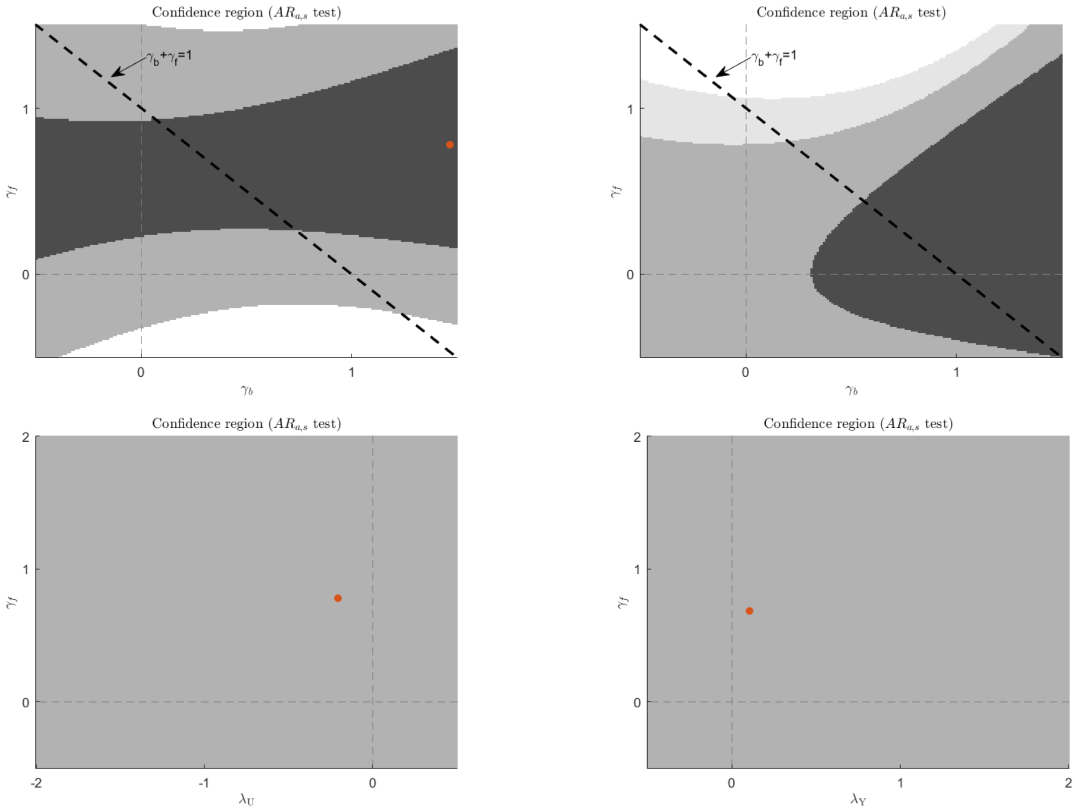
(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=10) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 7 – The U.S. GNKPC with H=10 – 1969Q2-2007Q4, RR id.

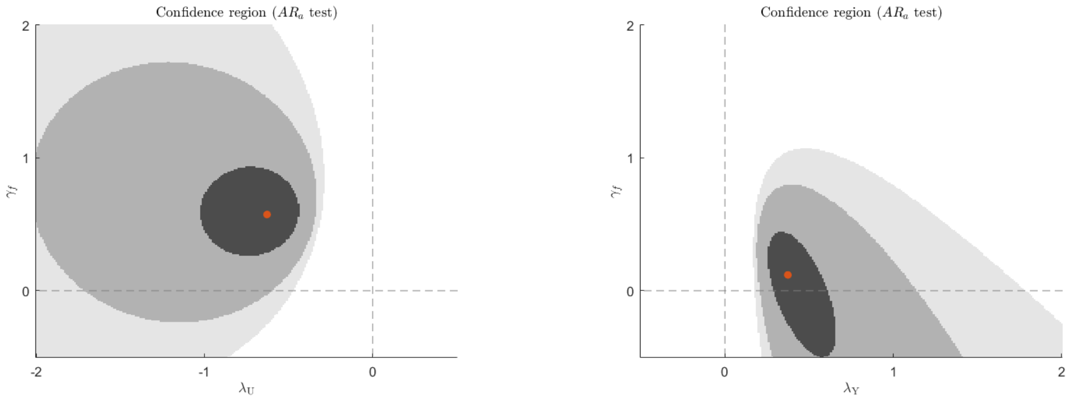
(a) Unemployment gap (b) Output gap



Notes: Robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=10) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 8 – The U.S. GNKPC with H=10 – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

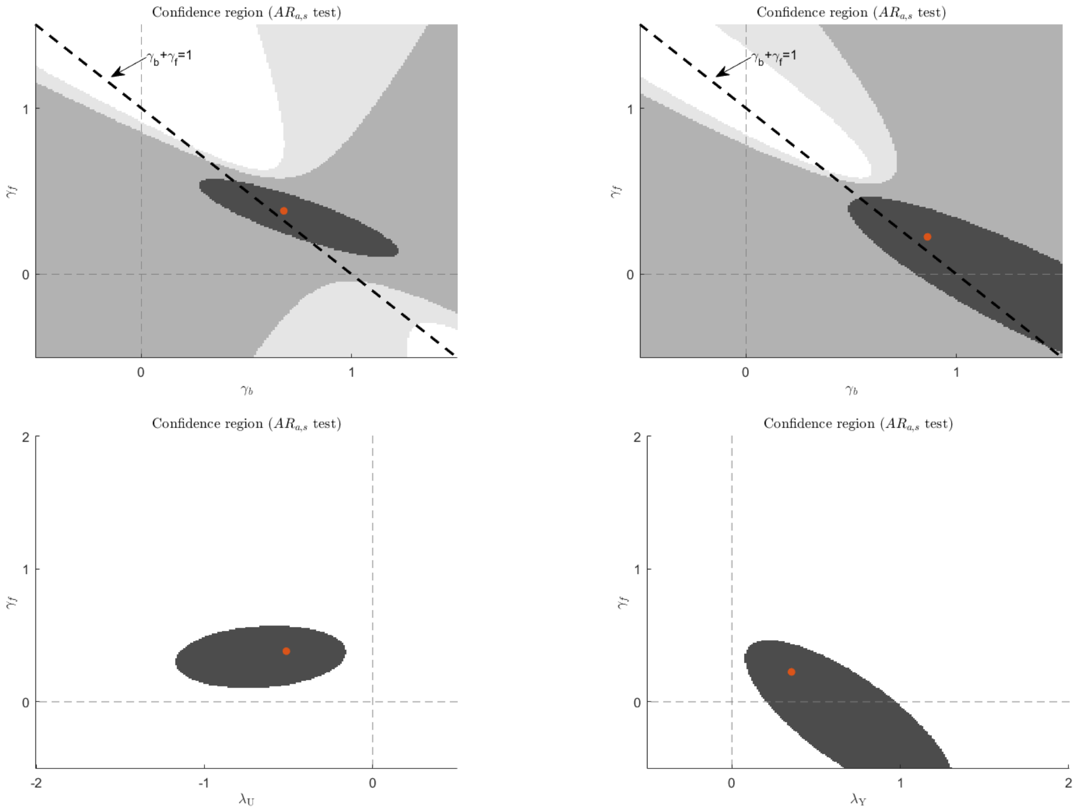
(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 9 – The U.S. NKPC with H=15 – 1969Q2-2007Q4, RR id.

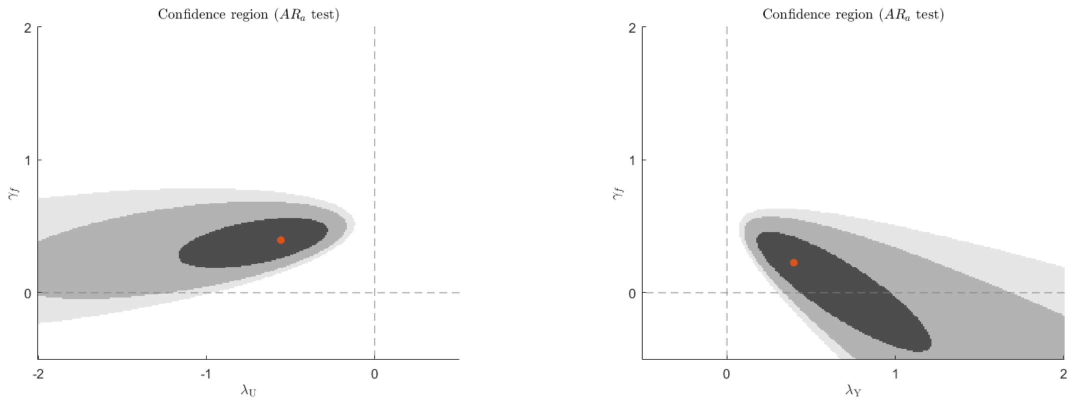
(a) Unemployment gap (b) Output gap



Notes: Robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=15) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 10 – The U.S. NKPC with H=15 – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

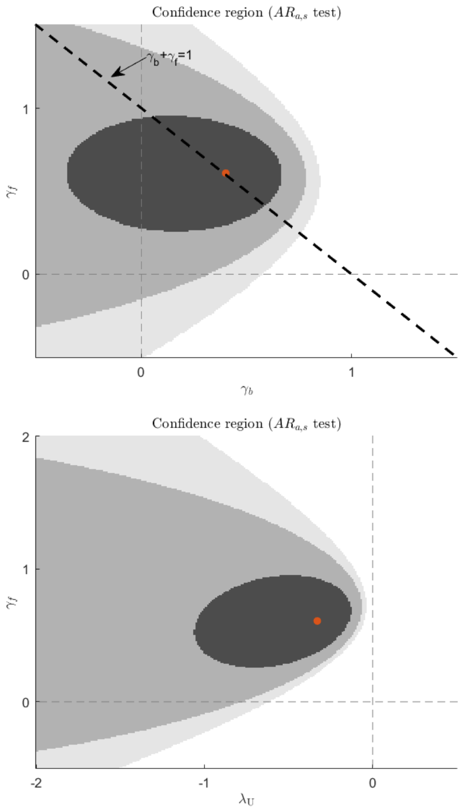
(a) Unemployment gap (b) Output gap



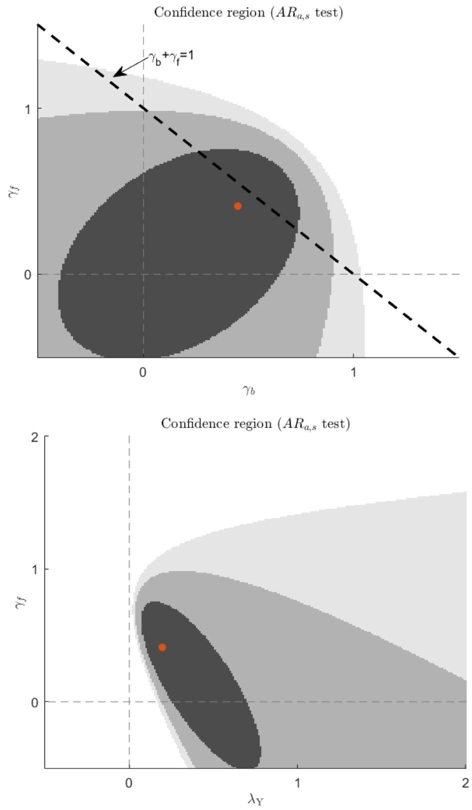
Notes: robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=15) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 11 – The U.S. GNKPC with H=15 – 1969Q2-2007Q4, RR id.

(a) Unemployment gap



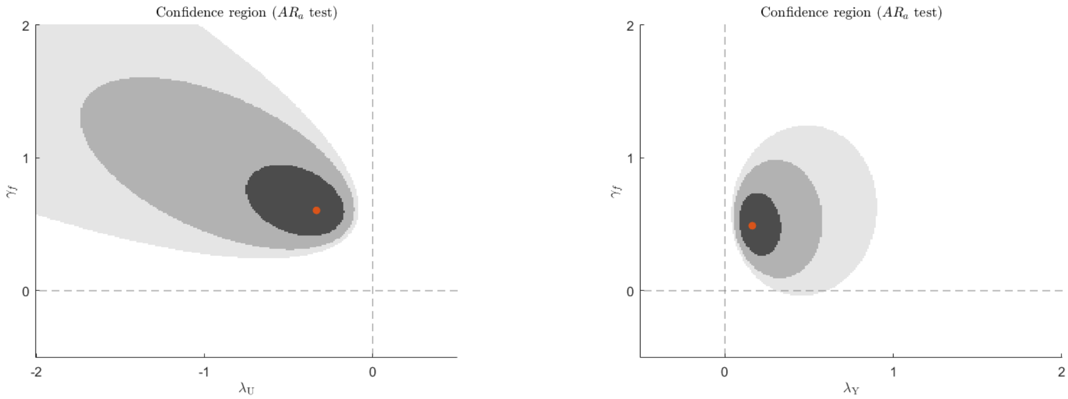
(b) Output gap



Notes: Robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=15) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 12 – The U.S. GNKPC with H=15 – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

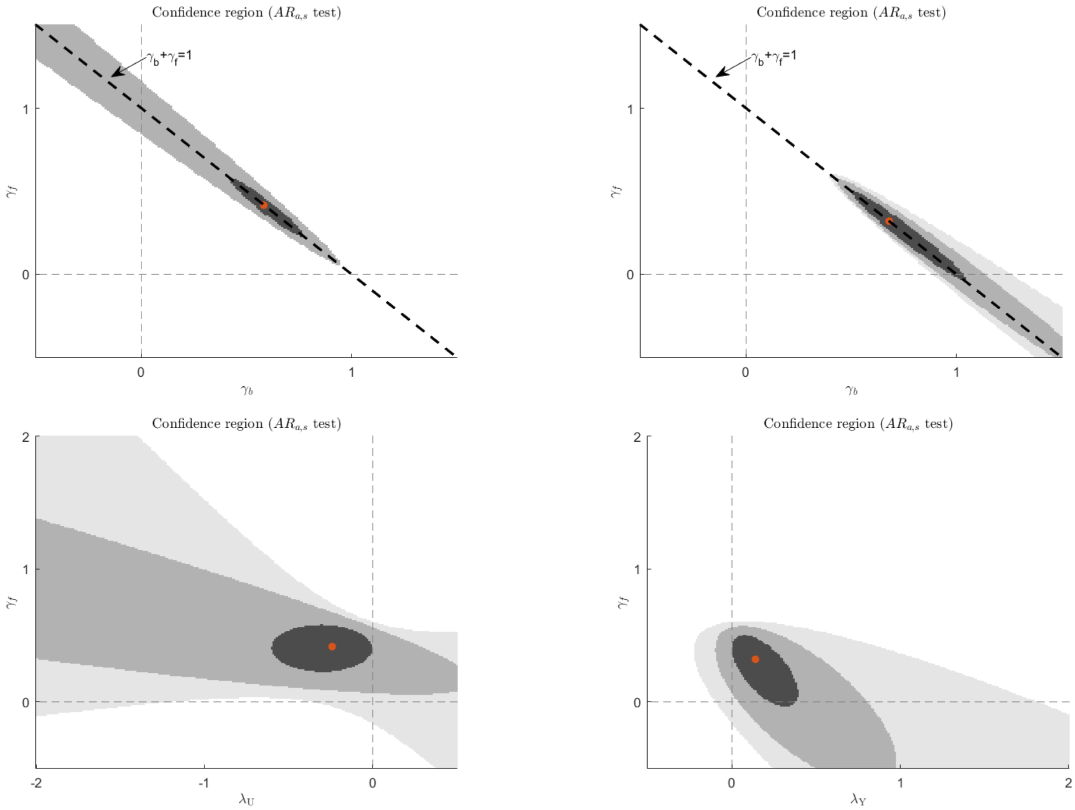
(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=25) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 13 – The U.S. NKPC with H=25 – 1969Q2-2007Q4, RR id.

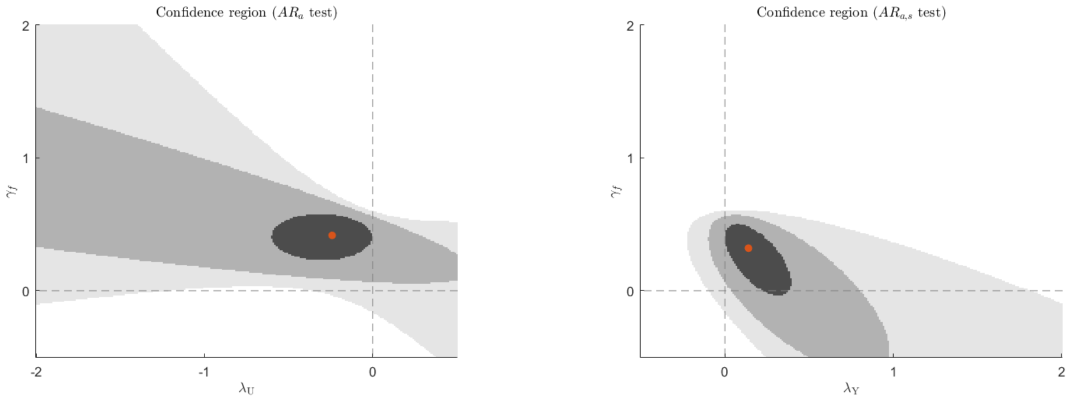
(a) Unemployment gap (b) Output gap



Notes: Robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f+\gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=25) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 14 – The U.S. NKPC with H=25 – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

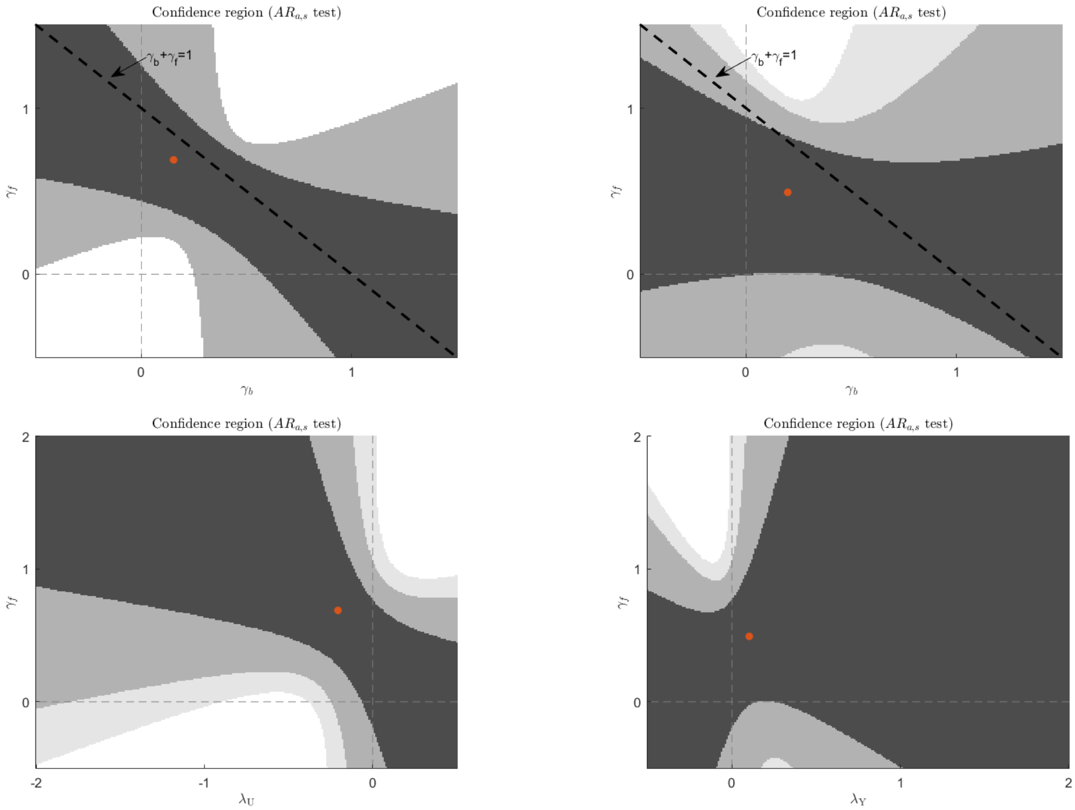
(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=25) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 15 – The U.S. GNKPC with H=25 – 1969Q2-2007Q4, RR id.

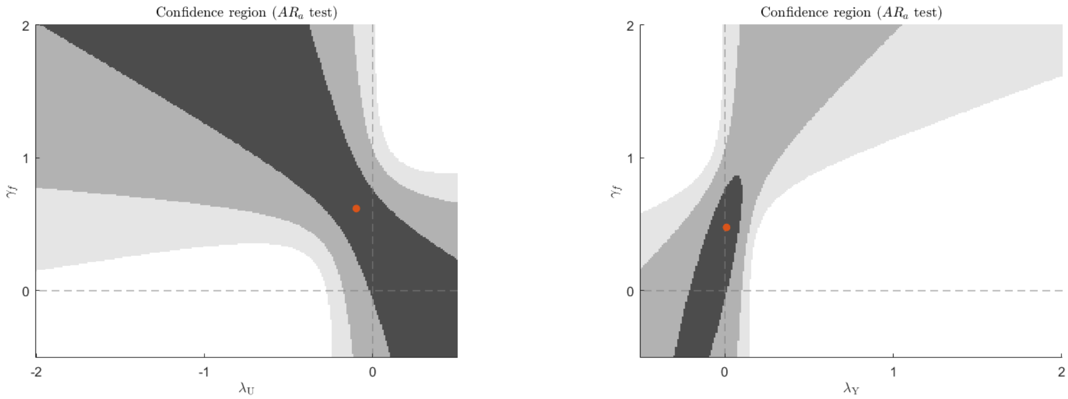
(a) Unemployment gap (b) Output gap



Notes: Robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=25) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 16 – The U.S. GNKPC with H=25 – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

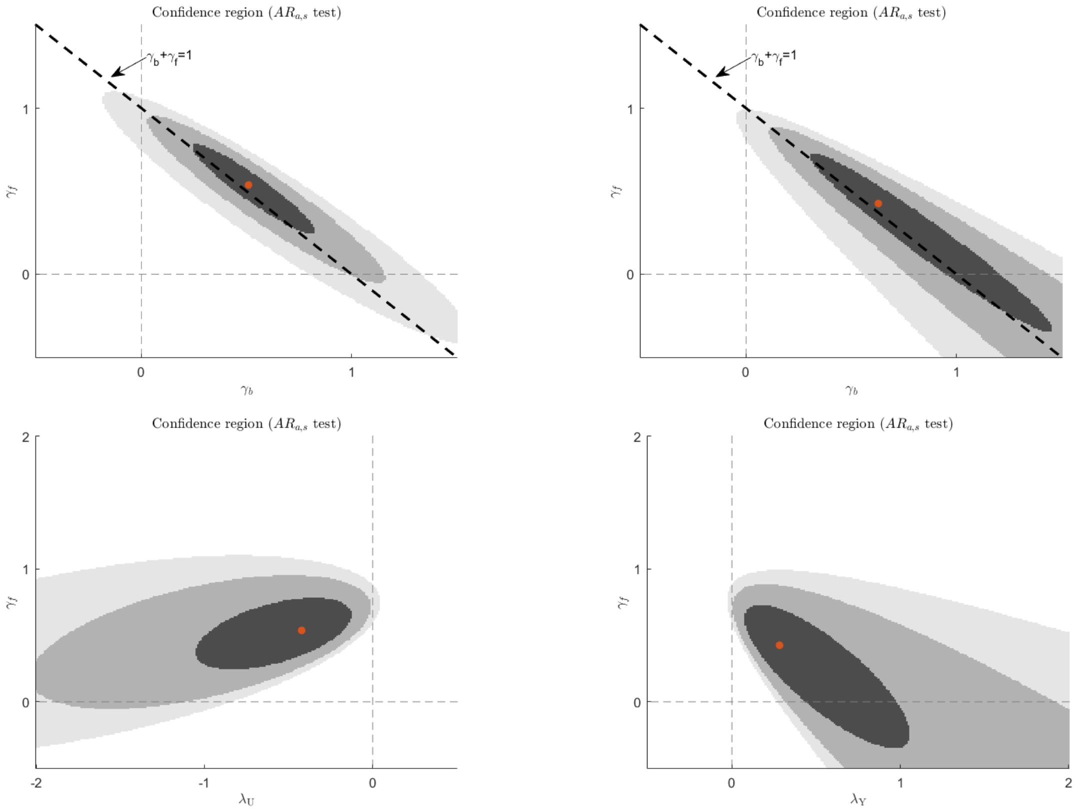
(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 17 – The U.S. NKPC with PCE gap as dependent variable – 1969Q2-2007Q4, RR id.

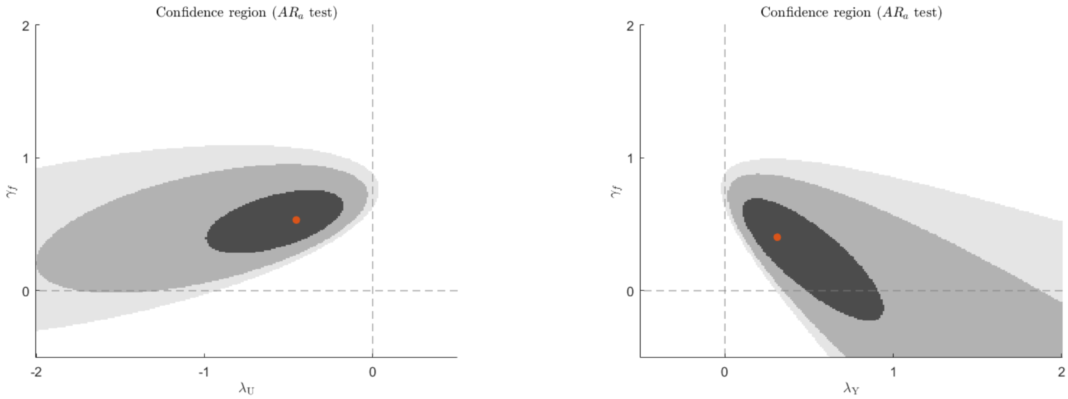
(a) Unemployment gap (b) Output gap



Notes: Robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=25) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 18 – The U.S. NKPC with PCE gap as dependent variable – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

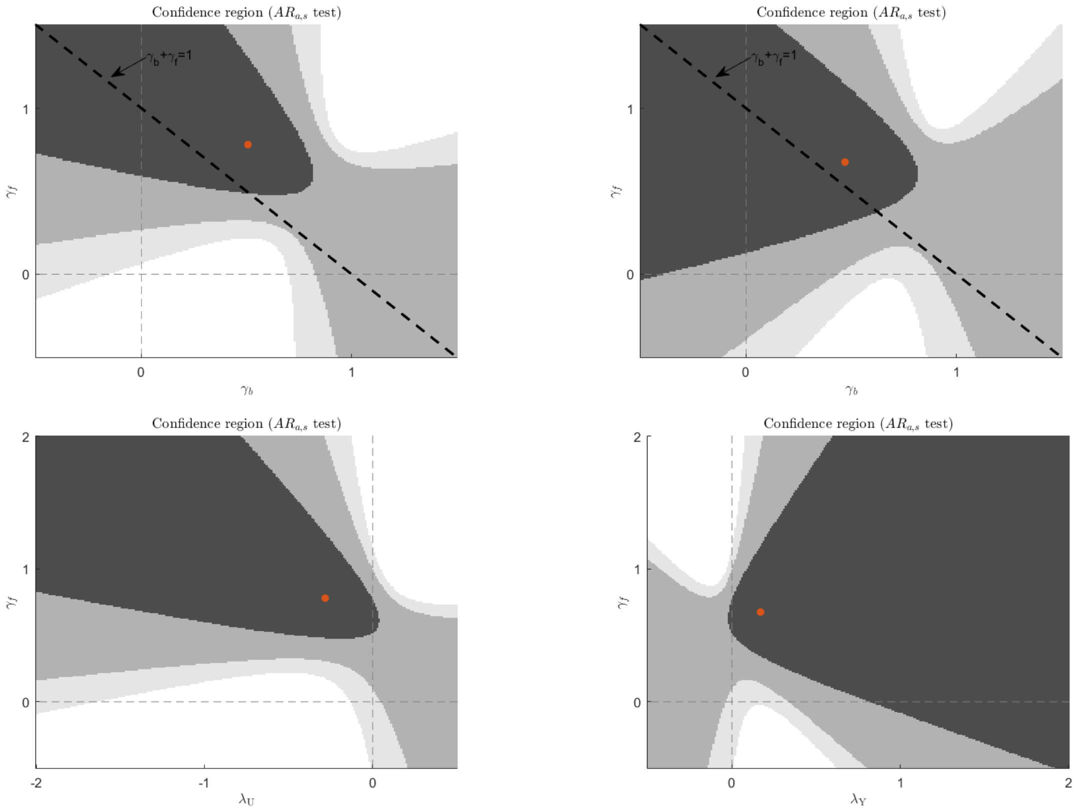
(a) Unemployment gap (b) Output gap



Notes: robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 19 – The U.S. GNKPC with PCE gap as dependent variable – 1969Q2-2007Q4, RR id.

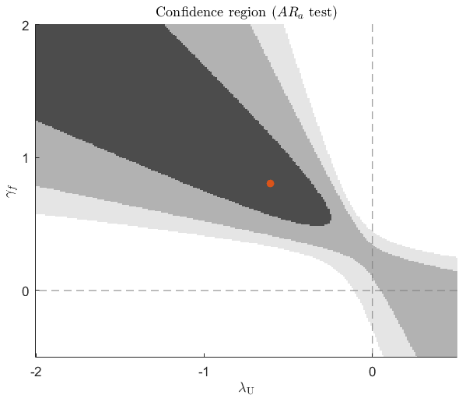
(a) Unemployment gap (b) Output gap



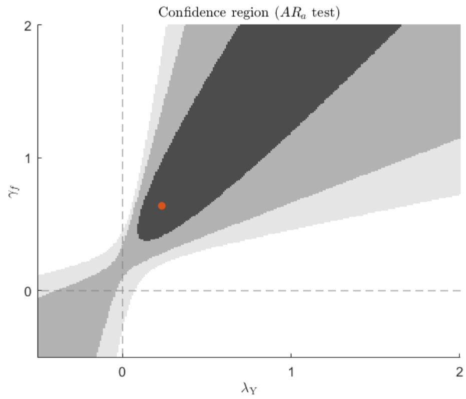
Notes: Robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 20 – The U.S. GNKPC with PCE gap as dependent variable – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

(a) Unemployment gap



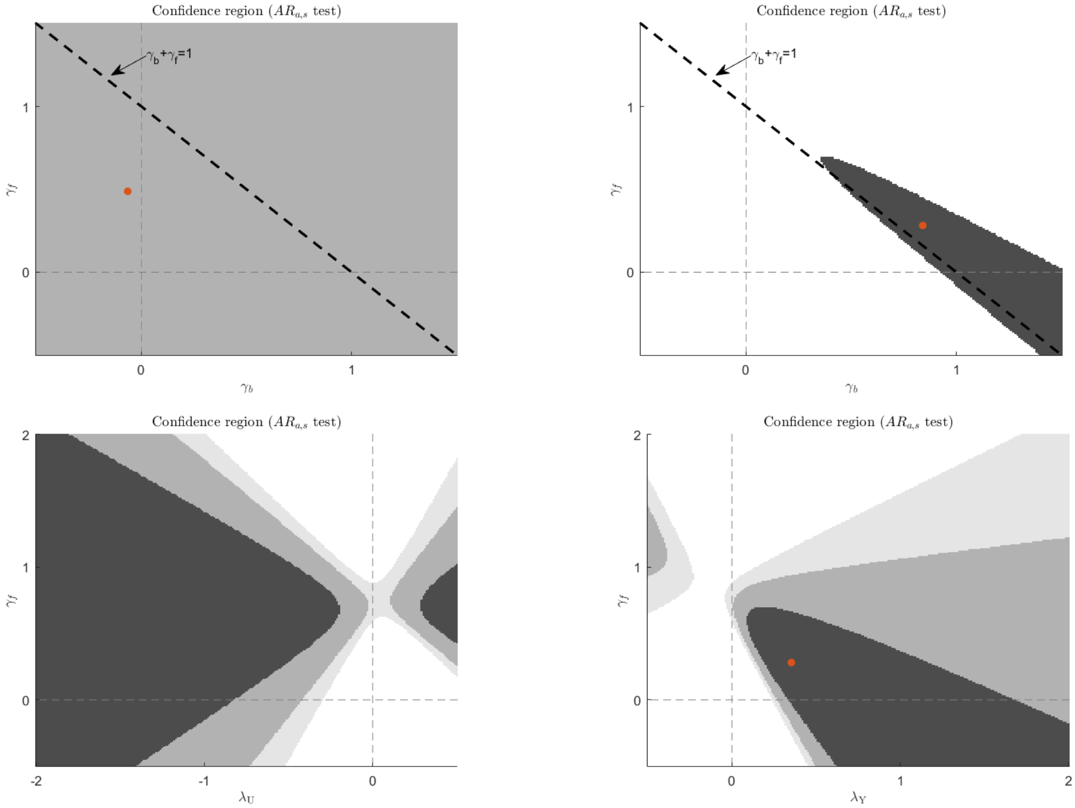
(b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 21 – The U.S. NKPC with CBO unemployment gap or CBO output gap as forcing variable – 1969Q2-2007Q4, RR id.

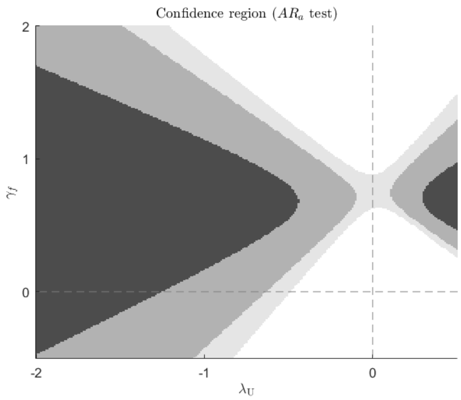
(a) Unemployment gap (b) Output gap



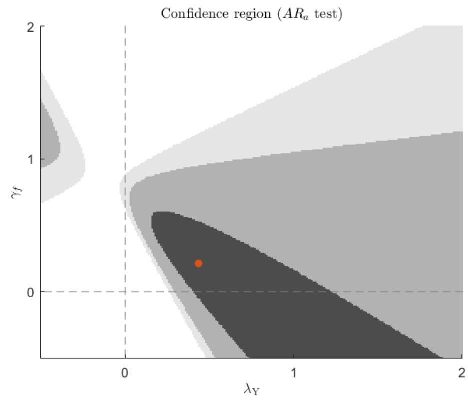
Notes: Robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 22 – The U.S. NKPC with CBO unemployment gap or CBO output gap as forcing variable – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

(a) Unemployment gap



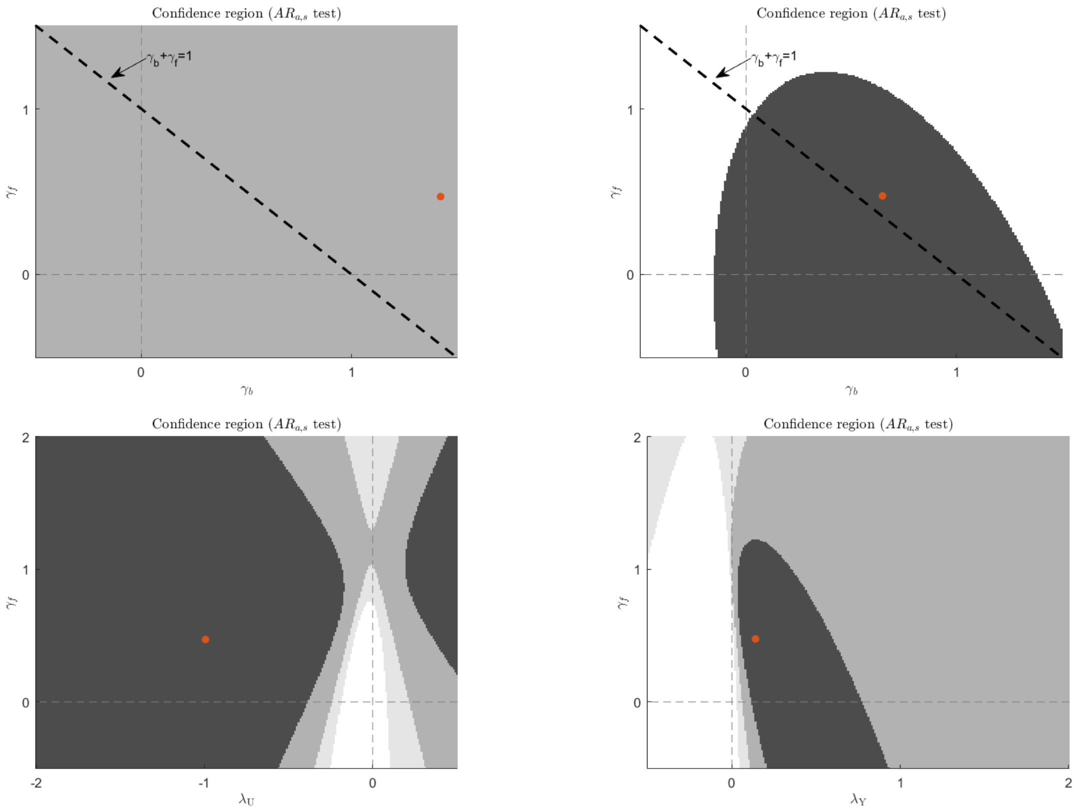
(b) Output gap



Notes: robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 23 – The U.S. GNKPC with CBO unemployment gap or CBO output gap as forcing variable – 1969Q2-2007Q4, RR id.

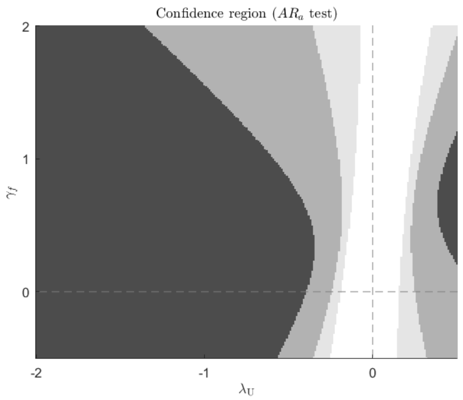
(a) Unemployment gap (b) Output gap



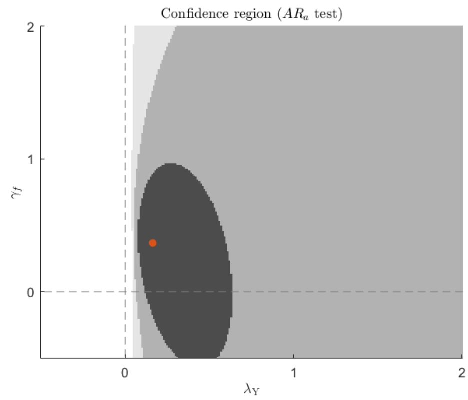
Notes: Robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the $AR_{a,s}$ statistic. Top row: 95%, 90%, and 68% confidence sets for γ_f and γ_b (the loading on expected and lagged inflation). The dashed line depicts the $\gamma_f + \gamma_b = 1$ set. Bottom row: confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. Specification with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 24 – The U.S. GNKPC with CBO unemployment gap or CBO output gap as forcing variable – 1969Q2-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

(a) Unemployment gap



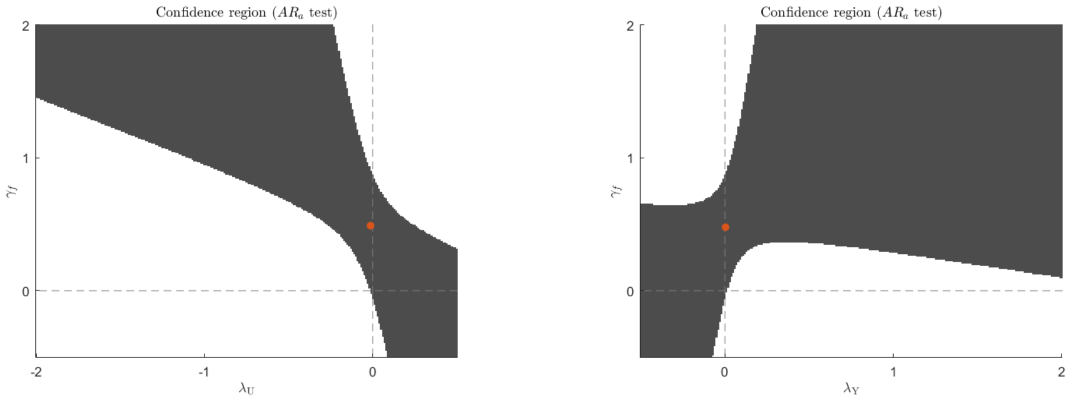
(b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1969Q2–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 25 – The U.S. NKPC – 1984Q1-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

(a) Unemployment gap (b) Output gap

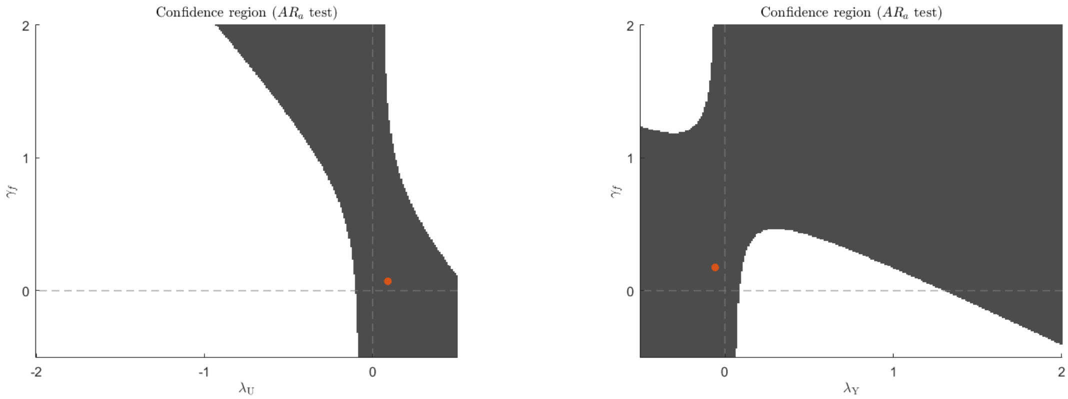


Notes: robust confidence sets for the U.S. NKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the NKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1984Q1–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.

Figure 26 – The U.S. GNKPC – 1984Q1-2007Q4, RR id, $\gamma_f + \gamma_b = 1$.

(a) Unemployment gap

(b) Output gap



Notes: robust confidence sets for the U.S. GNKPC coefficients are obtained by inverting the AR_a test. 95%, 90%, and 68% confidence sets for λ (the slope of the GNKPC) and γ_f (the loading on inflation expectations). The estimation is based on using the Romer and Romer (2004) monetary shocks as instruments (H=20) for 1984Q1–2007Q4. The inflation trend is measured following the approach of Kamber et al. (2018). The red dot is the Almon-restricted IV estimate. The specification imposes $\gamma_f + \gamma_b = 1$ with the unemployment gap (left column) or the output gap (right column) as the forcing variable.