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Keywords: Fiscal multipliers, fiscal policy, identification, instruments, structural vector autoregressions

JEL Classification: C52, E62,

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1 Introduction

The COVID-19 pandemic has triggered the most severe recession of the post-war era for all major economies (International Monetary Fund (2020)). With policy rates at their effective lower bound, fiscal policy stimulus packages of unprecedented scale have been implemented in most countries with the aim of sustaining aggregate demand. How effective these interventions are depends on the size of the fiscal multipliers, whose quantification is a difficult task. The reason is that spending and tax revenues are in large part endogenous, and tackling this endogeneity issue to identify the output effects of exogenous variations in fiscal variables - i.e., fiscal shocks - is challenging.

One way to identify causal effects that has recently gained a lot of traction is the "proxy-SVAR" (or "SVAR-IV") approach, which relies on the use of instruments for the identification of the shocks of interest (see Stock and Watson (2012) and Mertens and Ravn (2013) for early contributions, and Stock and Watson (2018) for a review).[1] There is, however, lack of consensus on the size of the estimated multipliers. Using a narrative measure of unanticipated exogenous variations in tax revenues, Romer and Romer (2010) and Mertens and Ravn (2011b, 2012, 2013, 2014) find tax multipliers between 2 and 3. Differently, Caldara and Kamps (2017), who employ Fernald's (2014) measure of total factor productivity (TFP) to identify exogenous changes of output in fiscal policy rules and then recover the fiscal policy shocks, estimate the tax multiplier to range between 0.5 and 0.7. Turning to the spending multiplier, Caldara and Kamps (2017) estimate it to be in between 1 and 1.3, larger than the estimates documented in the papers surveyed by Ramey (2019), which point to a 0.6-1 range. In light of policymakers' need to get reliable and robust indications on the size and relative strength of the spending and tax multipliers, the heterogeneity of the estimates provided by the extant literature is problematic.

Contributions of this paper. This paper employs fiscal and non-fiscal policy instruments jointly in a proxy-SVAR model, and provides a framework to reconcile the previous heterogenous estimates. We make two main contributions to the literature.

First, we show that the size of the tax multiplier crucially depends on the assumption of orthogonality (exogeneity) between the non fiscal proxy used to identify output shocks (TFP, as in Caldara and Kamps (2017)) and the tax shock. When this assumption is imposed, the tax multiplier is estimated to be below 1, as in Caldara and Kamps (2017). When this assumption is not imposed, the tax multiplier is three times as large, as in

[1] We will use the terms "instruments" and "proxies" interchangeably throughout the paper.

Mertens and Ravn (2014). Our fiscal proxy-SVAR specification is sufficiently flexible to not only recover the tax multiplier when the orthogonality of the TFP proxy to the tax shock is relaxed, but also to test for this assumption. We find that the orthogonality condition can indeed be rejected by the data. We show that this result holds across a number of proxy-SVAR specifications, starting from a standard three-variate fiscal VAR and then progressively enlarging the information set.[2]

Second, we find a fiscal spending multiplier larger than one and show that, unlike the tax multiplier, the estimate is very robust to the use of different instruments and modeling specifications. Our findings show that not only the estimates of the tax and spending multipliers differ in terms of heterogeneity across models, but also for the degree of uncertainty surrounding these estimates. We show that while the spending multiplier is estimated with high precision, the uncertainty surrounding the estimated tax multipliers is large.

Methodology. We obtain these results by working with a flexible proxy-SVAR that jointly models the observables and the instruments, as proposed by Angelini and Fanelli (2019). The joint (point-)identification of tax and fiscal spending shocks is achieved by combining the instruments with few additional, and possibly non-controversial, parametric restrictions. The novelty is that these few additional restrictions involve not only the on-impact coefficients associated with the target fiscal shocks, but also the on-impact coefficients associated with the auxiliary (non-fiscal) shocks. This allows us to trade relatively uncontroversial zero restrictions (e.g., the zero contemporaneous response of fiscal spending to output as in Blanchard and Perotti (2002), or the zero response of tax revenues to fiscal spending shocks as in Caldara and Kamps (2017)) with the orthogonality (exogeneity) condition of a proxy. This is of particular importance in our analysis, as it allows to unveil the negative and significant correlation between the TFP proxy and the tax shock and, consequently, to reconcile the different estimates of the tax multiplier obtained in the literature.

Instruments. Our baseline model employs both fiscal and non-fiscal instruments in a standard three-variate fiscal VAR that features quarterly US data on government spending, tax revenues and real GDP. Following Mertens and Ravn (2013), Mertens

[2] Our results are robust to employing the shock to the marginal efficiency of investment (MEI) estimated by Justiniano, Primiceri, and Tambalotti (2011) as an alternative proxy for the output shock. Also in this case, we find a sharp difference in the size of the tax multiplier depending on whether the orthogonality of the MEI proxy to the tax shock is imposed in estimation, or it is relaxed as suggested by the data. Results are reported in our Appendix.

and Ravn (2014), and Caldara and Kamps (2017), we investigate the sample 1950Q1-2006Q4. We consider two fiscal instruments. The first is the unanticipated tax shocks proposed by Mertens and Ravn (2011b). The second is a proxy of (unanticipated) fiscal spending shocks that we construct by "purging" the residuals obtained by regressing fiscal spending over a set of macroeconomic indicators and the measure of news spending shocks proposed by Ramey (2011). The logic behind the construction of this proxy is to remove from the one-step ahead fiscal spending forecast error the component which can actually be anticipated on the basis of narrative records. To our knowledge, ours is the first exercise in which a proxy for unexpected fiscal spending shocks is used to estimate the US fiscal spending multiplier in a proxy-SVAR context. In this sense, our contribution complements the one by Ramey (2011), who focuses on the output response to anticipated fiscal spending shocks.[3] The non-fiscal instrument is the factor utilization-adjusted total factor productivity (TFP) series produced by Fernald (2014), which - following Caldara and Kamps (2017) - we exploit to identify output shocks. While we use the two fiscal proxies to directly identify the fiscal shocks of interest, the latter instrument carry information for the identification of non-fiscal shocks that, via the moments related to the covariance matrix of the fiscal SVAR, can be exploited to identify fiscal elasticities and, consequently, spending and tax multipliers. Finally, in an extended version of the model, we include also inflation and the nominal interest rate, and one additional non-fiscal proxy, i.e., the oil shocks series proposed by Hamilton (2003) to instrument the inflation shock.[4]

Relation to the literature. Our point estimates of the fiscal spending multiplier fall in the 1.6-2.1 range, and are significantly larger than one from a statistical viewpoint. These point estimates, which are supported by different sets of instruments and model specifications, are quantitatively in line with the estimates by Caldara and Kamps' (2017), who work with non-fiscal instruments only, Canova and Pappa (2007), who work with sign restrictions in a panel SVAR framework modeling US and EU data, and Leeper, Traum, and Walker (2017), who work with different micro-founded structural

[3]Ramey and Zubairy (2018) estimate the multiplier generated by anticipated fiscal spending shocks with a local projections approach. See Plagborg-Møller and Wolf (2020) on the mapping between local projections and proxy-SVARs.

[4]As an additional check, we also include the Romer and Romer's (2004) monetary policy shocks series. Since this series is available from 1969Q1 only, the sample size available for estimation shrinks (all remaining variables are available since 1954Q1). Despite in our proxy-SVAR the proxies can cover a sample period shorter than that used to estimate the SVAR, we prefer not to pursue such a route to circumvent possible parameter instabilities. Thus, we confine the discussion of this further check in our Appendix. As we will discuss later, the main results of the paper are confirmed also in this scenario.

frameworks. Our estimates also support the 1.6 figure used by Christina Romer - at the time Chair of President Obama's Council of Economic Advisers - to predict the job gains possibly generated by the stimulus package approved by the US Congress in February 2009.[5]

Turning to the tax multiplier, depending on the model specification and the instruments we use, we can support point estimates ranging from 0.7 to 3.6. The "low" tax multiplier is obtained under the assumption that the TFP proxy is orthogonal to the tax shock, and is in line with the estimates by Caldara and Kamps (2017). The "high" tax multiplier, obtained when the orthogonality condition is not imposed, is in line with Romer and Romer's (2010) and Mertens and Ravn's (2011b, 2012, 2013, 2014). A related contribution on the heterogeneity of tax multipliers is Chahrour, Schmitt-Grohe, and Uribe (2012), who use data generated from a theoretical DSGE model in samples of length typically available to macroeconomists to show that small sample uncertainty may account for the observed differences in estimated tax multipliers. Within the proxy-SVAR class of models, our paper sheds instead light on the role played by different identification schemes in delivering substantially different estimates of the tax multiplier.

Our finding that the TFP proxy and the tax shock are negatively and significantly correlated supports those contributions that highlight the importance of accounting for the procyclicality of tax revenues. Mountford and Uhlig (2009) identify "business cycle" shocks by assuming that they generate a positive conditional correlation between output and tax revenues. They point out that this assumption is consistent with a number of theoretical views. Mertens and Ravn (2011a) show that permanent exogenous changes in income tax rates induce permanent changes in hours worked as well as in labor productivity, with relevant implications in the short run too. Building on Mertens and Ravn (2011a), Hussein (2015) shows that exogenous labor tax increases have negative long run effects on TFP, and rationalizes this finding with a DSGE model with endogenous TFP and learning-by-doing.

From a methodological viewpoint, we share with Mertens and Ravn (2014) the idea that the proxy-SVAR approach is not necessarily confined to a "partial identification" approach provided that other restrictions are imposed on the impact of the shocks

[5] See https://voxeu.org/article/determining-size-fiscal-multiplier. Auerbach and Gorodnichenko (2012), Bachmann and Sims (2012), Caggiano, Castelnuovo, Colombo, and Nodari (2015), and Ghassibe and Zanetti (2019) find this multiplier to be larger in recessions, and Klein and Linnemann (2019) to be particularly large during the Great Recession. For contrasting evidence, see Ramey and Zubairy (2018). Evidence on state-dependent output effects of tax shocks is provided by Sims and Wolff (2018).

that are not instrumented. Our approach is also close in spirit to Caldara and Kamps (2017). We show that their ingenious identification strategy, which exploits non-fiscal proxies to identify fiscal shocks, can be generalized to the case where both fiscal and non-fiscal instruments are jointly employed, and where the orthogonality assumption can be relaxed and empirically tested. Our approach also shows that the change in the estimated tax multiplier obtained by relaxing the orthogonality condition is due the tight link between the size of the estimated multipliers and the parameters that characterize the fiscal policy rules, consistent with Caldara and Kamps (2017). This is also consistent with Lewis (2021), who unveils the same link through a nonparametric approach that exploits the heteroskedasticity detected in the data.

This paper is structured as follows. Section 2 presents the econometric methodology and our identification approach. Section 3 documents our results. Section 4 documents some robustness checks. Section 5 concludes.

2 Econometric methodology

In this section, we first describe the identification problem in a standard proxy SVAR. We then present our approach based on a structural VAR that jointly models the observables and the instruments. We have in mind a point-identification setup. Next, we provide a specific example in the context of our baseline three variate fiscal VAR to show the flexibility of our identification approach, which allows to relax, and test for, the orthogonality conditions imposed in a standard proxy SVAR. Finally, we show what is the impact of relaxing the orthogonality conditions on the size of the multipliers.

Setting up the problem. Consider the following reduced-form VAR:

$$\Pi(L)Y_t = u_t \tag{1}$$

where Y_t is a vector of n observables, $\Pi(L) \equiv I_n - \Pi_1 L - \Pi_2 L^2 - ... - \Pi_p L^p$ is a matrix lag polynomial, and u_t is the vector of innovations with time-invariant covariance matrix $E(u_t u_t') = \Sigma_u$.[6]

Let the mapping between the vector of innovations u_t and that of structural shocks ε_t be

$$u_t = B\varepsilon_t, \qquad E(\varepsilon_t \varepsilon_t') = I_n. \tag{2}$$

[6] Constants and other deterministic terms are omitted for brevity. The extension of our formal expressions to cases in which constants and deterministic trends are present is straightforward.

We focus on the identification of a subset of $k \leq n$ structural shocks $\varepsilon_{1,t}$, where $\varepsilon_t = (\varepsilon_{1,t}', \varepsilon_{2,t}')'$. $\varepsilon_{1,t}$ collects the k target shocks of primary interest, which in our framework are the fiscal shocks, while $\varepsilon_{2,t}$ collects the remaining $n-k$ non-fiscal shocks, henceforth denoted auxiliary shocks.[7] Then, without loss of generality, we can re-write the mapping (2) in the form

$$u_t = B_1\varepsilon_{1,t} + B_2\varepsilon_{2,t} \tag{3}$$

where $B = (B_1\ ,\ B_2)$. B_1 contains the instantaneous impact coefficients associated with the shocks in $\varepsilon_{1,t}$, and B_2 those associated with the auxiliary shocks in $\varepsilon_{2,t}$.[8]

Assume that a vector of $r = k$ instruments, $v_{z,t}$, is available for the target shocks, $\varepsilon_{1,t}$.[9] For such instruments to be valid, the following two conditions have to hold:

$$E(v_{z,t}\varepsilon_{1,t}') = \Phi\ , \quad \text{rank}(\Phi) = k \tag{4}$$

$$E(v_{z,t}\varepsilon_{2,t}') = 0_{k\times(n-k)}. \tag{5}$$

Condition (4) states that the k instruments have to be relevant, i.e., significantly correlated with the k structural shocks of interest. Φ is a $k \times k$ full column rank matrix containing "relevance" parameters, and the rank condition in (4) implies that each column of Φ is non-zero and carries important information on the shocks in $\varepsilon_{1,t}$. Condition (5) states that the instruments have to be orthogonal (exogenous) to the non-instrumented shocks. A key point of this paper is that as long as point-identification is concerned, the orthogonality of $v_{z,t}$ to $\varepsilon_{2,t}$ can be relaxed without affecting the properties of the parameter estimator.[10]

Conditions (4)-(5) can be conveniently summarized as

$$v_{z,t} = \Phi\varepsilon_{1,t} + \omega_t, \tag{6}$$

where the measurement error ω_t is assumed to be orthogonal to the structural shocks $\varepsilon_t = (\varepsilon_{1,t}', \varepsilon_{2,t}')'$, with covariance matrix Σ_ω, assumed to be symmetric and positive

[7] Our framework covers the case $\varepsilon_{1,t} \equiv \varepsilon_t$, meaning that we can potentially instrument all structural shocks of the system with the benefit of leaving all elements in B unrestricted. This is a novelty in the proxy-SVAR literature, which will be fully explored in our empirical exercises presented below.

[8] We have ordered the target shocks $\varepsilon_{1,t}$ first for convenience: as it will be clear below, the ordering of the variables is irrelevant in our framework.

[9] Our framework can deal with $r \geq k$, meaning that we can allow the number of proxies to be be larger than the number of instrumented structural shocks. Below, we assume for simplicity that $r = k$.

[10] As shown later, this provides us with an important degree of flexibility and allows us to unveil the determinants of the heterogeneity in the tax multiplier estimates found in the proxy SVAR literature.

definite. By combining (3) with (6), we obtain the proxy-SVAR moment conditions

$$\Sigma_{u,v_z} = B_1 \Phi', \tag{7}$$

where the covariance matrix $\Sigma_{u,v_z} = E(u_t v_{z,t}')$ can be estimated from the data under fairly general conditions.

As known, for $k > 1$, the k instruments in $v_{z,t}$ do not suffice alone to point-identify the dynamic causal effects produced by the shocks $\varepsilon_{1,t}$ (see Mertens and Ravn (2013)). As shown by Angelini and Fanelli (2019), at least $\frac{1}{2}k(k-1)$ additional restrictions on the parameters of the matrix

$$G_1 = \begin{pmatrix} B_1 \\ \Phi \end{pmatrix} \tag{8}$$

must be imposed to achieve identification.[11] These restrictions can be placed on the on-impact coefficients in B_1 alone, on the relevance parameters in Φ alone, or can be distributed across both B_1 and Φ. Our novel identification strategy, discussed below, builds on this general finding, i.e. the identification of multiple shocks requires the combination of proxies with additional parametric restrictions.

The "augmented" VAR model. We consider the following "augmented" VAR, which jointly models the observables and the instruments:

$$\begin{pmatrix} \Pi(L) & 0_{n\times k} \\ \Gamma(L) & \Theta(L) \end{pmatrix} \begin{pmatrix} Y_t \\ Z_t \end{pmatrix} = \begin{pmatrix} u_t \\ v_{z,t} \end{pmatrix} \tag{9}$$

where Z_t collects the "raw" proxy variables, $v_{z,t} \equiv Z_t - E(Z_t | \mathcal{F}_{t-1})$, with $\mathcal{F}_{t-1}$ being the econometrician's information set at time $t-1$, and $\Gamma(L)$ and $\Theta(L)$ are matrix lag polynomials.[12]

The relationship between innovations, instruments and shocks is given by:

$$\begin{pmatrix} u_t \\ v_{z,t} \end{pmatrix} = \underset{\widetilde{G}}{\begin{pmatrix} B_1 & B_2 & 0_{n\times k} \\ \Phi & 0_{k\times(n-k)} & P_\omega \end{pmatrix}} \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \omega_t^o \end{pmatrix} \tag{10}$$

[11] See Angelini and Fanelli (2019) for details on the necessary and sufficient rank condition for local identification.

[12] The variables Z_t are allowed to be persistent (via $\Theta(L)$) and to depend on the lags of Y_t (via $\Gamma(L)$). Given the large number of coefficients featured by the system of equations (9), in our empirical analysis we impose that $\Theta(L)$ is diagonal when $k > 1$, i.e., the instruments are assumed to be dynamically unrelated to each other. These restrictions are supported by the data, i.e., the (cross-)correlations among the instruments used throughout the analysis are statistically equal to zero. Furthermore, in all estimated models discussed below the lag order q of $\Theta(L)$ and s of $\Gamma(L)$ is set to four, in line with the VAR lag order p.

where ω_t^o denotes the measurement error term ω_t in (6), normalized to have unit variance, and P_ω denotes any symmetric positive definite matrix such that $\omega_t = P_\omega \omega_t^o$.

The system (9)-(10) can be more compactly expressed as:

$$\begin{aligned} \widetilde{\Psi}(L)W_t &= \eta_t && (11) \\ \eta_t &= \widetilde{G}\xi_t && (12) \end{aligned}$$

where

$$\begin{aligned} W_t &\equiv \begin{pmatrix} Y_t \\ Z_t \end{pmatrix}, \ \eta_t \equiv \begin{pmatrix} u_t \\ v_{z,t} \end{pmatrix}, \\ E(\eta_t\eta_t') &= \Sigma_\eta = \begin{pmatrix} \Sigma_u & \Sigma_{u,v_z}' \\ \Sigma_{u,v_z} & \Sigma_\omega \end{pmatrix}, \ E(\xi_t\xi_t') = I_{n+k} \\ \widetilde{\Psi}(L) &\equiv \begin{pmatrix} \Pi(L) & 0_{n\times k} \\ \Gamma(L) & \Theta(L) \end{pmatrix}, \ \widetilde{G} \equiv \begin{pmatrix} B_1 & B_2 & 0_{n\times k} \\ \Phi & 0_{k\times(n-k)} & P_\omega \end{pmatrix}, \end{aligned}$$

where W_t and η_t are $(n+k)$-dimensional, and "$\sim$" indicates that $\widetilde{\Psi}(L)$ and $\widetilde{G}$ incorporate by construction zero restrictions.

Identification of the $(n+k)\times(n+k)$ matrix $\widetilde{G}$ would require the imposition of at least $\frac{1}{2}(n+k)(n+k-1)$ restrictions in addition to the covariance restrictions $\Sigma_\eta = \widetilde{G}\widetilde{G}'$. Given the restrictions already embedded in $\widetilde{G}$ by construction – the block of $(n-k)k+nk$ zeros in the positions (2,2) and (1,3) of $\widetilde{G}$; the $\frac{1}{2}k(k+1)$ symmetry restrictions embedded in P_ω, and the $\frac{1}{2}k(k-1)$ restrictions on the block G_1 corresponding to the first k columns of $\widetilde{G}$, as highlighted by Angelini and Fanelli (2019) – it can be shown that (point-)identification of all structural shocks requires the imposition of a few additional restrictions on the coefficients in B_2.[13]

What are the practical advantages of representing the proxy-SVAR in the form (11)-(12)? The main advantage in our context is that the "augmented" VAR gives us the flexibility of relaxing some (possibly controversial) orthogonality conditions by imposing other (possibly uncontroversial) parameter restrictions. The next example shows why this is crucial in our context.

Identification strategy: relaxing the orthogonality conditions. To see this point, we consider a three-variate fiscal proxy-SVAR and the scenario in which we use

[13] Importantly, identification can be achieved by imposing less restrictions than in the original n-dimentional SVAR (1)-(2) with no proxy variables. Thus, the SVAR in (11)-(12) retains the gains of using external proxies in identification.

TFP as instrument for the output shock ε_t^y as in Caldara and Kamps (2017). Then, the counterpart of system (3) becomes:

$$\begin{pmatrix} u_t^{tr} \\ u_t^g \\ u_t^y \end{pmatrix} = \underbrace{\begin{pmatrix} b_{tr,tr} & b_{tr,g} \\ b_{g,tr} & b_{g,g} \\ b_{y,tr} & b_{y,g} \end{pmatrix}}_{B_2} \begin{pmatrix} \varepsilon_t^{tr} \\ \varepsilon_t^g \end{pmatrix} + \underbrace{\begin{pmatrix} b_{tr,y} \\ b_{g,y} \\ b_{y,y} \end{pmatrix}}_{B_1} \varepsilon_t^y, \tag{13}$$

where $u_t = (u_t^{tr}, u_t^g, u_t^y)'$ is the vector of the VAR innovations, so that u_t^{tr}, u_t^g, u_t^y are the disturbances associated with the equation for tax revenues, fiscal spending, and output, respectively; and ε_t^{tr} and ε_t^g denote the tax and spending shocks, and ε_t^y is the output shock, i.e. the target shock in this example ($k = 1$).

The output shock is directly instrumented by the TFP proxy, denoted v_t^{TFP}. Hence the counterpart of (6) is given by the equation

$$v_t^{TFP} = \phi_1 \varepsilon_t^y + \omega_t^{TFP} \tag{14}$$

where $\phi_1 = Cov(v_t^{TFP}, \varepsilon_t^y)$ is the relevance parameter which captures the correlation between the TFP proxy and the output shock, while ω_t^{TFP} is a measurement error with standard deviation $\sigma_{\omega,TFP}$, assumed to be orthogonal to all structural shocks in the system. Under the condition $\phi_1 \neq 0$, the TFP proxy would be enough to identify the output shock. Suppose now that the following two additional restrictions hold: $b_{tr,g} = 0$, i.e., tax revenues do not instantaneously respond (within the quarter) to the fiscal spending shock; and $b_{g,y} = 0$, i.e., fiscal spending does not react contemporaneously (within the quarter) to changes in economic activity, as in Blanchard and Perotti (2002) and Mertens and Ravn (2014). The TFP proxy in (14) and the conditions $b_{tr,g} = 0$ and $b_{g,y} = 0$ imply the following structure for the matrix $\widetilde{G}$ in (10):

$$\widetilde{G} = \begin{pmatrix} b_{tr,tr} & 0 & b_{tr,y} & 0 \\ b_{g,tr} & b_{g,g} & 0 & 0 \\ b_{y,tr} & b_{y,g} & b_{y,y} & 0 \\ 0 & 0 & \phi_1 & \sigma_{\omega,TFP} \end{pmatrix} \tag{15}$$

which leads to an over-identified, testable SVAR model.[14]

Consider now the case where the v_t^{TFP} proxy is not exogenous to the tax shock, so that one proxy potentially brings information on two structural shocks. Then, the equation for the TFP proxy becomes

$$v_t^{TFP} = \phi_1 \varepsilon_t^y + \phi_2 \varepsilon_t^{tr} + \omega_t^{TFP}, \tag{16}$$

[14] Notice that the fiscal elasticities of tax revenues and fiscal spending to output can be recovered from $\widetilde{GI} \equiv \widetilde{G}^{-1}$.

where ϕ_1 has the same interpretation as before while the parameter $\phi_2 = Cov(v_t^{TFP}, \varepsilon_t^{tr})$ captures the relationship between the tax shock and the TFP proxy.

Is the model identified? The matrix $\widetilde{G}$ is now given by:

$$\widetilde{G} = \begin{pmatrix} b_{tr,tr} & 0 & b_{tr,y} & 0 \\ b_{g,tr} & b_{g,g} & 0 & 0 \\ b_{y,tr} & b_{y,g} & b_{y,y} & 0 \\ \phi_2 & 0 & \phi_1 & \sigma_{\omega,TFP} \end{pmatrix}, \tag{17}$$

and has similar structure to the $\widetilde{G}$ matrix in (15), the main difference being the presence of the parameter ϕ_2 in the first column. Even with $\phi_2 \neq 0$, this model is (just) identified. Notably, (17) nests the model based on (15), where the orthogonality condition holds, i.e. $\phi_2 = 0$. A key feature of our proxy-SVAR is that the parameter ϕ_2 can be estimated along with its standard deviation, so that a confidence interval around ϕ_2 can be interpreted as prima facie evidence about the relationship between the TFP proxy and the tax shock. Hypotheses of the type $\phi_2 = \breve{\phi}_2$, where $\breve{\phi}_2$ are pre-specified guess values are over-identifying and testable against the data.

The next step is to show the implications for the size of the tax multiplier of moving from the scenario in (15) (orthogonality) to that in (17) (non-orthogonality).

Relaxing the orthogonality condition: the size of the tax multiplier. Let us consider the tax policy rule, obtained by inverting the relationship $\eta_t = \widetilde{G}\xi_t$ in (12):

$$u_t^{tr} = \psi_g^{tr} u_t^g + \psi_y^{tr} u_t^y + \sigma_{tr}\varepsilon_t^{tr}, \tag{18}$$

where ψ_y^{tr} and ψ_g^{tr} are the elasticities of tax revenues to output and to fiscal spending, respectively, and σ_{tr} is the standard deviation associated with the tax shock.[15] To simplify the presentation (and in line with what the empirical evidence discussed below suggests), we assume that $\psi_g^{tr} \approx 0$, so that:

$$u_t^{tr} = \psi_y^{tr} u_t^y + \sigma_{tr}\varepsilon_t^{tr}. \tag{19}$$

Consider first the case in which the orthogonality condition holds, hence v_t^{TFP} is generated as in (14). Multiplying both sides of (19) by v_t^{TFP} gives:

$$u_t^{tr} v_t^{TFP} = \psi_y^{tr} u_t^y v_t^{TFP} + \sigma_{tr}\varepsilon_t^{tr} v_t^{TFP}. \tag{20}$$

[15] The parameters ψ_g^{tr}, ψ_y^{tr} and σ_{tr} are highly nonlinear function of the non-zero $b_{x,x}$-coefficients that appear in the 3×3 left-upper block of the matrix $\tilde{G}$.

Taking expectations and using the orthogonality condition $E(\varepsilon_t^{tr} v_t^{TFP}) = 0$, we can solve for the elasticity of tax revenues to output:

$$\psi_y^{tr} = \frac{E(u_t^{tr} v_t^{TFP})}{E(u_t^{y} v_t^{TFP})}. \tag{21}$$

Equation (21) shows that ψ_y^{tr} is equal to the ratio of two reduced form covariances, which can be estimated from the data.

Assume now that the orthogonality condition does not hold. The proxy v_t^{TFP} is given by (16), so that it is correlated not only with the output shock but also with the tax shock. As before, multiplying (19) by the proxy, taking expectations, and using $E(\varepsilon_t^{tr} v_t^{TFP}) = \phi_2$, gives:

$$\psi_y^{tr} = \frac{E(u_t^{tr} v_t^{TFP}) - \phi_2}{E(u_t^{y} v_t^{TFP})}. \tag{22}$$

This expression shows that ψ_y^{tr} now depends also on the correlation between the TFP proxy and the tax shock. If, as expected, $\phi_2 < 0$, the elasticity computed from (22) will be larger that the elasticity computed from (21). As shown by Caldara and Kamps (2017), this would imply a larger tax multiplier, unveiling the reason why the tax multiplier is sensitive to the relationship between the TFP proxy and the tax shock.

Data and instruments. We use US quarterly data on gross domestic product, y_t, federal tax revenues, tr_t, and government spending, g_t, defined as the sum of government consumption and investment. Following Caldara and Kamps (2017), all series are expressed in logs and real per capita terms, and are detrended by removing a linear trend.[16] The sample covers the period 1950Q1-2006Q4, which makes our results directly comparable with those documented in the extant literature (see e.g. Caldara and Kamps (2017)), and avoids the challenge of estimating the fiscal multipliers in presence of the zero lower bound (for contributions on this issue, see Christiano, Eichenbaum, and Rebelo (2011) and Wieland (2018)). In an "extended" model, we also include consumer price inflation π_t and the 3-month (nominal) Treasury bill rate i_t, so that $Y_t = (y_t, tr_t, g_t, \pi_t, i_t)'$.

In the baseline model, we include three proxies in the vector Z_t, two fiscal and one non-fiscal instrument. The two fiscal instruments are Mertens and Ravn's (2011b) series of unanticipated tax shocks (denoted MR), which is a subset of and Romer and Romer's (2010) shocks identified by studying narrative records on tax policy decisions, and a novel series of unanticipated fiscal spending shocks inspired by Auerbach and

[16] All the results of the paper are robust to re-estimating the VAR with variables in log-levels and including a linear trend. Results are shown in the Appendix.

Gorodnichenko's (2012) contribution (denoted AG). This latter proxy is the residual of the OLS regression of the log of fiscal spending over a linear trend, the spending news shocks series proposed by Ramey (2011), and three lags of output, fiscal spending, tax revenues (all in logs), and Ramey's series. Controlling for the contemporaneous (as well as the past) realizations of Ramey's (2011) anticipated shocks helps us isolate the truly unanticipated component of fiscal spending, which is our object of interest. As stressed by Mertens and Ravn (2014), using instruments that confound unanticipated and news shocks may lead to a failure of the exogeneity assumption, and therefore invalidate the econometric analysis. Turning to the non-fiscal instruments, the proxy employed for the output shock is the total factor productivity series by Fernald (2014), denoted TFP, which is adjusted for changes in factor utilization. In our "extended" model, which also includes inflation and a policy rate, we use one additional non fiscal proxy: the oil shocks series by Hamilton (2003), denoted OIL, which is a nonlinear function of the changes in the nominal price of crude oil.[17]

Estimation and bootstrap inference. The model is estimated via Maximum Likelihood, and in all specifications the reduced form VAR includes $p = 4$ lags and a constant. We make inference on the estimated parameters of interest and the estimated fiscal multipliers via moving block bootstrap (MBB). Inference in proxy-SVARs has recently been debated by Mertens and Montiel Olea (2018), Jentsch and Lunsford (2019b), Mertens and Ravn (2019), Jentsch and Lunsford (2019a), and Montiel Olea, Stock, and Watson (2020). Building on Brüggemann, Jentsch, and Trenkler (2016), Jentsch and Lunsford (2019b) show that when the dynamics of the external instruments is approximated by the zero-censored model:

$$v_{z,t} = D_t(\Phi\varepsilon_{1,t} + \omega_t), \tag{23}$$

where D_t is a $k \times k$ diagonal matrix with dummy variables on the diagonal that play the role of zero censoring the proxy, the MBB method is the resampling scheme which correctly estimates the variability of the estimated impulse response functions (see also Jentsch and Lunsford (2019a)).[18] Mertens and Ravn's (2011b) series of unanticipated tax shocks, MR_t, is characterized by a type of dynamics consistent with (23).

[17] All series but the instrument inspired by the Auerbach and Gorodnichenko (2012) paper are available in the replication package of the Caldara and Kamps (2017) paper, which is available at Dario Caldara's webpage: https://sites.google.com/view/dariocaldara/publications. Our AG instrument is available upon request.

[18] In particular, let $D_{i,t}$ be the dummy associated with the proxy $v_{z,i,t}$, $i = 1, ..k$, then $D_{i,t}$ takes value 1 with probability p_i and value 0 with probability $1 - p_i$, implying that $v_{z,i,t}$ can be either zero (with probability $1 - p_i$) or can take both positive and negative values (with probability p_i).

Multipliers. Let P be either the level of fiscal spending G or the level of taxes TR (not in logs); GDP be the level of output (not in logs); βy_h be the response of log-output at horizon h to a fiscal policy shock; and βp_0 be the impact of the fiscal policy shock to the corresponding fiscal variable expressed in logs. Then, the multiplier, defined as the dollar response of output to a shock of size one dollar, is given by:

$$\mathcal{M}p_h = (\beta y_h / \beta p_0)(GDP/P),$$

where GDP/P is a policy shock-specific scaling factor converting elasticities to dollars. As in Caldara and Kamps (2017), we set the scaling factors for the two shocks of interest (unexpected change in fiscal spending and tax revenues) to their sample means on the estimation period, i.e., $(GDP/G)^{-1} = 0.20$ and $(GDP/T)^{-1} = 0.18$, respectively.[19] We consider positive fiscal spending shocks and negative tax shocks to compare multipliers related to shocks expected to have a positive effect on output.[20]

3 Results

In this section, we present our baseline results for three scenarios: first, the case with fiscal instruments for the identification of fiscal shocks; second, the case with the non-fiscal instrument (TFP) to identify output shocks directly, and then indirectly the fiscal shocks; third, the case with both fiscal and non-fiscal instruments to jointly identify fiscal and non-fiscal shocks. A key result is that different assumptions on the correlation between TFP shocks and tax revenues shocks lead to dramatically different estimates of the tax multiplier. Instead, the estimates related to the output effects of fiscal spending shocks are relatively robust across scenarios. We then discuss the link between different estimates of the output-tax elasticity and the corresponding tax multiplier.

[19] This definition of the fiscal multipliers enhances the comparability of our results with those documented by the literature. For a discussion on this vs. alternative definitions, see Ramey (2019).

[20] We also report in the Appendix the cumulative spending multiplier, defined as

$$\mathcal{M}^c_{p_h} = \frac{\sum_h \beta y_h}{\sum_h \beta p_h} \frac{GDP}{P}$$

which accounts for the persistence of the response of government spending to its own shock. We do not report cumulative tax multipliers. Given the strong feedback from GDP to tax revenues, the concept of a cumulative tax multiplier is not well defined, and its calculation is problematic (see Mertens and Ravn (2013) and Ramey (2019)).

3.1 Fiscal instruments only approach

Fiscal spending shock: Auerbach and Gorodnichenko's (2012) instrument. We begin our analysis by instrumenting the fiscal spending shock with our novel AG proxy, which is meant to identify unexpected changes in fiscal spending. In this case, $Y_t = (y_t, tr_t, g_t)'$, $Z_t = (AG_t)$, and $\varepsilon_{1,t} \equiv \varepsilon_t^g$, and we estimate the "augmented" model for $W_t = (Y_t', Z_t)' = (y_t, tr_t, g_t, AG_t)$. While the proxy AG_t identifies the fiscal spending shock ε_t^g, we achieve just identification of all shocks (i.e. also the tax shock and the output shock in $\varepsilon_{2,t} \equiv (\varepsilon_t^{tr}, \varepsilon_t^y)$) by imposing that fiscal spending does not instantaneously respond to output shocks.[21] The robust first-stage F-statistic for this instrument is 2019.58. For brevity, the maximum likelihood estimates of the implied matrix $\widetilde{G}$ along with 68%-MBB confidence intervals for the estimated parameters are confined in the Appendix.

Figure 1 (left panel) plots the fiscal spending multiplier obtained from this specification. The on-impact multiplier ($\mathcal{M}g_0$ in our notation) is about 1.1, it increases to about 1.6 after two quarters, it stays at that level for about one year, then it gradually declines. The confidence interval associated with the peak multiplier, reported in Table 1, ranges from 1.1 to 2. While the just identified model cannot be offered formal statistical support by the overidentification restriction test, we notice that the estimated relevance parameter, which connects the AG_t instrument to the fiscal shock ε_t^g, is $\widehat{\phi}_{AG} = 0.0129$, is strongly significant, and implies a correlation of 96% with the identified fiscal shock.

Table 1 collects our estimate of the output-spending elasticity, given by $\psi_y^g = -(\widetilde{GI}_{3,1}/\widetilde{GI}_{3,3})$, where $\widetilde{GI} \equiv \widetilde{G}^{-1}$, and $\widetilde{GI}_{i,j}$ is the element located in the i-th row and j-th column of the $\widetilde{GI}$ matrix. We get a point estimate of $\hat{\psi}_y^g = -0.0029$, and the associated confidence interval is (-0.027, 0.025). This finding supports Blanchard and Perotti's (2002) choice of calibrating such elasticity to zero. Caldara and Kamps' (2017) analytical derivations show that a zero elasticity implies an on-impact multiplier equal to 1, which is in line with what we find.

[21] Formally, this is the constraint $b_{g,y} = 0$ discussed in Section 3 (albeit for a different proxy-SVAR). Blanchard and Perotti (2002) impose a zero contemporaneous response of fiscal spending to all shocks affecting output. The two restrictions are equivalent if output is not affected by fiscal shocks at time t. If it is, our restriction is less stringent than Blanchard and Perotti's (2002). The difference in these restrictions is due to the fact that they work with an "AB-model" (Lütkepohl (2005)) which accounts also for the contemporaneous relationships among the variables. Differently, we work with a "B-model", which focuses directly on the mapping going from the structural shocks to the VAR innovations.

Tax shock: MR instrument. We now turn to the identification of the tax revenues shock. The instrument we use is the series of unanticipated tax shocks produced by Mertens and Ravn (2011b), MR_t. Since $Y_t = (y_t, tr_t, g_t)'$, $Z_t = (MR_t)$ and $\varepsilon_{1,t} \equiv \varepsilon_t^{tr}$, we estimate the augmented model for $W_t = (Y_t', Z_t)' = (y_t, tr_t, g_t, MR_t)'$. In this case MR_t identifies directly the tax shock ε_t^{tr} but, consistently with the previous case, we achieve identification of all shocks (i.e. also the fiscal spending shock and the output shock in $\varepsilon_{2,t} \equiv (\varepsilon_t^g, \varepsilon_t^y)$) by imposing the restriction that fiscal spending does not instantaneously respond to output shocks. The robust first-stage F-statistic for this instrument is 1.55. The correlation between the residual associated with the tax revenue equation of the VAR, $\hat{u}_t^{tr}$, and the MR_t instrument is equal to 12%.[22] The point estimate of the relevance parameter for the MR_t instrument is $\widehat{\phi}_{MR} = 0.043$, which implies a correlation of 27% with the identified tax shock.[23]

Figure 1 (right panel) plots the implied tax multiplier. The multiplier takes the value of 2.1 on impact ($\mathcal{M}tr_0$), and reaches a peak value of 3.1 after three quarters. The size of the multiplier is in line with the estimates by Mertens and Ravn (2014) and part of the literature cited therein. The confidence interval for the peak tax multiplier ranges from 1.4 to 4.8. We then recover the output-tax elasticity as $\psi_y^{tr} = -(\widetilde{GI}_{2,1}/\widetilde{GI}_{2,2})$. Conditional on the estimated model, the point estimate is $\widehat{\psi}_y^{tr} = 3.36$, close to that reported in Mertens and Ravn (2014) and Mertens and Ravn (2011a), 3.13 and 3.7 respectively. The confidence interval for ψ_y^{tr} is (2.25, 4.45). Although the confidence interval reflects sizeable uncertainty about the value of this elasticity, the lower bound is still higher than the value 2.08 used by Blanchard and Perotti (2002), who rely on an application of the OECD methodology documented in Giorno, Richardson, Roseveare, and van den Noord (1995), and is considerably higher than the value 1.7 produced by Follette and Lutz (2010) for the US economy. We postpone the discussion on the plausibility of an output-tax elasticity around 3 to Section 3.3.

3.2 TFP only approach

We use Fernald's (2014) measure of TFP, TFP_t, as an instrument for output shocks. While such shocks are not of direct interest for the computation of the fiscal multipliers, as shown by Caldara and Kamps (2017), the information related to their impulse vector

[22] If the correlation is computed by considering only the non-zero elements of MR_t (and the corresponding elements in $\hat{u}_t^{tr}$), the correlation increases to 35%.

[23] These results would motivate the use of the weak-instrument robust approach for proxy-SVAR developed by Montiel Olea, Stock, and Watson (2020). For compoarative purposes we stick to Mertens and Ravn's (2014) approach and do not pursue the test inversions route.

can be fruitfully combined with that of the covariance matrix of our VAR to achieve full identification and recover the output effects of fiscal spending and tax shocks.[24] Thus, we have $Y_t = (y_t, tr_t, g_t)'$, $Z_t = (TFP_t)$ and $\varepsilon_{1,t} \equiv \varepsilon_t^y$, and we estimate the "augmented" model for $W_t = (Y_t', Z_t)' = (y_t, tr_t, g_t, TFP_t)'$. The robust first-stage F-statistic for this instrument is 61.61. To identify the three structural shocks of the system, we impose the two restrictions $b_{tr,g} = 0$ and $b_{g,y} = 0$ in the matrix $\tilde{G}$ in (15). While $b_{g,y} = 0$ (fiscal spending does not instantaneously respond to output shocks) is consistent with the proxy-SVARs estimated in the fiscal instruments only approach, the restriction $b_{tr,g} = 0$ (tax revenues do not instantaneously respond to fiscal spending shocks) is necessary for the identification of the model. The proxy-SVAR is overidentified, and the overidentification restrictions test returns a p-value of 0.41, which leads to not rejecting the model specification. The point estimate of the relevance parameter is $\widehat{\phi}_1 = 1.86$, which implies a correlation of 57% with the identified output shock.

As shown by Figure 1, the point estimates of the fiscal spending multipliers identified with TFP shocks turns out to be in line with the ones computed with the AG instrument. The impact multiplier ($\mathcal{M}g_0$) is equal to 1.1, while the peak - which occurs after two quarters - is equal to 1.9, and the associated confidence interval ranges from 1.3 to 2.4. The point estimate of the elasticity of fiscal spending to output ψ_y^g is negative, and zero is not included in the confidence interval (even though the upper bound is very close to zero). Overall, these results are close to those reported in Caldara and Kamps (2017).

Turning to the tax multiplier, the estimate is substantially lower relative to that obtained with the MR instrument. On impact, the multiplier is estimated to be 0.4, and the peak value - 0.76 - realizes five quarters after the shock. The confidence interval for the peak tax multiplier ranges from a value slightly less than zero to 0.93. Figure 1 shows that the drop of the tax multiplier relative to the MR case is substantial for at least 25 quarters after the shock. What is the driver of this drastic change in the tax multiplier when moving from the MR case to the TFP one? Table 1 collects the estimated value of the tax policy coefficient ψ_y^{tr} in this scenario, which is 2.1, with associated confidence interval (1.8, 2.5). The estimated elasticity, as well as the associated confidence interval, is significantly lower than the estimate obtained when using the MR instrument only. The fact that lower values of the tax elasticity, ψ_y^{tr}, are associated with lower values of the multiplier, $\mathcal{M}tr$, is consistent with the simulations proposed in Mertens and Ravn (2014), and with the analytical derivations documented in Caldara and Kamps (2017).

[24] For an early study on the connection between policy rules and policy shocks with an application to the identification of monetary policy shocks, see Leeper, Sims, and Zha (1996).

3.3 TFP only approach: Relaxing the TFP-tax shocks orthogonality condition

In all the previous proxy-SVARs, the multipliers have been estimated assuming orthogonality of the TFP instrument with respect to both fiscal shocks. While the exogeneity assumption for the spending shock is based on the well-known delays characterizing fiscal spending decisions and implementations (Blanchard and Perotti (2002)), the assumption of orthogonality between TFP and tax shocks is less uncontroversial, given the procyclicality of tax revenues.

TFP-tax shocks orthogonality condition: Empirical and theoretical evidence. Our model specification allows to formally test the orthogonality between the TFP proxy and the tax shock (internally) identified from our proxy-SVAR. To this end, we consider the model (16)-(17), where the TFP jointly serves as an instrument for the output shock and the tax shock. Given the matrix $\tilde{G}$ in (17), we can estimate and make inference not only on ϕ_1, i.e. the relevance parameter for output shocks, but also on ϕ_2, which connects the TFP instrument to the tax shock. We find that the relevance of the TFP instrument for the identification of both output and tax shocks is supported by the data. In line with the evidence in Caldara and Kamps (2017), the TFP is a relevant instrument for the output shock: the estimated relevance coefficient, $\widehat{\phi}_1$, is equal to 1.63, with a confidence interval $(1.42, 2.01)$, and an implied correlation with the output shock of 49.7%. More important for our analysis, TFP turns out to be empirically correlated to the tax shock: the estimated relevance coefficient, $\widehat{\phi}_2$, is equal to -0.89 with a confidence interval of $(-1.51, -0.64)$ and an implied correlation with the tax shock of -27%.[25]

Another key feature of our empirical model is that we can test for its validity. If ϕ_2 is pre-fixed to a given value, i.e. $\phi_2 = \breve{\phi}_2$, the proxy-SVAR is overidentified. We conduct the overidentification restrictions test as follows. We consider three guess values of the parameter ϕ_2: i) $\breve{\phi}_2 = -1.51$, which corresponds to the lower bound of the confidence interval; ii) $\breve{\phi}_2 = -1$, the central value of the confidence interval; and iii) $\breve{\phi}_2 = -0.64$, corresponding to the upper bound of the confidence interval. The p-values associated with the overidentification restrictions test in these three cases are 0.25, 0.87 and 0.75, respectively. Overall, these results show that relaxation of the orthogonality condition $\phi_2 = Cov(v_t^{TFP}, \varepsilon_t^{tr}) = 0$ is supported by the data, in line with the theoretical

[25] In the Appendix, we report additional evidence against the orthogonality condition between TFP and the tax shock based on reduced form residuals' correlation, and on the revisitation of the exogeneity test provided by Caldara and Kamps (2017).

arguments in Mertens and Ravn (2011a). The next key question is whether relaxing the orthogonality assumption makes a difference as regards the size of the estimated tax multiplier.

The connection between factor productivity and exogenous tax shocks has been examined by Mertens and Ravn (2011a). They show that, in the context of a stochastic growth model, permanent changes in income tax rates induce permanent changes in labor productivity. This finding violates the standard long-run identification strategy for technology shocks, based on the assumption that neutral technology shocks are the only source of long run changes in labor productivity. Mertens and Ravn (2011a) also show empirically using a VECM that tax shocks affect productivity significantly both in the short and in the long run. They also highlight several channels through which permanent income tax change can have permanent effects on labor productivity: in models with endogenous changes in labor productivity, such as models with educational choices or human capital accumulation, increases in labor income taxes lower the return on skills, and decrease labor productivity. In life cycle models, changes in labor income tax rates can affect the retirement decisions of older workers, and this may negatively affect labor productivity if skills are accumulated over the life cycle. An alternative mechanism works through the government budget constraint. For a given level of public spending, a change in labor income taxes will lead to a change with opposite sign in capital income taxes, which affects the long run level of labor productivity. Taken together, their findings point to rejection of the standard identifying assumption for productivity shocks based on the long run orthogonality between tax changes and factor productivity. Hussain (2015) provides further VAR-based evidence that exogenous permanent increases in taxes have strong, permanent, and negative effects on TFP. He then rationalizes this finding with a DSGE model with endogenous TFP and human capital accumulation. In his model, learning-by-doing takes the form of an externality: tax increases reduce human capital accumulation and labor productivity, because the TFP of all firms depends on the aggregate level of human capital.

TFP-tax shocks orthogonality condition: Implications for the multipliers. What are the implications for the multipliers? We first look at the peak fiscal spending multiplier, which is estimated to be around 2 with confidence interval ranging from 1.4 to 2.6. This figure is slightly larger than, but not statistically different from, those found when imposing the TFP-tax shocks orthogonality condition. Quite differently, the impact on the tax multiplier is dramatic, with the peak value jumping from 0.7 to

3.6. This latter figure is statistically in line with the tax multiplier around 3 estimated with the MR instrument. Admittedly, allowing for the non-zero correlation does not come without costs. The confidence interval for the peak tax multiplier ranges from 0.2 to 5.9, hence it tends to be larger relative to the confidence interval obtained with the MR_t instrument alone. We will discuss this issue in more depth when we present the results obtained when using multiple instruments.

What is the driver of the substantial difference between the small tax multiplier found when imposing the TFP-tax shocks orthogonality and the one around 3 obtained by relaxing such restriction? Mertens and Ravn (2014) and Caldara and Kamps (2017) document the mapping between the output-tax elasticity and the tax multiplier. In particular, Caldara and Kamps (2017) derive an analytical expression for the tax multiplier and show that, if ψ_y^{tr} belongs to the $(-1, 4)$ range, there is a positive correlation between the elasticity and the multiplier. Table 1 documents the substantial change in such elasticity when the TFP-tax shocks orthogonality is relaxed, with $\widehat{\psi}_y^{tr}$ moving from 2.1 (orthogonality imposed) to 3.8 (non orthogonality allowed).[26] This latter number is pretty close to the 3.7 estimate provided by Mertens and Ravn (2011a), who employ long run restrictions to identify movements in output due to a technology shock to tackle the tax-output endogeneity bias. Moreover, the associated confidence interval (2.3, 4.9) implies that estimates around 3 that are often found in the literature are statistically equivalent to ours.

Output-tax elasticity equal to 3: How sensible? As stated above, Blanchard and Perotti (2002) rely on an output-tax elasticity equal to 2.08, which is the one estimated by the OECD (Giorno, Richardson, Roseveare, and van den Noord (1995)). Such elasticity is slightly larger than that estimated by Follette and Lutz (2010) on yearly data (1.7). Instead, our results point to output-tax elasticities equal to 3 or larger. Are such large elasticities sensible? Mertens and Ravn (2014) critically review the construction of output-tax elasticity by the OECD, which is a weighted average of the output elasticities for different tax revenue components (personal income taxes, social security contributions, indirect taxes and corporate income taxes). Each component-specific elasticity is a product of two elasticities, i.e., the tax base-tax revenues one and the output-tax base one. Mertens and Ravn (2014) point out that, while both elasticities are (somewhat necessarily) computed by relying on many questionable assumptions, the second one in particular is typically estimated via OLS regressions that do not tackle the

[26] Further details can be found in the Appendix.

obvious endogeneity issue affecting the output-tax relationship. Importantly, Mertens and Ravn (2014) show that such endogeneity issue is likely to induce a negative bias in the estimated output-tax elasticity. As pointed out above, Mertens and Ravn (2011a) tackle this bias by estimating the response of the US federal tax revenues to a technology shock identified with long run restrictions, and find a value for the elasticity equal to 3.7. Caldara and Kamps (2017) derive the output-tax elasticity implied by the sign restriction approach pursued by Mountford and Uhlig (2009), and find a value equal to 3. Overall, a value of the output-tax elasticity equal to 3 or larger does not seem at odds with the US data.

3.4 Multiple instruments approach

As stressed in the Introduction and in Section 3, the methodology we work with allows us to jointly employ multiple instruments. We then combine all instruments jointly to re-estimate both multipliers. We estimate the "augmented" model for $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, MR_t, AG_t, TFP_t)'$. To our knowledge, this is the first instance in the proxy-SVAR literature in which the number of employed external instruments k is the same as the number of variables n the original SVAR comprises, i.e., all shocks in the VAR are instrumented. As before, we analyze two cases, one in which we impose the TFP-tax shocks orthogonality condition, and the other one in which we do not.

Fiscal shocks: AG & MR & TFP instruments - orthogonality condition. Figure 2 shows the fiscal spending and tax multipliers when we assume that the orthogonality condition holds. The fiscal spending multiplier peaks at a value equal to 1.8, which is relatively similar to those found in the one-instrument scenarios. Again, this multiplier is precisely estimated as the associated confidence interval ranges from 1.3 to 2.2. The peak realization of the tax multiplier is 1, with associated confidence interval ranging from 0.4 to 1.3. While being larger that the one estimated with the TFP instrument only under the assumption of TFP-tax shocks orthogonality (0.76), this values is three times smaller than the one obtained with the TFP instrument only when the orthogonality condition is relaxed. From a statistical standpoint, this model - which is overidentified - is supported by the data, the p-value of the overidentification restriction test being 0.72.

Fiscal shocks: AG & MR & TFP instruments - non orthogonality. We next turn to the case where the TFP-tax shocks orthogonality condition is not imposed. Figure 2 documents the spectacularly different implications for the two multipliers. The impact of relaxing the orthogonality condition on the estimated fiscal spending multiplier is virtually zero, i.e., the multiplier is exactly the same as the one estimated when imposing such condition. Differently, the tax multiplier records a peak value of 2.8 vs. the value of 1 estimated when imposing the orthogonality condition; the associated confidence interval ranges from 0.4 to 4.3. Figure 2 shows that the estimated tax multiplier under non-orthogonality is clearly not contained in the confidence interval surrounding the point estimates of the tax multiplier conditional on the assumption of orthogonality. As before, the driver of this dramatic increase of the value of the tax multiplier under non-orthogonality is the impact of the orthogonality/non-orthogonality assumption on the estimated output-tax elasticity, which moves from 2.3 (orthogonality imposed) to 3.3 (orthogonality not imposed). Turning to the output-fiscal spending elasticity, our model allows us to estimate it jointly with the rest of the system. Our point estimate, which is zero, lends once again support to the Blanchard and Perotti (2002) zero restriction typically used in this literature. Finally, this model estimated with multiple instruments and the relaxation of the TFP-tax shocks orthogonality condition is overidentified and supported by the data with a p-value of 0.89.

Also in this case, a note on the uncertainty surrounding our tax multiplier estimates conditional on the non-orthogonality case is in order. While the empirical analysis points to a non-zero correlation between the TFP proxy and the tax shock, we observe that the uncertainty surrounding the point estimates of the tax multiplier is much larger in this case than when orthogonality is imposed. In this respect, the estimated tax multiplier appears less robust than the estimated fiscal spending multiplier.

The higher uncertainty surrounding the estimated tax multiplier relative to the fiscal spending multiplier is not surprising. Chahrour, Schmitt-Grohe, and Uribe (2012) generate artificial data from a real business cycle model featuring a number of exogenous shocks and real rigidities that have been shown to be important for fitting the US postwar business cycle. They report that for samples of size similar to the length of the postwar period, small sample errors can be substantial. In particular, given two distinct identification schemes that correctly recover the tax shock (Blanchard and Perotti (2002) vs. Romer and Romer (2010)), one cannot reject, at standard confidence levels, the hypothesis that the observed differences in the estimated tax multipliers are due to small sample uncertainty.[27] Their evidence points out that even in theory-driven

[27] To illustrate, given the true (peak) tax multiplier of 1.78, Table 2 in Chahrour, Schmitt-Grohe, and Uribe (2012) shows that in samples of $T = 250$ quarters, and conditional on the correct identification of tax innovations, the 68% confidence interval is (0.65, 2.57) when the tax shock is identified by the Blanchard and Perotti's (2002) method, and is (-0.09, 3.55) when regressions a la Romer and Romer

models, the variability associated with the tax multiplier is inherently large.

4 Robustness checks

Monetary policy. Our baseline model is a fiscal policy-only model. Research on the fiscal-monetary policy mix shows that the output effects of fiscal shocks are importantly affected by the systematic monetary policy in place (see Leeper (1991) for an early theoretical contribution, Leeper and Leith (2016) for a more recent review, and Rossi and Zubairy (2011) for an empirical analysis). To control for the role of monetary policy, we work with an enriched model featuring also CPI inflation (π_t) and the 3-month Treasury bill rate (r_t). Hence, our vector of modeled variables becomes $Y_t = (y_t, tr_t, g_t, \pi_t, r_t)'$. We estimate this model by augmenting the set of instruments employed so far (AG, MR, and TFP) with one additional shock series: the measure of oil shocks (OIL) proposed by Hamilton (2003) as an instrument for the inflation shock, as done by Caldara and Kamps (2017). Hence, we estimate one additional model, where $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, \pi_t, r_t, MR_t, AG_t, TFP_t, OIL_t)'$. As in the previous sections, we study two different scenarios, one in which the TFP-tax shocks orthogonality condition is imposed, and one in which it is relaxed.[28]

Figure 3 shows the estimated multipliers in these two scenarios for each of the two cases. As before, the estimated fiscal spending multiplier is insensitive to the treatment of the orthogonality condition, and peaks at a value equal to 1.8 regardless of the assumption on the TFP-tax shocks orthogonality. The uncertainty around these estimates is also relatively low, with confidence intervals ranging from 1.5 to 2.3. Quite differently, the peak of the tax multiplier varies substantially: it is equal to 1.1 when the orthogonality condition is imposed, while it jumps to 3.1 when the orthogonality condition is not imposed. As in the baseline case, the uncertainty surrounding the estimated tax multipliers is again larger compared with that of the spending multiplier. It is important to stress that this latter model, which is again overidentified, is supported

(2010) are used. Interestingly, they show that in these samples the tax multiplier estimated with one method can be larger or smaller than the tax multiplier estimated with the other method with almost equal probability.

[28] As already mentioned in the Introduction, in an additional check we add the monetary policy shocks series proposed by Romer and Romer (2004). We estimate two more AC-SVAR models, one with $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, \pi_t, r_t, MR_t, AG_t, TFP_t, RR_t)'$, and one with $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, \pi_t, r_t, MR_t, AG_t, TFP_t, OIL_t, RR_t)'$ We confine to the Appendix the results of these checks since the monetary policy shock series is available from 1969Q1. As a consequence, the sample used to estimate our AC-SVAR when we include this proxy is shorter (1969Q1-2006Q4), relative to the baseline model (1954Q1-2006Q4).

by the overidentification restrictions test which delivers a p-value of 0.99. For this proxy-SVAR, the estimated coefficient for the relevance of TFP proxy as an instrument for the output shock is $\widehat{\phi}_1 = 1.69$ and implies a correlation with the output shock of 57.4%, while the estimated coefficient for the relevance of TFP as an instrument for the tax shock is $\widehat{\phi}_2 = -0.64$ (with associated confidence interval equal to (-0.98, -0.46)) and implies a correlations with the tax shock of -21.7%. Overall, these empirical results tend to confirm those documented in the previous sections with a more parsimonious VAR.[29]

Fiscal foresight. Anticipation effects are likely to be of great relevance for the identification and transmission of fiscal policy shocks. This phenomenon, often referred to as "fiscal foresight", makes SVAR analysis complicated. Standard VARs, which rely on current and past shocks to interpret the dynamics of the modeled variables, can be "non-fundamental", in that they do not embed the information related to "news shocks", i.e., future shocks anticipated by rational agents. Leeper, Walker, and Yang (2013) work with different fiscal models and show that the anticipation of tax policy shocks severely affects VAR exercises aiming at identifying fiscal shocks. Ramey (2011) shows that government spending shocks estimated with standard fiscal SVARs are predictable, i.e., they are non-fundamental. Forni and Gambetti (2014) propose a test for "sufficient information" to detect non-fundamentalness that is based on checking the predictability of the VAR shocks of interest with information external to the VAR. We implement their test by regressing the identified fiscal shocks against lagged realizations of the factors extracted from the large set of macroeconomic and financial variables put together by McCracken and Ng (2016).[30] We use two sets of regressors: i) the first estimated factor, which explains about 55% of the variance of the data; ii) the first four factors, which explain almost 90%. Table 2 collects the p-values of the F-tests for information sufficiency we run over all our models. For each shock or

[29] As already mentioned, we have conducted an additional check in which we also add the monetary policy shocks series proposed by Romer and Romer (2004). We estimate two more AC-SVAR models, one with $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, \pi_t, r_t, MR_t, AG_t, TFP_t, RR_t)'$, and one with $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, \pi_t, r_t, MR_t, AG_t, TFP_t, OIL_t, RR_t)'$ The results of these robustness checks are very similar to those of the baseline model: the value of the spending multiplier does not depend on the orthogonality assumption, while the tax multiplier is quite sensitive to whether or not the orthogonality is imposed. As for all previous cases, the model where the orthogonality is not imposed, which is overidentified, is supported by the data. Full details of these checks are reported in the Appendix.

[30] To maximize the number of observations to compute the factors, we work with monthly data. We convert monthly factors in quarterly ones by taking the last realization of the factors in each quarter. Given that the factors are estimated with a sample starting in 1959, our regressions regard the sample 1959-2006.

combination of shocks, we consider two scenarios: a) an univariate scenario in which each fiscal shock is regressed over a constant and the estimated factors (first two rows of each shock/combination of shocks); b) a multivariate one in which the vector of fiscal shocks is regressed over constants and the estimated factors (last row of each shock/combination of shocks). All models pass the information sufficiency test.[31]

5 Conclusions

This paper estimates US government spending and tax multipliers using a flexible proxy-SVAR approach. Under proper conditions, the suggested methodology allows to relax the orthogonality hypothesis according to which proxies must be uncorrelated with non-instrumented structural shocks.

We estimate the fiscal spending multiplier to be about 1.6-2.1, no matter what the model specification and the set of fiscal and non fiscal instruments are. Differently, we find the tax multiplier to be 3.1 when a tax instrument only is employed, while its estimate drops to 0.7 when TFP is used as an instrument to estimate the effects of output shocks, and the tax multiplier is then recovered via the moments associated to the covariance matrix of the VAR residuals. We show that these different estimates, which replicate those obtained by key contributions in the literature, are due to the imposition of the TFP-tax shocks orthogonality condition when TFP is used as an instrument. When we relax such assumption (imposing non-binding restrictions elsewhere in the proxy-SVAR), we find a peak tax multiplier that ranges from 2.8 to 3.6 across a set of proxy-SVARs with 3.1 being the estimate favored by the data. Crucially, we show that the relaxation of this orthogonality condition is supported by the data. In line with what observed in the literature, our tax multipliers tend to be surrounded by larger statistical uncertainty relative to what we document for the fiscal spending multiplier. These findings are robust to the joint use of fiscal and non-fiscal instruments, and to enlarging the system to account for the role of monetary policy.

From a modeling standpoint, our estimates confirm the positive relationship between changes in the output-tax elasticity and variations in the tax multiplier previously detected via counterfactual simulations by Mertens and Ravn (2014) and analytically worked out by Caldara and Kamps (2017). Policy-wise, our paper unveils a trade-off

[31] Canova and Sahneh (2018) note that Granger-causality tests might over-reject fundamentalness because of aggregation issues affecting the variables modeled with the VAR. The Forni and Gambetti (2014) tests we conducted over the different specifications of our VARs never reject fundamentalness. Hence, our VARs are not subject to the Canova-Sahneh critique.

fiscal policymakers might have to face when designing their fiscal plans. On the one hand, our point estimates point to a tax multiplier larger than the spending one. On the other hand, the former is surrounded by a larger statistical uncertainty. Hence, policymakers with an aversion towards parameter uncertainty may want to assign a larger weight to the fiscal spending lever than to taxes. We see the study of optimal fiscal policy under parameter uncertainty as the natural continuation of this research agenda.

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Instruments	ψ_y^g	ψ_y^{tr}	$\mathcal{M}g$	$\mathcal{M}tr$
AG only	-0.0029 $(-0.0275;0.0245)$	–	1.6531 (1.1518;2.0546)	–
MR only	–	3.3615 (2.2459;4.4506)	–	3.0863 (1.4182;4.8065)
TFP only - orth.	-0.1434 $(-0.2446;-0.0441)$	2.1142 (1.8285;2.4671)	1.9134 (1.2678;2.3752)	0.7583 $(-0.0015;0.9313)$
TFP only - non orth.	-0.3430 $(-0.4398;-0.1192)$	3.8566 (2.3135;4.9939)	2.1842 (1.3902;2.5508)	3.5831 (0.2393;5.8781)
AG & MR & TFP - orth.	-0.0053 $(-0.0295;0.0214)$	2.3115 (2.0936;2.6435)	1.7885 (1.3421;2.2185)	1.0409 (0.3851;1.2642)
AG & MR & TFP - non orth.	-0.0052 $(-0.0293;0.0220)$	3.3487 (2.4437;4.3210)	1.7826 (1.2885;2.1725)	2.8299 (0.3795;4.2754)
AG & MR & TFP & OIL - orth.	-0.0175 $(-0.0521;-0.0029)$	2.6225 (1.7481;3.2631)	1.8062 (1.5118;2.3833)	1.0586 (0.2510;1.4164)
AG & MR & TFP & OIL - non orth.	-0.0174 $(-0.0497;0.0014)$	3.6022 (2.5275;4.8102)	1.7982 (1.4892;2.3558)	3.1246 (0.6505;4.9533)

Table 1: **Estimated elasticities and multipliers: Linearly detrended data.** Bootstrapped (16th,84th) percentiles below point estimates based on 1,000 repetitions and the Moving Block-Bootstrap method. Multipliers: Peak values.

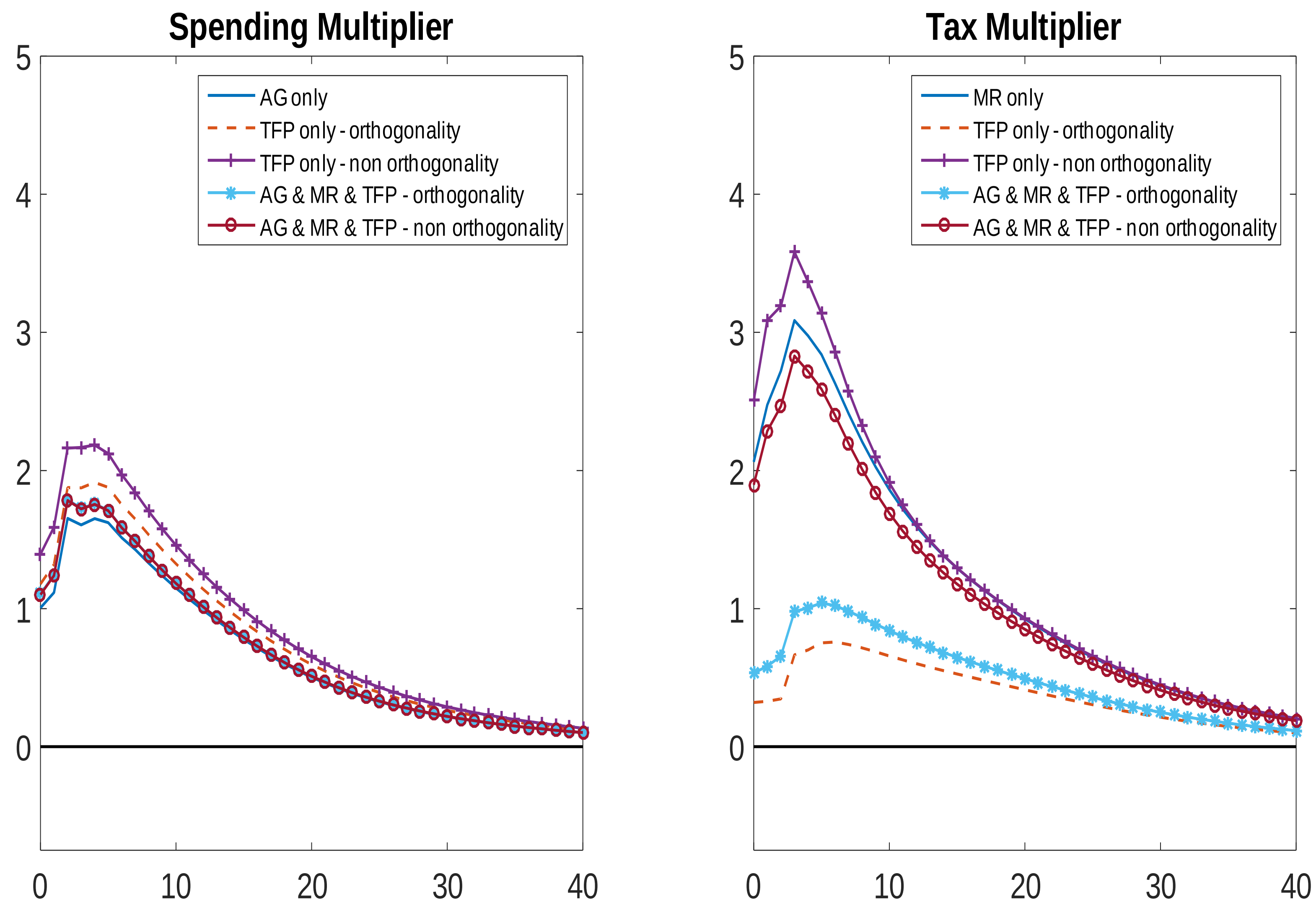

Figure 1: **Fiscal multipliers: Role of instruments.** Model with fiscal spending, taxes, output. AG: Auerbach and Gorodnichenko's (2012) fiscal spending instrument. MR: Mertens and Ravn's (2012) tax spending instrument. TFP: Fernald's (2014) TFP instrument.

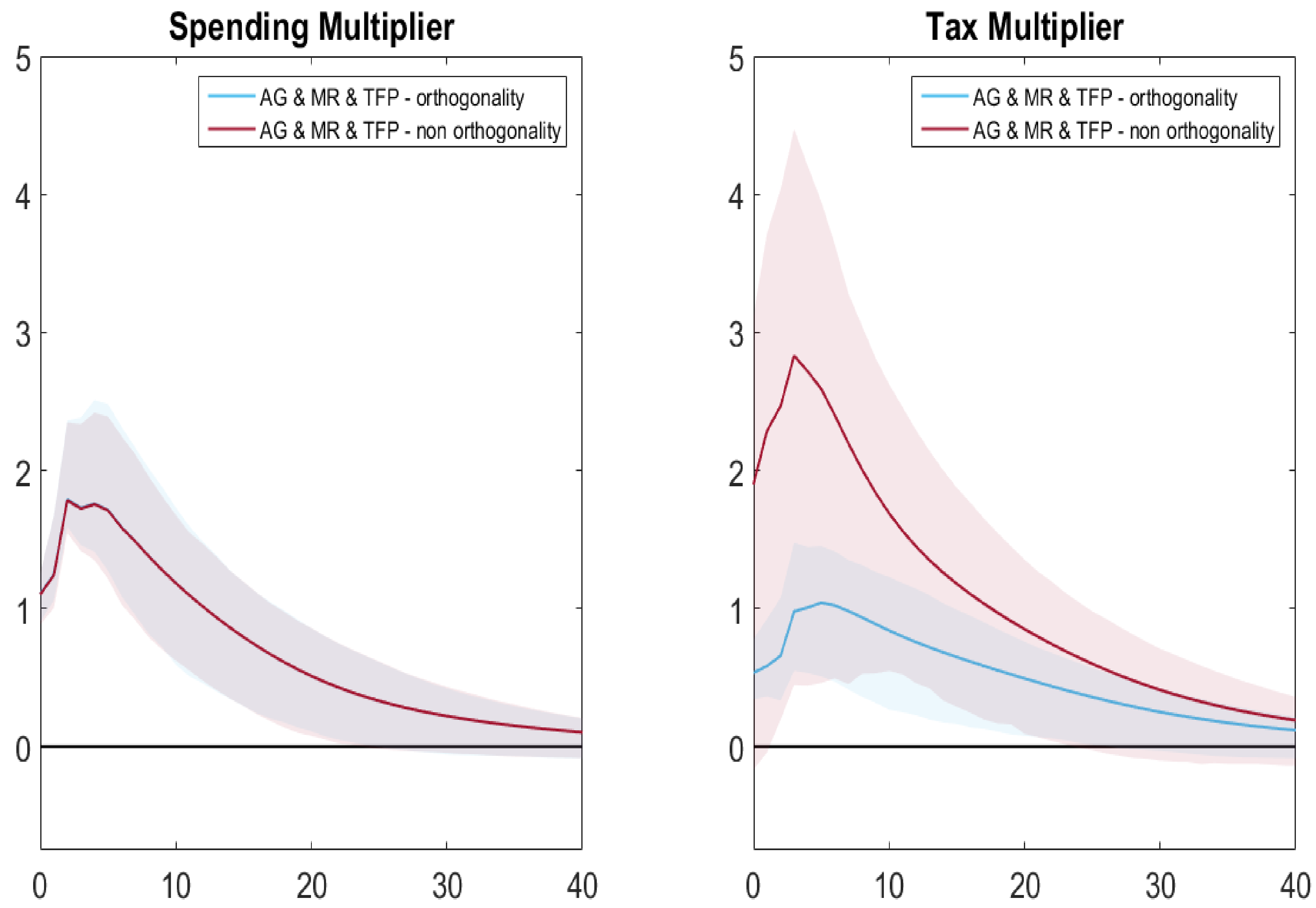

Figure 2: **Fiscal multipliers with alternative sets of instruments: Statistical difference.** Shaded areas: 68%-MBB confidence bands, see Jentsch and Lunsford (2019b). AG: Auerbach and Gorodnichenko's (2012) fiscal spending instrument. MR: Mertens and Ravn's (2012) tax spending instrument. TFP: Fernald's (2014) TFP instrument.

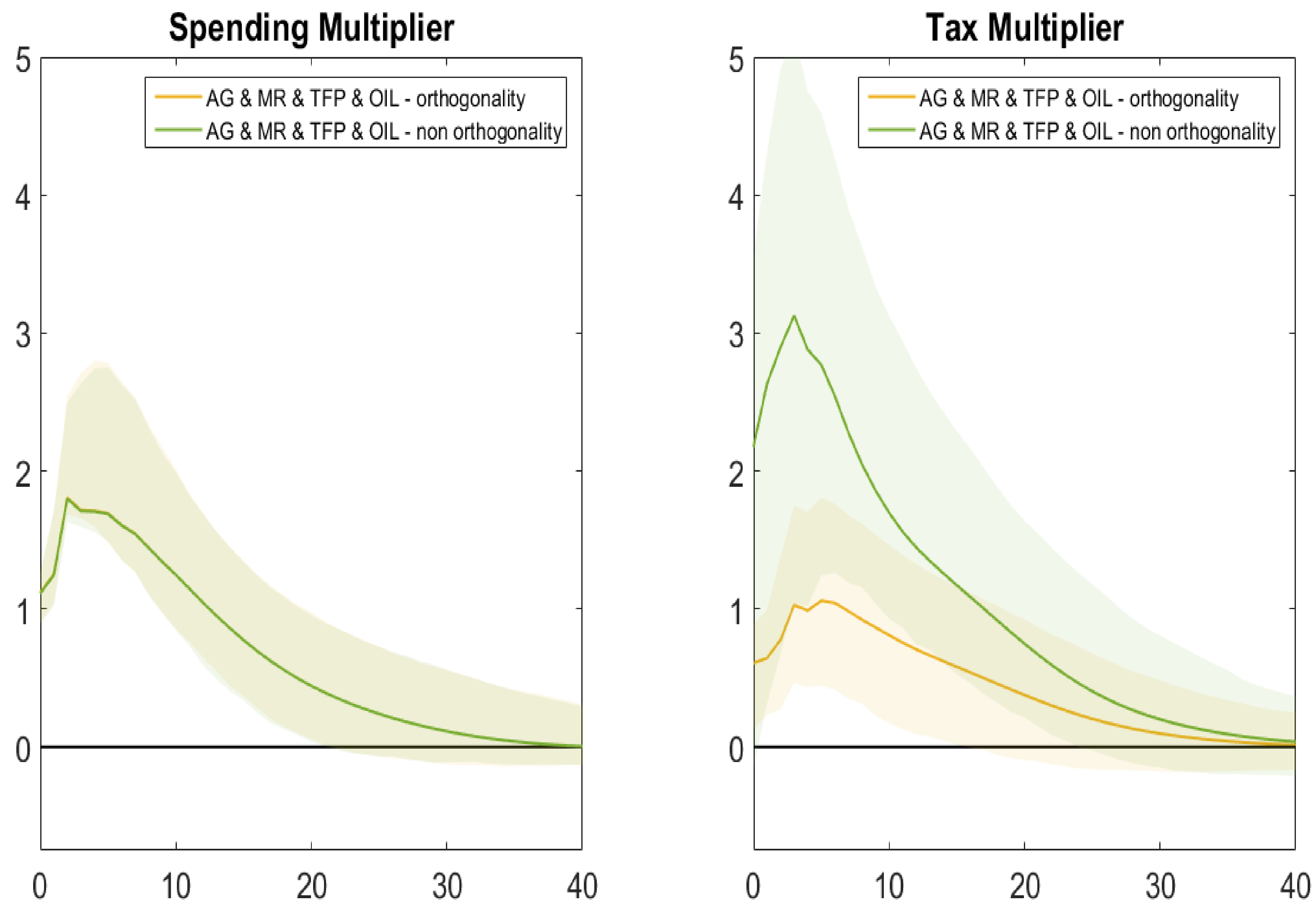

Figure 3: **Fiscal multipliers: Model with Monetary Policy.** Model with fiscal spending, taxes, output, inflation, 3-month Treasury bill rate. Shaded areas: 68%-MBB confidence bands, see Jentsch and Lunsford (2019b). AG: Auerbach and Gorodnichenko's (2012) fiscal spending instrument. MR: Mertens and Ravn's (2012) tax spending instrument. TFP: Fernald's (2014) TFP instrument. OIL: Hamilton's (2003) instrument.

Instruments	Shocks	$F_t = (F_{1,t})$	$F_t = (F_{1,t}, F_{2,t}, F_{3,t}, F_{4,t})$
AG only	$\hat{\varepsilon}_t^{tr}$	0.3612	0.2484
	$\hat{\varepsilon}_t^{g}$	0.8156	0.6457
	$\hat{\varepsilon}_t^{y}$	0.6922	0.4343
MR only	$\hat{\varepsilon}_t^{tr}$	0.1414	0.1326
	$\hat{\varepsilon}_t^{g}$	0.8028	0.7641
	$\hat{\varepsilon}_t^{y}$	0.3719	0.3248
TFP only - orth.	$\hat{\varepsilon}_t^{tr}$	0.3600	0.2697
	$\hat{\varepsilon}_t^{g}$	0.8942	0.5046
	$\hat{\varepsilon}_t^{y}$	0.6843	0.4088
TFP only - non orth.	$\hat{\varepsilon}_t^{tr}$	0.0250	0.1128
	$\hat{\varepsilon}_t^{g}$	0.6242	0.3856
	$\hat{\varepsilon}_t^{y}$	0.1298	0.1983
AG & MR & TFP - orth.	$\hat{\varepsilon}_t^{tr}$	0.4615	0.2487
	$\hat{\varepsilon}_t^{g}$	0.8104	0.6452
	$\hat{\varepsilon}_t^{y}$	0.7619	0.4432
AG & MR & TFP - non orth.	$\hat{\varepsilon}_t^{tr}$	0.1293	0.1598
	$\hat{\varepsilon}_t^{g}$	0.8107	0.6451
	$\hat{\varepsilon}_t^{y}$	0.3808	0.3287
AG & MR & TFP & OIL - orth.	$\hat{\varepsilon}_t^{tr}$	0.9990	0.5354
	$\hat{\varepsilon}_t^{g}$	0.3827	0.3207
	$\hat{\varepsilon}_t^{y}$	0.6597	0.4623
AG & MR & TFP & OIL - non orth.	$\hat{\varepsilon}_t^{tr}$	0.1289	0.3608
	$\hat{\varepsilon}_t^{g}$	0.3208	0.3826
	$\hat{\varepsilon}_t^{y}$	0.2190	0.3959

Table 2: **Informational sufficiency: Forni and Gambetti (2014) test.** P-values of F-tests reported in the Table. Per each shock or combination of shocks, we consider two scenarios: a) each fiscal shock regressed over a constant and the estimated factors (first two rows of each shock/combination of shocks); b) the vector of fiscal shocks regressed over constants and the estimated factors (last row of each shock/combination of shocks). Two lags of the factors included in all cases.

Appendix of the paper "Are Fiscal Multipliers Estimated with Proxy-SVARs Robust?" by Angelini, Caggiano, Castelnuovo, and Fanelli

Estimates of the $\widetilde{G}$ matrix

We report below the estimates of the $\widetilde{G}$ matrix in the $u_t = \widetilde{G}\varepsilon_t$ system for the cases analyzed in the paper, together with the restrictions imposed to achieve identification and the p-values related to the whole AC-VAR structure. The cells of the $\widetilde{G}$ matrix report the point estimates and the associated bootstrap standard errors based on 1,000 repetitions and the MBB method.

Fiscal spending shock: Auerbach and Gorodnichenko's (2012) instrument. $W_t = (y_t, tr_t, g_t, AG_t)'$. Additional restriction: $\varepsilon_t^y \nrightarrow g_t$; p-value for overidentifying restrictions: no overidentifying restrictions.

$$\begin{pmatrix} \widehat{u}_t^y \\ \widehat{u}_t^{tr} \\ \widehat{u}_t^g \\ \widehat{v}_{AG,t} \end{pmatrix} = \begin{pmatrix} \underset{(0.0072;0.0122)}{0.0073} & \underset{(-0.0141;-0.0021)}{-0.0033} & \underset{(0.0023;0.0033)}{0.0025} & 0 \\ \underset{(0.0177;0.0533)}{0.0207} & \underset{(0.0072;0.0244)}{0.0154} & \underset{(-0.0008;0.0037)}{0.0018} & 0 \\ 0 & \underset{(-0.0003;0.0001)}{0.0000} & \underset{(0.0121;0.0144)}{0.0124} & 0 \\ 0 & 0 & \underset{(0.0129;0.0148)}{0.0129} & \underset{(0.0028;0.0048)}{0.0035} \end{pmatrix} \begin{pmatrix} \widehat{\varepsilon}_t^y \\ \widehat{\varepsilon}_t^{tr} \\ \widehat{\varepsilon}_t^g \\ \widehat{\omega}_{AG,t}^0 \end{pmatrix}$$

Tax shock: Mertens and Ravn's (2012) instrument. $W_t = (y_t, tr_t, g_t, MR_t)'$. Additional restriction: ε_t^y shocks $\nrightarrow g_t$; p-value overidentifying restrictions: no overidentifying restrictions.

$$\begin{pmatrix} \widehat{u}_t^y \\ \widehat{u}_t^{tr} \\ \widehat{u}_t^g \\ \widehat{v}_{MR,t} \end{pmatrix} = \begin{pmatrix} \underset{(0.0061;0.0084)}{0.0067} & \underset{(-0.0068;-0.0037)}{-0.0045} & \underset{(0.0016;0.0033)}{0.0021} & 0 \\ \underset{(0.0214;0.0295)}{0.0226} & \underset{(0.0062;0.0159)}{0.0120} & \underset{(0.0002;0.0064)}{0.0031} & 0 \\ 0 & \underset{(-0.0038;0.0005)}{-0.0012} & \underset{(0.0112;0.0150)}{0.0123} & 0 \\ 0 & \underset{(0.0188;0.0489)}{0.0428} & 0 & \underset{(0.1292;0.1636)}{0.1492} \end{pmatrix} \begin{pmatrix} \widehat{\varepsilon}_t^y \\ \widehat{\varepsilon}_t^{tr} \\ \widehat{\varepsilon}_t^g \\ \widehat{\omega}_{MR,t}^0 \end{pmatrix}$$

Fiscal shocks: Fernald's (2014) instrument - orthogonality. $W_t = (y_t, tr_t, g_t, TFP_t)'$. Additional restrictions: ε_t^y shocks $\nrightarrow g_t$ and ε_t^g shocks $\nrightarrow tr_t$; p-value overidentifying restrictions: 0.4089 (1 df).

$$\begin{pmatrix} \widehat{u}_t^y \\ \widehat{u}_t^{tr} \\ \widehat{u}_t^g \\ \widehat{v}_{TFP,t} \end{pmatrix} = \begin{pmatrix} \underset{(0.0075;0.0091)}{0.0078} & \underset{(-0.0017;-0.0005)}{-0.0012} & \underset{(0.0028;0.0038)}{0.0030} & 0 \\ \underset{(0.0156;0.0202)}{0.0166} & \underset{(0.0176;0.0227)}{0.0198} & 0 & 0 \\ 0 & \underset{(0.0005;0.0025)}{0.0015} & \underset{(0.0113;0.0148)}{0.0123} & 0 \\ \underset{(1.6588;2.2557)}{1.8570} & 0 & 0 & \underset{(2.4732;2.8882)}{2.5000} \end{pmatrix} \begin{pmatrix} \widehat{\varepsilon}_t^y \\ \widehat{\varepsilon}_t^{tr} \\ \widehat{\varepsilon}_t^g \\ \widehat{\omega}_{TFP,t}^0 \end{pmatrix}$$

Fiscal shocks: Fernald's (2014) instrument - non orthogonality. $W_t = (y_t, tr_t, g_t, TFP_t)'$. Additional restrictions: ε_t^y shocks $\nrightarrow g_t$ and ε_t^{tr} shocks $\nrightarrow g_t$; p-value overidentifying restrictions: no overidentifying restrictions. Non-orthogonal TFP.

$$\begin{pmatrix} \widehat{u}_t^y \\ \widehat{u}_t^{tr} \\ \widehat{u}_t^g \\ \widehat{v}_{TFP,t} \end{pmatrix} = \begin{pmatrix} \underset{(0.0053;0.0079)}{0.0062} & \underset{(-0.0065;-0.0038)}{-0.0044} & \underset{(0.0031;0.0042)}{0.0035} & 0 \\ \underset{(0.0229;0.0289)}{0.0239} & \underset{(0.0011;0.0142)}{0.0097} & 0 & 0 \\ 0 & \underset{(0.0011;0.0028)}{0.0024} & \underset{(0.0108;0.0149)}{0.0121} & 0 \\ \underset{(1.4205;2.1011)}{1.6333} & \underset{(-1.5100;-0.6350)}{-0.8906} & 0 & \underset{(2.4959;2.9134)}{2.4976} \end{pmatrix} \begin{pmatrix} \widehat{\varepsilon}_t^y \\ \widehat{\varepsilon}_t^{tr} \\ \widehat{\varepsilon}_t^g \\ \widehat{\omega}_{TFP,t}^0 \end{pmatrix}$$

Log-levels

Table A1 below reports the estimates of the fiscal elasticities and multipliers when data are modeled in log-levels. As the Table shows, the main results of the paper are confirmed

TFP-tax shocks orthogonality condition: Additional evidence

A look at the data offers prima facie support to the correlation hypothesis. A necessary - but not sufficient - condition for the TFP proxy to be correlated with the tax shock is the detection of non-zero correlation between the TFP proxy, output and tax revenues in the data. In Figure A1, we plot the contemporaneous correlations between the VAR residuals of output ($\hat{u}_t^y$), tax revenues ($\hat{u}_t^{tr}$), and public spending ($\hat{u}_t^g$) on the one hand, and TFP residuals on the other ($\hat{v}_t^{TFP}$). Such reduced form correlations point to a significant (at a 1% level) comovement not only between TFP and output residuals (54%), but also between TFP and tax revenues residuals (38%). Differently, and as expected, the correlation between TFP and spending residuals is not significantly different from zero (-0.05%).

We use the evidence coming from the reduced form residuals as a motivation for a more formal scrutiny of the validity of the orthogonality assumption between TFP and the tax shock. As a preliminary step, we revisit the exogeneity test in Caldara and Kamps (2017). They test the exogeneity of the TFP instrument by regressing it against the Mertens and Ravn's (2011) narrative measure of tax shock and the Ramey's (2011) narrative measure of expected exogenous changes in military spending. The t and F-tests reported in Caldara and Kamps (2017) return, respectively, individually and jointly insignificant estimated coefficients, supporting the assumption of the TFP instrument as exogenous. However, the residuals in the Caldara and Kamps' (2017) regression display a significant first-order autocorrelation and conditional heteroskedasticity. Taking this into account and computing HAC standard errors leaves room for a non-negligible correlation: the t-statistic of the estimated coefficient of the measure of tax shocks increases (in absolute value) from 1.53 to 1.92, while the F-statistic goes from 1.44 up to 1.88.

Cumulative spending multipliers

Figure A2 reports the cumulative spending multiplier, defined as

$$\mathcal{M}^c_{p_h} = \frac{\sum_h \beta y_h}{\sum_h \beta p_h} \frac{GDP}{P}$$

for both the orthogonality and the non-orthogonality cases. As the Figure shows, results are robust to the orthogonality assumption, and the estimated values range between 1.2 and 1.7.

Romer and Romer (2004) monetary policy shock

In this Section, we discuss the results on the spending and the tax multiplier obtained when we add the Romer and Romer's (2004) monetary policy shocks series to the set of the non-fiscal proxies. The results are obtained by estimated two additional AC-SVAR models, one with $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, \pi_t, r_t, MR_t, AG_t, TFP_t, RR_t)'$, and one with $W_t = (Y_t', Z_t')' = (y_t, tr_t, g_t, \pi_t, r_t, MR_t, AG_t, TFP_t, OIL_t, RR_t)'$. The two VARs are estimated using the sample 1969Q1 - 2006Q4. Table A2 reports the same information of Table 1 in the paper, with four extra rows that refer to the additional robustness checks with the RR instrument. The main findings of the paper are confirmed: while the estimated spending multiplier is not affected by the assumption on the TFP-tax shocks orthogonality, the estimated tax multiplier changes substantially, jumping from around 1.9 to 4.8 in the first estimated model, and from 2.1 to 5.4 in the second case when all five proxies are jointly modeled. Relative to the cases reported in the paper, three multipliers obtained when using the monetary policy shocks series are estimated more imprecisely. This is not surprising, given the shorter sample size available. The spending and tax multipliers are plotted in Figures A3 and A4.

It is important to stress that also for the two estimated models including the Romer and Romer monetary policy shocks series the assumption of orthogonality is rejected by the data. For these proxy-SVARs, the estimated coefficients for the relevance of TFP proxy as an instrument for the tax shock, $\widehat{\phi}_2$, are equal to -0.79 (in the model with four instruments) and -0.74 (in the model with five instruments). The associated confidence intervals are equal to (-1.26, -0.47) and (-1.22,-0.37), respectively. The implied correlations with the tax shock are equal to -23% and -22%, respectively. Overall, these empirical results tend to confirm those documented in the paper.

Marginal Efficiency of Investment

We check whether the key finding of the non-orthogonality between the non-fiscal proxy and the tax shocks is specific to the TFP instrument we have employed in our baseline model. To this end, we use as an alternative proxy for output shocks the Marginal Efficiency of Investment (MEI) proposed by Justiniano, Primiceri, and Tambalotti (2011).

Figure A5 reports the spending and the tax multipliers obtained for our baseline three-variate VAR when use only MEI as an instrument. As for the baseline analysis, we report the multipliers along with the 68% confidence bands in two cases, one where the orthogonality between MEI and the tax shocks is imposed, and one where the orthogonality is not imposed. Figure A6 reports the same multipliers for the case where we jointly use the fiscal and the non-fiscal (MEI) proxies. The baseline findings are confirmed: while the spending multipliers are not affected by the orthogonality condition, the tax multiplier clearly depends on whether the orthogonality has been imposed. When the orthogonality assumption is relaxed, the estimated tax multiplier increases substantially.

The peak multipliers are reported in Table A3. When we use MEI instead of TFP as the non-fiscal proxy, we get very robust estimates of the spending multipliers, in the range of 1.7 and 2, regardless of the VAR specification. The estimates of the tax multipliers are instead quite heterogeneous: when the orthogonality assumption is imposed, we find a tax multipliers below 1 (0.7 when we use MEI as the only instrument, and 0.9 when we jointly use all three instruments); when the orthogonality assumption is not imposed, we get a much larger tax multiplier (1.79 when we use MEI in isolation, and 2.78 when we jointly use the three fiscal and non-fiscal proxies).

Is orthogonality between MEI and the tax shock supported by the data? Table A4 reports the estimated relevance coefficients along with the 68% confidence bands. As in the baseline case, MEI turns out to be a relevant proxy for output shocks ($\widehat{\phi}_1$ is strongly significant) and, crucially for our analysis, it is also a relevant proxy for tax shocks: the confidence intervals for the estimated parameter $\widehat{\phi}_2$ do not contain 0. This finding confirms that the orthogonality assumption between the non-fiscal proxies and the tax shocks is not specific to TFP, but is confirmed also when another proxy, which is a relevant instrument for output shocks, is used.

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Instruments	ψ_y^g	ψ_y^{tr}	$\mathcal{M}g$	$\mathcal{M}tr$
AG olny	-0.0018 $(-0.0249;0.0276)$	–	1.6874 (1.1562;2.1315)	–
MR olny	–	3.4127 (2.4173;4.4491)	–	3.0896 (1.472;4.9377)
TFP olny - orth.	-0.1446 $(-0.2621;-0.0578)$	2.1512 (1.8659;2.5268)	1.8707 (1.1211;2.2814)	1.3733 (0.5828;1.6376)
TFP olny - non orth.	-0.3174 $(-0.4490;-0.1373)$	3.7103 (2.5948;4.9870)	2.1566 (1.2464;2.5188)	4.0730 (1.0001;6.5062)
AG & MR & TFP - orth.	-0.0036 $(-0.0267;0.0244)$	2.3479 (2.0922;2.7218)	1.7316 (1.1290;2.1119)	1.5272 (0.8152;1.8654)
AG & MR & TFP - non orth.	-0.0037 $(-0.0276;0.0232)$	3.3303 (2.5368;4.2126)	1.7287 (1.1753;2.1029)	3.3570 (0.6015;4.9469)
AG & MR & TFP & OIL - orth.	-0.0172 $(-0.0489;0.0012)$	2.7554 (1.8069;3.4249)	1.7777 (1.4935;2.3302)	1.5024 (0.4737;2.0928)
AG & MR & TFP & OIL - non orth.	-0.0172 $(-0.0465;0.0038)$	3.7114 (2.7018;4.8641)	1.7738 (1.4661;2.3333)	3.5069 (1.1912;5.3720)
AG & MR & TFP & RR - orth.	-0.0012 $(-0.0484;0.0196)$	2.7544 (1.9668;3.8095)	1.9587 (1.6633;2.5349)	1.9400 $(-0.4614;2.5751)$
AG & MR & TFP & RR - non orth.	-0.0010 $(-0.0450;0.0179)$	4.1732 (3.5210;6.1593)	1.9520 (1.6684;2.5558)	4.8399 (2.0368;7.6300)
AG & MR & TFP & OIL & RR - orth.	-0.0002 $(-0.0448;0.0162)$	2.8440 (1.9335;3.9019)	1.9587 (1.6526;2.5323)	2.1484 (0.6341;2.8322)
AG & MR & TFP & OIL & RR - non orth.	0.0000 $(-0.0450;0.0182)$	4.3955 (3.9353;6.5410)	1.9510 (1.7222;2.5939)	5.4441 (4.0715;8.8116)

Table A1: **Estimated elasticities and multipliers:** Data in log-levels. Bootstrapped 68 confidence intervals (based on 1,000 repetitions and the MBB method) below point estimates. Multipliers: Peak values.

Instruments	ψ_y^g	ψ_y^{tr}	$\mathcal{M}g$	$\mathcal{M}tr$
AG olny	−0.0029 (−0.0275;0.0245)	–	1.6531 (1.1518;2.0546)	–
MR olny	–	3.3615 (2.2459;4.4506)	–	3.0863 (1.4182;4.8065)
TFP olny - orth.	−0.1434 (−0.2446;−0.0441)	2.1142 (1.8285;2.4671)	1.9134 (1.2678;2.3752)	0.7583 (−0.0015;0.9313)
TFP olny - non orth.	−0.3430 (−0.4398;−0.1192)	3.8566 (2.3135;4.9939)	2.1842 (1.3902;2.5508)	3.5831 (0.2393;5.8781)
AG & MR & TFP - orth.	−0.0053 (−0.0295;0.0214)	2.3115 (2.0936;2.6435)	1.7885 (1.3421;2.2185)	1.0409 (0.3851;1.2642)
AG & MR & TFP - non orth.	−0.0052 (−0.0293;0.0220)	3.3487 (2.4437;4.321)	1.7826 (1.2885;2.1725)	2.8299 (0.3795;4.2754)
AG & MR & TFP & OIL - orth.	−0.0175 (−0.0521;−0.0029)	2.6225 (1.7481;3.2631)	1.8062 (1.5118;2.3833)	1.0586 (0.251;1.4164)
AG & MR & TFP & OIL - non orth.	−0.0174 (−0.0497;0.0014)	3.6022 (2.5275;4.8102)	1.7982 (1.4892;2.3558)	3.1246 (0.6505;4.9533)
AG & MR & TFP & RR - orth.	−0.0024 (−0.0475;0.0149)	2.6132 (1.6008;3.6452)	1.9519 (1.7214;2.5626)	1.3062 (−0.3932;1.7091)
AG & MR & TFP & RR - non orth.	−0.0022 (−0.0472;0.0164)	3.7148 (2.7819;5.2476)	1.9464 (1.7974;2.6272)	3.1205 (−0.8322;4.6072)
AG & MR & TFP & OIL & RR - orth.	0.0044 (−0.0375;0.0210)	2.3364 (1.5458;3.1043)	1.9320 (1.7349;2.6139)	1.9497 (0.8712;2.4378)
AG & MR & TFP & OIL & RR - non orth.	0.0045 (−0.0407;0.0220)	3.2857 (2.0785;4.5706)	1.9264 (1.7584;2.5913)	3.4216 (−1.0148;4.6371)

Table A2: **Estimated elasticities and multipliers:** Data in detrended. Bootstrapped 68 confidence intervals (based on 1,000 repetitions and the MBB method) below point estimates. Multipliers: Peak values.

Instruments	ψ_y^g	ψ_y^{tr}	$\mathcal{M}g$	$\mathcal{M}tr$
MEI only - orth.	-0.1497 $(-0.2458;-0.0934)$	2.0291 (1.8410;2.3890)	1.9350 (1.4445;2.3686)	0.7049 (0.0833;0.9351)
MEI only - non orth.	-0.2230 $(-0.3213;-0.1120)$	2.9174 (1.3498;3.8683)	2.0052 (1.4736;2.4255)	1.7934 $(-0.1262;2.7982)$
AG & MR & MEI - orth.	-0.0112 $(-0.0266;0.0126)$	2.1505 (1.9400;2.4410)	1.7382 (1.1258;2.1002)	0.9067 (0.2422;1.1841)
AG & MR & MEI - non orth.	-0.0112 $(-0.0241;0.0112)$	3.3340 (2.0170;4.2533)	1.7377 (1.1271;2.0717)	2.7831 $(-0.0655;4.2768)$

Table A3: **Estimated elasticities and multipliers:** Data in detrended. Bootstrapped 68 confidence intervals (based on 1,000 repetitions and the MBB method) below point estimates. Multipliers: Peak values.

Instruments	$\hat{\phi}_1$	$\hat{\phi}_2$
MEI only - orth.	3.8760 (3.7222;4.7461)	–
MEI only - non orth.	3.7247 (3.5458;4.8586)	−1.0739 (−2.1674;−0.2641)
AG & MR & MEI - orth.	3.8771 (3.4320;4.5310)	–
AG & MR & MEI - non orth.	3.5916 (3.2349;4.3986)	−1.4597 (−2.4995;−0.6217)

Table A4: **Estimated relevance parameters:** Data in detrended. Bootstrapped 68 confidence intervals (based on 1,000 repetitions and the MBB method) below point estimates.

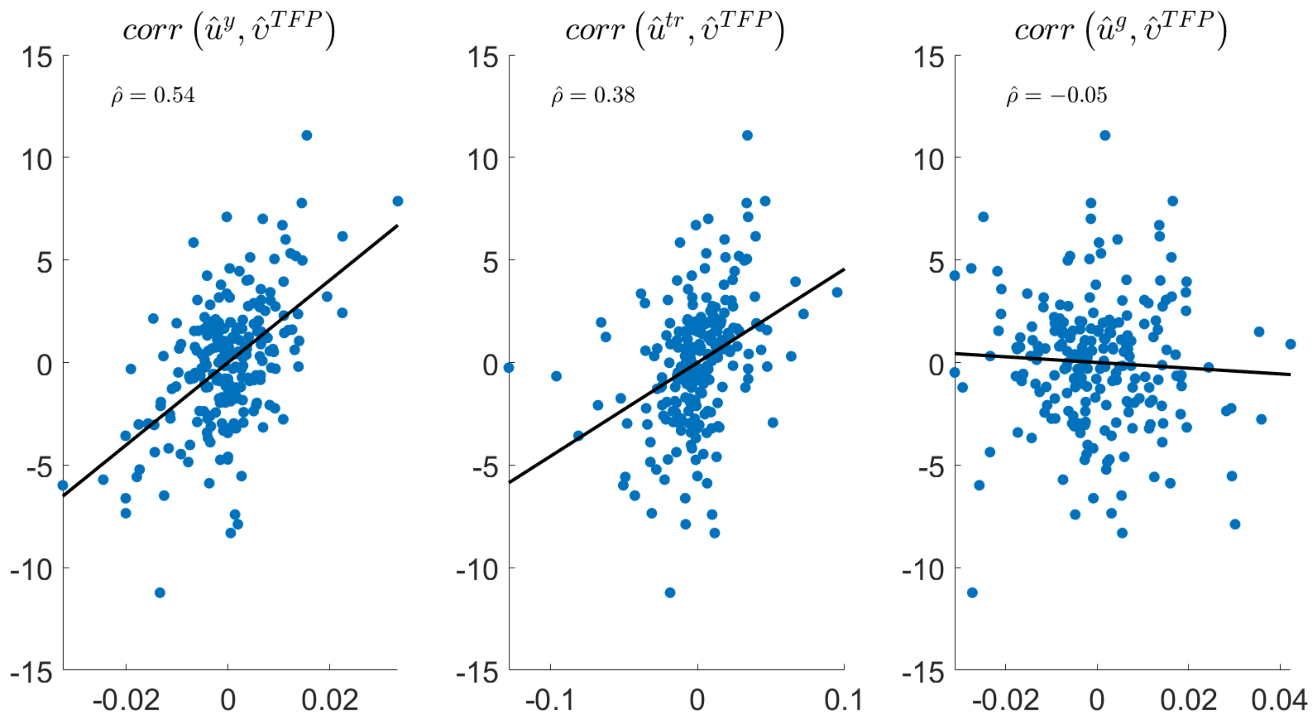

Figure A1: **Relevance of the TFP instrument: Correlation with output and tax revenues.** Scatter plots and correlations based on the residuals of our estimated AC-VAR with output, tax revenues, spending, and Fernald's (2014) TFP series.

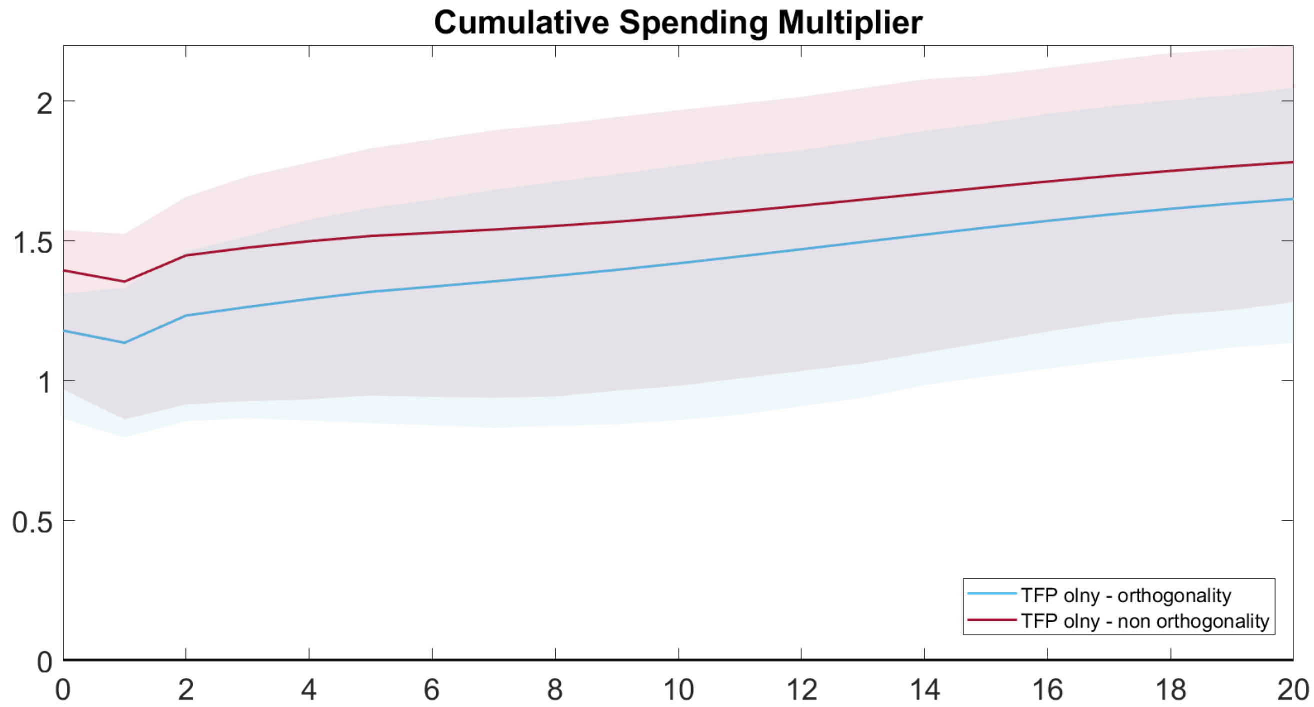

Figure A2: **Cumulative spending multipliers and 68 bootstrapped confidence intervals based on 1,000 repetitions and the MBB method.**

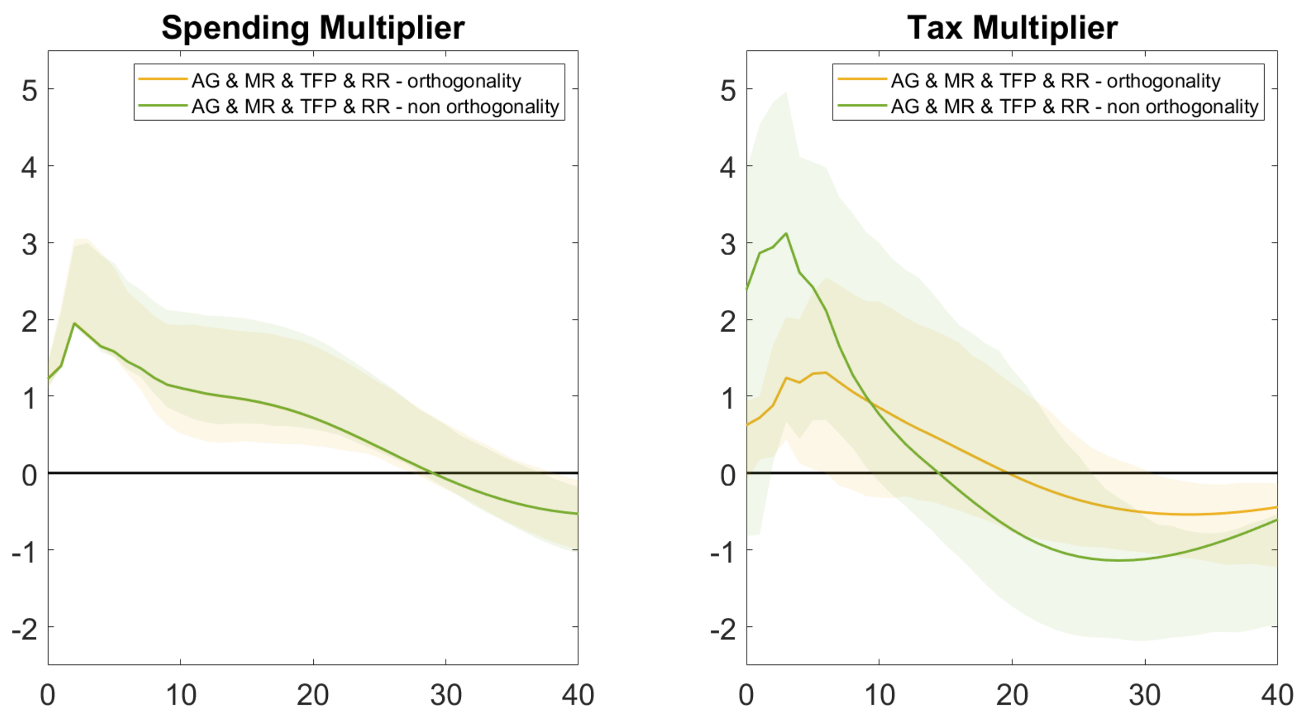

Figure A3: **Spending and tax multipliers: Romer and Romer monetary policy shock, four instruments case.**

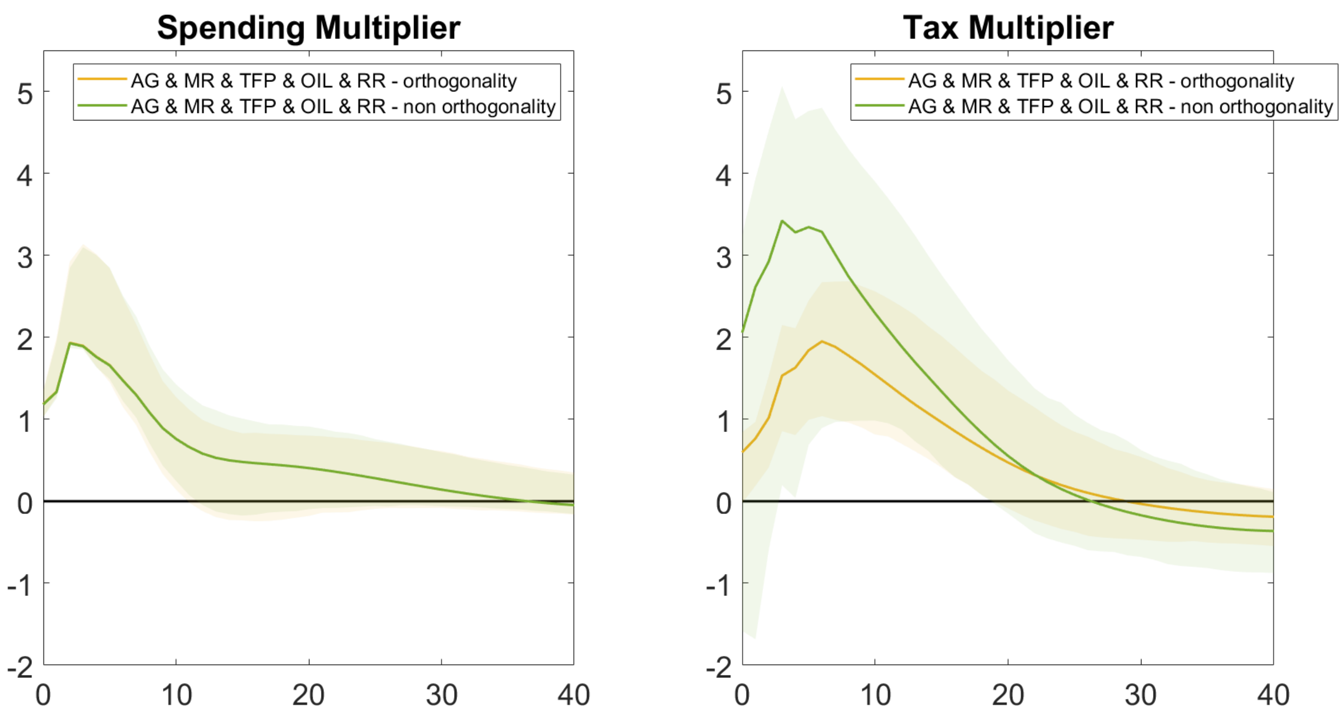

Figure A4: **Spending and tax multipliers: Romer and Romer monetary policy shock, five instruments case.**

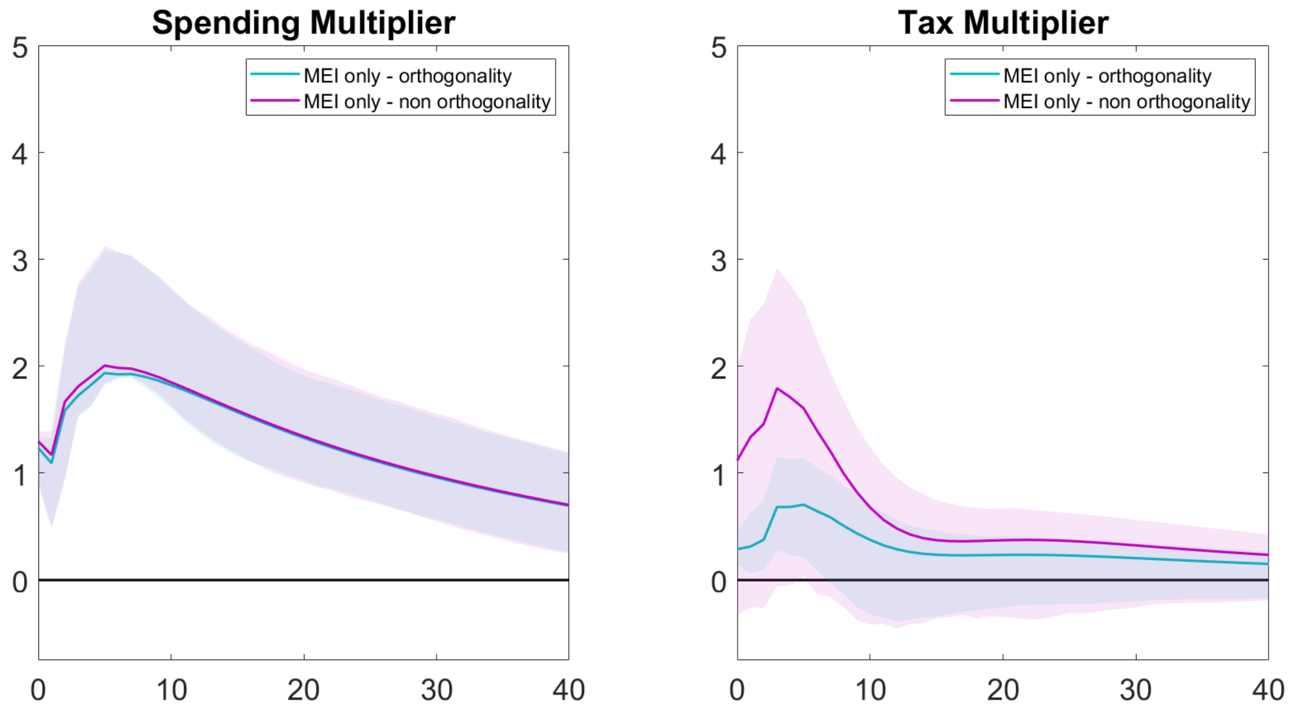

Figure A5: **Spending and tax multipliers:** MEI: Justiniano, Primiceri, and Tambalotti's (2011) MEI instrument

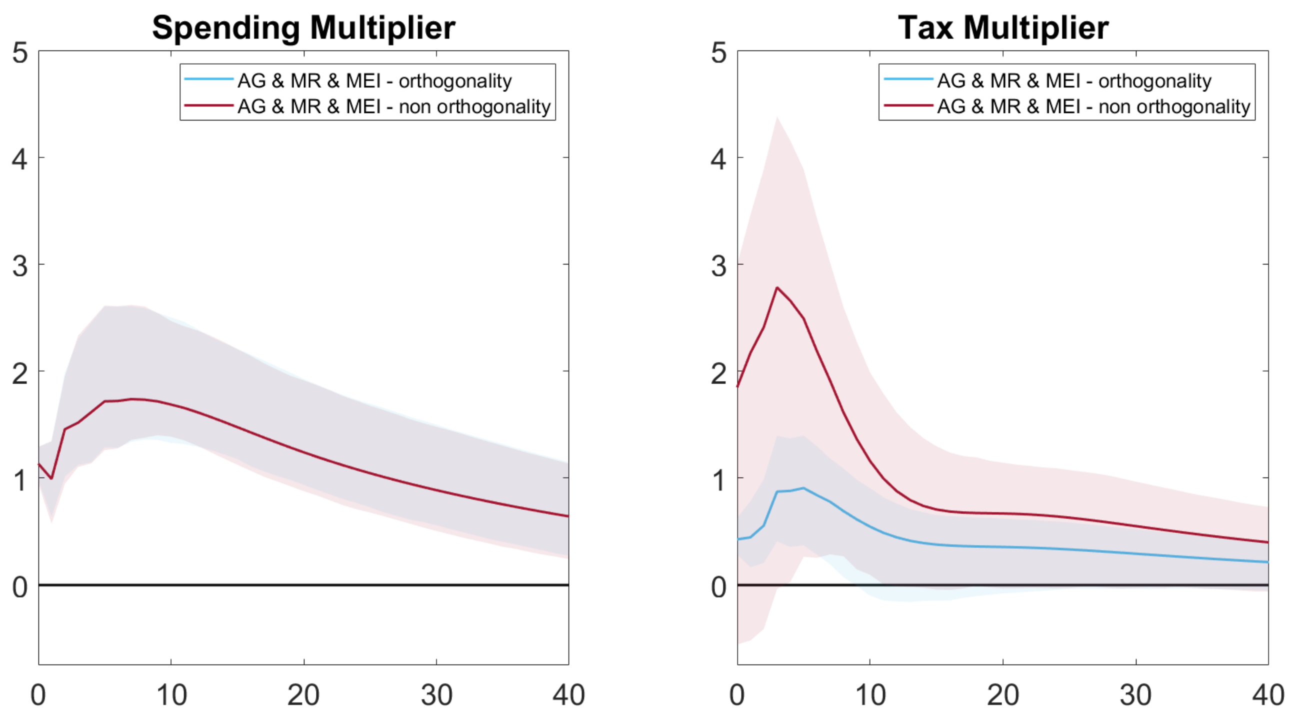

Figure A6: **Spending and tax multipliers:** MEI: Justiniano, Primiceri, and Tambalotti's (2011) MEI instrument; AG: Auerbach and Gorodnichenko's (2012) fiscal spending instrument.