Online Appendix

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July 14, 2019

1 Further sensitivity checks

1.1 Single equation estimation of the AR(1) shock processes

We apply the method kindly suggested by the referee and provide further sensitivity checks to the measurement method. We use the data set prepared by Ramey (2016) for the Handbook of Macroeconomics to compare several TFP shock identifications found in the literature (Table 1 below). As a benchmark we use in the DSGE literature well established procedure from King and Rebelo (1999). In addition, it is well known that the de-trending method affects the estimated coefficients of the driving process, therefore we report here the estimates coming from both linearly and HP filter detrended series.[1]

There is a general consensus in the literature that a business cycle model should explain fluctuations with an average periodicity of 8 to 32 quarters, however there is little agreement on how to obtain these fluctuations from the data (for detailed discussion see Canova (1998) and Canova and Ferroni (2011)) and there is only a partial understanding of the consequences that statistical filtering induces (see Canova and Sala (2009) and Del Negro and Schorfheide (2008)). Standard methods used in the literature to filter out the cyclical component are *i*) One-sided HP-filter (e.g. Stock and Watson (1999)),

*We thank the editor, Pok-sang Lam; two anonymous referees; Gianluca Benigno; Szabolcs Deak; Max Gillman; Istvan Konya; Albert Marcet, Patrick Minford; Zsuzsa Munkacsi; Marco del Negro; Panayiotis Pourpourides; David Staines and Mike Wickens for helpful comments. We are thankful for the support of the Czech Academy of Sciences (GACR P402/12/097). We are also grateful for the comments we received at the Slovak and Hungarian National Banks, the Cardiff Business School, the Young Economists' Meeting in Brno, a seminar at the CIMS at the University of Surrey and the Hungarian Economic Society conference. Corresponding author: lorantkaszab1@gmail.com

[1] Band Pass filter delivers very similar results to HP filter.

ii) Linear detrending (e.g. King and Rebelo (1999), *iii*) First differencing (e.g. Smets and Wouters (2007) and *iv*) Bandpass filter by Baxter and King (1999). The alternative option is to incorporate the trending component in the model usually done either via labor augmenting technology process or a unit-root in TFP or price of investment (King and Rebelo (1999), Fernandez-Villaverde and Rubio-Ramirez (2007) or Justiniano, Primiceri, and Tambalotti (2011)). Canova and Ferroni (2011) show that all the methods are problematic and will deliver different characteristics of the implied business cycles.

Table 1 first reports results we calculate based on structural VAR identification of TFP. In the second part of Table we show the estimated TFP from three DSGE models.[2] In the third section of the Table 1 we ask what calibration of the TFP process delivers the historically observed time series of output gap in our model. We apply HP filter to the series of output[3], calculate percentage deviations of output from its trend and use Kalman filter to back up the series of TFP shocks from historically observed series of output and compare it to King and Rebelo (1999) estimation of our benchmark model.

Table 1: Estimating model driving process for TFP

US data 1947 - 2015	Method	ρ_A linear	σ_A linear	ρ_A HP filter	σ_A HP filter
SVAR model					
King and Rebelo (1999)	CD PF	0.9803	0.0072	0.75	0.0064
Basu, Fernald, and Kimball (2006)	w util	0.979	0.0084	0.656	0.0074
Basu, Fernald, and Kimball (2006)	w/o util	0.978	0.0086	0.778	0.0079
Barsky and Sims (2011)	MR		0.01		
Ben Zeev and Khan (2015)	MR		0.0092		
DSGE model		ρ_A		σ_A	
Smets and Wouters (2007)	Bayesian	0.95		0.0045	
Justiniano, Primiceri, and Tambalotti (2011)	Bayesian	0.23		0.0088	
Andreasen (2012)	GMM	0.84		0.0105	
Our model					
King and Rebelo (1999)[4]	CD PF	0.988	0.0071	0.71	0.0062
Filtered shock	Kalman	0.996	0.0158	0.999	0.0162

Notes: CD PF stands for Cobb-Douglas production function. Utilization adjusted TFP is labeled w util. MR are medium horizon restrictions.

[2]Smets and Wouters (2007) specification of TFP is similar to ours. Justiniano, Primiceri, and Tambalotti (2011) disentangle the TFP shock into neutral total factor productivity, investment-specific technology and shock to marginal efficiency of investment. The GMM estimated TFP is taken from Andreasen (2012).

[3]Output is from NIPA Table 1.1.6 and is divided by the Population of age 16 and over. We used various other measurements of output gap, e.i. in the data set by Ramey (2011) or Andreasen (2012) with marginal impact on the estimated coefficients.

Barsky and Sims (2011)) stress that the standard deviation of the HP detrended Solow residual is roughly 33 percent larger than for the adjusted series. We show that in the current data set (either as provided by Ramey (2016) or by Fernald (2012)) the difference a bit smaller (about 24 %). The standard deviation of TFP[5] is 1.26 % and 0.98 % when adjusted for utilization from 1947Q1 to 2017Q1. For the sample 1969 till 2007, the standard deviation of the HP detrended Solow residual is roughly 27 percent larger than for the adjusted series. This is because Fernald frequently updates the adjusted TFP series based on new data and methodology. Kurmann and Sims (2017) document that some of this changes have significant impact on the cyclical behavior of Fernald's adjusted TFP series.

Again the de-trending method is important for the results. In case of linear de-trending or first differences the volatility of TFP and utilization adjusted TFP differs by less than 3 %.[6] Note that in Table 1 we report standard deviation of innovations which are needed to calibrate the model and not of TFP.

To conclude, the discussion above was meant to demonstrate that there is not unified measure of business cycles. Data provide us with some guidance and discipline how to calibrate the model but leave us also with some degree of freedom. We show that our model implied properties of macro and finance variables are in the range of what can be found in the data.

Next, we provide detailed discussion of the calibration procedure regarding government spending. To calibrate ρ_G, σ_G we use again the data set prepared by Ramey (2016) for the Handbook of Macroeconomics and data set accompanying seminal QJE paper by Ramey (2011). Shocks by construction should be orthogonal to the current state of the macroeconomy.[7] Our theoretical model implies the orthogonality of government spending shocks by assumption (shocks are exogenous disturbances). Ramey (2011) shows that defense spending accounts for almost all of the volatility of government spending[8] we thus use defense spending for the calibration exercise. This is in line with the literature, see for instance Rotemberg and Woodford (1992), Ramey and Shapiro (1998), Ben Zeev and Pappa (2015) and others. Again, all variables are in real per capita terms and divided by the total population. We follow Hall (1984) and Barro (1981) and identify the unanticipated shocks by regressing the military variables on their own lags an use the residuals. We find higher volatility than it is typical in SVAR and DSGE estimates. This is because our identification strategy assumes that all relevant information for predicting military spending is contained in lags of military spending.[9]

[5]Which corresponds to A_t in the model.

[6]Taking the first differences of Fernald TFP series gives $\rho_A = 0.26$ and $\sigma_A = 0.0084$. Further, King and Rebelo (1999) argue that introducing capital utilization into the Neoclassical model amplifies TFP shocks. Thus, when we use capital utilization series to calibrate TFP and introduce capital utilization into the model TFP keeps its explanatory power for business cycle fluctuations. Hence, our model does not feature capital utilization thus we use the TFP series without capital utilization.

[7]See the discussion on what is macroeconomic shock in Ramey (2016).

[8]Since state and local spending is driven in large part by cyclical fluctuations in state revenues, Ramey (2011) argues that aggregate VARs are not good at capturing shocks to this type of spending.

[9]See Ramey (2016) for further discussion.

Table 2: Estimating model driving process for government spending

	Sample	ρ_G linear	σ_G linear	ρ_G HP filter	σ_G HP filter
Regression					
rdef p.c.	1947-2007	0.975	0.0356	0.904	0.03
rdef p.c.	1969-2007	0.979	0.0237	0.616	0.019
rgov p.c.	1947-2007	0.961	0.0176	0.897	0.0154
rgov p.c.	1969-2007	0.953	0.009	0.768	0.0078
Ben Zeev and Pappa (2015)	1947-2007				0.0069
DSGE model		ρ_G		σ_G	
Smets and Wouters (2007)	Bayesian	0.97		0.0053	
Justiniano, Primiceri, and Tambalotti (2011)	Bayesian	0.99		0.0035	

Notes: rdef p.c. are real government defence expenditures divided by total population. rgov are real government expenditures.

1.2 Models with richer fiscal setups.

The fiscal policy outlined in the paper follows the advice of the referee. However, we also experimented with richer fiscal setups, such as the ones in Jaccard et al. (2013) and Leeper et al. (2010). We have two main findings.

First, we follow Jaccard et al. (2013) and write the government budget constraint in terms of the primary-surplus-to-GDP ratio, which also takes into consideration the transfer-to-GDP ratio. In their paper, transfers are exogenous and respond to the debt-to-GDP ratio. In a separate paper (Horvath et al. (2016)), we explore the macro-finance implications of spending reversals whereby government purchases respond to the debt-to-GDP ratio (which is also a feature of the Jaccard et al. setup).

Second, we find that the inclusion of transfers (and the government surplus-to-GDP ratio) do not influence our results as long as there is no spending or transfer reversal (the latter works similarly to the logic of spending reversal) in the model. Spending reversals weaken the negative relationship between consumption growth and inflation, making it more challenging to match finance moments.

In the setup of Jaccard et al. (2013), the empirical equivalents of primary surplus and government debt are constructed as follows. A initial level of government debt, the interest rate expense on the debt, the level of surplus and the change in the monetary base make it possible to calculate the value of government debt.

S: Primary surplus. This is computed as $S_t = TAXR_t - (G_t + TR_t)$, where G_t is government consumption, TR_t are net transfers and $TAXR_t$ are total federal tax revenues.

M: Adjusted Monetary Base. St. Louis Fed Database. Series AMBSL.

TR: Net transfers. This is computed as TR=net current transfers (line 22-line 16) + net capital transfers (line 43 - line 39) + subsidies (line 32) - current surplus of government enterprises (line 19). Source: BEA, Nipa Table 3.2

$TAXR$: Federal Tax Revenues. This is computed as $TAXR_t$=current tax receipts (line 2)+contributions for government social insurance (line 11). Source: BEA, Nipa Table 3.2

D: Federal Government Debt.

This is computed as $D_t = D_{t-1} + INT_t - S_t - (M_t - M_{t-1})$, where S_t is the primary net surplus, INT_t is the net interest payment of federal government debt and $M_t - M_{t-1}$ is seigniorage. The initial value of debt is set to equal to the market value of gross Federal debt at 1961q1. Source: BEA Nipa Table 3.2 and St. Louis Fed database for the initial value of the debt.

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