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Comment

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1 Introduction

Following the work of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003), many central banks are building and estimating dynamic stochastic general equilibrium (DSGE) models and are using them for monetary policy analysis. These models are also widely used in the academic literature to answer a variety of policy questions. A key assumption underlying the policy analysis with DSGE models is that the parameters characterizing preferences and technologies as well as the law of motion of aggregate shocks are invariant to the policy changes studied with the DSGE model. The paper by Jesús Fernández-Villaverde and Juan Rubio-Ramírez (FVRR), provides novel empirical evidence that changes in the conduct of monetary policy might coincide with changes in the structural parameters that determine the degree of nominal rigidity in the economy.

Fernández-Villaverde and Rubio-Ramírez use state-of-the-art econometric techniques developed in some of their earlier work to estimate a medium-scale DSGE model in which many of the key parameters are allowed to vary over time. The main finding of the empirical analysis is that the parameters controlling nominal rigidities drift in a substantial way and are strongly correlated with the target inflation rate. My comment will provide a discussion of the methodology employed in the empirical analysis. Moreover, I will contrast the authors' empirical findings with estimates obtained from a constant-parameter DSGE model that is fitted to three different post-war periods. Although posterior distributions for some of the model parameters have shifted, there is not much evidence that the transmission of monetary policy shocks and the inflation-output trade-off have significantly changed.

2 Shocks and Time-Varying Coefficients

Many DSGE models are built around a representative household that solves the following problem

$$\max \quad \mathbb{E}_t\left\{\sum_{s=0}^{\infty}\beta^{t+s}\left[\ln C_{t+s} - \frac{(H_{t+s}/B)^{1+1/\nu}}{1+1/\nu}\right]\right\} \tag{1}$$

$$\text{s.t.} \quad C_t + K_{t+1} - (1-\delta)K_t = (1-\tau_t)W_tH_t + R_tK_t + T_t.$$

Here C_t denotes consumption, H_t is hours worked, ν is the Frisch labor supply elasticity, K_t is the (predetermined) capital stock in period t, W_t is the wage, τ_t is the labor-income tax rate, R_t is the rental rate for capital, and T^* captures net lump-sum transfers. Taking first-order conditions leads to the labor supply function

$$H_t^{1/\nu} = (1-\tau_t)\frac{W_t}{C_t}B^{1+1/\nu}. \tag{2}$$

My discussion will for now focus on the preference parameter B. According to (1), B is a parameter that determines the marginal rate of substitution between consumption and leisure and hence shifts the labor supply function. Much of the analysis in FVRR has the flavor of replacing the constant parameter B by a time-varying process:

$$\ln B_t = (1-\rho)\ln B + \rho \ln B_{t-1} + \varepsilon_{b,t}.$$

Of course, time-varying parameters are not new to the DSGE model literature. They are commonly called *shocks*. The most prominent shock is a time-varying productivity parameter, which the literature refers to as *technology shock*. Time-varying Bs also have been widely used and are typically called *preference* or *labor supply* shocks.

While the literal interpretation of the labor supply shock is that of a stochastic preference shift of the representative agent, we might want to think of B_t as an omitted mechanism. It could represent labor supply fluctuations generated by variations in home production technology (e.g., Benhabib, Rogerson, and Wright [1991]). Hall (1997) conjectures that this shock captures unmodelled labor market search frictions. The work by Chang and Kim (2006) suggests that time variation in B can arise if equation (1) is used to approximate a heterogeneous agent economy, in which agents face idiosyncratic productivity shocks and incomplete asset markets. Time-varying coefficients or shocks in DSGE models are typically treated as exogenous and hence invariant to policy changes. However, if the time-variation proxies for an unmodelled mechanism, policy invariance is not self-evident. The point of departure of FVRR from the existing literature is not so much the introduction of time-varying coefficients but rather studying whether the time-variation in these coefficients is related to time-variation in policies.

3 Identifying Co-movements between Coefficients in a Simple Model

In order to ask the question whether time variation in preference parameters is correlated with time variation in policy parameters, the first step of the analysis consists of the identification of the time-varying coefficients. In the context of model (1), a natural question that one could ask is whether shifts in the preference parameter are systematically related to changes in the tax rate. Observations on the labor-income tax rate can potentially identify τ_t. The labor-supply equation (2), in combination with data on wages, hours worked, consumption, and an estimate of the labor supply elasticity can be used to infer the preference process B_t.

Note that auxiliary assumptions are important. Suppose one would allow for time-variation not just in the preference parameter B but also in the Frisch labor-supply elasticity ν. Taking logs of equation (2) and solving for $\ln H_t$ yields

$$\ln H_t = \nu_t[\ln(1 - \tau_t) + \ln W_t - \ln C_t] + (1 + v_t)\ln B_t. \tag{3}$$

Hence, potential time variation in both B and v would make it a lot more difficult to identify the parameters.

I will proceed conditional on the assumption that ν is constant and use U.S. data to determine τ_t and B_t. Using U.S. quarterly time series from Haver Analytics (Haver mnemonics are in italics), I define consumption as consumption of nondurables and services (*C – CD*). I use population sixteen years and older (*LN16N*) to convert the series into per capita terms, and the chained-price GDP deflator (*JDGP*) to obtain a measure of real consumption. The real wage is computed by dividing compensation of employees (*Y COMP*) by total hours worked and the GDP deflator. My measure of hours worked is computed by taking total hours worked reported in the National Income and Product Accounts, which is at an annual frequency, and interpolating it using growth rates computed from hours of all persons in the nonfarm business sector (*LXNFH*). I divide hours worked by *LN16N* to convert them into per

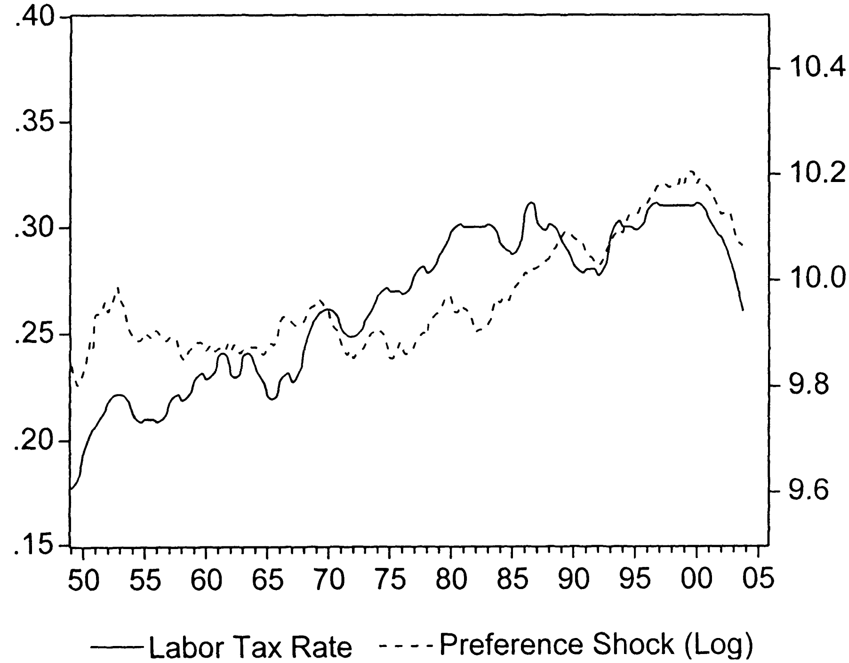

Figure 2C2.1
Time Series of Preference Shock and Labor Tax Rates

capita terms. Finally, a series on marginal labor tax rates was kindly provided by Selahattin Imrohoroglu. The construction of this series is described in detail in Chen, Imrohoroglu, and Imrohoroglu (2007). The sample period ranges from 1949:Q1 to 2003:Q4. With observations on H_t, W_t, C_t, and τ_t in hand, one only has to determine the Frisch labor supply elasticity to be able to compute B_t, based on (2). I conducted the subsequent analysis for $\nu = 0.5$ and $\nu = 2$. This interval spans most of the values used in the DSGE model literature. Since the results were qualitatively and quantitatively very similar, I only report the findings for $\nu = 2$.

The second step of the analysis consists of studying the comovement between policy and nonpolicy parameters. Figures 2C2.1 and 2C2.2 depict time series and scatter plots in $\ln B_t$ and τ_t. Casual inspection of the plots suggests that there is a positive correlation. I proceed by fitting a bivariate VAR(4) to the preference shock and tax rate series. Using a Choleski decomposition, I orthogonalize the VAR innovations, assum-

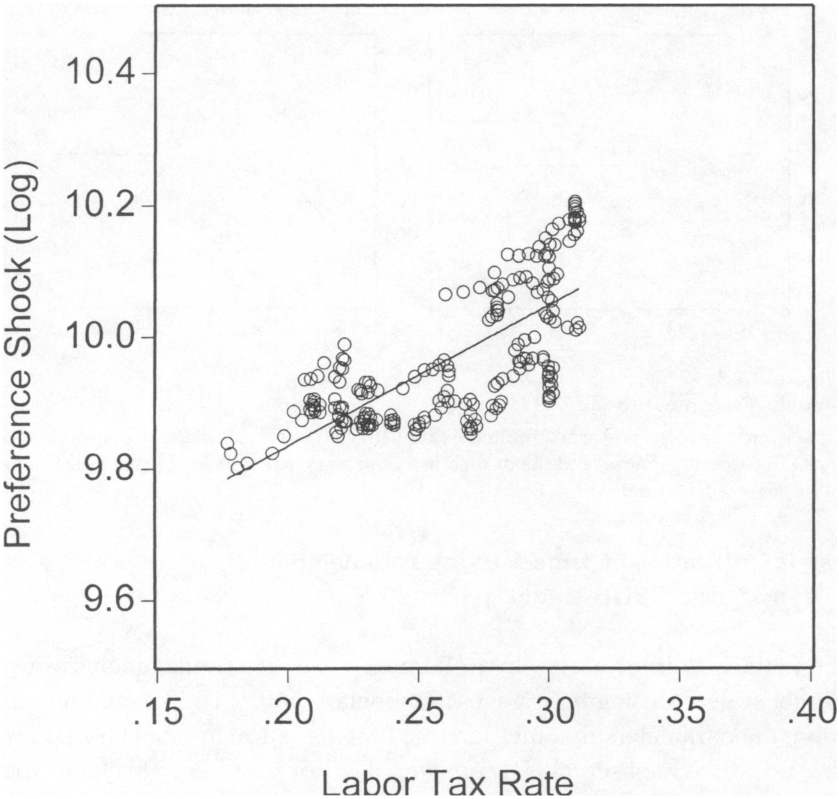

Figure 2C2.2
Scatter Plot of Preference Shocks and Labor Tax Rates

ing that a preference shock innovation does not affect the tax rates contemporaneously. Figure 2C2.3 shows the impulse response functions of τ_t and $\ln B_t$ to a labor tax innovation. The solid responses can be interpreted as posterior mean responses under an improper prior distribution, whereas the dotted lines correspond to asymptotic pointwise 95 percent credible intervals. According to the posterior mean estimates of the VAR coefficients, the largest eigenvalue is 0.97, which explains the persistence of the impulse responses. An increase of the tax rate by 1 percent raises the preference parameter B_t by approximately 1 percent. The empirical analysis suggests that the preference parameter B in (1) is correlated with the tax rate on labor income and hence potentially not invariant to policy changes.

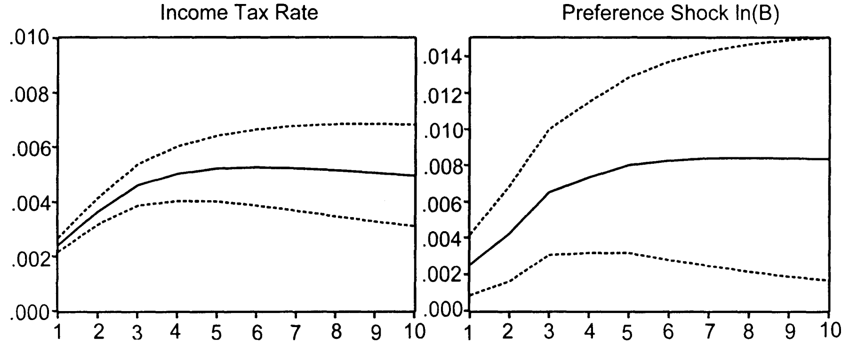

Figure 2C2.3
Impulse Responses to a Tax Rate Innovation
Notes: Impulse responses are computed with EVIEWS. The solid line can be interpreted as posterior mean response, and the dashed lines can be interpreted as approximate pointwise 95% credible intervals.

4 Identification of Time-Varying Parameters in a Large DSGE Model

Fernández-Villaverde and Rubio-Ramírez conduct a similar analysis on a larger scale, focusing on changes in monetary policy. Unlike my illustration, the parameters that measure the time variation in monetary policy are not directly observable. Moreover, it is not possible to back out the time-varying private sector coefficients based on simple calculation, as the one based on (2). Fernández-Villaverde and Rubio-Ramírez have to apply nonlinear filtering techniques to back out the equivalent of B_t and τ_t in my illustration. The large literature on single-equation and system-based estimation of monetary policy rules and New Keynesian Phillips curves suggests that their coefficients are difficult to identify and the estimates are often sensitive to seemingly innocuous auxiliary assumptions.

Given the scale of the estimated DSGE model, it is very difficult to understand what information in the data provides information about the parameters that determine the extent of nominal rigidity. Price and wage stickiness in the authors' DSGE model is based on the Calvo mechanism: only those firms (households) that receive a green light are allowed to reoptimize their price (wages). All other firms (households) have to keep their prices (wages) constant or update it using the previous period's inflation rate. Although the Calvo model is consistent with certain microlevel observations of price-setting behavior, it provides us with a reduced-form representation rather than a microfounded model of nominal rigidity. In particular, if trend inflation is high it becomes very costly for firms not to adjust their prices. Hence, one would expect that periods of high average inflation are periods in which either the fraction of firms that does not re-optimize its price in a given period is small, or that a large fraction of firms that are unable to re-optimize their prices indexes them by lagged inflation.

Using a slightly different notation than FVRR, one can express the solution to the firms' price-setting problem as the following system of equations:

$$\mathcal{F}_t^{(1)} = (p_t^o)^{-(1+\lambda)/\lambda} Y_t + \beta[\pi_t^{\chi_t} \pi_{**}^{(1-\chi_t)}]^{-1/\lambda} \times \mathbb{E}_t\left[\zeta_{t+1}\left(\frac{p_t^o}{\pi_{t+1} p_{t+1}^o}\right)^{-(1+\lambda)/\lambda} \Xi_{t+1|t}^p \mathcal{F}_{t+1}^{(1)}\right] \tag{4}$$

$$\mathcal{F}_t^{(2)} = (p_t^o)^{-[(1+\lambda)/\lambda]-1} Y_t MC_t + \beta[\pi_t^{\chi_t} \pi_{**}^{(1-\chi_t)}]^{-(1+\lambda)/\lambda} \times \mathbb{E}_t\left[\zeta_{t+1}\left(\frac{p_t^o}{\pi_{t+1} p_{t+1}^o}\right)^{-[(1+\lambda)/\lambda]-1} \Xi_{t+1|t}^p \mathcal{F}_{t+1}^{(2)}\right] \tag{5}$$

$$\mathcal{F}_t^{(1)} = (1+\lambda)\mathcal{F}_t^{(2)} \tag{6}$$

$$\pi_t = [(1-\zeta_t)[\pi_t(p_t^o)]^{-1/\lambda} + \zeta_t(\pi_{t-1}^{\chi_t} \pi_{**}^{1-\chi_t})^{-1/\lambda}]^{-\lambda} \tag{7}$$

Here π_t is the gross inflation rate, MC_t are real marginal costs, Y_t is aggregate output, and p_t^o is the price (relative to the aggregate price level) charged by a firm that is allowed to re-optimize its price in the current period. A time-varying fraction of firms ζ_t is unable to re-optimize its price in every period. A fraction χ_t of the firms that do not re-optimize indexes their prices by last period's inflation rate, π_t, whereas the remaining fraction uses the constant rate, π_{**}, to update their prices. While ζ_t and χ_t are typically constant, FVRR assume that they follow stationary stochastic processes.

$$\ln \zeta_t = (1-\rho_\zeta)\zeta_* + \rho_\zeta \ln \zeta_{t-1} + \sigma_\zeta \varepsilon_{\zeta,t}$$

$$\ln \chi_t = (1-\rho_\chi)\chi_* + \rho_\chi \ln \chi_{t-1} + \sigma_\chi \varepsilon_{\chi,t}$$

At the same time, the inflation rate π_t^*, targeted by the central bank, also evolves according to a stationary autoregressive process:

$$\ln \pi_t^* = (1-\rho_{\pi*})\ln \pi_* + \rho_{\pi*} \ln \pi_{t-1}^* + \sigma_{\pi*}\varepsilon_{\pi*,t}.$$

In the absence of steady-state price dispersion, that is, $\pi_{**} = \pi_*$, a log-linear approximation of the price-setting equations takes the familiar form

$$\tilde{\pi}_t = \frac{\beta}{1 + \chi_*\beta}\tilde{\pi}_{t+1} + \frac{\chi_*}{1 + \chi_*\beta}\tilde{\pi}_{t-1} + \frac{(1 - \zeta_*)(1 - \zeta_*\beta)}{\zeta_*(1 + \chi_*\beta)}\widetilde{mc}_t.$$

Thus, the degree of stickiness as well as the fraction of firms that use dynamic indexation is irrelevant in the steady state, and neither $\hat{\zeta}_t$ nor $\hat{\chi}_t$ appear in the first-order approximation. As a consequence, the Calvo and indexation shocks generate foremost higher-order dynamics.[1] Hence, the computationally costly estimation of a nonlinear DSGE model pursued in the paper is important. However at the same time, it remains unclear how well the nonlinearities and hence the time-variation in ζ_t and χ_t are identified from the data and how sensitive the results are to more-or-less arbitrary auxiliary assumptions.

The estimated processes $\hat{\zeta}_t$, $\hat{\chi}_t$, and $\hat{\pi}^*_t$ have a lot of high-frequency variability, more than one would normally attribute to changes in, say, the target inflation rate. Fernández-Villaverde and Rubio-Ramírez remove the high-frequency movements in the parameters using a Hodrick-Prescott (HP) filter, which produces the main results of the paper. Casual inspection of the plots suggests that the Calvo probability of not adjusting prices was low when target inflation was high. However, this story is not quite watertight: the Calvo probability reached its trough in 1965, many years before the target inflation rate reached its peak. By 1980 the Calvo probability had already risen quite substantially. The interpretation of the price indexation coefficient is even more difficult. As previously mentioned, indexation becomes more attractive for firms if trend inflation is large. Instead, the FVRR results indicate that indexation is relatively low in the late 1970s, when inflation is high.

Despite the very elaborate nonlinear estimation of the DSGE model, most of the substantive conclusions are drawn from fairly casual inspections of smoothed time-varying parameter estimates, obtained under the assumption that changes in policy rule coefficients and Calvo parameters are independent. Unlike in a regime-switching framework, which would force the change in parameters to occur concurrently, the AR(1) coefficient framework produces estimates that are often hard to interpret. The following exercises could shed more light on the empirical results: (a) estimate a model in which only the policy rule coefficient change, but not the coefficients of the preference and technology parameters; (b) allow for correlation between the innovations to the policy rule coefficients and the private sector coefficients that determine the degree of nominal rigidity.

5 What Can We Learn from Subsamples?

Based on the policy rule estimates reported by FVRR, I estimate a constant-coefficient DSGE model to three subsamples, ranging from 1955:I to 1969:IV (low target inflation), 1970:I to 1979:III (high target inflation), and 1987:III to 2004:I (low target inflation, strong response to inflation movements). In addition to the observations on consumption, hours worked, and wages (previously described), I am using data on real per capita output (*GDP* converted by *JGDP* and *LN16N*), real investment per capita ($I + CD$ converted by *JGDP* and *LN16N*), inflation defined as the log difference of the GDP deflator, and the effective Federal Funds Rate (*FFED*).

My analysis can be interpreted as follows: suppose there are three econometricians, equipped with the same prior distribution, and each econometrician studies one of the subsamples. Will these econometricians obtain markedly different posterior distributions? I am using the DSGE model studied in Del Negro, Schorfheide, Smets, and Wouters (2007), henceforth DSSW. The DSGE model is based on work by Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003) and contains numerous nominal and real frictions. The specification of the model is very similar to that of FVRR. The main difference is that neither the policy rule coefficients nor the parameters that determine the degree of nominal rigidity drift over time. Moreover, I solve the model using a log-linear instead of a high-order approximation to the equilibrium conditions. Details about the model specification, the choice of prior distribution, and the implementation of the Bayesian analysis can be found in DSSW and An and Schorfheide (2007).

Prior and posterior means and 90 percent credible intervals for the DSGE model parameters are reported in table 2C2.1. In line with the estimates reported by FVRR, the target inflation rate was high in the 1970s (around 6 percent annualized) and lower in the 1960s and during the Greenspan period. The estimated reaction to inflation movements was weaker in the 1970s than it was in the other two subsamples. [2] Most Interestingly, the estimated fraction of firms that are unable to reoptimize

Table 2C2.1
Subsample Parameter Estimates

	Prior		Posterior					
			1955:I to 1969:IV		1970:I to 1979:III		1987:III to 2004:I	
	Mean	90% Intv	Mean	90% Intv	Mean	90% Intv	Mean	90% Intv
			Policy Rule Coefficients					
Reaction to inflation ψ_1	1.55	[0.98, 2.10]	1.99	[1.43, 2.55]	1.58	[1.07, 2.08]	2.56	[2.01, 3.10]
Reaction to output ψ_2	0.20	[0.05, 0.35]	0.07	[0.03, 0.11]	0.12	[0.03, 0.21]	0.08	[0.03, 0.13]
Smoothing ρ_R	0.50	[0.16, 0.82]	0.87	[0.83, 0.92]	0.71	[0.58, 0.86]	0.84	[0.79, 0.88]
Target inflation $\pi^{(Q)}$	1.00	[–0.65, 2.65]	0.96	[0.44, 1.50]	1.52	[0.72, 2.28]	0.83	[0.55, 1.09]
			Nominal Rigidities					
Calvo prices ζ_p	0.60	[0.29, 0.93]	0.78	[0.73, 0.83]	0.57	[0.37, 0.74]	0.79	[0.73, 0.85]
Calvo wages ζ_w	0.60	[0.30, 0.95]	0.64	[0.54, 0.75]	0.66	[0.51, 0.81]	0.49	[0.34, 0.63]
			Preferences Parameters					
Habit formation h	0.70	[0.62, 0.78]	0.71	[0.63, 0.78]	0.78	[0.72, 0.84]	0.71	[0.65, 0.78]
Discount factor $1/\beta - 1 = r^{(Q)}$	0.50	[0.11, 0.86]	0.28	[0.07, 0.48]	0.20	[0.06, 0.34]	0.29	[0.11, 0.45]
Frisch elasticity ν_l	1.99	[0.82, 3.16]	1.02	[0.44,1.55]	1.23	[0.55, 1.90]	1.39	[0.65, 2.13]
			Technology Parameters					
Capital share α	0.33	[0.17, 0.49]	0.23	[0.21, 0.25]	0.29	[0.26, 0.32]	0.28	[0.27, 0.30]
Capital adjustment costs s'	4.01	[1.70, 6.36]	2.74	[1.19, 4.26]	1.90	[0.60, 3.09]	2.05	[1.03, 2.98]
Utilization costs α''	0.20	[0.04, 0.34]	0.27	[0.11, 0.43]	0.27	[0.09, 0.43]	0.29	[0.12, 0.45]
Technology growth γ	0.50	[0.12, 0.86]	0.21	[0.06, 0.35]	0.15	[0.03, 0.26]	0.35	[0.21, 0.48]

				Other Parameters				
Government spending $g*$	0.15	[0.07, 0.23]	0.31	[0.29, 0.32]	0.26	[0.25, 0.28]	0.20	[0.18, 0.21]
				Shocks				
Technology growth ρ_z	0.20	[0.04, 0.35]	0.24	[0.11, 0.36]	0.15	[0.04, 0.25]	0.16	[0.06, 0.26]
Technology growth σ_z	0.50	[0.21, 0.79]	1.00	[0.86, 1.16]	1.15	[0.93, 1.36]	0.69	[0.59, 0.79]
Preference shock ρ_ϕ	0.80	[0.72, 0.88]	0.77	[0.69, 0.85]	0.81	[0.72, 0.89]	0.87	[0.81, 0.94]
Preference shock σ_ϕ	1.25	[0.54, 1.97]	2.80	[1.58, 4.03]	3.12	[1.82, 4.41]	3.12	[1.84, 4.36]
Price mark-up ρ_{λ_f}	0.60	[0.29, 0.93]	0.12	[0.03, 0.21]	0.37	[0.09, 0.65]	0.15	[0.03, 0.26]
Price mark-up σ_{λ_f}	1.25	[0.55, 2.02]	0.32	[0.27, 0.36]	0.43	[0.34, 0.52]	0.30	[0.26, 0.35]
Inv-specific technology ρ_μ	0.80	[0.72, 0.88]	0.83	[0.77, 0.90]	0.75	[0.66, 0.84]	0.81	[0.74, 0.88]
Inv-specific technology σ_μ	1.25	[0.54, 1.96]	1.00	[0.78, 1.21]	1.43	[1.00, 1.83]	0.59	[0.47, 0.71]
Intertemp. preferences ρ_b	0.60	[0.27, 0.92]	0.90	[0.82, 0.97]	0.52	[0.28, 0.77]	0.76	[0.61, 0.92]
Intertemp. preferences σ_b	0.25	[0.11, 0.40]	0.61	[0.36, 0.86]	0.33	[0.25, 0.42]	0.31	[0.23, 0.39]
Government spending ρ_g	0.80	[0.72, 0.88]	0.86	[0.81, 0.92]	0.87	[0.82, 0.93]	0.95	[0.94, 0.97]
Government spending σ_g	0.38	[0.16, 0.59]	0.36	[0.30, 0.41]	0.61	[0.47, 0.73]	0.35	[0.29, 0.40]
Monetary policy σ_R	0.25	[0.11, 0.40]	0.14	[0.12, 0.16]	0.31	[0.25, 0.37]	0.16	[0.13, 0.18]

Notes: The following parameters are fixed in the estimation: capital depreciation $\delta = 0.25$; price and wage indexation $l_p = l_w = 0$; fixed costs $\mathcal{F}$; steady-state price markup $\lambda_f = 0.15$ and wage markup $\lambda_w = 0.3$. The parameter names match the model specification in DSSW.

their prices is lower in the 1970s than in the other two episodes. This result is consistent with the FVRR findings, which appears to be fairly significant in the sense that the 90 percent credible intervals for ζ_p essentially do not overlap. The estimate of the degree of wage stickiness, on the other hand, appears to be lower during the low-inflation Greenspan period than prior to 1980. In general, the interpretation of the subsample estimates is difficult because the posterior means of many of the preference and technology parameters as well as the shock autocorrelations and standard deviations shift at the same time. The same can be said for the estimates reported by FVRR: as Calvo parameters as well as the indexation parameters for prices and wages drift over time, it is very difficult to assess the effect on the overall degree of nominal rigidity in the economy.

To obtain a summary statistic for the degree of rigidity, I compute impulse responses to a monetary policy shock that lowers the nominal interest rate by 25 basis points, based on the three posterior distributions reported in table 2C2.1. Along the impulse response, I compute for the first eight periods the ratio of quarter-to-quarter inflation and output, which can—loosely speaking—be interpreted as the slope of the Phillips curve and a measure of nominal rigidity. The larger this slope, the smaller the nominal rigidity and the extent to which a monetary policy shock has an effect on real output. Figure 2C2.4 depicts pointwise 90 percent credible intervals for the output/inflation trade-off for the Greenspan period as well as the 1960s. The intervals essentially overlap. Figure 2C2.5 compares the response function from the Greenspan period to the responses in the 1970s. Again, the intervals for the "Phillips curve slope" overlap. While an econometrician who studies the 1970s and an econometrician who studies the Greenspan period would estimate different target inflation rates and Calvo adjustment probabilities, the two investigators would essentially come to the same conclusion about the magnitude of the output-inflation tradeoff and the effect of monetary policy shocks.

6 Conclusion

There is much to be learned from the FVRR paper. It is an impressive piece of work that breaks new ground in the estimation of DSGE models with time-varying parameters. The econometric and computational techniques have a wide range of applications and will be very useful for

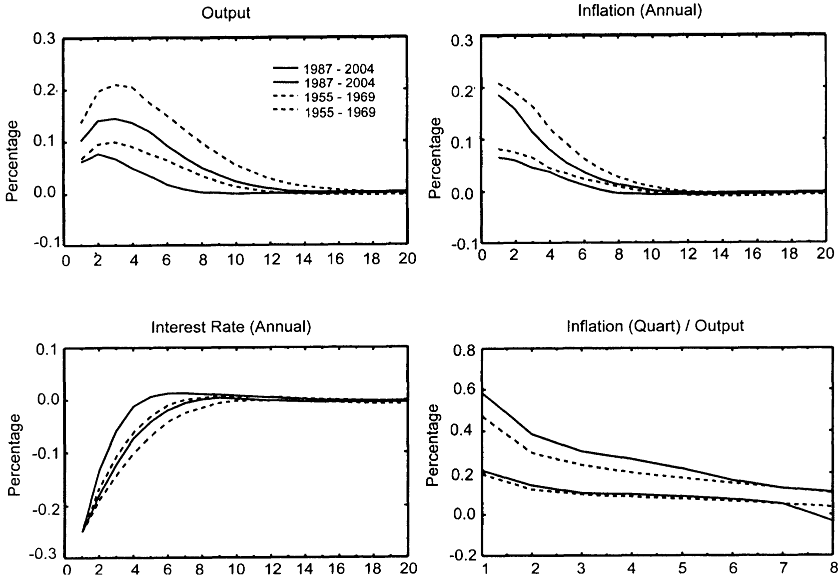

Figure 2C2.4
Impulse Responses to a Monetary Policy Shock: Sub-samples I and III

Notes: The figure depicts pointwise 90% credible intervals for responses to a monetary policy shock that lowers the annualized nominal interest rate by 25 basis points. Inflation response is annualized. The lower right panel depicts the ratio of quarter-to-quarter inflation and percentage deviations of output from steady state for the first 8 periods after the shock.

future research. The complexity of the empirical model raises identification problems and provides a challenge for the interpretation of the estimation results. The apparent co-movement of policy and taste-and-technology parameters is intriguing, and I view this paper as an important step toward a better understanding of how structural structural parameters really are. However, more research is needed to shed light on the causes and consequences of the parameter drift.

Acknowledgments

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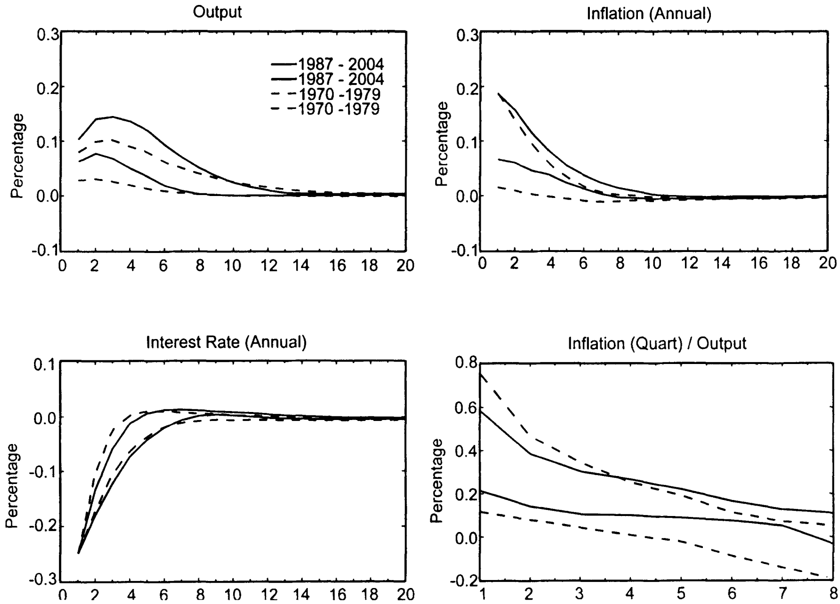

Figure 2C2.5
Impulse Responses to a Monetary Policy Shock: Sub-samples II and III
Notes: See figure 2C2.4.

their data on marginal income tax rates. I gratefully acknowledge financial support from the Alfred P. Sloan Foundation and the National Science Foundation under grant SES 0617803.

Endnotes

1. If there is a steady-state price dispersion, then $\hat{\zeta}_t$ and $\hat{\chi}_t$ do appear in the log-linear approximation.

2. Unlike Lubik and Schorfheide (2004), I restrict ψ_1 to the region of the parameter space that implies determinacy.

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