

Monetary Policy, the Tax Code, and Energy Price Shocks

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Abstract

This paper analyzes the effect of energy price shocks on business cycle fluctuations in a model with monetary policy and a tax code. The tax code includes a tax on realized nominal capital gains. When the monetary regime allows oil price shocks to affect long run inflation expectations, energy price shocks have an immediate and large impact on output and hours worked because changes in the expected inflation rate change the expected effective tax rate on capital gains. A tax on interest income magnifies the effect of all shocks on interest rates and inflation. The model helps to explain why the effect of energy price shocks was so large before 1980 and why the effect disappeared afterwards. The measurable real effects of monetary policy work through the interaction of inflation with the imperfectly indexed tax code.

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1 Introduction

Understanding the effects of energy price shocks on aggregate fluctuations has occupied research economists for the past 35 years. The first problem, from a theoretical perspective, is to understand how a relative price shock to energy could have such a large impact on hours worked and output when energy is such a small factor in production. A second problem is that energy price hikes were estimated to have a large negative impact whereas price declines had negligible positive effects. A third problem is understanding why the negative impact of price hikes seems to disappear after 1983.

In this paper, we develop a monetary model with taxes to account for the asymmetric and time-varying effect of energy price shocks on output and hours worked. The model includes energy as a third factor in a CES production with capital and labor. The model includes a tax code with taxes on income from labor, capital, bonds, and realized nominal capital gains. Shifts in the monetary policy regime change the way that inflation expectations respond to energy price shocks. The amplification mechanism from oil price shocks to output and hours operates both through the effect of oil price shocks on the cost of oil as a factor of production and through the interaction between monetary policy and the tax code. When the central bank allows the inflation objective to change in response to shocks, monetary policy has real effects because changes in inflation expectations change the expected effective tax rate on capital.

The model is used to compute the expected effects of energy price shocks under alternative policy regimes that are calibrated to post-World War II data. We find that energy price shocks had a large impact on the real economy before 1980 because the Fed allowed the inflation objective to change in response to economic shocks (Ireland, 2007). The Federal Reserve's medium- to long-run inflation objective rose with oil price shocks. Higher expected inflation raised the expected effective tax rate on capital gains. This effect was amplified by the tax rate on interest income. This higher expected capital gains tax caused an immediate decline in output and hours worked. Beginning in October 1979, Fed Chairman Paul Volcker announced a change in the policy regime which led to an aggressive anti-inflation policy. Under this regime, inflation expectations and effective capital gains taxes no longer responded to energy price shocks and energy price shocks appeared to have little or no effect on the real economy (Hooker, 1996).

The next section briefly reviews the literature on energy price shocks. Following that we describe the model used in this study with an emphasis on the tax code and the role of energy. We discuss the calibration of the structural parameters and the method used to estimate the driving processes for shocks to technology, monetary policy and energy conditional on the model structure. We use the estimated shocks to decompose the sources of aggregate fluctuations in output and hours worked. We show how changes in monetary policy have led to changes in the impact of energy price shocks on secular changes in capital and productivity as well as on cyclical fluctuations in output and hours worked.

2 Energy Shocks in the U.S. Postwar Economy

There is large literature on the empirical regularities involving oil prices, output, and inflation. Hamilton (1983, 2009) documents that all but one post-World War II recession was preceded by a significant increase in the price of crude petroleum. The tripling of oil prices prior to the recession in 1974 had a profound effect on conventional wisdom about the effects oil price shocks. Following this 1973 tripling of crude petroleum prices, the economy entered a deep recession in which output declined by 2.8 percent from the previous cycle peak to a level about 5 percent below trend and equity prices fell by about 50%. Baily (1981) argued that the capital

stock in place was dependent on low price energy and the oil price shock caused a significant share of the capital stock to become obsolete. Wei (2003) develops a general equilibrium model with putty-clay investment and shows that this feature cannot explain the magnitude of the fluctuations in output and hours worked nor the large drop in equity prices that occurred in 1973-1974. Alpanda and Peralta-Alva (2010) show that Wei's results for equity prices depend on the particular way that she defined investment. Using a standard definition of investment and the putty-clay model of capital, they find that the oil shock could explain about half of the decline in equity prices, but, as Wei found, it could not explain the large drop in output and hours worked.

The failure of the U.S. economy to accelerate after the oil price declines in 1986 and the mild recession following the oil price hikes in 1990 led researchers to ask whether changes in the oil market could explain the moderation in aggregate volatility that occurred around 1983 (the Great Moderation). Part of the decline in volatility is attributed to a decline in the size of shocks and part is attributed to the increase in efficiency as the ratio of oil consumption to GDP declined by about half from 1974 to 2008. Note, however, that whereas most of these studies posit a break in the efficiency with high and low efficiency periods, the actual decline was gradual over the three decades. There is a clear break in the ratio energy use to GDP, but it occurs around 1973-1974 after which the energy price series became much more volatile and per capita energy use is about constant. The energy to output ratio falls in a manner similar to the ratio of hours worked to output. Dhawan, Jeske, and Silos (2010) attribute the large effects of energy price shocks before 1984 to a spillover effect running from energy shocks to TFP. The lack of a large effect after 1984 is attributed to the disappearance of this spillover effect. They do not explain the mechanism responsible for the spillover effects nor why it disappears after 1980.

Rotemberg and Woodford (1996) argue that monopolistic competition is needed to capture a large effect of oil prices on the economy. Finn (2000) shows that making capacity utilization and the depreciation rate dependent on energy use has the same relative effect as introducing monopolistic competition. Leduc and Sill (2004) use a general equilibrium model with Finn's specification to sort out the effect of monetary policy versus oil prices on recessions. They calibrate the model so that oil shocks have relatively big effects operating through the effect of oil prices on capacity utilization. Monetary policy matters because households need cash-in-advance to purchase consumption goods and firms need cash-in-advance to hire labor. The total effect of oil price shocks on output is relatively invariant; what varies is the contribution of systematic monetary policy. They find that the effect of monetary policy on output was high in the 1970s not because the Fed allowed the inflation objective to rise, but because the Fed raised the federal funds rate so much following the shock.

Our main point in this paper is to investigate the role of monetary policy in the transmission mechanism from energy price shocks to output. Hence, we make the simplifying assumption that oil prices are exogenous. This is obviously not the case. Barsky and Kilian (2004) argue that oil prices respond to many factors including monetary policy. Nakov and Pescatori (2009) build a DSGE model in which oil is produced by both a dominant supplier (OPEC) and a competitive fringe. In their model the time-varying nature of oil-price effects is due to a variety of shocks to the economy as well as to the oil producers. They explore the idea in Kilian (2009) that there is a fundamental difference in the effect of energy price shocks due to growing world income and those to production caused by wars and other incidences of political unrest.

3 Basic Model

We add energy as a factor of production to the model developed in Gavin, Kydland and Pakko (2007). We abstract from open economy issues and the details of the world energy market. That model combines monetary policy shocks with taxes on four sources of income: labor, bonds, capital and nominal capital gains. The central bank implements policy using an interest rate rule. The use of an interest rate rule makes inflation highly persistent, leading to persistent changes in the expected marginal tax rate on real capital gains. In that model, monetary policy had important effects on the behavior of the business cycle before 1980 because the Fed did not respond aggressively to inflation shocks that were highly persistent. These shocks led to highly persistent shifts in expected capital gains taxes which led to significant cyclical fluctuations. Monetary policy reform around 1980 led to lower and more stable inflation. A more credible commitment to price stability after 1980 and a more aggressive response to inflation shocks has led to less persistent inflation dynamics and effectively eliminated the cyclical effects of the interaction between monetary policy and the nominal capital gains tax. We briefly review the standard aspects of the model and focus on elements that are important for this study.

3.1 Technology

The production function with energy as a third factor with capital and labor is given as

$$Y_t = z_t K_t^\alpha \{x_t [\psi N_t^v + (1 - \psi) E_t^v]\}^{(1-\alpha)/v}, \quad (1)$$

where K_t , N_t , and E_t are the capital, labor and energy inputs. The stationary technology shock z_t follows a first-order autoregressive process: $z_t = (1 - \rho_z) z_{ss} + \rho_z z_{t-1} + \varepsilon_t^z$, where z_{ss} is the steady state technology factor, $0 < \rho_z < 1$, and ε_t^z is i.i.d. as $N(0, \sigma_z^2)$. The labor augmenting technical process x_t increases at a deterministic (gross) growth rate of $\gamma_x^{v/(1-\alpha)}$. The implied growth rate for output, capital, and consumption, γ_x , defines a steady-state growth path for the real economy. The firm sells output at price P_t , and purchases labor, capital services, and energy at nominal wage W_t , rental price of capital V_t , and energy price P_t^e . Along with the CES assumption, profit-maximization under perfect competition implies that the real wage rate, $w_t = W_t/P_t$, rental price, $v_t = V_t/P_t$, and energy price, $p_t^e = P_t^e/P_t$ will be equated with the marginal products of labor, capital, and energy.

We assume a stochastic linear technology that transforms output into energy.

$$E_t = (1/p_t^e) Y_t^e \quad (2)$$

where Y_t^e is the amount of output that is converted into energy. The relative price of energy, p_t^e , evolves exogenously as

$$p_t^e = (1 - \rho_e) p_{ss}^e + \rho_e p_{t-1}^e + \varepsilon_t^e \quad (3)$$

The resource constraint is given as

$$C_t + I_t + p_t^e E_t = Y_t \quad (4)$$

where I_t is gross investment. All output is used as consumption, investment or converted into energy.

Capital—owned by the household—follows the law of motion

$$I_t = K_{t+1} - (1 - \delta) K_t \quad (5)$$

where δ is the depreciation rate.

3.2 Government

Government issues money and collects revenue by imposing taxes on nominal income from labor, τ_t^N , bond interest, τ_t^B , and capital, τ_t^K , and from capital gains, τ_t^G . Government tax revenues are

$$T_t = \tau_t^N W_t N_t + \tau_t^K (r_t - \delta) P_t K_t + \tau_t^B R_t B_t + \tau_t^G G_t \quad (6)$$

where T_t is the total government revenue from taxes, W_t is nominal wage, N_t is labor, r_t is return on capital, δ is capital depreciation rate, P_t is the price level, K_t is the capital stock, R_t is the nominal interest rate on bond from the previous period, B_t is government bond, and G_t is nominal capital gains. Without loss of generality, we assume that government borrowing is zero in each period, so that the household's first-order condition with respect to bonds defines the nominal interest rate. Tax rates are assumed to be constant.

If the capital gain tax is treated as an accrual tax,

$$G_t = (P_t - P_{t-1}) K_t, \quad (7)$$

or, the capital gain tax applies only to realized gains. In this case, the household manages a stock of unrealized capital gains U_t . The accumulation process for unrealized capital gains is described below.

The central bank uses an interest rate rule to achieve an inflation target:

$$R_t = R_{ss} + \nu_\pi (\pi_t - \gamma_{pt}), \quad (8)$$

where ν_π is the Fed's reaction to the deviation of inflation from target and π_t is the inflation rate. Under the interest rate rule, the money stock is determined endogenously from the money demand relationship. The Federal Reserve does not have an explicit target for inflation, but has allowed the actual target to vary over time. We capture this idea by assuming that the deviation of the inflation target from the steady state inflation rate follows an exogenous autoregressive process, $\gamma_{p,t} = (1 - \rho_p) \gamma_{pss} + \rho_p \gamma_{p,t-1} + \varepsilon_t^p$, where γ_{ss} is the steady state inflation rate, $0 < \rho_p < 1$, and ε_t^p is i.i.d. as $N(0, \sigma_p^2)$.

3.3 Households

The representative household maximizes a discounted stream of expected utility from consumption, C_t , and leisure, L_t ,

$$Max E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t)$$

with

$$u(C_t, L_t) = \frac{(C_t^\theta L_t^{1-\theta})^{1-\sigma}}{1-\sigma} \quad (9)$$

The nominal budget constraint for households can be written

$$(1 - \tau_t^N) W_t N_t + (1 - \tau_t^K) (r_t - \delta) P_t K_t - \tau_t^G G_t + T_t + [1 + (1 - \tau_t^B) R_t] B_t + M_t + \Delta_t^M = P_t C_t + P_t (K_{t+1} - K_t) + B_{t+1} + M_{t+1} \quad (10)$$

where M_t is the nominal money issued by the government, and $\Delta_t^M = M_{t+1} - M_t$ is the lump sum monetary transfer.

The household endowment of time is

$$L_t + N_t + S_t = 1 \quad (11)$$

$$S_t = \xi \left(\frac{P_t C_t}{M_t} \right)^\eta \quad (12)$$

With $\xi, \eta > 0$, and S_t is the shopping-time cost function of holding money balances.

When the capital gains tax applies on to realized gains, the households optimization problem is also constrained by the accumulation process for unrealized capital gains:

$$U_{t+1} = U_t + G_t - \Phi(G_t/U_t)U_t \quad (13)$$

We choose a specific quadratic form of the adjustment-cost function, $\Phi(G_t/U_t)$, so that $\Phi \geq 0$, $\Phi' > 0$, and $\Phi'' < 0$.

4 Stochastic General Equilibrium

To solve for the model's approximate dynamics, we deflate all real variables by $(\gamma_x)^t$ and all prices by the trend rate of inflation, $(\gamma_p)^t$. In the computational experiments, we treat $\gamma_{p,t}$ as

stochastic, allowing for shocks to the inflation trend. To ensure that the government's intertemporal budget constraint is satisfied, we impose the condition that the growth rate of bonds and money are cointegrated with the nominal growth trend. Stationarity also requires that the G/U ratio be constant over time, with each variable growing at the nominal growth trend. We write the transformed household optimization problem in which all nominal and real variables are stationary and noted by lower-case letters.

$$Max E_0 \sum_{t=0}^{\infty} \beta^t \frac{(c_t^\theta L_t^{1-\theta})^{1-\sigma}}{1-\sigma} \quad (14)$$

subject to

$$\begin{aligned} (1 - \tau_t^N)w_t N_t + (1 - \tau_t^K)(r_t - \delta)k_t - \tau_t^G g_t + \frac{t_t}{p_t} + [1 + (1 - \tau_t^B)R_t] \frac{b_t}{p_t} \\ + \frac{m_t}{p_t} + \frac{\Delta_t^m}{p_t} = c_t + (\gamma_x k_{t+1} - k_t) + \gamma_{pt+1} \gamma_x \frac{b_{t+1}}{p_t} + \gamma_{pt+1} \gamma_x \frac{m_{t+1}}{p_t} \end{aligned} \quad (15)$$

$$L_t + N_t + \xi \left(\frac{p_t c_t}{m_t} \right)^\eta = 1 \quad (16)$$

$$\gamma_{pt+1} \gamma_x \frac{u_{t+1}}{p_t} = \frac{u_t}{p_t} + \left(1 - \frac{p_{t-1}}{\gamma_{pt} p_t} \right) k_t - \Phi \left(\frac{g_t}{u_t} \right) \frac{u_t}{p_t} \quad (17)$$

The first-order conditions for $c_t, L_t, N_t, g_t, m_{t+1}, b_{t+1}, k_{t+1}$, and u_{t+1} are:

$$\theta c_t^{\theta(1-\sigma)-1} L_t^{(1-\theta)(1-\sigma)} = \lambda_t + \omega_t \eta \left(\frac{S_t}{c_t} \right) \quad (18)$$

$$(1 - \theta) c_t^{\theta(1-\sigma)} L_t^{-\sigma(1-\theta)-\theta} = \omega_t \quad (19)$$

$$\lambda_t w_t = \omega_t \quad (20)$$

$$\tau_t^G \lambda_t = \Phi'(g_t/u_t) \varphi_t \quad (21)$$

$$\beta E_t \{ [\lambda_{t+1} + \omega_{t+1} p_{t+1} \eta (S_{t+1}/m_{t+1})] / \pi_{t+1} \} = \lambda_t \gamma_x \quad (22)$$

$$\beta E_t \{ \lambda_{t+1} [1 + (1 - \tau_{t+1}^B) R_{t+1}] / \pi_{t+1} \} = \lambda_t \gamma_x \quad (23)$$

$$\beta E_t \lambda_{t+1} \{ 1 + [(1 - \tau_{t+1}^K)(r_{t+1} - \delta)] - \frac{\varphi_{t+1}}{\lambda_{t+1}} (1 - \frac{p_t}{\gamma_{pt+1} p_{t+1}}) \} = \lambda_t \gamma_x \quad (24)$$

$$\beta E_t \frac{\varphi_{t+1}}{\pi_{t+1}} \{ 1 - \Phi(\frac{g_{t+1}}{u_{t+1}}) + \frac{g_{t+1}}{u_{t+1}} \Phi'(\frac{g_{t+1}}{u_{t+1}}) \} = \varphi_t \gamma_x \quad (25)$$

where λ_t, ω_t , and φ_t are utility-denominated, present-valued shadow prices associated with constraints (15), (16), and (17), respectively.

We define the inflation rate by $\pi_{t+1} = \gamma_{pt+1} p_{t+1} / p_t$.

From the firm's profit-maximization condition, we can get the wage rate, w_t , the rate of return on capital, r_t , and the energy price p_t^e as:

$$w_t = (1 - \alpha) \left[\frac{\psi N_t^v}{\psi N_t^v + (1 - \psi) e_t^v} \right] \frac{y_t}{N_t} \quad (26)$$

$$r_t = \alpha \frac{y_t}{k_t} \quad (27)$$

$$p_t^e = (1 - \alpha) \left[\frac{(1 - \psi) e_t^v}{\psi N_t^v + (1 - \psi) e_t^v} \right] \frac{y_t}{e_t} \quad (28)$$

5 Steady State and Model Calibration

The model's dynamics will be approximated as proportional deviations from a baseline steady state, defined by the model parameters (including the baseline growth rates of technology and prices, γ_x and γ_p). The model is calibrated using empirical estimates of steady-state relations among the model's variables and parameters. Most of the estimates come from long-run or average values. Measurements from panel data also are used.

Production function: The parameter α in the production function equals the model's steady-state capital share of output and is set equal to 0.36. We use a quarterly depreciation rate, δ , of 0.02. We calibrate ψ and ν to hit targets for the ratio of energy use to hours worked and estimates of the elasticity of substitution between energy and labor inputs. Our decision to augment energy use and the labor input by a growing technology factor is motivated by that fact that both per capita energy use and hours worked have been approximately constant since 1994.

Household: The annual real interest rate is 4 percent, yielding a quarterly discount factor, β , of approximately 0.99. The risk-aversion parameter, σ , is set equal to 2, which means more curvature on the utility function than that corresponding to logarithmic utility. We calibrate the money-time trade-off so that the implied money demand function is consistent with the empirical evidence summarized by Lucas (2000) and Mulligan and Sali-Martin (1997). The money demand relationship in the model has a unitary elasticity of the scale variable (consumption). When we set η (the curvature parameter in the money-time trade-off) equal to -1, the interest rate elasticity equals -0.5. The scale parameter, ξ , is calibrated to target the average ratio the price level to an index of real money balances. In our model this is equivalent to targeting velocity. In line with the panel-data estimates of Ghez and Becker (1975), the preference parameter, θ , is calibrated to a target of 0.3 for hours worked (as a share of available time). Calibration of the parameters of the capital gains accrual equation requires quantitative restrictions on the adjustment cost function. On average, for this period, realized capital gains were about 40 percent of changes in the nominal capital stock measured as the net stock of private nonresidential assets. Accordingly, we calibrate the steady state ratio of capital gains realized to capital gains accrued to equal 0.4. This ratio results in a steady ratio of G/U of 0.0094 (the ratio of capital gains realized to accumulated unrealized gains). Note these ratios are so low because some capital gains are never realized. Some are held by tax exempt institutions such as pension funds and some are bequeathed to heirs, in which case the basis for the capital gains is reset to the current market value and no capital gain tax is paid (the estate may be taxed, however).

We choose a specific quadratic form of the adjustment-cost function $\Phi(G_t/U_t)$, with $\Phi \geq 0$, $\Phi' > 0$, and $\Phi'' < 0$. To meet these conditions and to hit our target for the G/U ratio, we specify the portfolio adjustment cost function as

$$\Phi(G_t/U_t) = -209.6611(G_t/U_t - G/U)^2 + 2.5833(G_t/U_t - G/U).$$

Government: Steady-state tax rates for labor, interest, capital income, and the capital gains tax are set to equal the average marginal tax rates for 1960 to 2002, calculated using the NBER TAXSIM model and reported in Table 9 of Feenberg and Poterba (2003). They report 24 percent for labor, 26 percent for interest income, 34 percent for capital income, and 20 percent for realized capital gains. The policy rules for the alternative monetary policy regimes are calibrated to match inflation volatility and persistence.

Shock processes: We estimate the error processes conditioned on the calibrated structure.

(Section 5 to be completed).

6 Computational Experiments (To be completed)

In this section we examine the effect of energy price shocks on output and hours under alternative assumptions about the policy regime and the production function.

7 Conclusions (To be completed)

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