Monetary Policy, the Tax Code and Energy Prices

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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 that includes a tax on realized nominal capital gains. The measurable real effects of monetary policy work through the interaction of inflation with the imperfectly indexed tax code. A tax on interest income can magnify the effect of all shocks on interest rates and inflation. When the monetary regime allows energy price shocks to affect long run inflation expectations, the shocks have a large impact on output and hours worked because changes in the expected inflation rate change the expected effective tax rates on capital gains and on interest income. The large impact on output and hours worked is followed by a gradual but very persistent effect on the capital stock. The relative decline in the capital stock is associated with a long period of low interest rates, low productivity growth and high inflation accounting for the stagflation of the 1970s. The effect of energy price shocks was so large before 1980 and disappeared afterwards because with the Volcker disinflation policy, the Fed stopped accommodating oil price shocks.
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 energy 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 and bonds.

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).

We use the model to comment on two recent papers. First, Dhawan, Jeske and Silos (2010) offer an atheoretical explanation for the time-varying effects of oil price shocks. They estimate a Markov switching model of TFP and energy price shocks revealing a spillover effect running from energy price shocks to TFP shocks before 1983. The model switches in 1983 and the post 1983 estimates show that the spillover effect disappears. Our model provides a theory that accounts for the spillover and the switching. Second, Kormilitsina (2011) estimates a New Keynesian model with oil in the production function and derives the optimal response to oil price shocks. She shows that the optimal response is to let the inflation target rise in response to oil price shocks. We modify our model to include a few of her New Keynesian features—monopolistic competition, Calvo pricing, and investment adjustment costs. With these changes we show that making the inflation target dependent on oil price shocks can reduce the distorting effects of oil price shocks as her model predicts. However, when we also add our tax code, the results change dramatically. The New Keynesian frictions do not prevent the depressing effects of higher inflation on the long run behavior of the capital stock. While the impact effects of adopting a higher inflation target are positive, the long run effects push the economy into a long period of stagflation similar to U.S. experience of the 1970s.

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. In this preliminary version, we compute the expected responses to oil price shocks using shock processes that are based on other work and estimated VARs. In this version we calibrated val-
ues for both structural parameters and the driving processes for shocks to technology, monetary policy and energy conditional on the model structure. Our preliminary results show that a monetary policy that accommodates energy price shocks can have large effects on the real economy, both in the short run on output and hours worked as well as on long-run changes in capital and productivity.

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. The real time estimates of GDP indicated that output declined 8.1 percent from the previous cycle peak in 1973:Q4 to the trough in 1975:Q1. Table 1 reports the values for GDP, inflation and interest rates for the period of GDP decline. Subsequent data revisions have reduced the estimated size of the decline. Five years after the shock, at the end of 1979, the decline from peak to trough was estimated to be 5.9 percent. As of 2011:Q3, the revised GDP data show that the decline is only 3.2 percent. The initial observation of 8.1 percent is twice as large as real time estimates of the peak to trough decline associated with the 2008 financial crisis and explains why the profession became obsessed with understanding the effects of energy price shocks following this episode.

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 account for 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 respond positively to 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 to 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 of 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.

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 effect of oil prices on capacity utilization to replicate the large effect of positive oil price shocks observed in the 1970s. They assume that a doubling of the relative price of oil leads
to about a 4.5% drop in output below trend. The main contribution of their paper is to show that the monetary policy rule matters. Money matters because households need cash-in-advance to purchase consumption goods and firms need cash-in-advance to hire labor. 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. Aguair-Conraria and Wen (2007) develop a model with increasing returns to scale and a multiplier-accelerator mechanism which tracks the real economy very well following the 1973 oil price shocks, but cannot explain why the economy did not respond to later oil price shocks in a similar manner. None of these papers address issues involving the tax code.

Our main point in this paper is to investigate the role of monetary policy as it interacts with the tax code 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 Model

We add energy as a factor of production to the model developed in Gavin, Kydland and Pakko (2007). 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. We briefly review the standard aspects of the model and focus on two new elements that may be important for this study. The first is the CES production function in which energy is combined with capital as a joint input with labor. This gives us a benchmark for measuring the effect of energy price shocks when policy does not respond to the shocks. In the final analysis, given the relatively small factor share of energy, the particular form of the production does not matter for our results because the effect operates mainly through the reaction of the policy to the exogenous energy price. The second is the tax structure. Of the four taxes we consider, the important two are the tax on bond income and the tax on nominal capital gains. A unique feature of our tax structure is the explicit modeling of the realized capital gains tax. Households are assumed to manage a portfolio of unrealized capital gains. The ability to avoid realizing some gains altogether and the ability to time the realization of gains means that the welfare-equivalent accrual tax rate would be much smaller than the statutory rate on realized gains. The labor and capital income taxes matter for the steady states and for welfare, but do not have significant cyclical effects.\footnote{We have not modeled the nonindexed income tax brackets that existed prior to the 1981 Tax Reform Act. Analysis in Altig and Carlstrom (1991) suggests that doing so would reinforce the cyclicial effects we find for output, hours worked and the capital stock.} We solve a model that is a linear approximation around the steady state of the nonlinear model presented. 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. Calibration and parameter assignments are discussed in this section and also summarized in Table 2.
3.1 Technology

The production function with capital, energy and labor is given as

\[ Y_t = z_t(K_t^\psi + (1 - \psi)E_t^{\nu})^{\alpha/\nu}(x_tN_t)^{1-\alpha} \]  

(1)

where \( K_t, N_t, \) and \( E_t \) are the capital, labor and energy inputs. This particular CES function has been used by Kim and Loungani (1991), Alpanda and Peralta-Alva (2010) and Dhwan, Jeske, and Silos (2010) in studies of the effect of energy price shocks. The particular calibration that we use \((\psi = -0.7)\) implies that capital and energy are complements. The parameter \( \alpha \) in the production function equals the model’s steady-state capital share of output and is set equal to 0.36. We assign values to the parameters of the combined energy-capital input based on the calibration in Kim and Loungani (1992) and Dhawan, Jeske and Silos (2010). They calibrate \( \psi \) and \( \nu \) to 0.9952 and -0.70 respectively to hit targets for the ratio of energy use to capital and estimates of the elasticity of substitution between energy and capital. Setting \( \nu < 0 \) ensures that energy and capital are complements.

The stationary technology shock \( z_t \) follows a first-order autoregressive process:

\[ \ln(z_t) = \rho_z \ln(z_{ts}) + \varepsilon_t^z, \]

where \( z_{ts} \) is the steady state technology factor, \( 0 < \rho_z < 1, \) and \( \varepsilon_t^z \) is i.i.d. as \( N(0, \sigma_z^2). \) The driving process for the technology factor is based on earlier works that attribute a large share of the cycle to this shock. As in Kydland and Prescott (1982), this process is calibrated to the Solow residual, a measure of what the model cannot explain. The parameter values are set so that \( \rho_z = 0.95, \) and the standard deviation of the technology shock, \( \sigma_z = 0.0075 \) percent at a quarterly rate. This assumption sets a benchmark for estimating the relative effect of the energy price shocks in the model. The labor augmenting technical process \( x_t \) increases at a deterministic growth rate of \( \gamma_x^{1/(1-\alpha)}. \) The implied growth rate for output, capital, and consumption, \( \gamma_x, \) defines a steady-state growth path for the real economy which is calibrated to match the post WWII average for per capital U.S. real GDP growth of 1.6% at an annual rate.

The firm sells output at price \( P_t, \) and purchases labor, capital services, and energy at nominal wage \( W_t, \) rental price of capital \( Q_t, \) 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, \( q_t = E_t/P_t, \) and energy price, \( p_t^e = P_t^e/P_t \) will be equated with the marginal products of labor, capital, and energy.

We abstract from the details of the world oil market and assume a stochastic linear technology that transforms output into energy

\[ E_t = (1/P_t^e)Y_t^e \]

(2)

where \( Y_t^e \) is the amount of output that is converted into energy and \( p_t^e, \) the relative price of energy, evolves exogenously as

\[ p_t^e = (1 - \rho_e)p_{ts}^e + \rho_e p_{t-1}^e + \varepsilon_t^e \]

(3)

The process for the oil price shock is taken from the time-varying Markov switching model estimated by Dhawan, Jeske and Silos (2010). For the early period, we set the persistence in the energy price shock, \( \rho_e = 0.92, \) and the standard deviation, \( \sigma_e = 0.03 \) In the steady state we assume that the share of energy in output is equal to 0.0544 which pins down the value of \( \psi. \) The steady state value of \( p_{ss}^e \) is normalized to unity.

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

\[ I_t = K_{t+1} - (1 - \delta)K_t \]

(4)

where \( I_t \) is gross investment and \( \delta \) is the depreciation rate. We use a quarterly depreciation rate, \( \delta, \) of 0.02.
All output is used as consumption, investment or converted into energy. The resource constraint is given as

\[ C_t + I_t + p_t^e E_t = Y_t \]  

(5)

3.2 Government

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

\[ T_t = \tau_t^N W_t N_t + \tau_t^K (q_t - \delta) P_t K_t + \tau_t^B R_{t-1} B_{t-1} + \tau_t^G G_t \]  

(6)

where \( T_t \) is the total government revenue from taxes, \( W_t \) is nominal wage, \( N_t \) is labor, \( q_t \) is return on capital, \( \delta \) 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.

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

\[ \ln(\frac{R_t}{R_{ss}}) = (1 + \nu_\pi) \ln(\frac{\pi_t}{\pi^*_t}) \]  

(7)

where \( \nu_\pi \) is the Fed’s reaction to the deviation of inflation from target and \( \pi_t \) 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 percentage deviation of the inflation target from the steady state inflation rate follows an exogenous autoregressive process, \( \ln(\frac{\pi_t}{\pi^*_t}) = \rho_p \ln(\frac{\pi_{t-1}}{\pi^*_{t-1}}) + \xi + \epsilon_t^p \), where \( 0 < \rho_p < 1 \), and \( \epsilon_t^p \) is i.i.d. as \( N(0, \sigma^2_p) \). We define the inflation rate by \( \pi_t = P_t / P_{t-1} \), the nominal interest rate \( R_t = r_t P_{t+1} / P_t \), while \( r_t \) is the real interest rate, and \( \pi^*_t \) is the inflation target at time \( t \). In the steady state, \( \pi_{ss} = \pi^*_ss = \pi^* \).

The policy rules for the baseline monetary policy regime is calibrated to match inflation volatility and persistence before 1980 when the policy parameters shift with the Volcker disinflation policy. Gavin, Kydland and Pakko (2007) discuss the change in monetary policy by the Volcker Fed. They summarize time series studies and estimate the persistence in the inflation rate separately for pre- and post-October 1979 periods and report estimates using an augmented Dickey-Fuller method. The parameterization of the stochastic inflation target is key to our results. Here we rely on those estimates—the persistence in the inflation target is set to \( \rho_p = 0.97 \) for the earlier period and \( \rho_p = 0.84 \) for the latter period. Ireland (2007) estimates a dynamic stochastic general equilibrium (DSGE) model of the U.S. economy. He finds that in the pre-1980 inflation targeting regime the inflation target can be modeled as a random walk with exogenous shocks or as a stochastic trend that reacts to other economic shocks. A variety of empirical evidence from this period has found that the inflation rate followed a stochastic trend and that the nominal inflation premium in long-term interest rates displayed a unit root. All the difference in inflation volatility across the two periods was estimated to be in the difference of the

\[ \text{For example, Kozicki and Tinsley (2005) estimate a unit root in trend inflation for this early period. Dewachter and Lyrio (2006) and Ellingsen and Soderstrom (2004) find that the inflation premium in long-term interest rates also has a unit root.} \]
persistence. The standard deviation of the inflation target shock is set so that \( \sigma_p = 0.004 \) in both periods.

We represent policy in the earlier period by setting the policy reaction to deviations of inflation from target such that \( \nu_p = 0.375 \). In the later period we set \( \nu_p = 0.5 \). Edge and Rudd (2007) show that the coefficient on inflation in a Taylor-type monetary policy rule must be significantly larger than one to assure a unique equilibrium in a model with a tax on nominal bond income. To see this, consider the first order condition for bonds

\[
 g \lambda_t = (B/\pi)((R_t - 1)(1 - \tau^B) + 1)E_t(\lambda_{t+1})
\]

Take the steady state version and solve for the nominal interest rate:

\[
 R = \frac{(\pi g/\beta) - 1}{(1 - \tau^B)} + 1.
\]

Substitute \( R \) into long-run after-tax Fisher equation linearized around the steady state to get

\[
 (1 - \frac{\beta \tau^B}{\pi g}) \hat{R}_t = \hat{\pi}_t + \hat{\pi}_t.
\]

Substitute the expression for \( \hat{R}_t \) into the linearized Taylor rule, \( \hat{R}_t = (1 + \nu_p)\hat{\pi}_t \), to get:

\[
 (\hat{\pi}_t - \hat{\pi}_t) = \left(1 - \frac{\beta \tau_B}{\pi g}\right) (1 + \nu_p)\hat{\pi}_t.
\]

The determinacy condition when bond tax is zero is known as the Taylor principle—that is, the Fed must raise the interest rate more than one for one with the deviation of inflation from target, or \( \nu_\pi > 0 \). When the bond tax is greater than zero the determinacy condition becomes

\[
 \nu_\pi - \frac{\beta \tau^B}{\pi g} - \nu_\pi \frac{\beta \tau^B}{\pi g} > 0.
\]

With our baseline calibrations, the borderline value of \( \nu_\pi \) is approximately 0.339.

In the baseline version, we assume that the Fed accommodated oil price shocks by allowing the implied inflation target to rise by some factor \( \xi = 0.25 \) times the shock. Kilian and Lewis (2009) argue that there is no evidence in data after 1987 that the Fed reacted to higher energy prices by raising the federal funds rate. They also argue that evidence for an earlier reaction is also weak. Our specification assumes that it was the inflation objective, not the interest rate that reacted to energy prices before 1982. We set the relative weight on the reaction to energy price shocks, \( \xi = 0.132 \) for the period before the Volcker disinflation and to zero afterwards. This value is based on the Ireland (2007) estimate of a 41 basis point response of the Fed’s inflation target to a one standard deviation cost push shock. The standard deviation of the energy price shock is estimated to be 3.1 percent at a quarterly rate. This implies a 13.2 basis point response of the inflation target to a 1 percent energy price shock.
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

\[
u(C_t, L_t) = \frac{(C_t^\theta L_t^{1-\theta})^{1-\sigma}}{1-\sigma}
\]

We assume that annual real interest rate is 4 percent, yielding a quarterly discount factor, \( \beta \), of approximately 0.99. The risk-aversion parameter, \( \sigma \), is set equal to 2. In line with the panel-data estimates of Ghez and Becker (1975), the preference parameter, \( \theta \), is calibrated to a target of 0.3 for hours worked (as a share of available time).

The nominal budget constraint for households can be written

\[
(1-\tau_t^N)W_t N_t + (1-\tau_t^K)q_t P_t K_t - \tau_t^G G_t + T_t + [1+(1-\tau_t^B)(R_{t-1}-1)]B_{t-1} + M_{t-1} + \Delta_{t-1}^M = P_tC_t + P_I I_t + B_t + M_t
\]

(9)

where \( M_t \) is the nominal money issued by the government at the period of \( t \), and \( \Delta_{t-1}^M = M_t - M_{t-1} \) is the lump sum monetary transfer. The governments budget constraint is given as

\[
T_t = \tau_t^N W_t N_t + \tau_t^K (q_t - \delta) P_t K_t + \tau_t^B R_{t-1} B_t + \tau_t^G G_t.
\]

We assume that the tax rates for labor, interest, capital income, and the capital gains tax are constant over the sample period. They 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 24.4 percent for labor, 25.8 percent for interest income, 34.1 percent for capital income, and 20.2 percent for realized capital gains.

The household endowment of time is

\[
L_t + N_t + S_t = 1
\]

(10)

\[
S_t = x \left( \frac{P_tC_t}{M_{t-1}} \right)^\eta
\]

(11)

With \( x, \eta > 0 \), \( S_t \) is the shopping-time cost function of holding money balances. 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 \( \eta \) (the curvature parameter in the money-time trade-off) equal to -1, the interest rate elasticity equals -0.5. The scale parameter, \( x \), is calibrated to target the average ratio the price level to an index of real money balances. In our model this is equivalent to choosing a calibration target for velocity. In the steady state, shopping time is 1 percent of labor time or 0.3 percent of available time.

The capital gains tax applies on to realized gains which is a choice variable for the household. The optimization problem is constrained by the accumulation process for unrealized capital gains; \( U_{t+1} \):

\[
U_{t+1} = U_t + (P_t - P_{t-1})K_t - \Phi(G_t/U_t)U_t
\]

(12)
Each period, accrued capital gains are equal to inflation times the capital stock, \((P_t - P_{t-1})K_t\).

In the steady state adjustment costs are zero and \(\Phi(G_t/U_t) = G/U\) so that the third term on the right hand side is just equal to steady state realized gains, \(G_t\). We assume that the capital gains/adjustment-cost function has the following properties: \(\Phi \geq 0\), \(\Phi' > 0\), and \(\Phi'' < 0\).

Calibration of the parameters of the capital gains accumulation equation requires quantitative restrictions on the adjustment cost function. On average, for this period, realized capital gains were about 40 percent of accrued gains—changes in the nominal capital stock measured as the net stock of private nonresidential assets. 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). 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). We do not choose an explicit form for the adjustment-cost function which determines realized capital gains plus adjustment costs. Adjustment costs are zero when the \(G/U\) is at the steady state and \(\Phi(G_t/U_t) = G/U\). The adjustment cost function has the following properties: \(\Phi \geq 0\), \(\Phi' > 0\), and \(\Phi'' < 0\). The steady state value of \(\Phi\) is determined by steady state first order conditions after we calibrate the parameters for the balanced growth trend, the inflation trend, the discount factor and \(G/U\). To compute the solution to the linear approximation we calibrate the second derivative, \(\Phi''\), to be equal to -1.1 based on the estimated elasticity of marginal adjustment costs with respect to the \(G/U\) ratio.\(^3\)

### 3.4 Stochastic General Equilibrium

To solve for the model’s approximate dynamics, we divide all the nominal variables by \(P_t\) to get real values, and then we deflate all real variables by \((\gamma_x)^t\).\(^1\) 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.

\[
\max_E \sum_{t=0}^{\infty} \beta^t \left( \frac{c_t L_t^{1-\theta} L_t}{1 - \sigma} \right)
\]

subject to

\[
\begin{align*}
(1 - \tau_t^K)w_t N_t + (1 - \tau_t^L)(g_t - \delta)k_t - \tau_t^G g_t + t_t + [1 + (1 - \tau_t^B)(R_{t-1} - 1)]b_{t-1}/\pi_t \\
= c_t + (\gamma_x k_{t+1} - k_t) + \gamma_x b_t + \gamma_x m_t \\
L_t + N_t + \pi_t c_t^{1-\gamma_x} = 1
\end{align*}
\]

\(^3\)The elasticity of marginal adjustment costs with respect to the \(G/U\) ratio, \(\zeta = (G?U)\Phi''(G/U)/\Phi'(G/U)\), is calibrated to be consistent with Auerbach’s (1988) regression results showing that a one-percent increase in the capital gains tax rate is associated with a 0.56 decline in realized capital gains. A simulation experiment using the time series property of Auerbach’s data on capital gains realizations generates approximately this result with an elasticity measure \(\zeta\) equal to 1.1.
\[ \gamma_x \pi_{t+1} u_{t+1} = u_t + \left(1 - \frac{1}{\pi_t}\right) k_t - \Phi \left( \frac{g_t}{u_t} \right) u_t \]  

(15)

The first-order conditions for \( c_t, L_t, N_t, g_t, m_t, b_t, k_t, \) and \( u_t \) are:

\[
\theta \epsilon_t^{(1-\sigma)-1} L_t^{(1-\sigma)(1-\sigma)} = \lambda_t + \omega_t \eta \left( \frac{S_t}{\epsilon_t} \right)
\]  

(16)

\[
(1 - \theta) \epsilon_t^{(1-\sigma)} L_t^{-(1+\delta)-\theta} = \omega_t
\]  

(17)

\[
\lambda_t (1 - \tau_N^N) u_t = \omega_t
\]  

(18)

\[
\tau_t^G \lambda_t = \Phi' \left( g_t / u_t \right) \varphi_t
\]  

(19)

\[
\beta E_t [\lambda_{t+1} / \pi_{t+1} + \omega_{t+1} \eta (S_{t+1} / m_t)] = \lambda \gamma_x
\]  

(20)

\[
\beta E_t \{ \lambda_{t+1} [1 + (1 - \tau^R_{t+1}) (R_t - 1)] / \pi_{t+1} \} = \lambda \gamma_x
\]  

(21)

\[
\beta E_t \lambda_{t+1} \{1 + [(1 - \tau^K_{t+1}) (q_{t+1} - \delta)] - \varphi_{t+1} \lambda_{t+1} (1 - \frac{1}{\pi_{t+1}})\} = \lambda \gamma_x
\]  

(22)

\[
\beta E_t \frac{\varphi_{t+1}}{\pi_{t+1}} \{1 - \Phi (g_{t+1} / u_{t+1}) + \frac{g_{t+1}}{u_{t+1}} \Phi' (g_{t+1} / u_{t+1})\} = \varphi \gamma_x
\]  

(23)

where \( \lambda_t, \omega_t, \) and \( \varphi_t \) are utility-denominated, present-valued shadow prices associated with constraints (13), (14), and (15), respectively.

From the firm’s profit-maximization condition, we can get the wage rate, \( w_t \), the rate of return on capital, \( q_t \), and the energy price \( p_t^e \) as:

\[
w_t = (1 - \alpha) \frac{y_t}{N_t}
\]  

(24)

\[
q_t = \alpha \frac{\psi k_t^v}{\psi k_t^v + (1 - \psi) e_t^v} y_t
\]  

(25)

\[
p_t^e = \alpha \frac{(1 - \psi) e_t^v}{\psi k_t^v + (1 - \psi) e_t^v} e_t
\]  

(26)

Details about the model equations, the steady state and the log-linearized model used in the computational experiments are available in an appendix.
4 Computational Experiments

In this section we examine the effect of energy price shocks on the economy under alternative assumptions about monetary policy, taxes, and the structure of the energy sector. The monetary regime is calibrated to match the inflation persistence of the pre-1980 U.S. economy and the second regime is calibrated to match the post 1982 period. We ignore the transition period from 1980 to 1982—the only period in recent history in which the Federal Reserve did not try to smooth inter-meeting interest rates, but based open market operations explicitly on weekly paths for reserves that were derived from target paths for the money supply.

We take the pre-1980 period as the baseline because the key issue is understanding why oil price shocks had such big effects before 1980. We show that if monetary policy stabilizes the inflation rate in the sense that long run inflation expectations are relatively constant, then this channel from inflation expectations through the tax code ceases to operate.

We show how the different taxes influence this channel. In the section on the oil sector, we replicate the Dhawan Jeske and Silos (2010) spillover effects and show that this tax channel can explain why the effects were estimated to be so large before 1980 and why they went away with the Volcker monetary policy reform. In the last section on policy implications for today, we show why the Kormilitsina (2011) policy that may appear to be optimal in a New Keynesian setting looks much worse when we take account of the U.S. tax code.

4.1 Monetary Policy

The response of the model economy to a one percent energy price shock is shown in Figure 1. The negative impact on output and hours is consistent with a large recession following the energy price shocks in 1973:Q4 and 1974:Q1. There is a gradual but deep decline in the capital stock. Labor productivity (here the same as real wages) rises initially as people consume more goods and more leisure, then falls as the marginal product of labor is reduced with the decline in capital. The long slow decline in the capital stock causes real wages (and productivity) to remain below trend for many years. The policy results in a large decline in investment and an initial increase followed by a long period of below trend consumption. The reason for the immediate decline in investment and house worked is that the expected higher tax on future capital causes the household to consume more goods and more leisure immediately. But the effect reverses as capital stock declines.

Figure 2 shows that the economic decline is associated with a rapid rise in the inflation rate. The higher inflation coupled with below trend output and productivity growth are landmarks of the 1970s stagflation. The inflation target rises by 0.132 percent while the actual inflation rate jumps by three times that much. This amplification is due to the tax on interest income. The nominal rate and inflation must rise by more than the rise in the inflation rate to equilibrate the bond market. Before taxes, the real interest rate rises, but the after-tax rate declines as the path for the desired capital stock falls below the steady state trend. The after-tax real interest rate is given as

\[ E_t \left\{ 1 + [(1 - \tau^K)(q_{t+1} - \delta)] - \frac{\tau^G}{\Phi'(g_{t+1}/u_{t+1})} (1 - \frac{1}{\pi_{t+1}}) \right\}. \]

The effect of interaction between inflation and the capital gains tax is given in the third term on the right hand side. The marginal cost of adjusting the capital gains portfolio is equal to unity if the tax is paid on accrual. Under the baseline calibration, the value is 3.26 and the gross inflation rate is 1.01 per quarter. As inflation rises to infinity, the third term goes to the expected value of \( \tau^G / \Phi'(g_{t+1}/u_{t+1}) \). With inflation at the steady state, the oil price shock alone would reduce
the expected return to capital, \( qt+1 \), because it is a complementary factor in production, but the effect is small relative to the effect of inflation working through the nominal capital gains tax.

In the bottom two panels of Figure 2 we show the path for realized capital gains and the deviation of the portfolio of unrealized capital gains from the steady state. The higher tax on nominal capital gains causes households to resist realizing gains for about 3 years—until the ratio of \( G/U \) gets back to the steady state. As the ratio goes above the steady state, the cost of being away from the steady state induces the households to raise the amount of gains realized. This expected tax flow makes the after tax return to capital fall after an oil price shock and leads to the dramatic decline in investment.

If we modify the model by adopting the post-1983 monetary policy regime, the effects of the oil shock are small, similar to those that would occur in a real model with no monetary policy or tax distortions. Figure 3 shows what happens if we set \( \xi = 0, \nu_n = 1.5 \) and \( \rho_n = 0.84 \). The effects on output are about 1/6 the size observed before 1980 and the effects on labor are more than an order of magnitude smaller. In the pre-1980 regime, the energy price shock has a big effect because the central bank accommodates the shock by raising the inflation target by 0.132 percentage points. There is no effect on the inflation target in the post-1983 regime.

The key parameters driving this large effect are the interest rate rule and the transition equation for the inflation target. Figure 4 shows that minor changes in any one of these parameters \( \rho_n, \nu_n, \) and \( \xi \) can change the magnitude of the impulse response functions significantly. The top row shows the responses to a one percent oil price shock under alternative assumptions when we lower \( \rho_n \)—the degree of persistence in the deviation of the inflation target from the steady state inflation rate—from the baseline 0.97 to 0.95. The effects are highly nonlinear, falling quite rapidly as the persistence falls to 0.95. In the next row, we show the effect of putting more weight on the deviation of inflation from the target. Here again, the effects are nonlinear. There are large effects of small movements away from 0.375 to 0.5. But as the reaction coefficient gets larger the inflation response converges to equal the response of the inflation target. Again, the effects of a weaker response get magnified because of the tax on bonds. In the bottom row we show the effect of lowering \( \xi \) from 0.132 to 0.1. The effect of changing \( \xi \) is linear—the more the bank accommodates the oil price shock, the proportionally larger are the effects on inflation and output.

### 4.2 Taxes

There are two necessary ingredients in our channel from oil price shocks to the economy. The first was the inflation target with feedback from oil price shocks. The second is a tax code that is imperfectly indexed to inflation. We do not model the progressive tax system that was in place for labor and capital rental income. Doing so would reinforce the direction and magnitude of the effects we report. For the purposes of this paper, those tax brackets have been indexed for inflation. We focus on the effects of taxes on nominal interest income and nominal capital gains. One reason for doing so is that these taxes remain unindexed and this mechanism would become operative again if the Fed decided to change the inflation target or to make it dependent on shocks to the economy.

Figure 5 shows how the baseline reaction of inflation and output changes as we change the tax rates on bond income and capital gains as well as on the assumption about the steady state ratio of realized to accrued capital gains. In the case of the tax rate on capital gains, the different assumptions will result in different steady states. Higher capital tax rates lead to a lower steady state capital stock. The bond tax does not affect the steady state level of capital. The two figures

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4This also explains why core measures of inflation—those excluding energy prices—were such poor predictors of inflation before 1983 and such good predictors afterwards. Those worried about pass-through from core to all-item inflation in 2011 are implicitly worried about another change in the monetary policy regime.
in the top row demonstrate the critical role of the tax on interest income. In general equilibrium, the inflation response to a temporary rise in the inflation target is magnified by this tax. If this tax rate were zero, the inflation response would approximately mirror the path of the inflation target. We show the effect of lowering the tax rate to 22 percent—the lowest average marginal tax rate in all the years reported by Feenberg and Poterba (2003). The impact effect on output is 40 percent smaller and the relative difference gets larger as the effects decay.

The middle row of figures show that changing the statutory tax rate on nominal capital gains has a bigger effect on output than it does on inflation. Again, the difference is understated, because the steady state capital stock is a bit lower with the higher capital gains tax rate. Also note, that in this case, lower the tax rate causes oil price shocks to have a greater positive impact on inflation and a smaller negative impact on real output. The reason for this is that at a higher \( \tau_G \) causes oil price shocks to have a smaller effect on before-tax real interest rates. Thus nominal rates and inflation do not have to jump up as much when \( \tau_G \) is a higher.

The bottom two panels in Figure 3 show the sensitivity of the impulse response functions to the assumption about the steady state ratio of realized to accrued capital gains. In our baseline case, only 40 percent of all capital gains ever get realized. The figure shows the effects of raising the ratio to 50%. Assuming a higher value for this ratio is the same as closing loopholes and causing more investors to pay the tax. As we saw with statutory capital gain tax rate, raising the steady state ratio causes the real rate (and thus, the nominal rate and inflation) to rise less and output to decline by more.

4.3 Technology and Preferences

For the utility function we consider, the only parameter that is important for our results is, \( \sigma \), the coefficient of relative risk aversion. Balcer and Judd (1987) report that the effects of the capital gains tax will depend on this parameter. The results are shown in Figure 6. In the baseline case, \( \sigma = 2 \). If we used log utility the impact effect of a one percent energy price shock on output would be about the same as if we had doubled the size of \( \xi \), the reaction of the inflation target to the energy price shock. There is no comparable effect on inflation. If we had set \( \sigma = 4 \), the impact effect on output would have been about 1/4 less on impact, but the effects would last much longer. Overall, the degree of risk aversion would matter for cyclical fluctuations, but the long run effects are more similar.

Because the channel operates on the exogenous oil price, our results are not sensitive to the parameters of the production function. The contribution of energy to production can approach zero and the effects still operate through the energy price shocks. The relative share of energy has to become unrealistically large for energy price shocks to have a significant effect on aggregate fluctuations. One of the reasons that Dhawan Jeske and Silos (2010) and Alpanda and Peralta-Alva (2010) give for the disappearance of the effects of energy price shocks is that the share of energy as a factor of production has fallen by half since the 1970s. The effects operating through the price effect on inflation and the tax code swamp any changes that appear when we change the production function.

Dhawan, Jeske, and Silos (2010) estimated a bivariate Markow switching model in total factor productivity (TFP) and the relative price of energy. They found significant evidence of a spillover effect before 1983 and attribute the large effect of energy price shocks in the 1970s, to this spillover effect going from energy price shocks to TFP. To show the effect of their estimates in our model, we adopt their version of the technology process:

\[
\ln\left(\frac{z_t}{z_{ss}}\right) = \rho_z \ln\left(\frac{z_{t-1}}{z_{ss}}\right) + \sum \gamma_i \varepsilon_{t-i} + \varepsilon_t
\]

where they estimate \( (\gamma_1, \gamma_2, \gamma_3, \gamma_4) = (-0.092, -0.026, -0.067, -0.046) \) for the period before 1983. For the period after 1983, the estimates are insignificant and have the wrong sign. They
do not have an economic explanation for the spillover or why it went away. They merely point out that the end of this spillover could account for the reduction in the volatility of the real economy that is associated with the Great Moderation. Figure 7 shows the response of the economy with the DJS spillover specification and a policy regime in which the Fed does not accommodate the energy price shock, that is, $\xi = 0$. We have also included the baseline case for our model where the effects are due to tax and monetary policy. Looking at the panels on the left, from top to bottom, we see that the output effects are quite similar. Investment and the capital stock decline a bit more with the policy model. Looking to the left side, we see the major differences implied by the models. Hours worked decline more in the case of the policy model where both consumption and leisure rise initially with the higher expected tax on capital gains. This implies that labor productivity declines much more gradually in the policy model. Finally, in the bottom right panel, we see that the spillover model has no important implications for inflation. By itself, the spillover cannot account for the impact of the energy price shock on both inflation and output.

Dhawan, Jeske and Silos (2010) argued the spillover effect could explain high volatility before 1980 and the moderation in volatility that appear around 1983. In Table 2 we report the output volatility statistics for the RBC model, the spillover version of our model and our model in which tax and monetary policy is the transmission mechanism. The standard deviation of deviations of output from a Hodrick-Prescott trend was 1.42 percent in the RBC model, 1.83 percent in the Dhawan, Jeske, and Silos version of our model, and 2.04 percent in our policy model. Our explanation for their spillover effect explains more of the volatility than does theirs and attributes more of it to the oil price shock. In our model, the oil price shock explains 53 percent of the volatility in current quarter output. This compares with only 1.7 percent that operates directly though the effect of oil as a factor of production.

4.4 Policy Implications

Kormilitsina (2011) uses a New Keynesian framework to show that the optimal monetary policy response to an oil price shock is to raise the inflation target to offset the negative output effects. This analysis and all such recommendations fail to consider the effects that operate through the U.S. tax code. To replicate Kormilitsina (2011) qualitative results we modify our model to include a Calvo pricing function for intermediate goods where firms have some monopoly power. We also include investment adjustment costs to prevent households from adjusting capital too quickly. These features allow the central bank to offset the negative output effects of oil price shocks by responding to an oil price shock with temporarily higher inflation. We calculate the effects of an energy price shock when prices are flexible and policy ignores the shock. The negative effect of an energy price shock on output is pretty small, but approximately optimal. The accumulated output loss from the steady state after 5 years is less than 0.6 percent of the steady state output level. Without taxes in the model, the central bank can approximate this outcome by setting $\xi = 0.05$. After 5 years the accumulated output loss is around 0.4 percent of output. When we consider the tax code and run the same policy, the accumulated loss over 5 years is about 1 percent of output.

Figure 8 shows the effects of accommodating oil shocks in a New Keynesian model with and without the taxes on interest income and nominal capital gains. As in our model, the inflation rate rises with the inflation target. When there are no taxes, there is no amplification effect and inflation rises approximately by the same amount as the temporary increase in the inflation target. When we add the taxes, the inflation rate jumps by a factor of 3. These differences are also reflected in the nominal interest rate. The higher expected inflation raises the expected tax rate on nominal capital gains and causes output to decline substantially more than in the case that ignores taxes. The decline in the capital stock also shows the substantial difference induced
by considering taxes.

5 Conclusion

This paper provides an account of how the oil price shocks in the 1970s could have led to a large decline in output and hours worked simultaneously with a sharp rise in the inflation rate. Before 1980, the Fed responded to oil price shocks by allowing the inflation rate to rise. It is true as many have argued, that the Fed raised interest rates, but not enough to prevent inflation and long-run inflation expectations from rising. This higher inflation raise the effective taxes on real bond income and on capital. The capital gains tax is paid on realized capital gains so that the accrual equivalent tax rate is much lower than the statutory rate. Households get to choose when to pay the tax and they can avoid the tax altogether on about 60% of their gains (in reality they do this by placing funds in tax-exempt retirement accounts or bequeathing the capital to heirs). Nevertheless, this mechanism is still powerful enough to generate sizeable effects of oil price shocks. The effects cease to operate after then Fed Chairman Paul Volcker adopts a disinflationary policy and stops accommodating energy price shocks.

Thus, our model provides solutions for several puzzles from the 1970s macroeconomic experience. First, it explains why the real economy reacted so sharply to the first oil shocks. Second, it explains why the effect goes away after 1980, and third, it explains why we could have both a stagnant economy and high inflation. This result contributes to our understanding of the past, but it also carries a warning for policymakers today. The U.S. tax code continues to tax nominal interest income and nominal capital gains. Policy recommendations to accommodate oil price shocks or raise the inflation rate to relieve real debt burdens should consider the tax effects before being taken seriously.
6 References

References


Table 1. The Effect of the 1973 Oil Price Shock and Subsequent Revisions to GDP

<table>
<thead>
<tr>
<th>Date</th>
<th>Real GDP 1958 dollars</th>
<th>Real GDP 1972 dollars</th>
<th>Real GDP 2005 dollars</th>
<th>FFR*</th>
<th>CPI Inflation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>vintage</td>
<td>75:Q4</td>
<td>79:Q4</td>
<td>11:Q3</td>
<td>11:Q3</td>
<td>11:Q3</td>
</tr>
<tr>
<td>1973:Q4</td>
<td>845.7</td>
<td>1242.6</td>
<td>4948.8</td>
<td>10.00</td>
<td>8.7</td>
</tr>
<tr>
<td>1974:Q1</td>
<td>830.5</td>
<td>1230.2</td>
<td>4905.4</td>
<td>9.32</td>
<td>10.4</td>
</tr>
<tr>
<td>1974:Q2</td>
<td>827.1</td>
<td>1224.5</td>
<td>4918</td>
<td>11.25</td>
<td>10.9</td>
</tr>
<tr>
<td>1974:Q3</td>
<td>823.1</td>
<td>1216.9</td>
<td>4869.4</td>
<td>12.09</td>
<td>11.9</td>
</tr>
<tr>
<td>1974:Q4</td>
<td>804</td>
<td>1199.7</td>
<td>4850.2</td>
<td>9.35</td>
<td>12.3</td>
</tr>
<tr>
<td>1975:Q1</td>
<td>780</td>
<td>1171.6</td>
<td>4791.2</td>
<td>6.30</td>
<td>10.3</td>
</tr>
</tbody>
</table>

Percent Change from Peak

| 1973:Q4   | -8.1                  | -5.9                  | -3.2                  | -3.70| 1.6           |
| 1974:Q1   | -5.9                  | -8.1                  | -5.9                  | -3.70| 1.6           |
| 1974:Q2   | -3.2                  | -5.9                  | -3.2                  | -3.70| 1.6           |
| 1974:Q3   | -3.70                 | -5.9                  | -3.70                 | -3.70| 1.6           |
| 1974:Q4   | -3.70                 | -5.9                  | -3.70                 | -3.70| 1.6           |
| 1975:Q1   | -3.70                 | -5.9                  | -3.70                 | -3.70| 1.6           |

* Note that the CPI and the federal funds rate are not subject to regular revisions.

Source: Real-Time Data Set, Federal Reserve Bank of Philadelphia
http://www.philadelfiafed.org/research-and-data/real-time-center/

Table 2. Output Volatility Implied by Alternative Models

<table>
<thead>
<tr>
<th>Model</th>
<th>RBC</th>
<th>DJS Spillover</th>
<th>Policy Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Deviation</td>
<td>1.42</td>
<td>1.83</td>
<td>2.04</td>
</tr>
<tr>
<td>Variance Decomposition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology Shock</td>
<td>93.7</td>
<td>56.1</td>
<td>42.4</td>
</tr>
<tr>
<td>Oil Price Shock</td>
<td>1.7</td>
<td>41.2</td>
<td>53.1</td>
</tr>
<tr>
<td>Inflation Target Shock</td>
<td>4.6</td>
<td>2.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Parameter assignments for the policy model:
\[ \xi = 0.132, \sigma_z = 0.0075, \sigma_{pe} = 0.031, \sigma_{\pi} = 0.004, \]
Figure 1. Economic Response to a 1 Percent Energy Price Shock Under the Pre-1980 Monetary Policy Regime
Figure 2. Monetary Transmission Mechanism Following a 1 Percent Energy Price Shock

**Inflation and Inflation Target**

- **Target**

**Nominal Interest Rate**

- **Before Tax**
- **After Tax**

**Real Interest Rate**

- **Before Tax**
- **After Tax**

**Return to Capital**

- **Before Tax**

**Realized Capital Gains**

**Unrealized Capital Gains**

0 8 16 24 32 40 48 56 64 72 80 88 96

0 0.1 0.2 0.3 0.4 0.5

0 0.2 0.4 0.6 0.8 1.0

0 0.02 0.04

0 0.02 0.04 0.06

0 0.02 0.04 0.06

0 0.02 0.04 0.06

0 0.02 0.04 0.06

0 0.02 0.04 0.06
Figure 3. Economic Response to a 1 Percent Energy Price Shock Under the Post-1983 Monetary Policy Regime

Output

Hours Worked

Investment

Inflation and Inflation Target

Return to Capital

Real Interest Rate
Figure 4.
Sensitivity to Monetary Policy Parameters
Figure 5. Sensitivity to Tax Parameters (Effects with Different Steady States)

Inflation

输出

输出

输出

输出

Inflation

输出

输出

输出

Inflation

G/(P_{t-1} - P_t) = 0.4

G/(P_{t-1} - P_t) = 0.5
Figure 6. Sensitivity to Curvature in the Utility Function—Output Response to a 1 Percent Energy Price Shock
Figure 7. Comparing the Energy Price Spillover to Technology with the Baseline Policy Model

Output

Hours Worked

Investment

Labor Productivity

Capital Stock

Inflation
This is a “New Keynesian” version of our model. The ‘No Taxes’ simulation approximates the optimal policy without taxes. The value of $\xi$ is set to 0.5 to approximate the optimal policy without taxes.