Inflation-Protected Income Taxes and Monetary Dominance*

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*Job Market Paper

October 20, 2014

Abstract

Considering a standard DSGE model with a labor income tax code derived from household income levels, I find that subtle alterations in this tax code can cause substantial changes in model dynamics. Specifically, I find that indexing the federal income tax code for inflation had a significant impact on the economy. My results are parallel to those of the recent monetary/fiscal policy coordination literature without considering government debt and to those of the Great Moderation literature without changing monetary policy. This suggests that the reductions in volatility seen in the data were not merely unilateral changes by monetary policy makers, but a combination of single-handed movements on both sides. One change without the other would not have resulted in the period of tranquility seen in the late 1980s through the mid 2000s.

JEL Classification: E31, E61, E63, H24

Key Words: Monetary-Fiscal Policy Coordination, Taxation, Inflation Indexed, Great Moderation

*I would like to thank those who participated in the Macro Research Seminar at the University of Kansas for their input and support. Additionally, I greatly appreciate the help of Athanasios Orphanides and Jang-Ting Guo, who were gracious enough to assist me with data acquisition.

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1 Introduction

Beginning with Leeper (1991), the standard monetary/fiscal policy interaction literature has considered lump sum tax rules based on government debt and/or spending. Analysis is typically focused on significant shifts or underlying uncertainties in such policies. But what about subtler fiscal policies such as changes to the basic structure of the tax code itself? In this paper, I construct a standard DSGE model with a labor income tax code derived from household income levels, following the actual, legislated tax code. With this, I explore the impact of indexing the federal income tax code for inflation. My finding are parallel to those of much of the monetary/fiscal interaction literature without considering government debt dynamics, suggesting that “small” policies have the potential to make “big” differences. Specifically, a non-indexed tax code yields the same “active” fiscal policy properties as seen in the literature. Only after the indexation of the tax code was active monetary policy, established almost five years earlier, allowed to be dominant, leading to the period of relative stability known as the Great Moderation. Unilateral moves by either the monetary or fiscal authorities would not have led to this period of tranquility.

1.1 Monetary-Fiscal Interaction and a Changing Fiscal Policy Landscape

The seminal paper in this literature, Sargent and Wallace (1981), shows that there are situations in which the monetary authority can be very limited in its control of inflation, even if the relationship between the monetary base and the price level remains strong. Also called the Fiscal Theory of the Price Level, it suggests that the central bank can be forced to makeup the differences between the funds needed for government spending and the public’s demand for government bonds through seignorage. Thus, in this situation, fiscal policy governs inflation dynamics and essentially reverses the standard interest rate channel. This model, along with those of Leeper (1991), Sims (1994), and Woodford (2001), to name a few, focused on tax rate rules that were dependent on the level of government debt and government spending. However the federal income tax code has remained relatively steady since the 1990s while debt has fluctuated. Figure 1, constructed in a similar fashion to the methods of Chen and Guo (2013), presents the legislated federal income tax code as average or effective tax rates for fixed, evenly spaced real income levels across the period 1950 to 2012. This shows that the tax code has remained relatively unaltered for the last two decades, suggesting that fiscal policy may not be as passive as the literature would suggest it is. For this purpose, I focus not on changing average lump sum taxes based on debt and spending, but more on the tax code as it is structured in legislation.

One specific piece of legislation during this period changed the economic landscape:

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1 In addition to the example mentioned above, see Sims (1994), Woodford (2001), Davig and Leeper (2011) and Leeper and Zhou (2013).

2 Though, as I mentioned, my tax rule is not a function of government debt, so a literal application of the Leeper definition may be a stretch.
the Economic Recovery Tax Act of 1981. Not only did it reduce the top marginal federal income tax rate from 70 to 50 percent, but also established that this particular tax code would be indexed for inflation starting in 1985. Indexation is a policy in which the nominal bounds on brackets in the tax code are adjusted annually for inflation. Indexing the tax code for inflation is important even in low inflation economies because, without it, we get a phenomenon known as bracket creep, which can be seen in Figure 1 especially in the high-inflation period of 1965-1980. This is the process by which a household ascends to higher tax liabilities when its nominal income increases, even if the purchasing power of that income remains constant. This causes the real disposable income of the household to fall over time.

As a more concrete example, consider a household in 1973 making $19,000 annually (roughly $99,600 in 2014 dollars) and filing its taxes. Given that the consumer price index increased by approximately 11% between 1973 and 1974 and assuming that this household received an equivalent cost-of-living adjustment to their salary, the real value of their tax liabilities increased, raising their effective tax rate from about 21.58% in 1973 to 22.42% in 1974. This is shown in more detail in Table 1. This is bracket creep in its simplest form, causing real disposable income to fall over time due to inflationary pressure. It is important to note that this example only considers the change from one year to the next, but the entire period between 1965 and 1980 saw accelerating price levels, meaning that households could lose around one percent of their disposable income every year. Again,

<table>
<thead>
<tr>
<th>Bracket</th>
<th>Taxable Income</th>
<th>Liability</th>
<th>Taxable Income</th>
<th>Liability</th>
</tr>
</thead>
<tbody>
<tr>
<td>14%</td>
<td>$1,000</td>
<td>$140</td>
<td>$1,000</td>
<td>$140</td>
</tr>
<tr>
<td>15%</td>
<td>$1,000</td>
<td>$150</td>
<td>$1,000</td>
<td>$150</td>
</tr>
<tr>
<td>16%</td>
<td>$1,000</td>
<td>$160</td>
<td>$1,000</td>
<td>$160</td>
</tr>
<tr>
<td>17%</td>
<td>$1,000</td>
<td>$170</td>
<td>$1,000</td>
<td>$170</td>
</tr>
<tr>
<td>19%</td>
<td>$4,000</td>
<td>$760</td>
<td>$4,000</td>
<td>$760</td>
</tr>
<tr>
<td>22%</td>
<td>$4,000</td>
<td>$880</td>
<td>$4,000</td>
<td>$880</td>
</tr>
<tr>
<td>25%</td>
<td>$4,000</td>
<td>$1,000</td>
<td>$4,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>28%</td>
<td>$3,000</td>
<td>$840</td>
<td>$4,000</td>
<td>$1,120</td>
</tr>
<tr>
<td>32%</td>
<td>$0</td>
<td>$0</td>
<td>$1,092.25</td>
<td>$349.52</td>
</tr>
<tr>
<td>36%</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$19,000</strong></td>
<td><strong>$4,100</strong></td>
<td><strong>$21,092.52</strong></td>
<td><strong>$4,729.52</strong></td>
</tr>
</tbody>
</table>

There are other methods of indexing a tax code (see Thuronyi, 1996), but is the largest component and thus is the focal point of this paper.
refer to the effective tax rates for fixed real income levels in Figure 1 to see how quickly tax liabilities can increase in a high inflation period.

Continuing this example at the macro-level, Table 2 shows a rough estimate of the additional tax revenue generated by inflation starting with the tax legislation of 1981 and prior to the indexation in 1985. Equivalently, this can be viewed as the loss in disposable income to inflation. I construct this time series by first calculating the effective personal income tax rates via nominal receipts from income taxes. I then apply them to their corresponding real incomes calculated using the change in average hourly earnings. Since

<table>
<thead>
<tr>
<th>Year</th>
<th>Effective Rate</th>
<th>Additional Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>11.0%</td>
<td>$0.00 billion</td>
</tr>
<tr>
<td>1982</td>
<td>10.7%</td>
<td>$16.27 billion</td>
</tr>
<tr>
<td>1983</td>
<td>9.7%</td>
<td>$26.78 billion</td>
</tr>
<tr>
<td>1984</td>
<td>9.1%</td>
<td>$36.91 billion</td>
</tr>
</tbody>
</table>

the new tax code and brackets were set in 1981, the additional revenue for the first year is null, but since prices rose at a faster pace during this period, these additional tax receipts accumulated quickly, even in the face of falling effective tax rates. While this is a rough estimate, these figures are robust to multiple measures of income and wage inflation.

1.2 The Traditional View: A Purely Monetary Phenomenon

At first, theories about the sudden fall in volatility were focused exclusively on monetary policy. Works such as Taylor (1999) and Clarida, Galí and Gertler (2000) suggested that there was a dramatic shift in the way monetary policy was conducted. This break was considered to come from one of two sources: a move from discretionary policy towards interest rate rules or an increased aggressiveness against inflation if rules were already the norm. Other explanations also surfaced, including Blanchard and Simon (2001) and Galí and Gambetti (2009), which suggest a sudden, structural shift in the relationships between variables in the economy. But even with all of the empirical evidence, Stock and Watson (2003) still estimate that 40-60% of the cause remains unknown, prompting a title of “good luck.” By this, it is generally meant that the variance of supply shocks has fallen dramatically since the 1980s.

Contrastingly Athanasios Orphanides and his coauthors dismissed the idea of discretionary policy, citing faulty information as the culprit, finding persistent differences in the real-time value of the output gap versus the refined measurements. If the Federal

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4 The effective tax rates fell due to the fact that the tax reductions were imposed over multiple years, but the brackets were established in 1981.

5 A select few of this large literature include Orphanides and van Norden (2002) and Orphanides (2003, 2004).
Reserve was utilizing the output gap as a primary indicator of economic activity, large measurement errors could easily derail monetary policy, making it seem discretionary. For this reason, this literature often refers to this period of high inflation and volatility as the “Great Inflation.”

1.3 The Great Moderation as a Monetary and Fiscal Phenomenon

This paper fits between the monetary/fiscal-interaction and Great Moderation literatures. Specifically, my results are parallel to those of Davig and Leeper (2011) and Bianchi (2012), who use Markov-switching models to show that the Great Moderation was a feat of monetary and fiscal policy coordination, not a unilateral shift. However, unlike the standard monetary/fiscal-interaction literature, I model an income tax code as a function of labor income, not government debt/spending. This is a more realistic representation of the current income tax code, which has not substantially changed since the early 1990s.

Theoretically, my model shows that only the combination of active monetary policy and an indexed tax code results in a stabilized economy, much like the active monetary/passive fiscal policy prescriptions in the literature. Any single-handed policy shift results in either sunspot solutions or explosive behavior. Empirically, the introduction of a tax-labor productivity channel causes universal determinacy in the non-indexed model, but indexation leads to decreases in variable volatilities and changes in variable correlations similar to the empirical results found by Galí and Gambetti (2009) and others. Combining these results suggests that bracket creep is a plausible cause of the measurement error in labor productivity described in Orphanides (2003).

The remainder of this chapter is organized as follows: Section 2 utilizes a standard New Keynesian model with a progressive tax code, Section 3 presents the results, including determinacy regions and application of the literature, and Section 4 concludes.

2 New Keynesian Model with Tax Policy

Here I present a simple DSGE model with nominal price rigidities. The essence of my model is very simple, such as those used in Ireland (2004, 2012) and Belongia and Ireland (2012), but with an individual income tax code that depends on the households wage income like those of Guo and Lansing (1998) and Chen and Guo (2013).

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6 Similarly, Keating and Valcarcel (2012) consider this period a “blip” on the metaphorical radar, suggesting that the Great Moderation may not have been the greatest.

7 See Woodford (2011); Galí (2009); and Rotemberg (1982) for details regarding this style of model and nominal price rigidities.
2.1 The Representative Household

In this model the representative household solves

$$\max_{\{c_t, h_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left( \eta^p_t \ln c_t - \frac{1}{\psi} h_t^\psi \right),$$

(1)

where $c_t = c_t/P_t$ and $h_t$ denote real consumption and labor hours, respectively. The parameters $\beta \in (0, 1)$ and $\psi > 0$ represent the subjective discount factor and the elasticity of substitution, respectively. The preference shock $\eta^p_t$ follows an autoregressive process

$$\ln \eta^p_t = \rho_p \ln \eta^p_{t-1} + \varepsilon^p_t,$$

such that $\rho_p \in (0, 1)$ and $\varepsilon^p_t$ is an i.i.d. innovation with zero mean and constant variance $\sigma_p > 0$. While solving (1), the household has to consider its own budget constraint. In every period, the household earns income via the returns on nominal discount bonds $B_t$ purchased in the previous period; its disposable labor income, with $W_t$ and $\tau_t$ representing the nominal wage and tax rates, respectively; and revenues from dividend payments $D_t$. We assume the household takes the tax rate $\tau_t$ as given since it is set by the fiscal authorities. This income is then divided between the purchase of real consumption goods $c_t$ at price $P_t$ and nominal bonds at price $1/r_t$, where $r_t$ is the gross nominal interest rate in the economy. All of this yeilds the following budget constraint:

$$P_t c_t + B_t/r_t \leq B_{t-1} + (1 - \tau_t) W_t h_t + D_t.$$

(2)

Along with this budget constraint, the first order conditions are

$$\frac{\eta^p_t}{c_t} = \beta \left[ \frac{1}{\eta^p_{t+1}} \frac{1}{c_{t+1} \pi_{t+1}} \right],$$

(3)

and

$$\frac{W_t}{P_t} = \frac{h_t^{\psi-1} c_t}{\eta^p_t (1 - \tau_t)},$$

(4)

where $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate. As we can see, the Euler equation remains unaltered from the standard New Keynesian models, but our intratemporal condition now depends on the tax rate $\tau_t$.

2.2 The Final Goods-Producing Firm

Like so many standard New Keynesian models, I consider a final good-producing firm which simply aggregates the differentiable goods $y_t(i)$ for $i \in [0, 1]$ produced by the continuum of

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8The results of Guo and Lansing (1998) show that this specification does not change their determinacy results.
intermediate goods-producing firms for consumption by the households. It does so with a CES production function

\[ y_t = \left[ \int_0^1 y_t(i) \frac{\eta_t(i)}{\eta_t} \, di \right]^{\frac{\eta_t}{\eta_t - 1}}, \]

where \( \eta_t \) is an exogenous process governing the elasticity of substitution. I consider innovations to this as markup shocks, which follow the autoregressive process

\[ \ln \eta_t = (1 - \rho_s) \ln \eta_s + \rho_s \ln \eta_{t-1} + \varepsilon_t, \]

where \( \rho_s \in (0, 1) \), \( \eta_s > 0 \), and \( \varepsilon_t \) is the i.i.d. innovation with zero mean and constant variance \( \sigma_s > 0 \). The final goods-producing firm maximizes its profits in a perfectly competitive market, yielding its demand for each intermediate good

\[ y_t(i) = \left[ \frac{P_t(i)}{P_t} \right]^{-\eta_t} y_t, \]

for all \( i \in [0, 1] \).

### 2.3 The Intermediate Goods-Producing Firms

As was mentioned above, there is a continuum of monopolistic-competitive, intermediate good-producing firms labeled by \( i \in [0, 1] \). For simplification, we assume that all of these firms face the same production technology given by

\[ y_t(i) \leq z_t h_t(i) \]

for all \( i \), where \( z_t \) is a labor-augmenting productivity process governed by

\[ \ln z_t = (1 - \rho_z) \ln z + \rho_z \ln z_{t-1} + \rho_z \ln \left( \frac{T_t}{T} \right) + \varepsilon_t, \]

such that \( z > 0 \), \( \rho_z \in [0, 1] \), and \( \varepsilon_t \) is an i.i.d. innovation with zero mean and variance \( \sigma_z > 0 \). Notice that I have included the tax rate in the productivity process, giving the model what Vartia (2008) calls the entrepreneurial channel of fiscal policy. With \( \rho_z \leq 0 \), this matches the empirical results that increasing tax rates reduces labor productivity. Interestingly, Rogerson and Wallenius (2009) shows that micro-level estimates of labor supply elasticity to tax rates are much lower than their macro-level counterparts, suggesting that this channel is stronger in the aggregate sense. While I turn this channel off for the baseline analysis, this adds a dynamic to this New Keynesian model that most do not...
contain, making productivity a partly endogenous variable. I also consider a standard cost of price adjustment
\[ \Phi_t(i) = \mu \left( \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right)^2 c_t \]
for all \( i \), which is measured in units of the consumption good. With \( \mu \geq 0 \) regulating the magnitude, this cost of adjustment constraint makes these firms’ problems dynamic. I also assume that all profits from these firms are remitted to dividends \( D_t(i) \), so that the profit functions simplify to
\[ D_t(i) = P_t(i)y_t(i) - W_t h_t(i) - P_t \Phi_t(i) \]
for all \( i \). With this in mind, each intermediate goods-producing firm’s problem is given by
\[
\max_{\{P_t(i), h_t(i), D_t(i)\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\eta^p_t D_t(i)}{P_t},
\]
subject to the constraints above. The first term in (7) is the discounted marginal utility value to the household of additional future profits. Each firm’s optimizing conditions are therefore:
\[
(1 - \eta^p_t) \left( \frac{P_t(i)}{P_t} \right)^{-\eta^p_t} \frac{\eta^p_t}{P_t} + \eta^p_t \left( \frac{P_t(i)}{P_t} \right)^{-\eta^p_t - 1} \frac{\eta^p_t W_t}{z_t P_t^2} - \mu \left( \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right) \frac{c_t}{\pi P_{t-1}(i)}
\]
\[ + \beta \mu \mathbb{E}_t \left[ \left( \frac{P_{t+1}(i)}{\pi P_t(i)} - 1 \right) \frac{P_{t+1}(i)}{\pi P_t(i)^2} \frac{\eta^p_{t+1} c_t}{\eta^p_t} \right] = 0 \]
for all \( i \), which, when linearized, gives me a New Keynesian Philips Curve.

2.4 The Government and Its Progressive Tax Code

The government sector is similar to that of Christiano et al. (2011), where the government has the following budget constraint
\[ P_t g_t + B_{t-1} \leq \frac{B_t}{r_t} + \tau_t W_t h_t \]
where \( g_t \) represents the level of real government spending. The tax rate \( \tau_t \) evolves according to
\[
\tau_t = \begin{cases} 
1 - \theta \left( \frac{wh}{wh_t} \right)^{\phi} & \text{if not indexed} \\
1 - \theta \left( \frac{wh}{wh_t} \right)^{\phi} & \text{if indexed}
\end{cases}
\]
where \( \theta \in [0, 1] \) dictates the steady state tax rate and \( \phi \in (-1, 1) \) represents the income elasticity of the tax code, or simply the progressiveness.\(^{10}\) I assume that, when the tax

\(^{10}\) By “progressive,” I mean that the average (effective) tax rate for a household is lower than the highest marginal tax rate it finds itself in, or that the effective tax rate increases with an increase in income. When considering the level of progressiveness, I am generally referring to how much the marginal tax rate increases relative to an increase in income.
code is set or adjusted, the price level index as it is related to the new tax code is reset to unity, allowing me to omit a price level in the numerator. A tax policy in which \( \phi > 0 \) is considered progressive, whereas policies in which \( \phi = 0 \) and \( \phi < 0 \) are considered flat and regressive, respectively (see Guo and Lansing, 1998; Chen and Guo, 2013). When linearized, (8) results in a tax policy similar to those in Leeper (1991) and Davig and Leeper (2011), only this is a function of labor income, not government debt. It is also worth noting that a flat tax rate results in the standard models with much simpler distortionary tax codes, which makes this model a generalized version of many in the monetary policy literature. Those models with no tax policy would be equivalent to setting \( \phi = 0 \) and \( \theta = 1 \).

2.5 The Monetary Authority

The monetary policy rule considered here is standard in the literature:

\[
\ln \left( \frac{r_t}{r} \right) = \rho_r \ln \left( \frac{r_{t-1}}{r} \right) + \rho_\pi \ln \left( \frac{E_t[\pi_{t+1}]}{\pi} \right) + \rho_x \ln \left( \frac{x_t}{x} \right) + \varepsilon_t^r,
\]

where \( \rho_r, \rho_\pi, \) and \( \rho_x \) are all non-negative; \( r \) and \( \pi \) represent the steady state value of the interest rate and target inflation rate respectively and \( \varepsilon_t^r \) is an i.i.d. innovation to monetary policy with zero mean and variance \( \sigma_r > 0 \). Also, I assume that the monetary authority targets the output gap \( x_t \) as measured using the efficient allocation. Thus, potential output \( Q_t \) is given as in Ireland (2004)

\[
Q_t = \eta_t^{p1/\psi} z_t,
\]

which is a measure of output that varies only with the preference shock and productivity. Considering this measure, the output gap \( x_t \) is considered to be

\[
x_t = \frac{y_t}{Q_t}.
\]

See Appendix A for more details.

2.6 The Model Log-Linearized

Reducing the dimensionality of the model and log-linearizing it around its deterministic steady state provides a simple context for analysis. This particular example considers the non-indexed fiscal policy. These equations can be easily adjusted to accommodate other policies.

\[
\mathbb{E}_t (\bar{y}_{t+1} - \bar{y}_t) = \alpha \mathbb{E}_t (\bar{g}_{t+1} - \bar{g}_t) + (1 - \alpha) \left[ \mathbb{E}_t (\bar{\eta}_t^{p1} - \bar{\eta}_t^P) + \bar{r}_t - \mathbb{E}_t (\bar{\pi}_{t+1}) \right]
\]

(9)

\[
\tilde{\pi}_t = \tilde{\pi}_{t-1} - \tilde{\pi}_t - \tilde{\pi}_t - \alpha (1 - \phi) (1 - \alpha) \bar{g}_t - \bar{\eta}_t^P - 2 \bar{\eta}_t^P - \frac{1}{2} \tilde{\eta}_t^s
\]

(10)
\[ \tilde{r}_t = \rho \tilde{r}_{t-1} + \rho_t \tilde{x}_t + \rho_z \left( \tilde{y}_t - \frac{1}{\psi} \tilde{\eta}_t^p - \tilde{z}_t \right) + \tilde{e}_t^{\tau} \]
\[ \tilde{\tau}_t = \frac{(1 - \tau) \phi}{\tau(1 - \phi)} \left[ (\psi + 1) \tilde{y}_t - \tilde{y}_t - \psi \tilde{z}_t - \tilde{\eta}_t^p + \tilde{P}_t \right] \]
\[ \tilde{z}_t = \rho_z \tilde{z}_{t-1} + \rho^x \tilde{r}_t + \tilde{e}_t^x \]
\[ \tilde{\eta}_t^p = \rho_p \tilde{\eta}_{t-1}^p + \tilde{e}_t^p \]
\[ \tilde{\eta}_t^s = \rho_s \tilde{\eta}_{t-1}^s + \tilde{e}_t^s \]

Where \( \alpha \equiv g/y \) is the steady state ratio of government spending to output, which is calibrated to the average ratio of 0.20. Additionally, I define the following for simplicity

\[ \kappa_y \equiv \frac{(\eta^s - 1) \left( \psi + \frac{\alpha}{1 - \alpha} + \phi \right)}{\mu(1 - \phi)} \]
\[ \kappa_p \equiv \frac{(\eta^s - 1) \phi}{\mu(1 - \phi)} \]
\[ \tilde{Z}_t \equiv \frac{(\eta^s - 1) \psi}{\mu(1 - \phi)} \tilde{z}_t \]

such that \( \kappa_y \) is the slope of the Philips curve when presented in the standard \((\tilde{y}_t, \tilde{\pi}_t)\) space, \( \kappa_p \) represents the degree of permanency resulting from transitory shocks, and \( \tilde{Z}_t \) is the reduced-form technology residual which includes the structural shock. Here, equation (9) is a forward-looking IS curve, while equation (10) is a New Keynesian Philips curve.

3 Results

3.1 The Entrepreneurial Channel and Monetary Policy

To start on a simple note, consider the linearized model which includes equations (9) and (10) and the shock processes. If the entrepreneurial channel is active \( (\rho_z \tilde{r}_t < 0) \) the model becomes completely stationary when the tax code is not indexed for inflation, regardless of monetary policy. This is because the output gap (which is a function of the tax rate) becomes a function of the price level, making monetary policy makers implicitly target the price level. If the tax code is indexed, the price level falls out of the interest rate rule and the monetary policy component of my model is equivalent to those in much of the monetary policy literature. Thus, as it is with fiscal policy, from a monetary policy standpoint, this model is a generalized version of other models. As is presented below, the inclusion of this channel directly impacts the volatility in the model, the correlations between variables, and the variance decompositions.
3.2 Indexing the Tax Code

Notice that, when the tax code is not indexed for inflation, the price level appears in the New Keynesian Philips Curve, disrupting the classical dichotomy. If the monetary authority does not target the price level, then all transitory shocks will have a permanent effect. Two fiscal policy changes can eliminate the permanent effects of these shocks. The first is by simply indexing the tax code for inflation, at which point the price level term falls out of the Philips curve. The second is by considering a flat tax rate ($\phi = 0$), where the tax rate does not move regardless of whether it is indexed or not. On a related note, the slope of the Philips curve is a positive function of the level of progressiveness, even inverting the curve when considering a regressive tax rate.

3.3 Estimating Time-Varying Fiscal and Monetary Policy Parameters

The tax policy used in the model contains two structural parameters ($\phi, \theta$) which determine the progressiveness and the steady state effective income tax rate in the economy. To get an idea of where these parameters lie, I replicate the results of Chen and Guo (2013) for each year starting in 1950 and ending in 2011. I consider 1,000 nominal incomes spread evenly between $\$1$ and $\$400,000$, which is roughly the cutoff for the bottom 99% of income earners today. Using the nominal income tax brackets from the tax code in each year, I calculate the total tax liability at each income level. Dividing this value by the synthesized taxable income level yields the average income tax rate for each income level. Figure 2 shows how these average tax rates progressed for selected years. As can be seen, the progressiveness of the tax code has steadily fallen since World War II.

Using the values gathered for each year, I then use simple OLS to estimate the natural logarithm of my tax model

$$\ln(1 - \tau) = \ln \theta + \phi \ln \left( \frac{Y^*}{Y} \right),$$

where $Y$ are the 1,000 nominal income values and $Y^*$ is the average taxable income in each year, calculated by taking the total taxable income divided by the number of individual tax returns filed in that year.\textsuperscript{11} Doing this for every year gives us time-varying parameter estimates for the tax code. Figure 3 shows these estimates from 1966 to 2011.\textsuperscript{12} These estimates show that, while the average tax rate ($1 - \theta$) didn’t change much over the years, the progressiveness of the tax code did. These estimates capture the substantial high-income tax cuts in 1981 and in 1986, as well as the surtaxes of the late-1960s.

For the monetary policy parameters, I consider a simple Kalman filter using data on the effective federal funds rate, the inflation rate as calculated by CPI, and the output gap

\textsuperscript{11} This data can be found in the SOI Tax Stats of the US Internal Revenue Service, specifically Historical Tables 8 and 9.
\textsuperscript{12} The years prior to 1966 yielded values of $\theta$ in excess of one, which is not plausible for the model considered here. Because of this, I simply cut off my estimates where Chen and Guo (2013) did.
calculated by taking the ratio of GDP to potential GDP. Figure 4 provides the smoothed results with one standard deviation confidence bands. With these values, I now have a complete rendering of monetary and fiscal policy through the entire sample period.

3.4 Baseline Model: Standard Monetary and Fiscal Policy Channels

For the baseline model, I make a simple assumption that stylizes my monetary policy regime to match the literature.

Assumption: The entrepreneurial channel of fiscal policy is inactive, meaning \( \rho^C_z = 0 \) and productivity is a completely exogenous process.

I assume this now because it specifies monetary policy as a pure inflation-targeting regime and eliminates the added fiscal policy channel, which gives me a standard model with a more explicit tax code. With this, I explore the determinacy properties of the model for both the pre-1985 and post-1985 economies. This includes analyzing determinacy regions as well as calculating the probability of obtaining a unique solution given time-varying estimates of both fiscal and monetary policy parameters. For the various policy parameters held constant in each example, I calibrate \( \theta, \phi, \rho_r, \) and \( \rho_x \) to 0.90, 0.15, 0.50, and 0.35; respectively.

3.4.1 Determinacy Regions

An economic model is said to be determinant if it has a unique solution. The figures below map out not only the determinant areas, but also those parameter spaces which yield an infinite number of solutions and no solution. The first example, shown in Figure 5, looks at the interaction between the fiscal and monetary policy parameter governing the progressiveness of the tax code \( \phi \) and the reaction to inflation \( \rho_{\pi} \), seeing how they work together when the tax code is not indexed for inflation. Due to the permanency of the shocks, only a flat or regressive tax code \((\phi \leq 0)\) yields a unique solution to the model. Otherwise the economy will either find itself in a situation of sunspots (infinite solutions) or explosive behavior (no solution). The next question to ask is if the monetary authority can overcome a non-indexed tax code through some combination of inflation and output gap targeting. Figure 6 shows that a non-indexed tax code means that monetary policy makers cannot push the economy to a region of determinacy, at least within the empirically plausible set of parameter values. Though my tax rule does not consider government debt, these results are nearly identical to the situation of active fiscal policy in Leeper (1991) and Davig and Leeper (2011), where passive monetary policy creates sunspot equilibria and active policy leads to explosive behavior.

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13 Even though the Federal Reserve currently considers the personal consumption expenditures price index for its inflation targets, it has only done so since 2000. Prior to this it used the consumer price index.

14 See Blanchard and Kahn (1980) for further discussion of causes and implications of each type of result.
If the tax code is indexed for inflation, such as it was after 1985, the results are drastically different. Figure 7 shows the interaction between monetary and fiscal policy after the indexation of the tax code. Now there is very little tradeoff between monetary and fiscal policy. At this point, as long as monetary policy is active, the model yields a determinant solution. With this in mind, how should monetary policy conduct itself to ensure a unique solution? In Figure 8 the determinacy regions look fairly similar to those of standard models with slight alterations due to a progressive tax code. For the most part, simply adhering to the Taylor Principle yields determinancy and stability, which again matches the literature when fiscal policy is passive. Thus, the indexation of the tax code can be viewed as fiscal policy becoming passive, allowing monetary policy to dictate inflation dynamics.

3.4.2 Assessing the Probability of a Determinant Solution

Now that the determinacy regions have been mapped, I take the estimated monetary policy parameters from the literature and estimate the probability of the model yielding each type of solution (or non-solution). The literature considered here is Clarida et al. (2000), which estimates an interest rate rule similar to that in this model for both the pre- and post-Great Moderation periods. Then, taking the estimates given, I draw 50,000 times from normal distributions and apply the resulting parameter values to the model, using the log-linearized version of the model in Dynare for efficiency purposes.\footnote{Dynare version 4.4.0 with Matlab version R2011a for Mac.} Table 3 lays out the resulting probabilities as well as the probabilities associated with related counterfactuals. Once again, I find that the increased probability of a unique solution is not solely a monetary policy phenomenon, but also relies on fiscal policy via indexation. Simply increasing the aggressiveness of monetary policy in the Volcker era would have only moved the economy into a parameter space that results in explosive behavior (active monetary and fiscal policy), but the indexation of the tax code eliminated fiscal policy from having a major impact on the dynamics of the economy, giving monetary policy control and producing a unique solution (active monetary/passive fiscal policy). Monetary policy makers had the right idea, but they needed fiscal policy makers to relinquish control.

Extending these simple, sub-sample results, Figure 9 shows the time-varying probabilities across the entire sample period as in Coibion and Gorodnichenko (2011). To be as

<table>
<thead>
<tr>
<th></th>
<th>Tax Code Not Indexed</th>
<th>Tax Code Indexed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Infinite</td>
<td>Unique</td>
</tr>
<tr>
<td>Pre-Volcker</td>
<td>64.35</td>
<td>0.03</td>
</tr>
<tr>
<td>Volcker-Greenspan</td>
<td>0.08</td>
<td>1.27</td>
</tr>
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</table>
thorough as possible, for each year I draw 10,000 times from normal distributions for the monetary policy parameters and utilize the time-varying tax code estimates from Figure 3, again plugging them into the log-linearized model and solving via Dynare. Again, notice that while the probability of sunspot equilibria is very similar in the non-indexed and indexed models, the remaining probabilities go in opposite directions. For the non-indexed model, the increased reaction by monetary policy makers to inflation in the late-1970s results in explosive behavior in the economy.\textsuperscript{16} As for the indexed model, the added aggression yields determinacy in the economy. Thus, the model predicts that monetary policy makers did not achieve determinacy in 1979. Rather, they had to wait for fiscal policy to catch up and index the income tax code in 1985, which roughly matches the estimated break in volatility from the literature.\textsuperscript{17} These results are directly comparable to those found in Davig and Leeper (2011, Figure 1).

3.5 Expanded Model: Open Monetary and Fiscal Policy Channels

For the expanded model, I reverse the assumption on $\rho^\tau_z$.

**Assumption:** The entrepreneurial channel of fiscal policy is active, meaning $\rho^\tau_z < 0$ and productivity is a semi-endogenous process.

I calibrate $\rho^\tau_z = -0.10$ which means, in a linearized model, that only about ten percent of the deviation in the tax rate from its steady state directly impacts productivity. The chosen value of this parameter is mostly arbitrary while leaning towards the more conservative side. As was mentioned earlier, Rogerson and Wallenius (2009) find that estimates of labor supply elasticity to tax rates are lower at the micro level than at the macro level, so this calibration of $\rho^\tau_z$ should be fair.

The expansion of the model to include this channel is done for three reasons. Considering the strong assumptions on the tax code and the somewhat outside-the-box results that follow, this allows for another plausible angle with which to tackle this debate. Suggesting that there was no way for monetary policy makers to induce determinacy in the economy without an indexed tax code is a strong statement, so coming at the question from a different direction should only strengthen the argument. The second reason behind this arrangement is that, as shown in Section 3.1, introducing this channel makes the model stationary in both of the active monetary policy scenarios, allowing us to analyze variances, correlations, and impulse responses, which are key for this type of analysis. The third reason is simply because there is a vast literature that suggests this is an empirically viable channel, whether it is strong or not. Analysis of the model shows that any value of

\textsuperscript{16} In Figure 3 the non-smoothed parameter results show a large jump in inflation reaction, while the smoothed results suggest increased persistence. Both results yield similar probabilities.

\textsuperscript{17} Also realize that the tax brackets were first adjusted in 1985, which means the effect of indexation, specifically the elimination of bracket creep, began in 1984, exactly matching the estimated starting period of the Great Moderation in the literature.
\( \rho^\tau_{z} < 0 \) results in stationarity, so this is not a question of how strong the channel is.\(^{18}\) The data suggests this channel exists, so it is something worth exploring.

### 3.5.1 Impulse Responses

In this section I present the impulse responses for the expanded model, considering both the indexed and non-indexed situation. For conciseness, I present only the results for negative monetary policy, positive productivity, and positive demand shocks. The impulse responses in Figure 10 depict output growth, the output gap, productivity, and the tax rate. The first thing to notice is that, since not indexing the tax code causes the monetary authority to implicitly target the price level along with targeting inflation, the impulse response functions are damped oscillations instead of monotonically converging. The second thing to notice is that, while the dynamics of output growth do not change much from one scenario to the other, the change in the dynamics of the output gap, an input into the interest rate rule, is quite large, especially when it comes to monetary policy shocks.

An important interpretation of a monetary policy shock is a measurement error of one or more of the input arguments. Thus, a negative monetary policy shock can be likened to a measurement error that causes monetary policy makers to lower interest rates further than needed. What I find in this instance matches the theories proposed by Orphanides (2004), who suggests that the perceived passivity of monetary policy was caused more by mismeasurement of productivity than a blatant rejection of the Taylor Principle. Looking at the impulse response, I find that a measurement error of this type actually has a larger negative impact on productivity when the tax code is not indexed for inflation. This, in turn, leads to output gap levels that are higher than originally reported, which was indeed the case during the “Great Inflation,” where ex post estimates of the output gap were much larger than originally estimated. If this is not taken into consideration, an initial measurement error can, in theory, lead to further measurement errors, causing interest rates to be low for too long and cause elevated levels of inflation, just as was evident in the 1970s.

Extending on this idea, notice that the response of productivity (output gap) always ends up lower (higher) when the tax code is not indexed for inflation. So if the monetary authorities are estimating the state of the economy via the black line, they are under-estimating the output gap. Recall that this is an annual model, which means the under-estimation can actually last for long periods of time. Add in the measurement errors after the initial shocks, and policy makers can easily compound the effects of the initial shock, whether it be a supply- or demand-side shock.\(^{19}\) These results imply that inflation-

\(^{18}\) Though larger (magnitude) values of \( \rho^\tau_{z} \) do produce much quicker returns of the variable to steady state.

\(^{19}\) The evidence suggests that the influence of a non-indexed tax code was not taken into consideration. The only mention of “bracket creep” by the Board of Governors shows up in short conversation in the transcript of the FOMC Meeting for December 21, 1981, after the Economic Recovery Tax Act of 1981
induced bracket creep, while subtle, is a plausible explanation for measurement errors in labor productivity during this time period.

It is also worth noting that the decreased impact of non-technology shocks on productivity matches the general empirical results found in Galí and Gambetti (2009) without adjusting the aggressiveness of monetary policy. To an extent the impulse responses for output to non-technology shocks also match after the immediate impact, which are very similar in each scenario. Finally, technology shocks have less of an impact on output growth in the indexed model than they do in the non-indexed version. Thus, it would not necessarily take smaller shocks to induce a reduced volatility, as the “good luck” theorists claim.

Figure 11 depicts the impulse responses for the interest rate, the inflation rate, real income, and nominal income. Here I find that nominal income changes permanently once the tax code is indexed. Second, the interest rate response to technology shocks is actually reversed depending on the state of the tax code. This is because these technology shocks impact the economy in much different ways before and after indexation. This is reminiscent of some noted empirical anomalies in which identified supply shocks act as demand shocks at different periods of time.

3.5.2 Matching Theoretical Moments in the Literature

The important findings regarding the Great Moderation typically consider the theoretical moments of certain variables as well as the correlations between them. Tables 4 and 5 present the changes in standard deviations and correlations between differenced output, labor hours, and productivity along with whether the directions of these shifts match those found by Galí and Gambetti (2009) and Stiroh (2009). As can be seen, the results presented in this model match those found empirically in the literature outside of the change in labor hours. The difference there can at least partially be attributed to the overly simple modeling of the production process. Otherwise, we see a decrease in the standard deviation of output growth and productivity growth.

Similarly, I find that the correlation between output growth and productivity growth, as well as that between labor hours and productivity growth, fall. This also matches the empirical results found in the literature. Again, the correlation between output growth and the growth in labor hours does not match, but a more developed labor market could change that. For the most part, the changes in theoretical moments and variable interactions within this simple, generalized model of monetary-fiscal interaction match what has been

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20 For example, the labor market matching literature provides a simple approach to modeling a more accurate labor market, but I consider this beyond the scope of this paper.
Table 4: Standard Deviations of Selected Variables

|                  | Non-Indexed | Indexed | Match
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<thead>
<tr>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>$\Delta y_t$</td>
<td>0.0060</td>
<td>0.0053</td>
<td>Yes</td>
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<tr>
<td>$\Delta h_t$</td>
<td>0.0099</td>
<td>0.0104</td>
<td>No</td>
</tr>
<tr>
<td>$\Delta z_t$</td>
<td>0.0101</td>
<td>0.0097</td>
<td>Yes</td>
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</table>

* This column refers to whether the movements in each variable’s standard deviation matches the movements in Galí and Gambetti (2009).

found in the data, all without changing the parameters of either the interest rate rule or the tax rule.

Table 5: Correlations of Selected Variables

|                  | Non-Indexed | Indexed | Match
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta y_t$, $\Delta h_t$</td>
<td>0.2663</td>
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<td>No</td>
</tr>
<tr>
<td>$\Delta h_t$, $\Delta z_t$</td>
<td>-0.8227</td>
<td>-0.8602</td>
<td>Yes</td>
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<tr>
<td>$\Delta y_t$, $\Delta z_t$</td>
<td>0.3283</td>
<td>0.1556</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* This column refers to whether the movements in each variable’s standard deviation matches the movements in Galí and Gambetti (2009).

One last result is the fall in the contribution of all supply shocks with the indexation of the tax code. While this does not match that of Galí and Gambetti (2009), it does match the results presented in Arias et al. (2007). This again suggests that the theory that supply shocks are simply smaller now may be flawed.

4 Concluding Remarks

This paper explores both the empirical and theoretical implications of tax policies introduced in the early-1980s, especially the fallout of indexing the federal income tax code for inflation. The most basic takeaway from this is that seemingly insignificant policy changes, such as indexation, can have dramatic impacts on the economy, like paving the way for a long period of tranquility and prosperity. Using both a simplified and expanded model, I find that the indexation of the tax code was imperative to the reductions in volatility seen in the data, moving the economy from what the literature describes as an active/active monetary/fiscal policy system in the early 1980s to an active/passive scheme. In this model, I use the estimates from the literature for post-Great Moderation monetary policy and find that, without the indexation of the tax code, the economy would have remained in a high
volatility and/or explosive state. These results naturally lead to even more policy questions. Would an indexation policy that only indexes during inflationary times be beneficial for a recessed economy experiencing deflation? Are there potential problems associated with using different measurements of inflation in each policy branch? This is the current state of the Federal Reserve and the US Government, which use PCE and CPI for their respective targets and indexing schemes. Or generally, in the era the world economy finds itself in today, maybe the question that should be asked is “are we focusing on the right monetary and fiscal policies, or are their other, seemingly insignificant forces at work?” Sometimes the little policy makes the big difference.
References


Appendix

A Solving the Model

This section is devoted to solving the New Keynesian model found in section 2. A Bellman method is used because it is generally more tractable and simple than a Lagrangian method.

A.1 The Representative Household’s Problem

Considering equations (A.1), (A.2), and (A.3) above, we can form the Bellman Equation for the representative household.

\[ V_h(B_{t-1}) = \max_{c_t, h_t, B_t} \left\{ \eta^p_t \ln c_t - (1/\psi)h_t^\psi + \beta \mathbb{E}_t [V_h(B_t)] \right. \]
\[ + \Lambda_t \left[ B_{t-1} + (1 - \tau_t)W_t h_t + D_t - B_t/r_t - c_t \right] \}

where \( \Lambda_t \geq 0 \) represents the shadow price of the budget constraint. Solving this problem for consumption, labor hours, and nominal bond holdings yields the following first order conditions:

\[ \frac{\eta^p_t}{c_t} = \Lambda_t, \tag{A.1} \]
\[ h_t^{\psi-1} = \Lambda_t (1 - \tau_t) \frac{W_t}{P_t}, \tag{A.2} \]

and

\[ \beta \mathbb{E}_t [V'_h(B_t)] = \frac{\Lambda_t}{r_t P_t}. \tag{A.3} \]

The Benveniste-Shienkman condition follows accordingly as

\[ V'_h(B_{t-1}) = \frac{\Lambda_t}{P_t}. \tag{A.4} \]

Combining equations (A.1)–(A.4) yields the optimizing conditions found in (??) and (??).

A.2 The Final-Good Firm’s Problem

The profits of the firm are given by

\[ \Pi^f_t = P_t y_t - \int_0^1 P_t(i) y_t(i) di \]
\[ = P_t \left[ \int_0^1 y_t(i) \frac{\eta^p_t - 1}{\eta^p_t - 1} \frac{\eta^p_t}{\eta^p_t - 1} \right] P_t(i) y_t(i) di. \]
In this situation, the final goods-producing firm chooses the amount of each intermediate good \( y_t(i) \) for all \( i \). Since this is not a dynamic problem, first order condition is simply

\[
P_t(i) = P_t \left[ \int_0^1 y_t(i) \frac{\eta_{t-1}}{\eta_t} \, di \right]^{\frac{1}{\eta_t}} y_t(i)^{\frac{-1}{\eta_t}}
\]

\[
\Rightarrow P_t(i) = P_t y_t(i)^{\frac{-1}{\eta_t}}.
\]

Solving for \( y_t(i) \) provides the demand equation for the intermediate goods by the final goods-producing firm. Using this, the implicit price aggregator is

\[
P_t y_t = \int_0^1 P_t(i) \left( \frac{P_t(i)}{P_t} \right)^{\eta_t} y_t \, di
\]

\[
\Leftrightarrow P_t = \left[ \int_0^1 P_t(i)^{1-\eta_t} \, di \right]^{\frac{1}{1-\eta_t}}
\]

**A.3 The Intermediate-Good Firm’s Problem**

After combining all of the constraints with (??), the Bellman equation for each firm \( i \)'s dynamic problem is as follows:

\[
V_f(P_{t-1}(i)) = \max_{P_t(i)} \left\{ \left( \frac{P_t(i)}{P_t} \right)^{1-\eta_t} y_t \frac{\eta_t}{c_t} - \left( \frac{P_t(i)}{P_t} \right)^{-\eta_t} y_t W t \frac{\eta_t}{Z_t P_t c_t} \right. \\
- \mu \left( \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right) \eta_t^p + \beta E_t \left[ V_f(P_t(i)) \right] \right\}
\]

Since we combined all the constraints into the problem, there is only one first order condition

\[
(1 - \eta_t^p) \left( \frac{P_t(i)}{P_t} \right)^{-\eta_t} y_t \frac{\eta_t}{P_t c_t} + \eta_t^p \left( \frac{P_t(i)}{P_t} \right)^{-\eta_t} y_t W_t \frac{\eta_t}{Z_t P_t^2 c_t} \\
- \mu \left( \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right) \frac{\eta_t^p}{\pi P_{t-1}(i)^2} + \beta E_t \left[ V_f(P_t(i)) \right] = 0, \quad (A.5)
\]

for all \( i \in [0, 1] \) and one Benveniste-Shienkman condition

\[
V_f'(P_{t-1}(i)) = \mu \left( \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right) \frac{P_t(i)}{\pi P_{t-1}(i)^2} \eta_t^p. \quad (A.6)
\]

for all \( i \in [0, 1] \). Combining (A.5) and (A.6) provides the intermediate goods-producing firms' first order conditions.
A.4 The Efficient Allocation

In order to solve for the output gap, consider a social planner who can overcome the frictions in the economy caused by the nominal price rigidity. Following Ireland (2004), in each period $t$, the social planner instructs $n_t(i)$ units of the representative household’s labor to produce $Q_t(i)$ of the intermediate good, which is then combined into the final good using the same constant returns to scale technology as above. Thus, the social planner maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \eta_t^p \ln Q_t - \frac{1}{\psi} \left( \int_0^1 n_t(i) di \right)^{\psi} \right]$$

subject to the resource constraint

$$z_t \left( \int_0^1 n_t(i) \frac{\eta_t^{\psi - 1}}{\eta_t - 1} di \right)^{\frac{\eta_t^{\psi - 1}}{\eta_t - 1}} = Q_t.$$ 

Solving this problem gives us the efficient allocation.
Figures

Figure 1: Time series of effective tax rates for 24 evenly-spaced, synthesized real income levels between $10,000 and $2 million from 1950-2012 considering only the legislated, federal personal income tax code.

Figure 2: Selected Effective (Average) Income Tax Rates
Figure 3: Tax Code Parameters Estimated with Ordinary Least Squares: 1966–2012

Figure 4: Smoothed Time-Varying Monetary Policy Parameters
Figure 5: Monetary-Fiscal Interaction Determinacy Regions: Tax Code Not Indexed for Inflation

Figure 6: Monetary Policy Determinacy Regions with Fiscal Policy Held Constant: Tax Code Not Indexed for Inflation
Figure 7: Fiscal-Monetary Interaction Determinacy Regions: Tax Code Indexed for Inflation

Figure 8: Monetary Policy Determinacy Regions with Fiscal Policy Held Constant: Tax Code Indexed for Inflation
Figure 9: Time-Varying Probabilities of Solution Possibilities Considering both Monetary and Fiscal Policy
Figure 10: Selected Impulse Responses: Entrepreneurial Channel of Fiscal Policy Active

Figure 11: Selected Impulse Responses: Entrepreneurial Channel of Fiscal Policy Active