# Inflation-Protected Income Taxes and Monetary Dominance*

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**Abstract**

In this paper I find that subtle alterations to a tax code within a relatively standard DSGE model can cause substantial changes in the model's dynamics. Specifically, the model predicts that indexing an income tax code for inflation, much like the Federal Income Tax Code was in 1985, can have a significant impact on the economy. Focusing on a legislated, historical event allows me to analyze monetary and fiscal policy coordination while abstracting from the fiscal sustainability question and the estimation uncertainties that follow. My results suggest that the reductions in volatility seen in the data were not merely unilateral changes by monetary policy makers, but a combination of movements from 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

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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.[1] But what about subtler fiscal policies such as changes to the basic structure of the tax code itself? In this paper, I implant a labor income tax code derived from household income levels within an otherwise standard New Keynesian model. This tax code is constructed with actual legislation in mind. With it, I explore the impact of indexing the federal income tax code for inflation. Viewing tax policy from a legislative perspective allows me to analyze monetary and fiscal policy coordination while abstracting from fiscal sustainability issues and the empirical estimation problems that follow. Since the Federal Income Tax Code was indexed in 1985, estimating fiscal policy changes is unnecessary. Even so, my model predicts a similar timeline for differing policy regimes as those who consider the fiscal sustainability issues. Specifically, an indexed tax code yields the same "passive" fiscal policy properties as seen in the literature.[2] 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 A Legislative View of Policy Coordination

Sargent and Wallace (1981) show 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, focus on tax rate rules

[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.

that are dependent on the level of outstanding government debt and government spending. However the federal income tax code has remained relatively steady since the 1990s while debt has fluctuated. Figure 1 presents the legislated federal income tax code as average or effective income tax rates for fixed, evenly spaced real income levels across the the period 1950 to 2011. These data are constructed by applying 200 synthesized real income levels to the Federal Income Tax Code from 1950–2011 to calculate the real tax liability owed at each income level. The effective rates are then calculated by dividing the liability by the income level. 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: 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.[3] Doing so 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. While this is a tailored exampled used to make a point, 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

[3]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.

Table 1: Changes in Tax Liabilities Due to Inflation: 1973–1974

| | 1973 | | 1974 | |
|---|---|---|---|---|
| Bracket | Taxable Income | Liability | Taxable Income | Liability |
| 14% | $1,000 | $140 | $1,000 | $140 |
| 15% | $1,000 | $150 | $1,000 | $150 |
| 16% | $1,000 | $160 | $1,000 | $160 |
| 17% | $1,000 | $170 | $1,000 | $170 |
| 19% | $4,000 | $760 | $4,000 | $760 |
| 22% | $4,000 | $880 | $4,000 | $880 |
| 25% | $4,000 | $1,000 | $4,000 | $1,000 |
| 28% | $3,000 | $840 | $4,000 | $1,120 |
| 32% | $0 | $0 | $1,092.25 | $349.52 |
| 36% | $0 | $0 | $0 | $0 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| **Total** | $19,000 | $4,100 | $21,092.52 | $4,729.52 |

of their disposable income every year. Again, 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. More distinctly, we can show the changes in the effective tax rates over time for chosen income levels. Figure 2 shows the movements in the effective tax rates for real incomes of $40,000, $70,000, and $100,000 measured in 1982 dollars. The major changes in these time series correspond to legislative alterations to the tax code. These include the initiation and removal of the Vietnam War surtax in 1966 and 1969, respectively, as well as the adjustment for bracket creep in 1976 and the major tax overhauls in 1981 and 1986. But notice that there are persistent changes in these tax rates between the legislative adjustments. Outside of the 1976 adjustment, tax rates rose steadily between 1970 and 1980. Depending on the real income level, we see increases in tax liabilities of anywhere between 0.5 and 2.0 percentage points per year. After 1984, the only tax rate changes are results of legislation, not bracket creep.

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 2: Estimates of Additional Tax Revenue Due to Inflation

| Year | Effective Rate | Additional Revenue |
|---|---|---|
| 1981 | 11.0% | $ 0.00 billion |
| 1982 | 10.7% | $16.27 billion |
| 1983 | 9.7% | $26.78 billion |
| 1984 | 9.1% | $36.91 billion |

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.[4] While this is a rough estimate, these figures are robust to multiple measures of income and wage inflation.

## 1.2 Volatility Reductions and the Timing of Indexation

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 estimates of the output gap versus the revised measurements.[5] This is typically considered to be an effect of an unanticipated reduction in productivity growth, causing

[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).

estimates of the output gap to be lower than it truly was. If the Federal 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. But as Orphanides (2003) notes, there is a sudden reduction in this measurement error in the mid-1980s. For this reason, this literature often refers to this period of high inflation and volatility as the "Great Inflation."[6]

In either case, the empirical work in this field suggests that the sudden reduction in volatility occurred at about the same time as the indexation of the income tax code. Stock and Watson (2003) narrow the literature's results, saying that much of the evidence points to a structural break in the first quarter of 1984. Considering the fact that tax laws are annual by nature, if the tax code was first indexed for inflation in 1985, bracket creep would have ended at the beginning of 1984, corresponding the the structural breaks found the in the literature.

## 1.3 The Great Moderation as a Monetary and Fiscal Phenomenon

This paper ties together the monetary/fiscal-interaction and Great Moderation literatures. Using time-varying parameter estimates, my model predicts a similar timeline of breaks in model dynamics as Davig and Leeper (2011) and Bianchi (2012). However, many papers in this line use sophisticated Markov-switching models to estimate regime changes within fiscal policy. My model considers actual legislation, allowing me to pinpoint regime changes in fiscal policy without estimation. This is a more realistic representation of the current income tax code, which has not substantially changed since the early 1990s.

My model predicts that only the combination of active monetary policy and an indexed tax code results in a unique solution, much like the active monetary/passive fiscal policy prescriptions in the literature. Any unilateral policy shift results in either sunspot equilibria or explosive behavior. Extending my model by introducing a tax-labor productivity channel results in a unique solution even in the non-indexed specification, while 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. Additionally, impulse response analysis suggests that bracket creep is a plausible cause of the labor productivity slowdown

[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.

and indexation removed much of the noise from the data as described in Orphanides (2003).

The remainder of this paper is organized as follows: Section 2 analyzes 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 5 concludes.

# 2 New Keynesian Model with Tax Policy

Here I present a DSGE model with nominal price rigidities.[7] The essence of my model much like those used in Ireland (2004, 2012) and Belongia and Ireland (2012), but with a fiscal agent which enlists an individual income tax code that depends on the households wage income like those of Guo and Lansing (1998) and Chen and Guo (2013).

## 2.1 The Representative Household

In this model the representative household solves

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

where $c_t$ 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 $\eta_t^p$ follows an autoregressive process in its natural logarithm

$$\ln \eta_t^p = \rho_p \ln \eta_{t-1}^p + \varepsilon_t^p, \tag{2}$$

such that $\rho_p \in (0,1)$ and $\varepsilon_t^p$ 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

[7] See Woodford (2011); Galí (2009); and Rotemberg (1982) for details regarding this style of model and nominal price rigidities.

assume the household takes the tax rate $\tau_t$ as given since it is set by the fiscal authorities.[8] 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 his yields the following budget constraint:

$$P_t c_t + {}^{B_t}/_{r_t} \leq B_{t-1} + (1-\tau_t) W_t h_t + D_t. \tag{3}$$

Along with this budget constraint, the first order conditions are

$$\frac{\eta_t^p}{c_t} = \beta r_t \mathbb{E}_t \left[ \frac{\eta_{t+1}^p}{c_{t+1}} \frac{1}{\pi_{t+1}} \right] \tag{4}$$

and

$$\frac{W_t}{P_t} = \frac{h_t^{\psi-1} c_t}{\eta_t^p (1-\tau_t)}, \tag{5}$$

where

$$\pi_t = {}^{P_t}/_{P_{t-1}} \tag{6}$$

is the gross inflation rate. Derivation of these optimization conditions can be found Appendix A. As we can see, the Euler equation remains unaltered from the standard New Keynesian models, but our intratemporal condition now depends on the labor income tax rate $\tau_t$.

## 2.2 The Final Goods-Producing Firm

Like so many 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 intermediate goods-producing firms for consumption by the households. It does so with a CES production function

$$y_t \leq \left[ \int_0^1 y_t(i)^{\frac{\eta_t^s - 1}{\eta_t^s}} \mathrm{d}i \right]^{\frac{\eta_t^s}{\eta_t^s - 1}},$$

where $\eta_t^s$ is an exogenous process governing the elasticity of substitution. I consider innovations to this as price markup shocks, which follow an autoregressive process in its natural

[8] The results of Guo and Lansing (1998) show that this specification does not change their determinacy results.

logarithm

$$\ln \eta_t^s = (1-\rho_s)\ln \eta^s + \rho_s \ln \eta_{t-1}^s + \varepsilon_t^s, \tag{7}$$

where $\rho_s \in (0,1)$, $\eta^s > 0$, and $\varepsilon_t^s$ 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

$$y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\eta_t^s} y_t, \tag{8}$$

for all $i \in [0,1]$.

## 2.3 The Intermediate Goods-Producing Firms

As was mentioned above, there is a continuum of monopolisticly-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

$$y_t(i) \leq z_t h_t(i) \tag{9}$$

for all $i$, where $z_t$ is a labor-augmenting productivity process governed by

$$\ln z_t = (1-\rho_z)\ln z + \rho_z \ln z_{t-1} + \varepsilon_t^z, \tag{10}$$

such that $z > 0$, $\rho_z \in [0,1]$, and $\varepsilon_t^z$ is an i.i.d. innovation with zero mean and variance $\sigma_z > 0$. I also introduce a Rotemberg (1982) cost of price adjustment

$$\Phi_t(i) = \frac{\mu}{2}\left(\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right)^2 c_t$$

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

$$D_t(i) = P_t(i)y_t(i) - W_t h_t(i) - P_t\Phi_t(i) \tag{11}$$

for all $i$. With this in mind, each intermediate goods-producing firm's problem is given by

$$\max_{\{P_t(i),h_t(i),D_t(i)\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\eta_t^p}{c_t} \frac{D_t(i)}{P_t}, \tag{12}$$

subject to constraints (8) and (11). The first term in (12) is the discounted marginal utility value to the household of additional future profits. Each firm's optimizing conditions are therefore:

$$(1-\eta_t^s)\left(\frac{P_t(i)}{P_t}\right)^{-\eta_t^s}\frac{y_t}{P_t} + \eta_t^s\left(\frac{P_t(i)}{P_t}\right)^{-\eta_t^s-1}\frac{y_t W_t}{z_t P_t^2} - \mu\left(\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right)\frac{c_t}{\pi P_{t-1}(i)}$$
$$+\beta\mu\mathbb{E}_t\left[\left(\frac{P_{t+1}(i)}{\pi P_t(i)} - 1\right)\frac{P_{t+1}(i)}{\pi P_t(i)^2}\frac{\eta_{t+1}^p c_t}{\eta_t^p}\right] = 0 \tag{13}$$

for all $i$, which, when linearized, gives me a New Keynesian Philips Curve. A derivation of these conditions can be found in Appendix A.

## 2.4 The Fiscal Authority and the Labor Income Tax Code

The fiscal agent in this model is responsible each period for producing real government goods $g_t$ and settling its debt from last period $B_{t-1}$. To do so, it sells nominal discount bonds $B_t$ at price ${}^{1}/_{r_t}$ and collects tax revenue through a labor income tax. Considering this, the government's budget constraint is

$$P_t g_t + B_{t-1} \leq \frac{B_t}{r_t} + \tau_t W_t h_t. \tag{14}$$

Similar to the specification used in Chen and Guo (2013), the effective labor income tax rate $\tau_t$ evolves according to

$$\tau_t = 1 - \theta\left(\frac{wh}{w_t h_t P_t^{\mathbb{1}_n}}\right)^{\phi} \tag{15}$$

where $w_t \equiv {}^{W_t}/_{P_t}$ is the real wage rate, $\theta \in [0,1]$ dictates the steady state tax rate, $\phi \in (-1,1)$, and $\mathbb{1}_n$ is an indicator function that holds a value of one when the tax code is not indexed for inflation and zero when it is indexed for inflation. I assume that, when the tax 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. With $\tau_t$ representing the effective rate, I define the marginal tax rate $\tau_t^m$ to be the change to be the change in tax liability relative to the change in labor income. This implies

$$\tau_t^m \equiv \frac{\partial(\tau_t w_t h_t P_t^{\mathbb{1}_n})}{\partial(w_t h_t P_t^{\mathbb{1}_n})} = \tau_t + \phi\theta\left(\frac{wh}{w_t h_t P_t^{\mathbb{1}_n}}\right)^{\phi}. \tag{16}$$

Thus, we can see that if $\phi > 0$, the marginal tax rate at any given income level is greater than the effective tax rate, which is the definition of a *progressive* tax code. If $\phi < 0$, the marginal rate is less than the effective rate at every level of income, which defines a *regressive* tax code. Typical models in this literature assume income tax codes with $\phi = 0$, in which case the marginal tax rate and the effective tax rates are equal at all times. This is the standard definition of a *flat* tax code. From another persepective, this parameter governs the labor income elasticity of the effective tax rate, given by

$$\frac{\partial\tau_t}{\partial(w_t h_t P_t^{\mathbb{1}_n})}\frac{w_t h_t P_t^{\mathbb{1}_n}}{\tau_t} = \phi\frac{1-\tau_t}{\tau_t},$$

where, combining this with (16), we can see that setting $\phi = 0$ will make the effective tax rate and the marginal tax rate unresponsive to changes in the income level. When linearized, (15) 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. Those models with no labor income tax policy would be equivalent to setting $\phi = 0$ and $\theta = 1$.

Now let's consider the theoretical impact of not indexing a labor income tax code. Assuming that the general trend of the price index is upward, as has been historically, then at any time after the price index is reset to one, $P_t \geq 1$. If I also assume that the tax code is progressive, as has been the case since its inception in 1913, then by (16), the model claims

$$(\tau_t^m - \tau_t)\Big|_{\mathbb{1}_n=1} \leq (\tau_t^m - \tau_t)\Big|_{\mathbb{1}_n=0}$$

which implies that the tax code becomes less progressive (becomes "flatter") as the price level rises. This is intuitive since there is always a top marginal tax rate. Once a household's income reaches the top marginal rate, bracket creep will cause a larger percentage of said income to fall into that top marginal bracket. The result is that the effective rate approaches the marginal rate from below. While this model does not consider multiple households, the distributional implications of a non-indexed tax code could be significant.

## 2.5 The Monetary Authority

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

$$\ln\left(\frac{r_t}{r}\right) = \rho_r \ln\left(\frac{r_{t-1}}{r}\right) + \rho_\pi \ln\left(\frac{\mathbb{E}_t\left[\pi_{t+1}\right]}{\pi}\right) + \rho_x \ln\left(\frac{x_t}{x}\right) + \varepsilon_t^r, \tag{17}$$

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)

$$Q_t = \eta_t^{p\,1/\psi} z_t, \tag{18}$$

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

$$x_t = \frac{y_t}{Q_t}. \tag{19}$$

See Appendix A for more details.

## 2.6 Symmetric Equilibrium

In equilibrium, I assume that the household and the intermediate goods-producing firms solve their respective optimization problems and that the household does so with a binding budget constraint. Since the production technology remains constant across the continuum of intermediate goods-producing firms, I assume that they make identical decisions. Thus I find that $y_t(i) = y_t$, $D_t(i) = D_t$, $h_t(i) = h_t$, and $P_t(i) = P_t$ for all $i \in (0, 1)$. I also assume that there is no slack in the fiscal authority's budget constraint and that $B_t = 0$ for all $t$, implying a balanced budget in equilibrium. With these assumptions, my model reduces to equations (2)–(7), (9)–(11), (13)–(15), and (17)–(19) which can be used to solve for the following 15 variables: $\eta_t^p, \eta_t^s, z_t, P_t, \pi_t, c_t, h_t, W_t, y_t, D_t, r_t, x_t, g_t, \tau_t, Q_t$. As was done already for the tax code with nominal wages, I can express dividends in real terms by dividing by the price level, giving me $d_t \equiv D_t/P_t$. Doing this for both the nominal wage rate and the dividends ensures that the model's variables, outside of the unit root in the price level itself, will be stationary.

## 2.7 The Linearized Model

Since the model contains a tax code that may or may not be indexed for inflation, it is important to linearize the model and possibly analyze permanent shifts in the variables. Let the "$\sim$" signify each respective variable's deviation in natural logarithm from its steady state, which we express as the variable without a time subscript. Below is the full list of log-linearized equations.

$$c\tilde{c}_t = (1-\tau)wh(\tilde{w}_t + \tilde{h}_t) - \tau wh\tilde{\tau}_t + d\tilde{d}_t$$

$$\tilde{\eta}^p_t - \tilde{c}_t = \tilde{r}_t + \mathbb{E}_t\left[\tilde{\eta}^p_{t+1} - \tilde{c}_{t+1} - \tilde{\pi}_{t+1}\right]$$

$$\tilde{w}_t = (\psi-1)\tilde{h}_t + \tilde{c}_t - \tilde{\eta}^p_t + \frac{\tau}{1-\tau}\tilde{\tau}_t$$

$$\tilde{\pi}_t = \tilde{P}_t - \tilde{P}_{t-1}$$

$$\tilde{y}_t = \tilde{z}_t + \tilde{h}_t$$

$$d\tilde{d}_t = y\tilde{y}_t - wh(\tilde{w}_t + \tilde{h}_t)$$

$$\tilde{\pi}_t = \beta\mathbb{E}_t[\tilde{\pi}_{t+1}] + \frac{\eta^s wy}{\mu zc}(\tilde{w}_t - \tilde{z}_t) + \frac{\eta^s y}{\mu c}\left(\frac{w}{z} - 1\right)\tilde{\eta}^s_t$$

$$\tilde{g}_t = \tilde{\tau}_t + \tilde{w}_t + \tilde{h}_t$$

$$\tilde{\tau}_t = \frac{1-\tau}{\tau}\phi(\tilde{w}_t + \tilde{h}_t + \mathbb{1}_n\tilde{P}_t)$$

$$\tilde{r}_t = \rho_r\tilde{r}_{t-1} + \rho_\pi\mathbb{E}_t[\tilde{\pi}_{t+1}] + \rho_x\tilde{x}_t + \varepsilon^r_t$$

$$\tilde{Q}_t = \frac{1}{\psi}\tilde{\eta}^p_t + \tilde{z}_t$$

$$\tilde{x}_t = \tilde{y}_t - \tilde{Q}_t$$

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

$$\tilde{\eta}^s_t = \rho_s\tilde{\eta}^s_{t-1} + \varepsilon^s_t$$

$$\tilde{z}_t = \rho_z\tilde{z}_{t-1} + \varepsilon^z_t$$

Notice that, when the tax code is not indexed for inflation ($\mathbb{1}_n = 1$), the price level appears in the tax code, which then makes it appear in the New Keynesian Philips curve. If the monetary authority does not target the price level, then all transitory shocks will have a permanent effect. Another important component of this model is the feedback effect between the tax rate and the wage rate. As the tax rate rises, it puts upward pressure on the wage rate, which then causes the tax rate to rise (holding labor hours constant). Thus, the natural drift in the prices causes explosive behavior through a wage rate channel. Two fiscal policy changes can eliminate the permanent effects of these shocks. The first is by simply indexing the tax code for inflation ($\mathbb{1}_n = 0$), 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. This is the typical assumption in most models that consider taxation and, as can be seen in the equations, will negate the price level term. Considering the legislative history of the United States, a flat tax rate has never been used, though income taxes were indexed for inflation in 1985.[9]

# 3 Results

In this section I present the solution process and results of the model outlined in section 2. I begin by parameterizing the model. The structural components of the model are calibrated in a simple fashion, while the parameters that guide the exogenous processes are set by matching moments with the literature. I then present the steady state solutions for the model's variables and analyze the general dynamic properties with determinacy regions. Using these regions, I then apply the data to the model to find the probability of obtaining a determinant solution to my model across time.

## 3.1 Parameter Calibration

In order to solve the model above, specific values must be assigned to the 17 parameters in the model: $\beta$, $\psi$, $\pi$, $\mu$, $\theta$, $\phi$, $\eta^s$, $\rho_p$, $\rho_s$, $\rho_z$, $\rho_r$, $\rho_\pi$, $\rho_x$, $\sigma^p$, $\sigma^s$, $\sigma^r$, and $\sigma^z$. A summary table of the parameter values can be found in Table (3). Since $r = 1/\beta$ in steady state, I calibrate

[9] It is worth noting that the federal income tax was adopted with the Sixteenth Amendment to the United States Constitution in 1913. Prior to this, Article I, Section 8 required that any taxes be imposed uniformly, making income taxes unpopular.

the subjective discount factor $\beta$ to match the fact that the average annual effective federal funds rate was approximately five percent from 1955 to 2013, which sets it at 0.95. I then set the steady state inflation target to $\pi = 1$. While, this is not very realistic, it

Table 3: Base Parameter Values

| | Parameter | Value |
|---|---|---|
| Subjective Discount Factor | $\beta$ | 0.95 |
| Elasticity of Substitution | $\psi$ | 0.181 |
| Cost of Price Adjustment | $\mu$ | 13.25 |
| Steady State Inflation Rate | $\pi$ | 1.00 |
| Level of the Tax Code | $\theta$ | 0.90 |
| Progression of the Tax Code | $\phi$ | 0.15 |
| Elasticity of Demand | $\eta^s$ | 6.00 |
| Smoothing Response | $\rho_r$ | 0.75 |
| Inflation Response | $\rho_\pi$ | 0.35 |
| Output-Target Response | $\rho_y$ | 0.15 |
| Preference Shock Persistence | $\rho_p$ | 0.50 |
| Technology Shock Persistence | $\rho_z$ | 0.85 |
| Cost-Push Shock Persistence | $\rho_s$ | 0.50 |
| Preference Shock St. Dev. | $\sigma^p$ | 0.01 |
| Elasticity Shock St. Dev. | $\sigma^s$ | 0.01 |
| Productivity Shock St. Dev. | $\sigma^z$ | 0.01 |
| Monetary Policy Shock St. Dev. | $\sigma^r$ | 0.0025 |

keeps the model stationary from being explosive in all situations when the tax code is not indexed ($\mathbb{1}_n = 1$), providing a basis for analysis. As for the tax code, much of my analysis will involve analyzing the dynamics of the model as $\theta$ and $\phi$ are adjusted. But for those situations requiring fixed values, I calibrate these parameters to be the average of time-varying estimates described in more detail in section 3.4.2 below. Doing so implies that these parameters are about $\theta = 0.90$ and $\phi = 0.15$, ensuring that the labor income tax code is progressive. Setting $\eta^s = 6$, as in Ireland (2004, 2012), fixes the steady state markup of price over marginal cost at 20%. Similarly, I set the level of price adjustment as is done in King and Watson (1996) and Ireland (2000). These papers suggest that discrepancies between the current price level and the desired price level are eliminated at about a 10% per quarter rate. Given that this is an annual model, I assume a 40% reduction per year, which implies a value of $\mu = 13.25$. For the remaining structural parameters, I calibrate the household's elasticity of labor substitution to be $\psi = 0.181$, pinning labor hours at

$h = 0.330$ and suggesting that households work approximately 1/3 of their day.

### 3.2 Steady State

Given the calibrated parameters above, the steady state values can be solved analytically. Since I assume that the steady state price level is set to one, the indexed and non-indexed models are identical in steady state. I also normalize output to equal one, just as a simplification. With this, I find that government spending is 8.25% of total output in the model. While this is less than the data-recommended average of 20%, it is calculated using the estimated tax parameters. Another reason to consider this as accurate is that my model only incorporates income taxes, which would make government spending less.

Table 4: Steady State Values of the Model Variables

| | Variable | Value |
|---|---|---|
| Real Output | $y_t$ | 1.0 |
| Real Consumption | $c_t$ | 0.9175 |
| Real Government Spending | $g_t$ | 0.0825 |
| Productivity | $z_t$ | 3.0303 |
| Tax Rate | $\tau_t$ | 0.10 |
| Nominal Interest Rate | $r_t$ | 1.05 |
| Real Wage Rate | $w_t$ | 2.5 |
| Labor Hours | $h_t$ | 0.330 |
| Real Dividends | $d_t$ | 0.1750 |

### 3.3 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.[10] The first example, shown in Figure 6, looks at the interaction between the fiscal and monetary policy parameters 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

[10] See Blanchard and Kahn (1980) for further discussion of causes and implications of each type of result.

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). Intuitively, the next question to ask is if the monetary authority can overcome the problems associated with a non-indexed tax code through some combination of inflation and output gap targeting. Figure 7 shows 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 outstanding government debt, these properties 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.

If the tax code is indexed for inflation, such as it was after 1985, the results are drastically different. Figure 8 shows, again, the interaction between monetary and fiscal policy, but this time the tax code is indexed. Now there is very little tradeoff between monetary and fiscal policy. At this point, as long as monetary policy is active, the model predicts a determinant, stable solution. With this in mind, how should monetary policy conduct itself to ensure a unique solution? In Figure 9 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 provides the needed unique solution, which again is similar to the dynamic properties explored in 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 Assessing the Probability of a Determinant Solution

Now that the determinacy regions have been mapped, I consider the values of the policy parameters and the dynamic properties they incur. I start with a simple two-period breakdown, applying estimates generated in the literature. I then extend this so that the parameters are time varying, allowing my model to predict exactly when these dynamic changes occurred.

### 3.4.1 The Two-Period Case

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,

Table 5: Solution Probabilities Based on Estimates from the Literature: Clarida *et al.* (2000)

| | Tax Code Not Indexed | | | Tax Code Indexed | | |
|---|---|---|---|---|---|---|
| | Infinite | Unique | Explosive | Infinite | Unique | Explosive |
| Pre-Volcker | 64.35 | 0.03 | 35.62 | 99.36 | 0.64 | 0.00 |
| Volcker-Greenspan | 0.08 | 1.27 | 98.64 | 0.22 | 99.78 | 0.00 |

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.[11] Table 5 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 do their part as well.

### 3.4.2 A Time-Varying Parameter Extension

To see how these policies played out over time, I extend the above analysis to incorporate time-varying parameters for both the fiscal and monetary policy side.

**Estimation Methods** 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

[11] Dynare version 4.4.0 with Matlab version R2011a for Mac.

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 3 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 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.[12] Doing this for every year gives us time-varying parameter estimates for the tax code. Figure 4 shows these estimates from 1966 to 2011.[13] 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 Kalman filter using data on the effective federal funds rate, the inflation rate as calculated by CPI, and the output gap calculated by taking the ratio of GDP to potential GDP.[14] The Kalman filter is a recursive algorithm that estimates an unobserved-state vector. Since interest rates, inflation, and the output gap are known, I can used the data to estimate the unobserved monetary policy parameters $\beta = [\rho_r \ \rho_\pi \ \rho_x]'$ across time. Following the process as explained by Kim and Nelson (1999), I obtain time-varying estimates of these parameters. For this model, I consider the state space model, where the measurement equation is the interest rate rule given by (17), where I make a simplifying assumption that expected inflation rate is equal

[12] This data can be found in the SOI Tax Stats of the US Internal Revenue Service, specifically Historical Tables 8 and 9.

[13] 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. Somewhat of a concern is the sensitivity of these estimates to the number of sample points within the fixed income bounds.

[14] 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.

to the current period's inflation rate. The transition equation, since I am considering policy parameters, is assumed to be a random walk. In matrix notation,

$$r_t = X_t \beta_t + \varepsilon_t^r \qquad \varepsilon_t^r \sim i.i.d.\, N(0, \sigma^r)$$

$$\beta_t = \beta_{t-1} + \upsilon_t \qquad \upsilon_t \sim i.i.d.\, N(0, Q)$$

where $X_t = [r_{t-1} \quad \pi_t \quad x_t]$ and all variables are natural logarithm form. For the initial estimates, I use the adapted pre-Volcker estimates from Clarida *et al.* (2000), giving me $\beta_{0|0} = [0.68 \ \ 0.2656 \ \ 0.086]'$. The prediction phase of the filter considers the random walk assumption so that $\beta_{t|t-1} = \beta_{t-1|t-1}$. Predicting the covariance matrix of the parameters $V_t$ also becomes simple, such that $V_{t|t-1} = V_{t-1|t-1} + Q$. From these, I can assess the prediction error $\eta_{t|t-1} = r_t - X_t \beta_{t|t-1}$ and its conditional variance $f_{t|t-1} = X_t V_{t|t-1} X_t' + \sigma^r$. Knowing the prediction error and its variance, I then update my parameter estimates

$$\beta_{t|t} = \beta_{t|t-1} + V_{t|t-1} X_t' f_{t|t-1}^{-1} \eta_{t|t-1}$$

and my conditional variance estimates

$$V_{t|t} = V_{t|t-1} - V_{t|t-1} X_t' f_{t|t-1}^{-1} X_t V_{t|t-1}.$$

The term $V_{t|t-1} X_t' f_{t|t-1}^{-1}$ is the weight assigned to new information when updating my estimates, commonly called the Kalman gain. Continuing to do this for all $t$ yields the time-varying parameter estimates. Additionally, we can obtain smoothed parameter estimates by updating our original estimates given all the information. If I denote the final period of the sample as $T$, the smoothed estimates adhere to the recursive algorithm

$$\beta_{t|T} = \beta t|t + V_{t|t} V_{t+1|t}^{-1} (\beta_{t+1|T} - \beta_{t|t})$$

$$V_{t|T} = V_{t|t} + V_{t|t} V_{t+1|t}^{-1} (V_{t+1|T} - V_{t+1|t}) V_{t+1|t}^{-1}{}' V_{t|t}'$$

for all $t$. In this case, I work backwards from $t = T$ to $t = 0$, instead of forwards like I did for the original estimates. Figure 5 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.

**Applying the Parameters to the Model** Figure 10 shows the time-varying probabilities across the entire sample period as in Coibion and Gorodnichenko (2011). To be as 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 4, again plugging them into the log-linearized model and solving via Dynare.[15] 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.[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 stability in 1979. Rather, they had to wait for fiscal policy to catch up and index the income tax code in 1985, which matches the estimated break in volatility in the Great Moderation literature.[17] Additionally, these results are directly comparable to the timetable presented in Davig and Leeper (2011, Figure 1), which uses a Markov-switching model and a tax policy that targets real outstanding government debt. This suggests that the estimates found in this regime-switching literature may be picking up subtle changes in fiscal policy such as the indexation of the tax code.

## 4 Adding a Fiscal Policy Channel to the Model

The model given in section 2 is a fairly standard model, but this poses a problem when considering policies that can cause explosive behavior. To get around this and further my analysis of this policy, I introduce a fiscal policy channel through labor productivity. It implies that rising tax rates will cause productivity to decrease, a concept that is in no way new to the empirical literature, but is universally abstracted from in the theoretical literature. Vartia (2008) provides an extensive review of the empirical literature,

[15]Use of only the fiscal policy estimates is done for two reasons. First, drawing from the fiscal policy parameter distributions dramatically increases the dimensions of this analysis, resulting in an immense amount of computing time. Second, the fact that the estimates of $\theta$ are very close to its upper bound suggests that drawing randomly from an assumed distribution would cause more problems that it would solve.

[16]In Figure 4 the non-smoothed parameter results show a large jump in inflation reaction, while the smoothed results suggests increased persistence. Both results yield similar probabilities.

[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.

which typically considers the implications of various taxes on entrepreneurial activity and research and development. She then finds a negative relationship between top marginal personal income tax rates and total factor productivity, which she claims is also through this entrepreneurial channel. Carroll *et al.* (2001) also finds that high marginal income tax rates can hurt productivity, especially the growth rates of small firms. Since my model only considers labor income taxes charged to households, this channel could be considered a *Laffer channel* in which increasing tax rates may cause the tax base to fall through falling productivity, reducing overall tax revenues. To model this, I simply add a tax component to the otherwise exogenous process in equation (10)

$$\ln z_t = (1 - \rho_z) \ln z + \rho_z \ln z_{t-1} - \rho_z^\tau \ln \left( \frac{\tau_t}{\tau} \right) + \varepsilon_t^z, \tag{20}$$

with $\rho_z^\tau \geq 0$. This matches the empirical results that increasing tax rates reduces labor productivity. Interestingly, Rogerson and Wallenius (2009) show 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.[18] While I do not consider this channel for the baseline analysis in section 3, it adds a dynamic to New Keynesian models that most do not contain, making productivity a partly endogenous variable.

One issue modeling this channel in this way is that the parameter $\rho_z^\tau$ is hard to pin down. The closest empirical analysis that applies to a channel modeled in this way is Bloom *et al.* (2000), in which they estimate the short-run user cost of capital elasticity to taxes to be -0.1, while the long-run estimate is closer to -1.0. Since this is the closest I can currently get, I calibrate $\rho_z^\tau = 0.10$ 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. I choose this value 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 $\rho_z^\tau$ 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

[18] For a more in depth look at the entrepreneurial channel, see Meltzer and Richard (1981) and Carroll, Holtz-Eakin, Rider and Rosen (2000, 2001).

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 4.1 below, 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 literature that suggests this is an empirically viable channel, whether it is strong or not. Analysis of the model shows that any value of $\rho_z^\tau > 0$ results in stationarity, so this is not a question of how strong the channel is.[19] The data suggests this channel exists, so it is something worth exploring.

### 4.1 The Impact of this Fiscal Channel on the Model

If the entrepreneurial channel is active ($\rho_z^\tau > 0$) 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.

### 4.2 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 11 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

[19]Though larger values of $\rho_z^\tau$ do produce much quicker returns of the variable to steady state.

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. Orphanides (2003) considers a simple interest rate rule like the one below targeting inflation and the output gap and introduces noisy information in both inputs ($\epsilon_t^\pi, \epsilon_t^x$) respectively

$$r_t - r = \gamma(\pi_t - \pi) + \delta x_t - [(1-\gamma)\epsilon_t^\pi + \delta\epsilon_t^x],$$

showing that measurement error can derail even theoretically sound monetary policy. When comparing this rule to (17), the term in brackets can be defined to be $\varepsilon_t^r$, implying that a negative monetary policy shock can be likened to a measurement error that causes monetary policy makers to lower interest rates further than needed. With this intuitive theory, Orphanides (2003, 2004) concludes that the perceived passivity of monetary policy was caused more by mismeasurement of productivity growth than discretionary policy. 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 the case during the "Great Inflation," where ex-post estimates of the output gap were much larger than their original counterparts. 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. Additionally, the interest rate response to a technology (productivity) shock in Figure 12 shows the difference in monetary policy responses when the tax code is not indexed. In this case, instead of interest rates rising with inflation, they fall with the output gap. Supply shocks were large and occurred often during the 1970s, so if bracket creep was causing measurement error, then the situation is the same as that implied in the equation above.

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.[20] These results imply that inflation-induced bracket creep, while subtle, is a plausible explanation for measurement errors in labor productivity during this time period.

Figure 13 presents some additional impulse responses. Here we can see that, after indexation, the response of real disposable income $(1 - \tau_t)w_t h_t$ greatly increases. This is a testament to the impact of bracket creep on households. Having a tax code that allows a household's tax liabilities to drift upward results in an erosion of its purchasing power. Additionally, the impact on government spending shows how revenues $\tau_t w_t h_t P_t^{\mathbb{1}_n}$ were impacted. Since this model assumes a balanced budget, the fiscal authority can only spend what it brings in through tax revenues. Considering the indexed ($\mathbb{1}_n = 0$) and non-indexed ($\mathbb{1}_n = 1$) models are identical in steady state, its fairly intuitive that the initial impacts on revenues are similar. The bracket creep, however, shows up in the increased persistence of government spending. Although the tax rate is falling back to steady state, it happens more gradually because the price level has to adjust as well. This provides a boost to government revenues for a longer period of time, something that is well known by those familiar with the impact of bracket creep.

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.

[20]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 had been passed into law. This suggests that, while they may have been aware of it, they may not have considered it as a major factor in their policy decisions. Thus, when considering these measurement errors, they easily could have thought the economy was following the black line, while the economy was actually following the blue line.

## 4.3 Structural Changes in the Theoretical Moments

The important findings regarding the Great Moderation typically consider the theoretical moments of certain variables as well as the correlations between them. Tables 6 and 7 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.[21] Otherwise, we see a decrease in the standard deviation of output growth and productivity growth.

Table 6: Standard Deviations of Selected Variables

| | Non-Indexed | Indexed | Match[a] |
|---|---|---|---|
| $\Delta y_t$ | 0.0060 | 0.0053 | Yes |
| $\Delta h_t$ | 0.0099 | 0.0104 | No |
| $\Delta z_t$ | 0.0101 | 0.0097 | Yes |

[a] This column refers to whether the movements in each variable's standard deviation matches the movements in Galí and Gambetti (2009).

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

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

[21]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 7: Correlations of Selected Variables

| | Non-Indexed | Indexed | Match[a] |
|---|---|---|---|
| $\Delta y_t, \Delta h_t$ | 0.2663 | 0.3698 | No |
| $\Delta h_t, \Delta z_t$ | -0.8227 | -0.8602 | Yes |
| $\Delta y_t, \Delta z_t$ | 0.3283 | 0.1556 | Yes |

[a] This column refers to whether the movements in each variable's standard deviation matches the movements in Galí and Gambetti (2009).

shocks are simply smaller now may be flawed.

## 5 Concluding Remarks

While much of the monetary/fiscal policy coordination literature considers lump sum tax policies structured around real outstanding government debt, this paper takes a more legislative approach. Implanting a labor income tax code structured around income levels into an otherwise standard New Keynesian model, I analyze the dynamic impacts of indexing such a tax code for inflation. This type of policy was implemented in the federal income tax code in 1985, eliminating bracket creep in the process. Though this policy has been overlooked in the literature, my model predicts that it had a substantial impact on the dynamics of the economy. Specifically, an indexed tax code yields the same dynamic properties as "passive" fiscal policy in the Leeper (1991) sense. Without indexation, my model predicts that the active monetary policy enacted in the late 1970s would have produced and active/active policy scenario which results in explosive behavior. Only after the indexation of the tax code was monetary policy allowed to be dominant, providing determinacy in the model at the precise moment suggested in the Great Moderation literature. Thus, the reduction in volatility seen in the data was not simply a monetary-policy phenomenon, but a combination of movements from both sides of policy. One change without the other would not have resulted in the period of tranquility seen in the late-1980s through the mid-2000s. This timeline of events matches that found in the Markov-switching model estimates of Davig and Leeper (2011), suggesting that their estimates may have been picking up this subtle fiscal policy change. While some in the literature find the same timeline as my model suggests, the drawback of these regime-switching models is the interpretation of the estimated shifts. My model gets around this by focusing on specific legislation, providing easy interpretation of what actually happened.

Extending the model to include a fiscal policy channel through productivity, I find that the productivity slowdown and associated output gap mismeasurement suggested by Orphanides (2003) may have had its roots in bracket creep. Increasing tax rates caused by bracket creep put downward pressure on labor productivity, causing any shocks to the model to have substantially larger impacts on productivity and the output gap. Had monetary policy makers not considered the impacts of bracket creep, their estimates of the output gap would be much lower than the true value, which was exactly the case in the mid-1970s. Thus, any initial measurement error is compounded, resulting in seemingly discretionary monetary policy when considering revised variable estimates. Even when holding monetary policy as active, indexation of the tax code results in decreased standard deviations of key variables discussed in the literature. This policy also alters the structural relationships between the variables in the same manner as those explored in the literature. This includes the correlations between variables such as output growth and productivity growth as well as reducing the impact of supply shocks on the economy. Thus, this policy may have also reduced the impact of supply shocks, which would debunk the “good luck” theories of the Great Moderation.

All of these results stem from a fiscal policy that does not consider large changes in government spending or big swings in the tax rates, which are the focus of most of the literature. This policy, on the other hand considers a change in how the tax code is implemented, revealing substantial impacts on the model dynamics. Thus, maybe we should be less worried about the big-ticket policies, and a little more interested in some of these subtler policies. For example, an extension to this paper is to consider the impact of monetary and fiscal policy makers utilizing differing measurements of inflation. The Federal Reserve began targeting inflation based on the personal consumption expenditure price index, while the taxes and transfer payments of the US Government are still indexed using the consumer price index. Do subtleties in monetary and fiscal policy such as indexation or the use of differing inflation measurements have significant impacts on the economy? Maybe these are the questions we should be asking.

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# 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 is it is generally more tractable and simple than a Lagrangian method.

### A.1 The Representative Household's Problem

Considering equations (15), (1), and (3) above, we can form the Bellman Equation for the representative household.

$$\mathcal{V}_h(B_{t-1}) = \max_{c_t, h_t, B_t} \Bigg\{ \eta_t^p \ln c_t - ({}^1/_\psi) h_t^\psi + \beta \mathbb{E}_t \left[ \mathcal{V}_h(B_t) \right] + \Lambda_t \left[ \frac{B_{t-1} + (1-\tau_t) W_t h_t + D_t - {}^{B_t}/_{r_t}}{P_t} - c_t \right] \Bigg\},$$

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:

$$\frac{\eta_t^p}{c_t} = \Lambda_t, \tag{A.1}$$

$$h_t^{\psi-1} = \Lambda_t (1-\tau_t) \frac{W_t}{P_t}, \tag{A.2}$$

and

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

The Benveniste-Shienkman condition follows accordingly as

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

Combining equations (A.1)–(A.4) yields the optimizing conditions found in (4) and (5).

## A.2 The Final-Good Firm's Problem

The profits of the firm are given by

$$
\begin{aligned}
\Pi_t^f &= P_t y_t - \int_0^1 P_t(i) y_t(i) \mathrm{d}i \\
&= P_t \left[ \int_0^1 y_t(i)^{\frac{\eta_t^s - 1}{\eta_t^s}} \mathrm{d}i \right]^{\frac{\eta_t^s}{\eta_t^s - 1}} - \int_0^1 P_t(i) y_t(i) \mathrm{d}i.
\end{aligned}
$$

In this situation, the final goods-producing firm chooses the amount of each intermediate good $y_t(i)$ for all $i$. Since this not a dynamic problem, first order condition is simply

$$
\begin{aligned}
& P_t(i) = P_t \left[ \int_0^1 y_t(i)^{\frac{\eta_t^s - 1}{\eta_t^s}} \mathrm{d}i \right]^{\frac{1}{\eta_t^s - 1}} y_t(i)^{-\frac{1}{\eta_t^s}} \\
\Rightarrow \quad & P_t(i) = P_t y_t^{\frac{1}{\eta_t^s}} y_t(i)^{-\frac{1}{\eta_t^s}}.
\end{aligned}
$$

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

$$
\begin{aligned}
P_t y_t &= \int_0^1 P_t(i) \left( \frac{P_t(i)}{P_t} \right)^{-\eta_t^s} y_t \, \mathrm{d}i \\
\Leftrightarrow \qquad P_t &= \left[ \int_0^1 P_t(i)^{1-\eta_t^s} \mathrm{d}i \right]^{\frac{1}{1-\eta_t^s}}
\end{aligned}
$$

## A.3 The Intermediate-Good Firm's Problem

After combining all of the constraints with (12), the Bellman equation for each firm $i$'s dynamic problem is as follows:

$$
\begin{aligned}
\mathcal{V}_f\left(P_{t-1}(i)\right) = \max_{P_t(i)} \Bigg\{ & \left( \frac{P_t(i)}{P_t} \right)^{1-\eta_t^s} \frac{y_t \eta_t^p}{c_t} - \left( \frac{P_t(i)}{P_t} \right)^{-\eta_t^s} \frac{y_t W_t \eta_t^p}{Z_t P_t c_t} \\
& - \frac{\mu}{2} \left( \frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right)^2 \eta_t^p + \beta \mathbb{E}_t \left[ \mathcal{V}_f\left(P_t(i)\right) \right] \Bigg\}.
\end{aligned}
$$

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

$$(1-\eta_t^s)\left(\frac{P_t(i)}{P_t}\right)^{-\eta_t^s}\frac{y_t\eta_t^p}{P_t c_t}+\eta_t^s\left(\frac{P_t(i)}{P_t}\right)^{-\eta_t^s-1}\frac{y_t W_t\eta_t^p}{Z_t P_t^2 c_t}$$
$$-\mu\left(\frac{P_t(i)}{\pi P_{t-1}(i)}-1\right)\frac{\eta_t^p}{\pi P_{t-1}(i)}+\beta\mathbb{E}_t\left[\mathcal{V}_f'\left(P_t(i)\right)\right]=0, \tag{A.5}$$

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

$$\mathcal{V}_f'\left(P_{t-1}(i)\right)=\mu\left(\frac{P_t(i)}{\pi P_{t-1}(i)}-1\right)\frac{P_t(i)}{\pi P_{t-1}(i)^2}\eta_t^p. \tag{A.6}$$

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

$$\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left[\eta_t^p\ln Q_t-\frac{1}{\psi}\left(\int_0^1 n_t(i)\mathrm{d}i\right)^{\psi}\right]$$

subject to the resource constraint

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

Solving this problem gives us the efficient allocation

# Figures

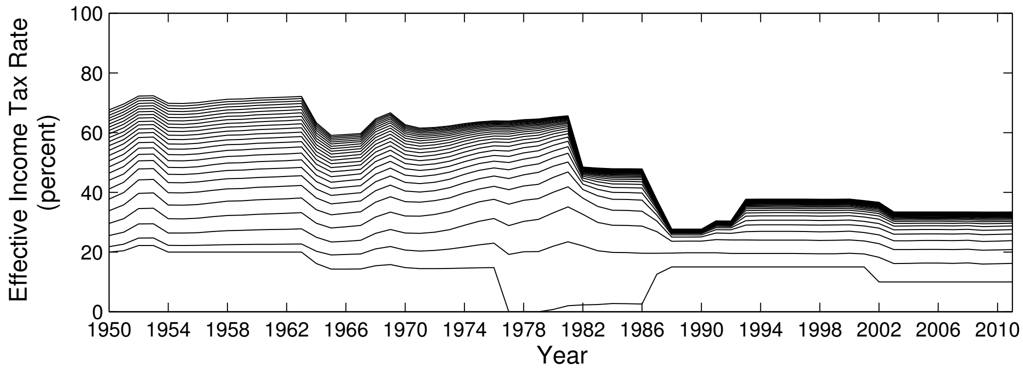


Figure 1: Time series of effective tax rates for 24 evenly-spaced, synthesized real income levels between $10,000 and $2 million from 1950-2012 considering only the legislated, federal personal income tax code.

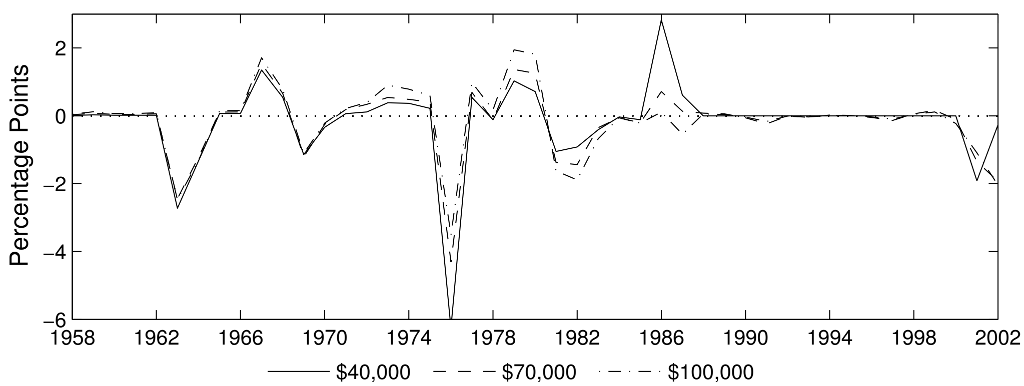


Figure 2: Percentage point change in legislated effective labor income tax rates for selected real incomes measured in 1982 dollars.

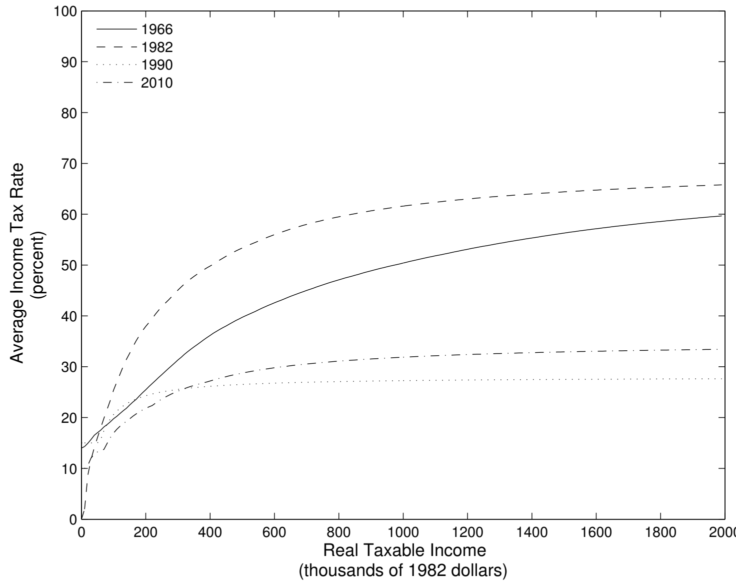


Figure 3: The effective labor income tax code for selected years.

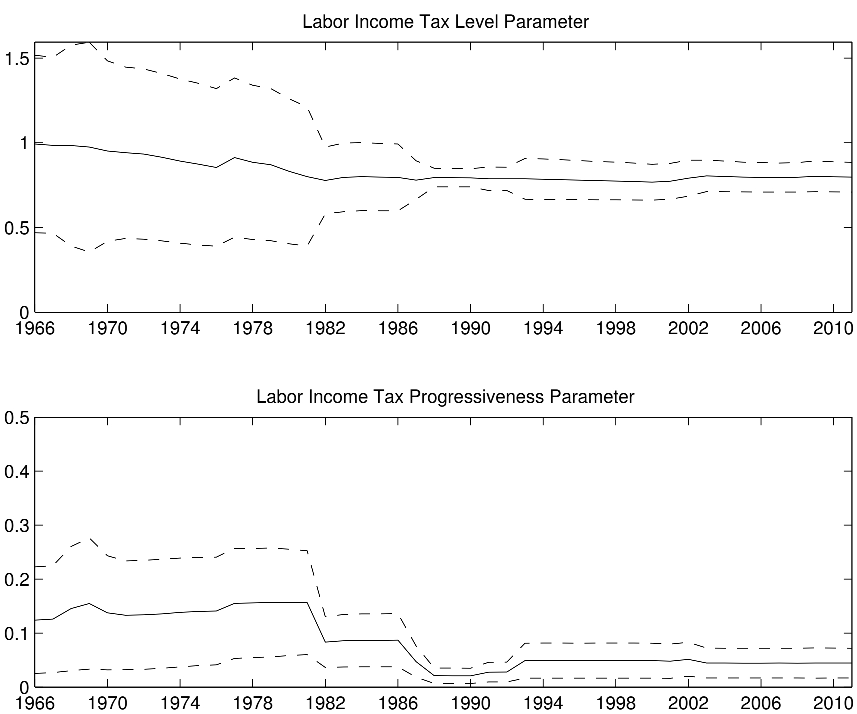


Figure 4: Tax Code Parameters Estimated with Ordinary Least Squares: 1966–2011

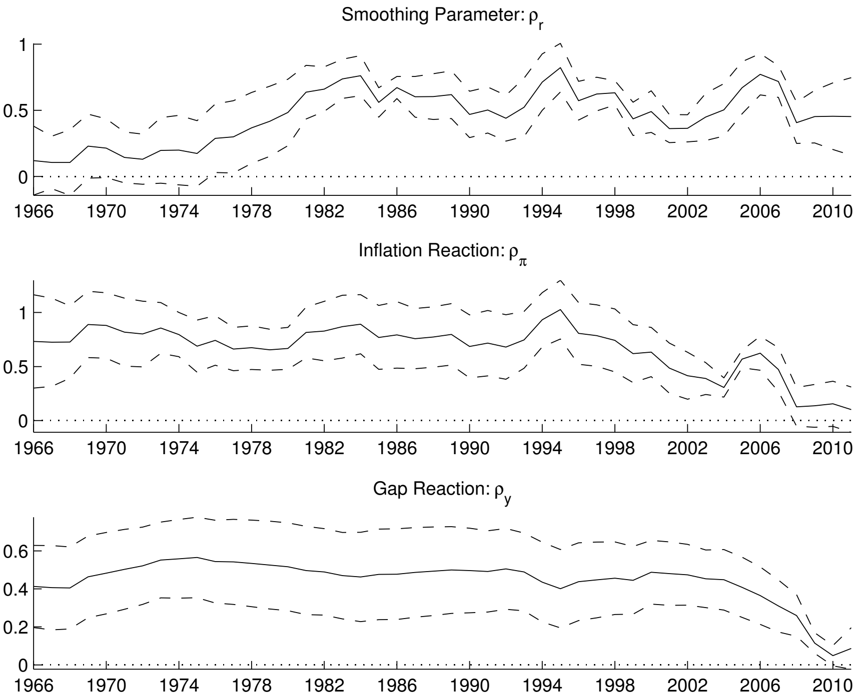


Figure 5: Smoothed Time-Varying Monetary Policy Parameters

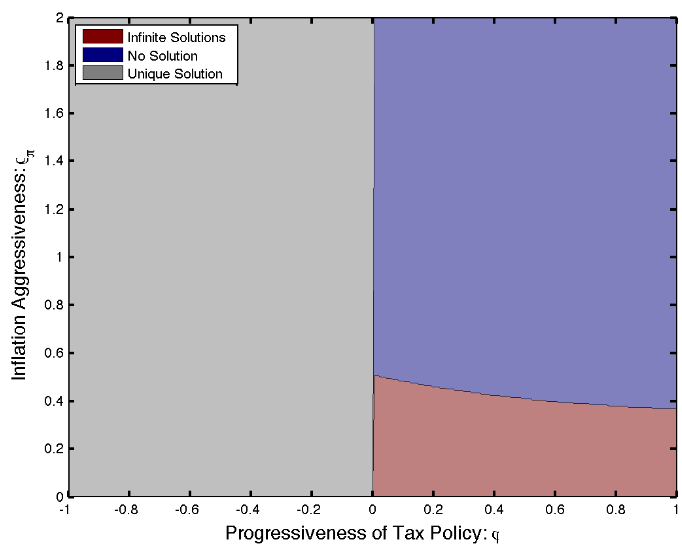


Figure 6: Monetary-Fiscal Interaction Determinacy Regions: Tax Code Not Indexed for Inflation

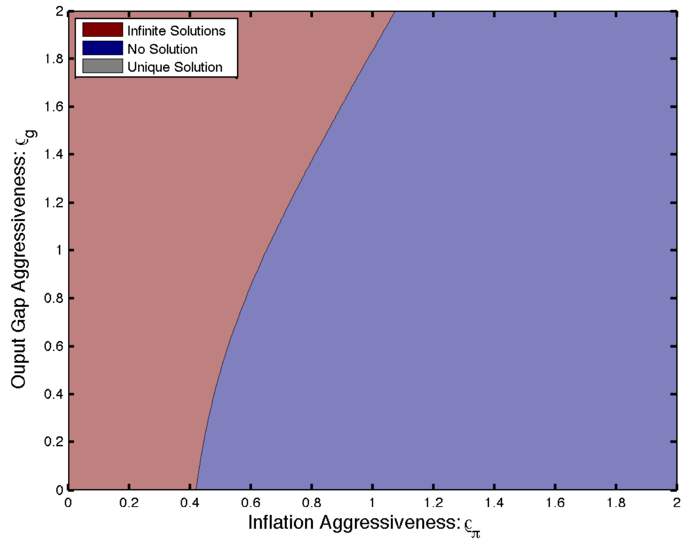


Figure 7: Monetary Policy Determinacy Regions with Fiscal Policy Held Constant: Tax Code Not Indexed for Inflation

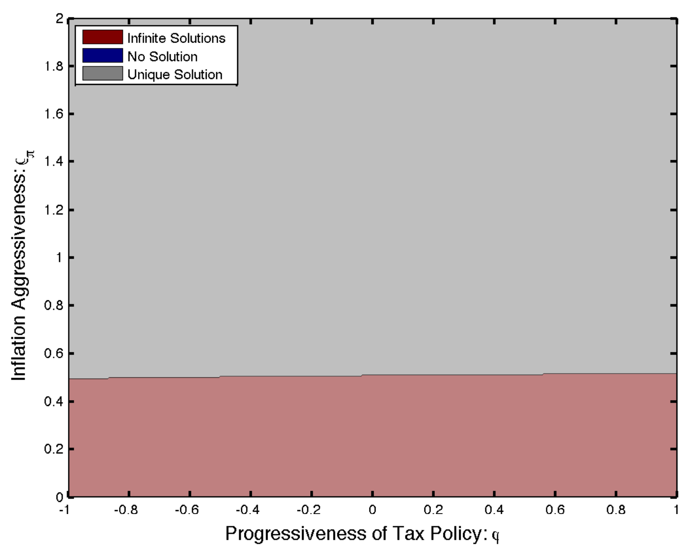


Figure 8: Fiscal-Monetary Interaction Determinacy Regions: Tax Code Indexed for Inflation

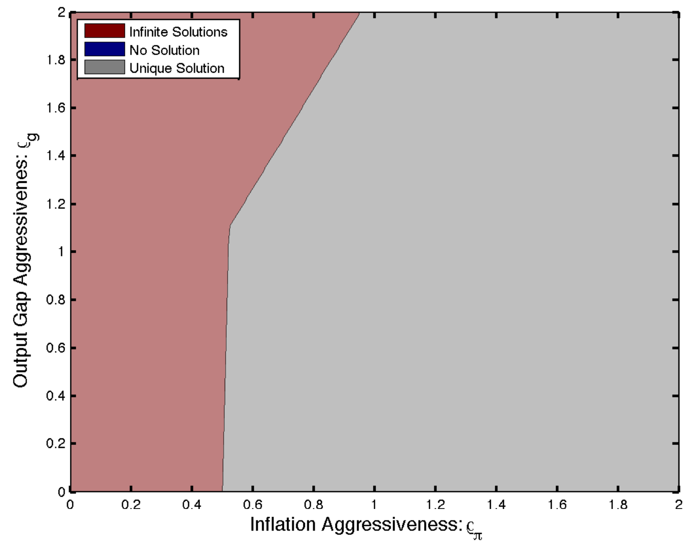


Figure 9: Monetary Policy Determinacy Regions with Fiscal Policy Held Constant: Tax Code Indexed for Inflation

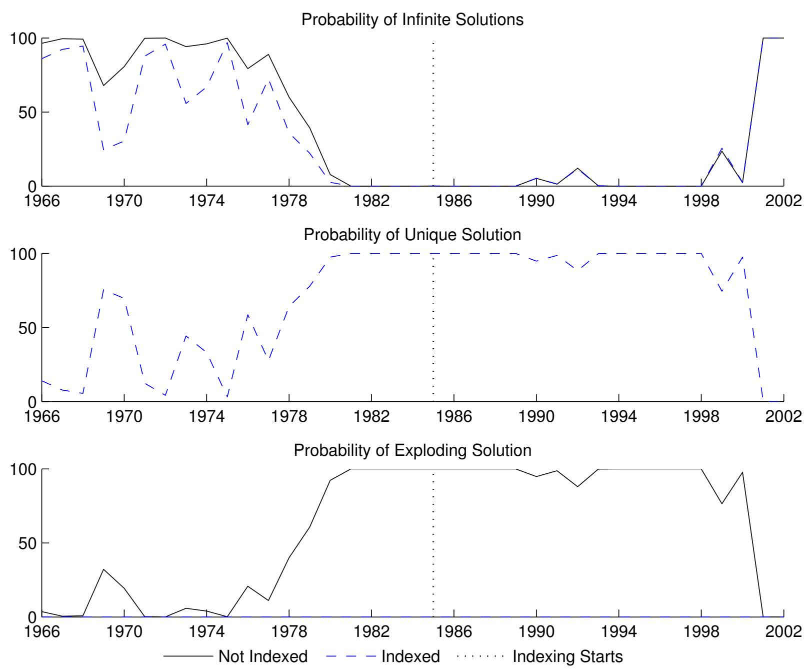


Figure 10: Time-Varying Probabilities of Solution Possibilities Considering both Monetary and Fiscal Policy

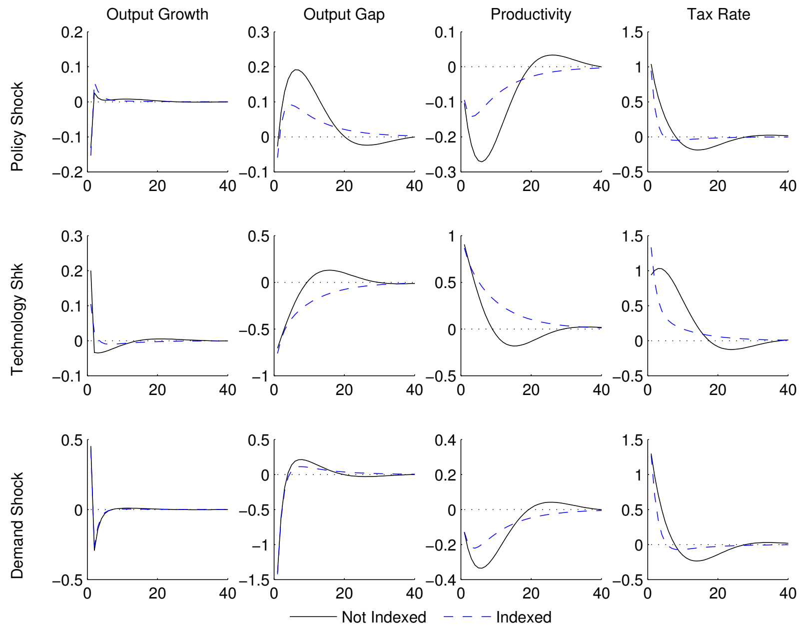


Figure 11: Selected Impulse Responses

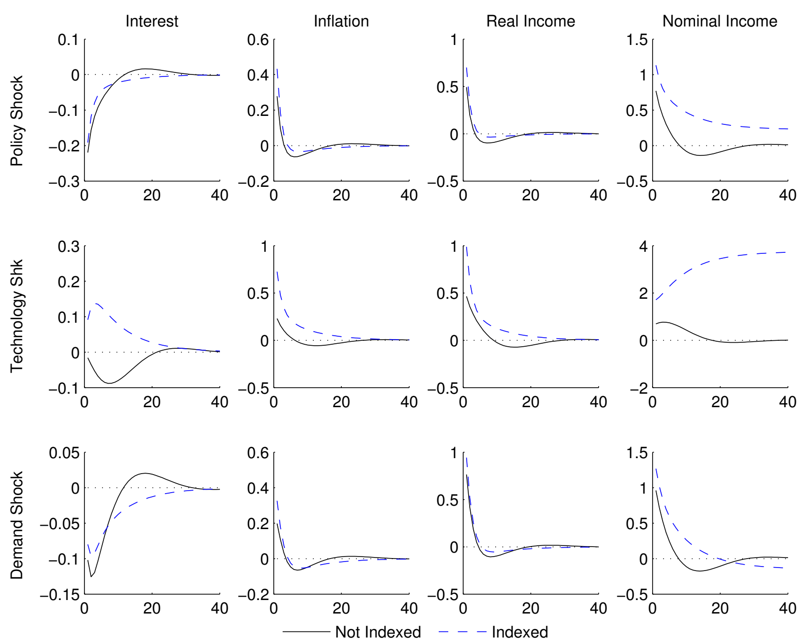


Figure 12: Selected Impulse Responses

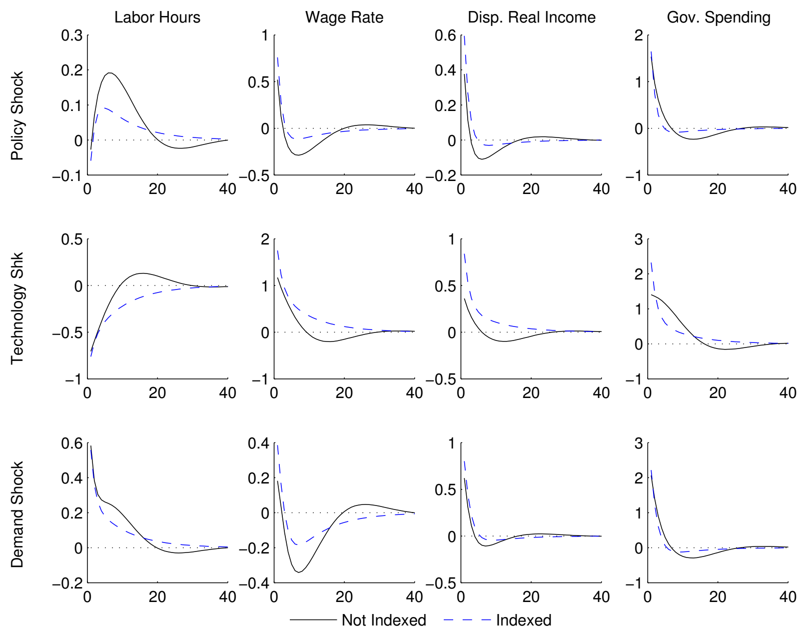


Figure 13: Selected Impulse Responses