

State-Dependent Fiscal Multipliers: Calvo vs. Rotemberg*

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Abstract

This paper studies the properties of the fiscal multiplier in both the [Calvo \(1983\)](#) and [Rotemberg \(1982\)](#) variants of the New Keynesian model. Though identical to first order, the two variants of the model are not the same globally or to higher order. We solve both versions of the model using a third order approximation, and compute the distributions of fiscal multipliers by drawing from the ergodic distributions of states. The multiplier is significantly more variable across states in the Rotemberg model. These differences are magnified when the nominal interest rate is pegged instead of governed by an active Taylor rule.

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1 Introduction

There has recently been renewed interest in the use of fiscal policy as a macroeconomic stabilization tool, particularly in models with nominal rigidities and passive monetary policy. The textbook New Keynesian (NK) model incorporates nominal rigidity either via the [Calvo \(1983\)](#) assumption of staggered price-setting or the [Rotemberg \(1982\)](#) assumption that firms face a quadratic cost of price-adjustment. To a first order approximation about a zero inflation steady state, the two variants of the model are identical; this is not true globally or to a higher order approximation. Because the Rotemberg model features one fewer state variable, authors employing global solution methodologies to study the fiscal multiplier (e.g. [Boneva et al. 2016](#)) often favor its use to the Calvo model.

The objective of this paper is to examine the properties of the fiscal multiplier in both the Calvo and Rotemberg variants of the NK model. We parameterize the two variants of the model to be identical to first order, but solve the models via a third order approximation. In a higher order approximation, the effects of any shock depend on the initial state vector. We generate the ergodic distribution of states from both variants of the model and compute fiscal multipliers at each realization of the state vectors. The multiplier in the Rotemberg model is substantially more volatile than in the Calvo model, with a standard deviation across states that is roughly four times larger. We also compute multipliers across states when monetary policy is characterized by a transient interest rate peg instead of a Taylor rule. For both versions of the model, the mean and volatility of the multiplier across states is larger the longer is the duration of the interest rate peg, though the differences between the properties of the multiplier in the Rotemberg model relative to the Calvo model are accentuated. When the interest rate is pegged for eight periods, for example, the min-max range for the multiplier in the Rotemberg model is 1.4-2.9, compared to 1.7-2.0 for the Calvo model.

Our paper is related to previous work comparing the Calvo and Rotemberg models of price stickiness. [Ascari and Rossi \(2012\)](#) study the differences between the two variants of the NK model when steady state inflation differs from zero. [Richter and Throckmorton \(2016\)](#) estimate non-linear versions of the Calvo and Rotemberg models taking a ZLB constraint into account, and argue that the data favor the Rotemberg model. They argue that the Rotemberg model endogenously generates more volatility at the ZLB. Our results are similar in that we find the fiscal multiplier is more volatile across states in the Rotemberg model, though they do not study the fiscal multiplier. [Ngo and Miao \(2015\)](#) compare the fiscal multiplier in the Calvo and Rotemberg models in a fully non-linear solution. Our results are complementary to theirs in that we document substantial differences between the two variants of the model. Our paper differs from theirs in studying the two models under a Taylor rule in addition to periods where monetary policy is passive. We also focus on distributions of fiscal multipliers across all states, whereas they only focus on comparing multipliers in the two model variants when the interest rate is constrained by zero due to a preference shock.

2 Model

We briefly lay out the elements of a basic NK model under both the Calvo and Rotemberg models of price stickiness. The household, monetary, and fiscal sides of both versions of the model are identical. There is a representative household who saves through one period bonds and supplies labor. A monetary authority sets the nominal interest rate according to a Taylor rule. A fiscal authority chooses government consumption exogenously and finances this spending with lump sum taxes on the household.

The optimality conditions for the household are:

$$\omega N_t^{\frac{1}{\eta}} = \frac{1}{C_t} w_t \quad (1)$$

$$\frac{1}{C_t} = \beta(1 + i_t) \mathbb{E}_t \frac{\nu_{t+1}}{\nu_t} \frac{1}{C_{t+1}} (1 + \pi_{t+1})^{-1} \quad (2)$$

C_t is consumption, N_t is labor supply, and w_t is the real wage. ω is a scaling parameter and η is the Frisch labor supply elasticity. π_t is the inflation rate. (1) is an intratemporal labor supply condition and (2) is an intertemporal Euler equation. The nominal interest rate is i_t . ν_t is an exogenous preference shock which follows an AR(1) with non-stochastic mean of unity:

$$\ln \nu_t = \rho_\nu \ln \nu_{t-1} + s_\nu \varepsilon_{\nu,t}, \quad 0 \leq \rho_\nu < 1, \quad \varepsilon_{\nu,t} \sim N(0, 1) \quad (3)$$

The Taylor rule and process for government spending are:

$$i_t = (1 - \rho_i) i^* + \rho_i i_{t-1} + (1 - \rho_i) \phi_\pi (\pi_t - \pi^*) + s_i \varepsilon_{i,t}, \quad 0 \leq \rho_i < 1, \quad \phi_\pi > 1 \quad (4)$$

$$\ln G_t = (1 - \rho_G) \ln G^* + \rho_G \ln G_{t-1} + s_G \varepsilon_{G,t}, \quad 0 \leq \rho_G < 1, \quad \varepsilon_{G,t} \sim N(0, 1) \quad (5)$$

The non-stochastic steady state value of government spending is G^* . The non-stochastic mean of the interest rate is i^* , and π^* is an exogenous inflation target. A continuum of firms, indexed by $j \in (0, 1)$, produce differentiated goods according to the production technology:

$$Y_t(j) = A_t N_t(j) \quad (6)$$

A_t is an exogenous productivity shock and follows an AR(1) with non-stochastic mean of unity:

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t}, \quad 0 \leq \rho_A < 1, \quad \varepsilon_{A,t} \sim N(0, 1) \quad (7)$$

Intermediates are bundled into a final output good via a CES technology with elasticity of substitution $\epsilon > 1$. Cost-minimization implies that all firms have the same real marginal cost:

$$mc_t = \frac{w_t}{A_t} \quad (8)$$

2.1 Calvo Model

In the Calvo model a randomly selected fraction of firms, $1 - \theta$, with $\theta \in [0, 1)$, can adjust their price in a given period. All updating firms adjust to the same price, $P_t^\#$. The optimal reset price, $1 + \pi_t^\# = \frac{P_t^\#}{P_{t-1}}$, satisfies:

$$\frac{1 + \pi_t^\#}{1 + \pi_t} = \frac{\epsilon}{\epsilon - 1} \frac{x_{1,t}}{x_{2,t}} \quad (9)$$

$$x_{1,t} = \frac{1}{C_t} mc_t Y_t + \theta \beta \mathbb{E}_t (1 + \pi_{t+1})^\epsilon x_{1,t+1} \quad (10)$$

$$x_{2,t} = \frac{1}{C_t} Y_t + \theta \beta \mathbb{E}_t (1 + \pi_{t+1})^{\epsilon-1} x_{2,t+1} \quad (11)$$

Inflation evolves according to:

$$(1 + \pi_t)^{1-\epsilon} = (1 - \theta)(1 + \pi_t^\#)^{1-\epsilon} + \theta \quad (12)$$

The aggregate production function is:

$$Y_t = \frac{A_t N_t}{v_t^p} \quad (13)$$

v_t^p is a measure of price dispersion:

$$v_t^p = (1 + \pi_t)^\epsilon \left[(1 - \theta)(1 + \pi_t^\#)^{-\epsilon} + \theta v_{t-1}^p \right] \quad (14)$$

The aggregate resource constraint is:

$$Y_t = C_t + G_t \quad (15)$$

2.2 Rotemberg Model

In the Rotemberg model, firms face a quadratic cost of adjusting their price governed by the parameter $\psi \geq 0$. This resource cost is proportional to nominal GDP. In equilibrium all firms behave identically and charge the same prices. The inflation rate satisfies:

$$\epsilon - 1 = \epsilon m c_t - \psi(1 + \pi_t)\pi_t + \beta \mathbb{E}_t \frac{C_t}{C_{t+1}} \psi(1 + \pi_{t+1})\pi_{t+1} \frac{Y_{t+1}}{Y_t} \quad (16)$$

The aggregate production function and resource constraints are:

$$Y_t = A_t N_t \quad (17)$$

$$Y_t = C_t + G_t + \frac{\psi}{2} \pi_t^2 Y_t \quad (18)$$

2.3 First Order Equivalence

A log-linear approximation about a zero inflation steady state gives rise to a Phillips Curve in both variants of the model of the form:

$$\pi_t = \gamma(\ln m c_t - \ln m c^*) + \beta \mathbb{E}_t \pi_{t+1} \quad (19)$$

In the Calvo model, $\gamma = \frac{(1-\theta)(1-\theta\beta)}{\theta}$, while in the Rotemberg model, $\gamma = \frac{\epsilon-1}{\psi}$. Given a value of θ , ψ can be chosen so that the two variants of the model are identical to first order.

3 Quantitative Analysis

We solve both variants of the NK model using a third order approximation. The values assigned to parameters are listed in Table 1. We parameterize θ to imply an average duration between price changes in the Calvo model of four quarters. The parameter ψ in the Rotemberg model is chosen to be equivalent to the Calvo model to first order. Given our parameterization of the shock processes, the productivity shock accounts for 33 percent of the unconditional variance of output, while the preference, monetary, and government spending shocks account for 57, 8, and 2 percent, respectively.

For each version of the model, we simulate 10,100 periods of data with the same draw of shocks and discard the first 100 periods as a burn-in. We then compute generalized impulse responses to a one standard deviation shock to government spending starting from each of the remaining 10,000

simulated vectors of states. The fiscal multiplier is defined as the ratio of the impact response of output to the impact response of government spending.

Table 2 displays statistics concerning the distribution of fiscal multipliers across states in both variants of the NK model. The multipliers evaluated in the non-stochastic steady state are similar to one another at 0.84 for Calvo and 0.85 for Rotemberg. The average multipliers are very similar to the multipliers evaluated in the steady state. The fiscal multiplier in the Calvo model is close to constant across states, with a standard deviation of 0.005 and a min-max range of 0.82-0.86. The multiplier in the Rotemberg model however, is significantly more volatile across states. The standard deviation of the multiplier is 0.02, or nearly four times larger than in the Calvo model, and the min-max range is 0.79-0.94.

What is the intuition for these results? In the Calvo model, inflation generates price dispersion, which drives a wedge between output and hours. In the Rotemberg model, there is a resource cost of inflation. In both models, an increase in government spending results in higher inflation. Figure 1 plots on the vertical axis how the output cost of inflation varies in the two variants of the model for a small, positive increase in inflation. On the horizontal axis is an initial inflation rate. While not a state variable in either model, one can think about different initial states mapping into different initial values of inflation. The dashed blue line plots how the output cost of more inflation varies with the initial level of inflation in the Rotemberg model. As the resource cost is quadratic, this plot is linear and increasing in the inflation rate. The plot crosses zero at an initial value of inflation of zero. The solid black line plots how price dispersion changes with an increase in inflation in the Calvo model. We assume an initial value of price dispersion equal to steady state, so $v_{t-1}^p = 1$. Similarly to the Rotemberg model, this plot is upward-sloping and crosses zero at an initial inflation rate of zero. Differently than in the Rotemberg model, this plot is fairly flat near an initial inflation rate of zero.

Understanding how higher inflation interacts with the cost of inflation in the two variants of the model is key to understanding why there is more state-dependence in the Rotemberg model. In the Calvo model, an increase in inflation triggered by higher government spending does not have much effect on price dispersion for initial levels of inflation near zero. This is because there are two competing effects of higher inflation on price dispersion, both evident in (14). The direct effect of higher inflation is to increase price dispersion, while the indirect is to raise reset price inflation, $\pi_t^\#$, which works in the other direction. For low initial levels of inflation, these effects roughly cancel out (i.e. the plot is relatively flat near an inflation rate of zero). Only at high levels of initial inflation is the direct effect significantly stronger. In contrast, the resource cost of higher inflation is significantly more sensitive to the initial inflation rate in the Rotemberg model when initial inflation is in the neighborhood of zero (i.e. the plot is steeper than in the Calvo model). Since the cost of inflation varies significantly more across states in the Rotemberg model, it is therefore natural that there is more state-dependence in the fiscal multiplier in this model than in the Calvo model.

We next study the state-dependence of fiscal multipliers in each variant of the model when monetary policy obeys a transient interest rate peg. The nominal interest rate is pegged at its most recent value for a known number of periods, after which time it reverts to obeying the Taylor rule (4). Formally:

$$E_t i_{t+q} = \begin{cases} i_{t-1} & \text{if } q \leq Q \\ (1 - \rho_i)i^* + \rho_i i_{t+q-1} + (1 - \rho_i)\phi_\pi(\pi_{t+q} - \pi^*) & \text{if } q > Q \end{cases} \quad (20)$$

Q is the number of periods for which the interest rate is pegged. Our implementation of the interest rate peg is based on Laseen and Svensson (2011). In particular, we solve the model where the Taylor rule is augmented by $Q - 1$ “forward guidance” shocks. Formally:

$$i_t = (1 - \rho_i)i^* + \rho_i i_{t-1} + (1 - \rho_i)\phi_\pi(\pi_t - \pi^*) + s_i \varepsilon_{i,t} + \sum_{q=1}^{Q-1} s_{i,q} \varepsilon_{i,q,t-q} \quad (21)$$

We consider the same distribution of simulated states as when the economy obeys a Taylor rule without anticipated shocks. At each simulated vector of states, we consider a one standard deviation shock to government spending. We then simultaneously solve for the sequence of current and anticipated monetary policy shocks which leave the nominal interest rate unaffected for the desired number of periods, Q . These shocks are observed by agents at the time of the government spending shock. This is a tractable way to approximate the effects of a passive monetary policy regime while still employing perturbation methods.

Results for both variants of the model under an interest rate peg are summarized in Table 3. Columns correspond to different durations of the peg. For both variants of the model, the mean multipliers are increasing in the duration of the peg. The intuition for this is straightforward – when the nominal interest rate is unresponsive, higher inflation from an increase in government spending results in a lower, rather than higher, real interest rate, which tends to “crowd-in” private spending. The longer the interest rate is unresponsive, the more inflation increases, the more the real interest rate falls, and the more output expands.

For the Calvo model, the mean multipliers tend to be slightly smaller than what obtains via a first order approximation, and this difference is increasing in the length of the peg. The reverse is true for the Rotemberg model. Consonant with our intuition developed above, the standard deviation of the multiplier tends to be larger the longer the interest rate is pegged in both model variants. Similar to when policy is characterized by a Taylor rule, the multiplier is more volatile in the Rotemberg model than in the Calvo model at all peg lengths. The difference in volatilities is increasing in the peg length. At a four quarter peg, the standard deviation of the multiplier in the Rotemberg model is 0.0683 with a min-max range of 0.97-1.48; for the Calvo model, the standard deviation is 0.01 and the min-max range is only 1.11-1.19. At an eight quarter peg, the standard deviation of the multiplier in the Rotemberg model is 0.21, compared to 0.04 in the Calvo model.

4 Conclusion

This paper studies the properties of the fiscal multiplier in both the Calvo and Rotemberg models of price stickiness. Even though the models are identical to first order, at a higher order approximation there are significant differences in the distributions of multipliers across states, with the multiplier more variable across states in the Rotemberg model. These differences are accentuated when monetary policy is characterized by a transient interest rate peg. Unlike in a first order approximation, the model of price stickiness is not innocuous and may impact conclusions about the properties of the fiscal multiplier.

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Table 1: **Parameter Values**

Parameter	Value	Description
β	0.99	Discount factor
ϵ	10	Elasticity of substitution
η	2	Frisch elasticity
G^*	$\frac{G^*}{Y^*} = 0.2$	SS government spending share
θ	0.75	Calvo price stickiness
ψ	$\frac{\theta(\epsilon-1)}{(1-\theta)(1-\theta\beta)}$	Rotemberg price stickiness
ω	$N^* = 1/3$	Labor disutility
ρ_i	0.8	Taylor rule smoothing
ϕ_π	1.5	Taylor rule inflation
ρ_ν	0.6	AR preference shock
ρ_A	0.9	AR productivity shock
ρ_G	0.9	AR government spending shock
s_ν	0.03	SD preference shock
s_A	0.01	SD productivity shock
s_G	0.01	SD government spending shock
s_i	0.0025	SD Taylor rule shock

Note: This table shows parameter values we use in quantitative simulations of the model.

Table 2: **State-Dependence of Multipliers**

	Calvo	Rotemberg
Steady State	0.8427	0.8477
Mean	0.8427	0.8528
Standard Deviation	0.0047	0.0198
Minimum	0.8237	0.7881
Maximum	0.8602	0.9352
First Order Approx	0.8399	0.8399

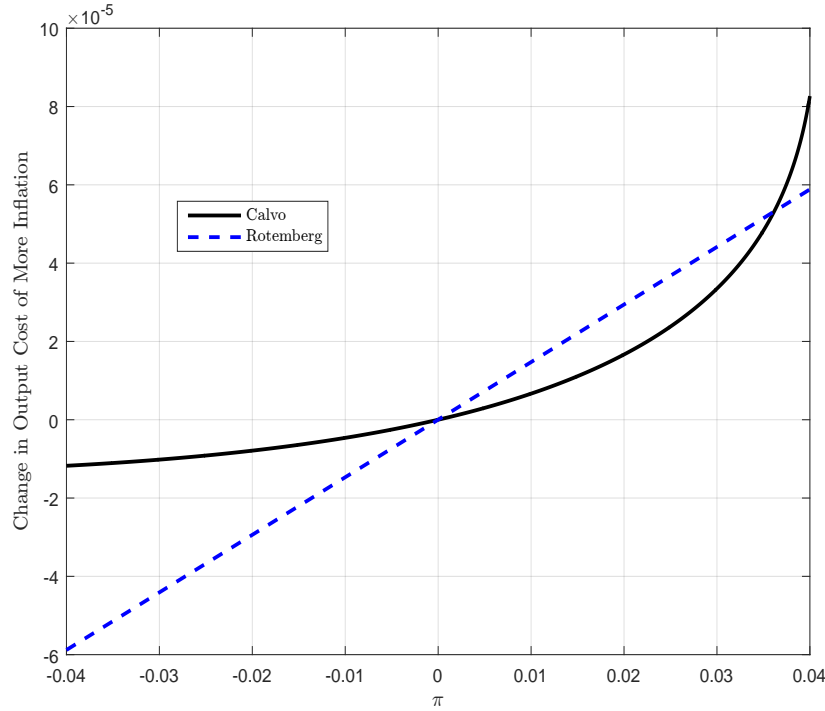
Note: This table shows statistics for the multipliers in both the Calvo and Rotemberg variants of the NK model. Monetary policy is characterized by the Taylor rule. These statistics are based on simulating 10,000 periods of data from each version of the model, and computing the multiplier at each realization of the state vector.

Table 3: **State-Dependence of Multipliers
under an Interest Rate Peg**

	Peg Length							
	1	2	3	4	5	6	7	8
Calvo								
Steady State	0.8981	0.9598	1.0426	1.1413	1.2620	1.4196	1.6018	1.8234
Mean	0.8977	0.9595	1.0428	1.1423	1.2645	1.4244	1.6098	1.8359
Standard Deviation	0.0024	0.0030	0.0057	0.0100	0.0155	0.0228	0.0307	0.0399
Minimum	0.8876	0.9464	1.0231	0.1106	1.2158	1.3515	1.5118	1.7110
Maximum	0.9058	0.9718	1.0723	1.1943	1.3403	1.5274	1.7343	1.9952
First order approx	0.8988	0.9670	1.0494	1.1512	1.2784	1.4384	1.6403	1.8953
Rotemberg								
Steady State	0.9140	0.9893	1.0814	1.1961	1.3410	1.5244	1.7603	2.0662
Mean	0.9198	0.9980	1.0937	1.2131	1.3640	1.5551	1.8010	2.1197
Standard Deviation	0.0261	0.0366	0.0505	0.0683	0.0912	0.1202	0.1575	0.2055
Minimum	0.8226	0.8646	0.9131	0.9717	1.0447	1.1368	1.2554	1.4065
Maximum	1.0171	1.1376	1.2888	1.4798	1.7223	2.0296	2.4246	2.9353
First order approx	0.8988	0.9670	1.0494	1.1512	1.2784	1.4384	1.6403	1.8953

Note: This table shows statistics for the multipliers in both the Calvo and Rotemberg variants of the NK model. Monetary policy is characterized by an interest rate peg of deterministic duration as indicated in columns. These statistics are based on simulating 10,000 periods of data from each version of the model when policy is characterized by the Taylor rule, and then computing the multiplier at each realization of the state vector assuming that the interest rate is pegged for the duration listed in each column.

Figure 1: **Output Costs of Increase in Inflation**



Note: This figure plots how the output cost of an increase in inflation (vertical axis) changes in response to a small increase in inflation (an increase of 0.00025) starting from a given initial level of inflation (horizontal axis) for both variants of the NK model (solid black: Calvo; dashed blue: Rotemberg)