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Abstract

This paper studies the empirical performance of a widely used model of nominal rigidities: the Calvo model of sticky goods prices. We describe an extended version of this model with variable elasticity of demand of the differentiated goods and imperfect capital mobility. We find little evidence against standard versions of the model without the extensions, but the estimated frequency of price adjustment is implausible. With the extended model the estimates are more reasonable. This is especially so if the sample is split to take into account a possible change in monetary regime around 1980.

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1. Introduction

In this paper we analyze the aggregate implications of the widely used model of sticky prices due to Calvo (1983).[1] This model makes the simplifying assumption that the number of firms adjusting prices in any given period is exogenous. We address the question of whether models with this assumption make sense empirically.[2]

To do this, we study a generalized version of the Calvo model. Standard versions of the Calvo model assume that monopolistically competitive firms face a constant elasticity of demand. Following Kimball (1995), we allow for the possibility that the elasticity of demand is increasing in the firm's price. Another standard assumption is that capital can be instantaneously reallocated after after a shock. Following Sbordone (2002), we also consider the possibility that capital is fixed in place and is not reallocated in response to shocks. These two extensions to the Calvo model in principle enable it to account for the dynamics of inflation with lower degrees of price rigidities.

The parameters of the extended Calvo model are not separately identified using aggregate time series data. In particular, one cannot separately identify the probability that a firm reoptimizes its price, the nature of demand elasticities, and the degree of capital mobility. Still, we can identify the frequency of reoptimization if we have information or priors about demand elasticities and the degree of capital mobility.

Our main findings are as follows. We find strong evidence against the standard Calvo model, that is the version of the model with a constant demand elasticity, mobile capital, and no lag between the time that firms reoptimize and the time that they implement their new plans. This is true regardless of whether or not we allow for a structural break in monetary policy in the early 1980s. When we allow for a one period implementation lag, the model is no longer rejected. Interestingly, this is the specification adopted in Chari, Kehoe and McGrattan (2001) and Christiano, Eichenbaum and Evans (2001) among others.

Evidently, allowing for a one quarter delay in the implementation on new prices renders

[1] See for example, Clarida, Gali and Gertler (2001), Christiano, Eichenbaum and Evans (2001), Erceg, Henderson and Levon (2000), Rotemberg and Woodford (1997, 2003), Woodford (2003), and Yun (1996).

[2] We do not consider models which endogenize the number of firms changing prices, such as in the ones studied by Dotsey, King and Wolman (1999) and Goloslov and Lucas (2003). While models of this kind seem very promising they are more difficult to work with than Calvo-style models. There is some theoretical evidence that endogenizing the number of firms setting prices may not effect policy analysis for the inflation rates typically seen for the US. For example. For example, Burstein (2002) shows that for moderate changes in the growth rate of money (less than or equal to 5% on a quarterly basis), traditional Calvo models are a good approximation to a model where the number of firms adjusting prices is endogenous.

the standard Calvo model consistent with the aggregate data in a *statistical* sense. But that does not mean the estimated model makes *economic* sense. Here the model does less well. Specifically, according to our point estimates, firms reoptimize prices on average roughly once every two and a half *years*. This seems implausible on *a priori* grounds. More importantly, it is inconsistent with results based on microeconomic data (see for example Bills and Klenow (2002)).

In the extended Calvo model the estimated frequency of reptimization may be more reasonable. Based on the full sample results, the model with immobile capital and non-constant elasticity of demand is consistent with the view that firms reoptimize prices roughly once every year, using the relatively low upper bound for the demand elasticity as suggested by Bergin and Feenstra (2000). Using the higher benchmark elasticity of Chari, Kehoe and McGrattan (2000), the model with mobile capital and non-constant elasticity of demand is consistent with the view that firms reoptimize prices roughly once every three quarters.

Even more favorable results emerge if we take as given that there is split in the sample period owing to a change in monetary policy. Averaging across the two subsamples, we find that the model with mobile capital and the non-constant elasticity of demand is consistent with the view that firms reoptimizing prices every three quarters, if we are willing to use the higher benchmark elasticity. The model with immobile capital and the non-constant elasticity of demand is consistent with the view that firms reoptimize prices more often than once every three quarters, regardless of the which benchmark elasticity we assume.

The rest of the paper is organized as follows. First we describe the extended Calvo model and our empirical methodology. Then we discuss the empirical results. In the penultimate section we interpreting the parameters of the estimated Calvo model. In the final section we summarize our results.

2. The Calvo Model of Sticky Prices

In this section we display an extended version of the Calvo model. In the first subsection we consider a version of the model in which intermediate good firms face a non constant elasticity of demand for their output. In addition, we allow for a finite lag between the time firms reoptimize prices and when they implement new plans. In the next subsection we incorporate into our analysis the assumption that firms' capital is fixed in place and is not reallocated in response to shocks.

2.1. The Calvo Model with Non Constant Elasticity of Demand

At time t, a final good, Y_t, is produced by a perfectly competitive firm. The firm does so combining a continuum of intermediate goods, indexed by $i \in [0,1]$ using the following technology suggested by Kimball (1995):

$$\int_0^1 G(Y_{it}/Y_t)di = 1. \tag{1}$$

Here G is increasing, strictly concave and $G(1) = 1$. In addition, Y_{it} is the input of intermediate good i. The standard Dixit-Stiglitz specification corresponds to the special case:

$$G(Y_{it}/Y_t) = (Y_{it}/Y_t)^{(\mu-1)/\mu},\ \mu > 1. \tag{2}$$

For convenience we refer to the general version of $G(\cdot)$ that we work with as the non Dixit -Stiglitz aggregator.

The final goods firm chooses Y_t and Y_{it} to maximize profits

$$P_t Y_t - \int_0^1 P_{it} Y_{it} di$$

subject to (1). Here P_t and P_{it} denote the time t price of the final and intermediate good i, respectively. The first order conditions to the firm's problem imply

$$Y_{it} = Y_t G'^{-1}\left(\frac{P_{it}Y_t}{\lambda_t}\right). \tag{3}$$

Here λ_t,the time t Lagrange multiplier on constraint (1), is given by:

$$\lambda_t = \frac{P_t Y_t}{\int G'(Y_{it}/Y_t)\cdot(Y_{it}/Y_t)di}. \tag{4}$$

Throughout the symbol "$'$" denotes the derivative operator and $G'^{-1}(\cdot)$ denotes the inverse function of $G'(\cdot)$. Our assumptions on $G(\cdot)$ imply that the firm's demand for input Y_{it} is a decreasing in its relative price.[3]

[3]Here we have used the fact that, given our assumptions on G, if $x = G'^{-1}(z)$,then $dG'^{-1}(z)/dz = 1/G''(x)$.

Intermediate good $i \in [0,1]$ is produced by a monopolist who uses the following technology:

$$Y_{it} = A_t K_{it}^{\alpha} L_{it}^{1-\alpha} \tag{5}$$

where $0 < \alpha < 1$. Here, L_{it} and K_{it} denote time t labor and capital services used to produce intermediate good i, respectively. Intermediate good firms rent capital and labor in economy wide perfectly competitive factor markets. The variable A_t denotes possible stochastic disturbances to technology.

Profits are distributed to the firms' owners at the end of each time period. Let s_t denote the representative firm's real marginal cost. Given our assumptions on factor markets, all firms have identical marginal costs. Consequently, we do not index s_t by i. Marginal cost depends on the parameter α and factor prices which the firm takes as given. The firm's time t profits are:

$$\left[\frac{P_{it}}{P_t} - s_t\right] P_t Y_{it},$$

where P_{it} is the price of intermediate good i.

Intermediate good firms set prices according to a variant of the mechanism spelled out in Calvo (1983). In each period, a firm faces a constant probability, $1-\theta$, of being able to reoptimize its nominal price. So on average a firm reoptimizes its price every $(1-\theta)^{-1}$ periods. Following the literature, we assume that the firm's ability to reoptimize its price is independent across firms and time. For now we leave open the issue of what information set the firm has when it resets its price.

We consider two scenarios for what happens if a firm does not reoptimize its price. In the first scenario, the firm adopts what we call the *static indexing* scheme, i.e. it updates its price according to the rule:

$$P_{it} = \bar{\pi} P_{it-1}. \tag{6}$$

Here $\bar{\pi}$ is the long run average gross rate of inflation.[4] In the second scenario, the firm adopts what we call the *dynamic indexing* scheme, i.e. it sets its price according to[5]

$$P_{it} = \pi_{t-1} P_{it-1}. \tag{7}$$

[4] Other authors who make this assumption include Erceg, Henderson and Levin (2000) and Yun (1996).
[5] See Christiano, Eichenbaum and Evans (2001) for a discussion of this form of indexation.

Let $\tilde{P}_t$ denote the value of P_{it} set by a firm that can reoptimize its price. In addition, let $\tilde{Y}_t$ denote the time t output of this firm. Our notation does not allow $\tilde{P}_t$ or $\tilde{Y}_t$ to depend on i because all firms who can reoptimize their price at time t choose the same price (see Woodford, 1996 and Yun, 1996). In what follows we focus, for convenience, on specification (6).The firm chooses $\tilde{P}_t$ to maximize

$$E_{t-\tau}\sum_{l=0}^{\infty}(\beta\theta)^l v_{t+l}\left[\tilde{P}_t\bar{\pi}^l - s_{t+l}P_{t+l}\right]\tilde{Y}_{t+l} \tag{8}$$

subject to (3). Here, $E_{t-\tau}$ denotes the conditional expectations operator and the firm's $t-\tau$ information set which includes the realization of all model variables dated $t-\tau$ and earlier. In addition, v_{t+l} is the time-varying portion of the firm's discount factor. The intermediate good firm views s_t, P_t, v_t and λ_t as exogenous stochastic processes beyond its control.

Let $\tilde{p}_t = \tilde{P}_t/P_t$. Log linearizing the first order condition of the firm around the relevant steady state values we obtain:

$$\widehat{\tilde{p}}_t = E_{t-\tau}\sum_{l=1}^{\infty}(\beta\theta)^l\hat{\pi}_{t+l} + AE_{t-\tau}\left[\hat{s}_t + \sum_{l=1}^{\infty}(\beta\theta)^l(\hat{s}_{t+l}-\hat{s}_{t+l-1})\right] \tag{9}$$

where

$$A = \frac{1+G''(1)/G'(1)}{2+G'''(1)/G''(1)}. \tag{10}$$

Throughout $\hat{x}_t$ denotes the percent deviation of a variable x_t from its steady steady state value.

Several features of (9) are worth emphasizing. First, if inflation is expected to be at its steady state level and real marginal cost is expected to remain constant after time t, then the firm sets $\widehat{\tilde{p}}_t = AE_{t-\tau}\hat{s}_t$. Second, suppose the firm expects real marginal costs to be higher in the future than at time t. Anticipating those future marginal costs, the firm sets $\widehat{\tilde{p}}_t$ higher than $AE_{t-\tau}\hat{s}_t$. It does so because it understands that it may not be able to raise its price when those higher marginal costs materialize. Third, suppose firms expect inflation in the future to exceed its steady state level. To avoid a decline in its relative price, the firm incorporates expected future changes in the inflation rate into $\widehat{\tilde{p}}_t$.

The degree to which $\widehat{\tilde{p}}_t$ responds to current and future values of $\hat{s}_t$ is increasing in A which in turns depends on the properties of $G(\cdot)$. One way to interpret A is that it governs the degree of pass through from a rise in marginal cost to prices. For example, according to (9), a highly persistent 1% increase in time t marginal cost from its steady state value, induces the firm to initially raise its relative price by approximately A percent.

A different way to interpret A involves the elasticity of demand for a given intermediate good, $\eta(x)$,

$$\eta(x) = -\frac{G'(x)}{xG''(x)} \tag{11}$$

where $x = \tilde{Y}/Y$. In the Appendix we show that

$$A = \frac{1}{(\zeta - 1)\epsilon + 1}, \tag{12}$$

where

$$\epsilon = \frac{\tilde{P}}{\eta(1)} \frac{\partial \eta(1)}{\partial \tilde{P}}, \tag{13}$$

which is the percent change in the elasticity of demand due to a one percent change in the the relative price of the good, evaluated in steady state. The variable ζ denotes the firm's steady state markup

$$\zeta = \frac{\eta(1)}{\eta(1) - 1}. \tag{14}$$

In the standard Dixit Stiglitz case, ϵ is equal to zero and A is equal to one.

Relation (12) and (9) imply that the larger is ϵ, the lower is A and the less responsive is $\widehat{\tilde{p}}_t$ to current and future values of $\hat{s}_t$. Other things equal, a rise in marginal cost induces a firm to increase its price. A higher value of ϵ means that, for any given rise in its price, the more elastic is the demand curve for the firm's good. So, relative to the case where $\epsilon = 0$, the firm will raise its by price by less.

Zero profits in the final goods sector and our assumption about the distribution of θ across firms and time imply,

$$P_t Y_t = \int_0^1 P_{it} Y_{it} = (1-\theta)\tilde{P}_t Y_{t+l} G'^{-1}\left(\frac{\tilde{P}_t Y_t}{\lambda_t}\right) + \theta \bar{\pi} P_{t-1} Y_t G'^{-1}\left(\frac{\bar{\pi} P_{t-1} Y_t}{\lambda_t}\right).$$

Linearizing this relationship about steady state yields

$$\widehat{\tilde{p}}_t = \frac{\theta}{1-\theta}\hat{\pi}_t \tag{15}$$

Combining (9) and (15) we obtain

$$\hat{\pi}_t = \beta E_{t-\tau}\hat{\pi}_{t+1} + \frac{(1-\beta\theta)(1-\theta)}{\theta} A E_{t-\tau}\hat{s}_t. \tag{16}$$

When $\tau = 0$ and $A = 1$ (the Dixit Stiglitz case), (16) reduces to the standard relationship between inflation and marginal costs studied in the literature.[6]

Iterating forward on (16) yields

$$\hat{\pi}_t = \frac{(1-\beta\theta)(1-\theta)}{\theta} A E_{t-\tau} \sum_{j=0}^{\infty} \beta^j \hat{s}_{t+j} \tag{17}$$

Relation (17) makes clear a central prediction of the model: deviations of inflation from its steady state value depend only on firms' expectations of current and future deviations of real marginal cost from its steady state value. The lower is A, i.e. the more sensitive is the elasticity of demand for intermediate goods to price changes, the less responsive is $\hat{\pi}_t$ to changes in expected values of $\hat{s}_{t+j}$. Similarly, the higher is θ, the smaller will be the response of $\hat{\pi}_t$ to expected changes in marginal cost. So the version of Calvo model considered in this subsection has two distinct mechanisms which can account for a small response of inflation to movements in marginal cost.

In the case where firms adopt the dynamic indexing rule, (7), the linearized first order condition is

$$\hat{\tilde{p}}_t = E_{t-\tau}\left\{ \hat{s}_t + \sum_{l=1}^{\infty} (\beta\theta)^l \left(\hat{s}_{t+l} - \hat{s}_{t+l-1}\right) + \sum_{l=1}^{\infty} (\beta\theta)^l \left(\hat{\pi}_{t+l} - \hat{\pi}_{t+l-1}\right) \right\} \tag{18}$$

and (16) takes the form

$$\Delta\hat{\pi}_t = \beta E_{t-\tau}\Delta\hat{\pi}_{t+1} + \frac{(1-\beta\theta)(1-\theta)}{\theta} A E_{t-\tau}\hat{s}_t. \tag{19}$$

[6] We derived (16) by linearizing around steady state inflation $\bar{\pi}$. Various authors assume that firms which do not reoptimize prices, leave their price unchanged, i.e. $p_{it} = p_{it-1}$. The model is then linearized around $\bar{\pi} = 1$. Since $\hat{\pi}_t$ is defined as the percentage deviation from steady state, (16) does not depend on the assumed value of $\bar{\pi}$.

In addition (17) is replaced by

$$\Delta\hat{\pi}_t = \frac{(1-\beta\theta)(1-\theta)}{\theta} A E_{t-\tau} \sum_{j=0}^{\infty} \beta^j \hat{s}_{t+j} \tag{20}$$

Here it is the first difference of $\hat{\pi}_t$ that is a weighted average of the the conditional expected value of current and future values of the deviation of real marginal cost from its steady state value.

2.2. Allowing for Fixed Firm Capital

Standard variants of the Calvo model assume that capital is perfectly mobile and that firms instantly reallocate their capital after a shock. In conjunction with the assumption that labor is perfectly mobile, this implies that firms' have the same marginal cost. Sbordone (2002) considers a variant of the Calvo model in which $A = 1$, where firm capital is fixed in place and is not reallocated in response to shocks. This implies that intermediate good firms do not have the same marginal cost. The fixed capital assumption enables the Calvo model to account for the time series behavior of inflation with lower degrees of price rigidities, i.e. lower values of θ.

The basic intuition for this claim can be described as follows. When capital is mobile, firm i takes marginal cost as given. As shown in the Appendix, when capital is immobile, firm i's marginal cost depends partly on economy wide factors but is also an increasing function of its own level of output. Consider a shock that raises the economy-wide component of marginal costs, say a rise in the real wage rate. Other things equal firm i will respond by raising its price. But this reduces its output and leads to a countervailing fall in the firm specific component of marginal cost. On net, this leads the firm to raises its price by less than it would if capital were perfectly mobile.

We now describe a version of the Calvo model with immobile capital and with intermediate good firms that do not necessarily face a constant elasticity of demand for their goods. We refer the reader to the appendix for details. Consistent with Galí et. al. (2001) and Sbordone (2002) we assume that the capital stock of firm i is proportional to the aggregate capital stock.

With static indexation scheme, the analog to (16) in this model is given by

$$\hat{\pi}_t = \beta E_{t-\tau}\hat{\pi}_{t+1} + \frac{(1-\beta\theta)(1-\theta)}{\theta} \cdot A \cdot D \cdot E_{t-\tau}\hat{s}_t \tag{21}$$

where A is defined in (12) and D is given by

$$D = \frac{1}{1 + A\frac{\alpha}{1-\alpha}\frac{\zeta}{(\zeta-1)}}. \tag{22}$$

When $A = 1, (21)$ reduces to the case considered Sbordone (2002). Under dynamic indexation we obtain

$$\Delta\hat{\pi}_t = \Delta\beta E_{t-\tau}\hat{\pi}_{t+1} + \frac{(1-\beta\theta)(1-\theta)}{\theta} \cdot A \cdot D \cdot E_{t-\tau}\hat{s}_t \tag{23}$$

As long as α is between zero and one, and the steady state value of the markup ζ exceeds one, then $D \leq 1$. So for any given value of θ, fixed firm capital, like a non constant elasticity of demand, reduces the response of $\hat{\pi}_t$ to movements in $\hat{s}_t$.

3. Assessing the Empirical Plausibility of the Model

This section describes our empirical methodology and the data used in the analysis.

3.1. Methodology

In principle there are a variety of ways to evaluate our model empirically. For example, one could embed it in a fully specified general equilibrium model of the economy. This would involve, among other things, modeling household labor and consumption decisions, credit markets, fiscal policy and monetary policy. If in addition, one specified the nature of all the shocks impacting on the economy, one could estimate and test the model using a variety of statistical methods like maximum likelihood.[7] Another strategy would be to assess the model's predictions for a particular shock, such as a disturbance to monetary policy or a shock to technology.[8]

Here we apply the econometric strategy pioneered by Hansen (1982) and Hansen and Singleton (1982) and applied recently to the Calvo model by Galí and Gertler (1999) and

[7] For examples of this approach see for example Ireland (2002) and Cho and Moreno (2002) and Moreno (2003).

[8] See for example Christiano, Eichenbaum and Evans (2001) and Altig, Christiano, Eichenbaum and Linde (2003), respectively.

Galí, Gertler and López-Salido (2001). The idea is to exploit the fact that in *any* model incorporating Calvo pricing, certain restrictions must hold. One can analyze these restrictions, without making assumptions about other aspects of the economy. Of course, in the end, we need a fully specified model of the economy within which to assess the consequences of alternative policies. The approach that we discuss here has the advantage of focusing on the empirical plausibility of one key building block that could be an element of many models.

To derive the testable implications of the model, it is convenient to focus on the model with static indexation and define the random variable

$$\psi_{t+1} = \hat{\pi}_t - \beta\hat{\pi}_{t+1} - \frac{(1-\beta\theta)(1-\theta)}{\theta} \cdot A \cdot D \cdot \hat{s}_t. \tag{24}$$

The method below provides a procedure for simultaneously estimating the structural parameters of interest and testing this implication. Throughout we set β equal to 0.96 on an annual basis.

Since $\hat{\pi}_t$ is in agents' time $t-\tau$ information set, (16) can be written as:

$$E_{t-\tau}\psi_{t+1}(\sigma) = 0. \tag{25}$$

where σ denotes the structural parameters of the model. It follows that

$$E\psi_{t+1}(\sigma)X_{t-\tau} = 0 \tag{26}$$

for any k dimensional vector $X_{t-\tau}$ in agents' time $t-\tau$ information set. We exploit (26) to estimate the true value of σ, σ_0, and test the overidentifying restrictions of the model using Hansen's (1982) Generalized Method of Moments procedure.[9] Our estimate of σ is

$$\hat{\sigma} = \arg\min_{\sigma} J_T(\sigma), \tag{27}$$

where

$$J_T(\sigma) = g_T(\sigma)' W_T g_T(\sigma), \tag{28}$$

[9] We require that $\{\hat{\pi}_t, \hat{s}_t, X_t\}$ is a stationary and ergodic process.

and

$$g_T(\sigma) = (\frac{1}{T}) \sum_{t=1}^{T} \left[\psi_{t+1}(\sigma) X_{t-\tau} \right]. \tag{29}$$

Here T denotes the size of our sample and W_T is a symmetric positive definite matrix that can depend on sample information. The choice of W_T that minimizes the asymptotic covariance matrix of $\hat{\sigma}$ is a consistent estimate of the spectral density matrix of $\{\psi_{t+1}(\sigma_0)X_{t-\tau}\}$ at frequency zero. Our theory implies that $\psi_{t+1}(\sigma)X_{t-\tau}$ has a moving average representation of order τ. So we choose W_T^{-1} to be a consistent estimate of

$$\sum_{k=-\tau}^{\tau} E[\psi_{t+1+k}(\sigma) X_{t+k-\tau}][\psi_{t+1+k}(\sigma) X_{t+k-\tau}]' \tag{30}$$

The minimized value of the GMM criterion function, J_T, is asymptotically distributed as a chi-squared random variable with degrees of freedom equal to the difference between the number of unconditional moment restrictions imposed (k) and the number of parameters being estimated.[10]

One does not have to impose the restriction that $\psi_{t+1}(\sigma)X_{t-\tau}$ has an $MA(\tau)$ representation constructing an estimate of W_T^{-1}. Specifically, one could allow for higher order serial correlation in the error term than the theory implies. However, as we describe below, whether one does so or not has an important impact, in practice, on inference.

It is evident from (24) and (27) - (28) that θ, A and D are not separately identified. All that can be identified given the assumptions made so far is the parameter

$$c = A \cdot D \cdot \frac{(1-\beta\hat{\theta})(1-\hat{\theta})}{\hat{\theta}}.$$

But given given any value of c and assumed values for A and D, one can deduce the implied estimate of θ, $\hat{\theta}$. When capital is mobile, we have $D = 1$ and $\hat{\theta}$ can be derived from the relation

$$A = \frac{\hat{\theta}c}{(1-\beta\hat{\theta})(1-\hat{\theta})}.$$

[10] According to relation (17), $\hat{\pi}_t$ is predetermined at time $t-\tau$. If we were only interested in assessing the hypothesis that inflation is predetermined at time $t-\tau$, we could test whether any variable dated between time $t-\tau$ and t has explanatory power for time t inflation.

When firm capital is fixed, one can deduce $\hat{\theta}$ using (22),

$$A = \frac{\hat{\theta}c}{D(1-\beta\hat{\theta})(1-\hat{\theta})}$$

and values for α and ζ. These expressions imply that with information or priors about the nature of demand for goods and the degree of capital mobility we can identify the frequency of reoptimization which is required to render the extended Calvo model consistent with the data.

3.2. Data

Our benchmark sample period is 1959:1 - 2001:4. However, numerous observers have argued that there was an important change in the nature of monetary policy with the advent of the Volker disinflation in the early 1980s. It is also often argued that the Fed's operating procedures were different in the early 1980s than in the post-1982 period. Accordingly we reestimated the model over two distinct subsamples: 1959:1-1979:2 and 1982:3- 2001:4. We report results for two measures of inflation: the GDP deflator and the price deflator for personal consumption expenditures.[11] We measure $\hat{\pi}_t$ as the difference between actual time t inflation and the sample average of inflation.

With mobile capital, real marginal costs are equal to the real product wage divided by the marginal product of labor. Given the production function (5), this implies that real marginal cost is proportional to labor's share in national income, $W_t L_t/(P_t Y_t)$, where W_t is the nominal wage. In practice we measure $W_t L_t$ as nominal labor compensation in the non-farm business sector and we measure $P_t Y_t$ as nominal output of the non-farm business sector. The variable $\hat{s}_t$ is then measured as the difference between the log of our measure of labor's share and its mean. This is a standard measure of $\hat{s}_t$ which has been used by Galí and Gertler (1999), Galí et. al. (2001) and Sbordone (2001). As it turns out, this is the correct measure of $\hat{s}_t$ even when capital is not mobile (see the Appendix).

Rotemberg and Woodford (1999) discuss possible corrections to this measure that are appropriate for different assumptions about technology. These include corrections to take

[11] All data sources are listed in the Appendix. We also considered the price deflator for the non farm business sector and the consumer price index (CPI) and found that our key results are insensitive to these alternative measures.

into account a non-constant elasticity of factor substitution between capital and labor, and the presence of overhead costs and labor adjustment costs. We redid our analysis for these alternative measures of marginal costs and found that they do not affect the qualitative nature of our results.

Consider next the instrument vector $X_{t-\tau}$. Let Z_t denote the four dimensional vector consisting of the time t value of real marginal cost, quadratically detrended real GDP, inflation, and the growth rate of nominal wages in the non farm business sector. Our specification of $X_{t-\tau}$ is given by[12]

$$X_{t-\tau} = \{1, Z_{t-\tau,}\psi_{t-\tau}\}'.$$

4. Empirical Results

In this section we present our empirical results. To facilitate comparisons with the literature, we report point estimates of θ corresponding to the identifying assumption that capital is mobile and $G(\cdot)$ in (1) is of the Dixit-Stiglitz form. The first subsection reports results for the case in which there are no delays in implementing new optimal price decisions ($\tau = 0$). When $A = 1$ and capital is mobile, this corresponds to the standard Calvo model. In the second subsection, we discuss the impact of allowing for a delay in implementing new optimal price decisions. In the third subsection, we modify the model to allow for variants of the rule of thumb firms considered by Galí and Gertler (1999).

4.1. The Standard Calvo Model

We begin by analyzing results for the standard Calvo model ($\tau = 0$) in the case where firms adopt the static indexing scheme. The top panel of Table 1 summarizes results obtained using the full sample. We report our estimate of the parameter θ (standard error in parenthesis) and the J_T statistic (p-value in square brackets). The label L refers to the maximal degree of

[12] Gali and Gertler (1999) use an instrument list consisting of a constant and lagged values of Z_t where the latter is augmented to included an index of commodity prices and the spread between the annual interest rate on the ten year Treasury Bond and three month bill. We redid our basic analysis setting X_t to $\{1, Z_{t-j}, j = 0, 1, 2, 3\}'$ and $\{1, Z_{t-j}, j = 1, 2, 3, 4\}$. Gali et. al (2001) adopt the same specification as we do but set $X_t = \{1, Z_{t-j}, j = 1, 2, 3, 4\}$. It turns out that the point estimates are similar across different specifications of X_t, including the specification of X_t used in this paper. However, using a larger set of instruments leads to misleading inference about the plausibility of the overidentifying restrictions implied by the model. Specifically, often we cannot reject the model with a larger set of instruments on the basis of the J_T statistic but we can do so with the smaller set of instruments.

serial correlation that we allow for when estimating the weighting matrix W_T. We consider two values for L : (1) $L = 0$, which corresponds to the degree of serial correlation in ψ_{t+1} implied by this version of the model, and (2) $L = 12$, the value used by Galí and Gertler (1999). Both values of L are admissible. But, by setting L to zero we are imposing all of the restrictions implied by the model. This may lead to greater efficiency of our estimator and more power in our test of the model's overidentifying restrictions.

Recall that Table 1 presents our estimates of the model's parameters, under the assumption that A and D equal one. Notice that θ is estimated with relatively small standard errors. In addition the point estimate itself is reasonably robust across the different inflation measures and the two values of L. The point estimates range from a low of 0.87 to a high of 0.91. This implies that on average firms wait between 7.5 and 11 quarters before reoptimizing their prices.

We hesitate to attribute much importance to these point estimates. When $L = 12$ the model cannot be rejected at the 5% significance level, although it can be rejected at the 1% significance level. However, when we set $L = 0$ the model is strongly rejected for both inflation measures. Evidently, imposing all of the relevant restrictions implied by the model on the weighting matrix has an important impact on inference.

The middle and bottom panels of Table 1 report our sub sample results. Note that when $L = 12$, there is virtually no evidence against the model for either measure of inflation, regardless of which subsample we consider. In the first sample period, when $L = 0$, the model is rejected at the 5% significance level for both measures of inflation. Interestingly, when $L = 0$, the model is decisively rejected using data from the second subsample when we measure inflation using the GDP deflator. There is considerably less evidence against the model in this case when we use the PCE deflator based measure of inflation. Comparing the point estimates in the three panels, we see that inference about θ is reasonably robust to allowing for a split in the sample. As above, we are hesitant to attach much importance to this result in light of the overall statistical evidence against the standard Calvo model.

Table 2 reports results when we allow for dynamic indexation. Our estimation strategy is the same as the one described above except that the random variable ψ_{t+1} is defined as

$$\psi_{t+1} = \left[\Delta\hat{\pi}_t - \beta\Delta\hat{\pi}_{t+1} - \frac{(1-\beta\theta)(1-\theta)}{\theta} A\hat{s}_t \right]. \tag{31}$$

The key thing to note is that this version of the model is also rejected when we set $L = 0$.

4.2. Alternative Timing Assumptions

Table 3 reports the results of estimating the model when $\tau = 1$ and we assume that firms adopt the static indexation scheme (6). In the previous subsection we showed that imposing the degree of serial correlation in ψ_{t+1} implied by the model on the estimator of the weighting matrix W_T improves the power of our statistical tests. So for the remainder of the analysis we report results only for the case where these restrictions are imposed. In the case of $\tau = 1$, this means setting $L = 1$. The instrument used are

$$X_{t-1} = \{1, Z_{t-1}, \psi_{t-1}\}' \tag{32}$$

Two key results from Table 3 are worth reporting. First, regardless of which sample period we consider or which measure of inflation we use, there is virtually no statistical evidence against the model. Second, θ is estimated with reasonable precision with the point estimates ranging from a low of 0.83 to 0.91. This corresponds to firms changing prices on average from between 6 quarters and 11 quarters. This frequency seems high relative to evidence based on microeconomic data (see for example Bils and Klenow 2003).

Table 4 reports the results of estimating the model when $\tau = 1$ and we assume that firms adopt the dynamic indexation scheme (7). As with the static indexing scheme, there is virtually no statistical evidence against the model. Moreover the point estimates of the parameters θ are quite similar, now ranging from a low 0.83 to a high of 0.89.

We conclude that allowing for a one period lag ($\tau = 1$) in the implementation of new pricing plans is sufficient to overturn our statistical evidence against the standard Calvo model with either indexing scheme. But it is not sufficient to generate economically plausible parameter estimates of the degree of price stickiness. This is true for both the static and dynamic indexing schemes. Of course this conclusion is conditional on the assumption that intermediate goods are combined via a Dixit -Stiglitz technology to produce final goods ($A = 1$) and that capital is mobile across firms ($D = 1$). Before exploring the quantitative trade-off between the parameter A, capital immobility and the degree of price stickiness, we investigate the claim that the standard Calvo model must be modified to allow for the presence of non-optimizing firms.

4.3. 'Rule of Thumb' Firms

Galí and Gertler (1999) have argued it is necessary to allow for backward looking 'rule of thumb' firms to render the Calvo model consistent with the data. In the previous section we argued that there was little evidence against the Calvo model, amended to allow for a one quarter delay between when firms reoptimize their price plans and when they actually implement the new plan. That argument was based on the J_T statistic that formed the basis of a test of the model's over identifying restrictions. Galí and Gertler (1999) argue that this test may have low power against specific alternatives. In this section, we accomplish two tasks. We begin by confirming Galí and Gertler's result that there is evidence of backward looking firms under the static indexation scheme. We then show that this evidence disappears under the dynamic indexing scheme. For simplicity we derive the model under the assumption that capital is mobile and $A = 1$.

4.3.1. Optimizing Firms with Static Indexing

As in Galí and Gertler (1999) we assume that there are two types of firms in the economy. A fraction $(1-\omega)$ of intermediate good firms are optimizing Calvo type firms. That is, they face a constant probability, $1-\theta$, of being able to reoptimize their nominal price. As above, when they reoptimize, they solve problem (8) subject to (3). When they do not reoptimize, they adopt the static optimization scheme, (6). A fraction ω of intermediate good firms adopt the rule of thumb for setting prices discussed in Galí and Gertler (1999). With probability θ, rule of thumb firm i sets its price according to[13]

$$P_{it} = \bar{\pi} P_{it-1}. \tag{33}$$

With probability $(1-\theta)$, the firm sets its price according to

$$P_t' = \pi_{t-1} \bar{P}_{t-1}. \tag{34}$$

Here

$$\bar{P}_t = (1-\omega)\tilde{P}_t + \omega P_t'. \tag{35}$$

[13] This rule is precisely the same as the one considered by Gali and Gertler (1999) except that they assume $\bar{\pi} = 1$.As explained above, this has no impact on the estimation equations used in the analysis.

and $\tilde{P}_t$ denotes the price set by firms that can reoptimize their price at time t. The aggregate price level is given by,

$$P_t = \left[(1-\theta) \left(\bar{P}_t \right)^{\frac{1}{1-\mu}} + \theta \left(\bar{\pi} P_{t-1} \right)^{\frac{1}{1-\mu}} \right]^{1-\mu} \tag{36}$$

Log linearizing (33)-(36) and combining the resulting expressions with (**??**) one can show that the analog to (16) is given by:

$$\hat{\pi}_t = \frac{\beta\theta}{\phi} E_{t-\tau}\hat{\pi}_{t+1} + \frac{\omega}{\phi}\hat{\pi}_{t-1} \frac{(1-\omega)(1-\beta\theta)(1-\theta)}{\phi} E_{t-\tau}\hat{s}_t \tag{37}$$

where $\phi = \theta + \omega \left[1 - \theta(1-\beta) \right]$. When $\omega = 0$, (37), collapses to the analog expression for $\hat{\pi}_t$ in the standard Calvo model with static indexing.

We estimate the parameters of the model assuming $\tau = 1$, using the methodology and instruments described in section 3. Table 5 summarizes our results. Four key findings are worth noting. First, using the full sample, we estimate that roughly 50% of firms behave in a rule of thumb manner, with the exact percent depending on how we measure inflation. In both cases, we can reject, at conventional significance levels, the null hypothesis that there are no rule of thumb firms ($\omega = 0$). Second, there is virtually no evidence against the over-identifying restrictions imposed by the model. Third, the point estimates of θ continue to be implausibly large relative to evidence based on micro data. Fourth, there is little evidence of rule of thumb firms once we allow for a split in sample if we measure inflation using the GDP deflator. But there is still evidence that ω is greater than zero when we measure inflation using the PCE deflator, at least in the second subsample.

Viewed overall, the results in Table 5 are consistent with Galí and Gertler's conclusion that to render the standard Calvo model consistent with the data, one must allow for the presence of some firms who use backward looking rules when setting prices.

4.3.2. Optimizing Firms with Dynamic Indexing

We now modify the model considered in the previous subsection on exactly one dimension: we assume that optimizing firms adopt the dynamic optimization scheme (7) instead of the static scheme (6). With this modification, the aggregate price level is given by:

$$P_t = \left[(1-\theta) \left(\bar{P}_t \right)^{\frac{1}{1-\mu}} + \theta \left((1-\omega)\pi_{t-1} P_{t-1} + \omega \bar{\pi} P_{t-1} \right)^{\frac{1}{1-\mu}} \right]^{1-\mu} \tag{38}$$

Replacing (36) with (38) in the derivation with static indexation one can show that the analog to (16) is now given by:

$$E_{t-1} \left\{ \begin{array}{c} \Delta\hat{\pi}_t - \frac{\beta\theta}{\phi'}\Delta\hat{\pi}_{t+1} - \frac{\omega\theta}{\phi'}(1-\omega)\Delta\hat{\pi}_{t-1} \\ -\frac{\omega\theta}{\phi'}(1-\omega)(1-\beta\theta)\hat{\pi}_{t-1} - \frac{(1-\omega)(1-\beta\theta)(1-\theta)}{\phi'} E_{t-\tau}\hat{s}_t \end{array} \right\} = 0. \tag{39}$$

where $\phi' = \theta(1-\omega) + \omega$. When $\omega = 0$, (39), collapses to the analog expression for $\hat{\pi}_t$ in the standard Calvo model under the dynamic indexing scheme.

We estimate the parameters of the model assuming $\tau = 1$, using the methodology and instruments described in section 3. Table 6 summarizes our results. Three key findings emerge. First, our point estimates of ω are substantially smaller than those emerging under the assumption that optimizing firms adopt the static indexation scheme. Indeed for the full sample our point estimates are roughly equal to zero. Second, our point estimates of θ are similar to those obtained when we estimated the model under the constraint that ω is equal to zero (see Table 4). Perhaps most importantly, there is virtually no evidence of rule of thumb firms. Regardless of which sample we consider, or which measure of inflation we use, we cannot reject the null hypothesis that $\omega = 0$. We conclude that the evidence for rule of thumb of firms disappears once we allow for dynamic indexation.

5. Interpreting the Parameters of the Estimated Calvo Model

Our empirical results indicate that the Calvo sticky price model is consistent with the aggregate time series data if we assume that $\tau = 1$ and optimizing firms use the dynamic indexation scheme. Specifically, there is little evidence against the over identifying restrictions imposed by that version of the model and there is little evidence of 'rule of thumb' firms. However, the degree of price stickiness implied by the model is implausibly large relative to existing microeconomic evidence.

Taken at face value, these results imply that the Calvo model can be rescued statistically, but not in any interesting economic sense. But as stressed above, this conclusion emerges under the maintained assumptions that capital is mobile across firms ($D = 1$) and that $A = 1$. In this section we explore the quantitative nature of the trade-off between A, θ and the assumption of capital mobility. Throughout we base our calculations on the estimated Calvo model with $\tau = 1$ and dynamic indexation (Table 4). Our results are displayed in Tables 7 and 8. Table 7 reports values of A and ϵ, the percent change in the elasticity of demand due to a one percent change in the relative price of good i,.for values for $\theta \in \{0.25, 0.50, 0.60, 0.75\}$. Table 8 reports values of θ for two values of ϵ, 10 and 33.

Panel A of Tables 7 and 8 reports the results of these calculations based on estimates of c using the full sample period. As can be seen, our results are similar for the two inflation measures (in Panel's B and C as well). For convenience, we focus our discussion on the case where inflation is measured using the GDP deflator. Three key features emerge from Panel A. First, if we assume that $\theta \leq 0.75$, so that firms reoptimize prices at least once a year, then A is substantially less than one. While not evident from the Table, the joint hypothesis that $\theta \leq 0.75$ and $A = 1$ can be rejected at conventional significance levels.[14]. That is, one cannot adopt the Calvo model and simultaneously take the position that $\theta \leq 0.75$ and the production technology $G(\cdot)$ is Dixit - Stiglitz. This is true regardless of whether or not capital is mobile.

Second, when $\theta = 0.75$, the value of ϵ in the mobile capital case is just a bit above 33, the benchmark value considered in Chari, Kehoe and McGrattan (2000) and Kimball (1995). Given the non linear relationship between θ and A, the implied value of ϵ rises very quickly for further reductions in θ. So with this version of the model, it seems to be difficult to rationalize values of θ substantially below 0.75. Bergin and Feenstra (2000) argue that ϵ is roughly equal to 10. If we take this to be the relevant benchmark value, it is difficult for this version of the model to rationalize values of θ much less than roughly 0.83.

Third, notice that in the immobile capital case, ϵ is actually negative when $\theta = 0.75$. That is, given our point estimate of c, if capital is immobile, firms must reoptimize prices *more* frequently than once a year, for the model to be internally consistent. As it turns out, ϵ is zero when $\theta = 0.71$. This is our point estimate of θ when we estimate the model assuming capital is immobile and we impose the restriction that $A = 1$. Interestingly, if we assume that ϵ is 10 or 33 then θ is 0.69 and 0.66, respectively. So with immobile capital, the model

[14] We tested this joint hypothesis using the asymptotic distribution of A given the estimated sampling distribution of c

is consistent with the view that firms reoptimize prices roughly once every three quarters.

Panels B and C report the analog results on the subsample periods. A number of key results emerge here. First, as above, we can always reject, at conventional significance levels, the joint hypothesis that $\theta \leq 0.75$ and $A = 1$. Second, we find that for both the mobile and immobile capital cases, the model is consistent with lower values of θ once we allow for a split in the sample. The decline in θ is particularly notable in the case of the second subsample. For example, suppose we assume that $\epsilon = 33$. Then, for the case of mobile and immobile capital, we obtain values of θ equal to 0.67 and 0.56, respectively. If we assume that $\epsilon = 10$, we obtain values of θ equal to 0.77 and 0.60, in the two cases.

To summarize, based on the full sample results, the model with immobile capital and the non Dixit Stiglitz aggregator is consistent with the view that firms reoptimize prizes roughly once every three quarters. This is true even if we take as our upper bound for ϵ the value of 10, suggested by Bergin and Feenstra (2000). If we take as our upper bound for ϵ, the benchmark value of 33, used by Chari, Kehoe and McGrattan (2000), the model with mobile capital and A different from 1 is consistent with the view that firms reoptimize prices roughly once a year.

Even more favorable results emerge if we take as given that there is split in the sample period owing to a change in monetary policy. Averaging across the two subsamples, we find that the model with mobile capital and the non Dixit Stiglitz aggregator is consistent with the view that firms reoptimizing prices every 3 quarters, if we are willing to assume that $\epsilon = 33$. The model with immobile capital and the non Dixit Stiglitz aggregator is consistent with the view that firms reoptimize prices more often than once every three quarters even if we assume that $\epsilon = 10$.

6. Conclusion

This paper discussed the empirical performance of the Calvo model of sticky goods prices. We argued this model can be rescued statistically by assuming dynamic indexation and a one quarter implementation lag of a reoptimized price. Yet, the estimated frequency of reoptimization does make much economic sense. This conclusion emerges under the maintained assumptions that capital is mobile across firms and that output is a Dixit-Stiglitz aggregate. Finally, we explored the quantitative nature of the trade-off between non-Dixit-Stiglitz aggregation, the frequency of reoptimization, and the assumption of capital mobility.

Based on the full sample results, the model with immobile capital and the non Dixit Stiglitz aggregator is consistent with the view that firms reoptimize prizes roughly once every three quarters, using the relatively low upper bound for the demand elasticity as suggested by Bergin and Feenstra (2000). Using the higher elasticity of Chari, Kehoe and McGrattan (2000), the model with mobile capital and A different from 1 is consistent with the view that firms reoptimize prices roughly once a year.

More favorable results emerge if we take as given that there is split in the sample period owing to a change in monetary policy. Averaging across the two subsamples, we find that the model with mobile capital and the non Dixit Stiglitz aggregator is consistent with the view that firms reoptimizing prices every 3 quarters, using the larger elasticity. The model with immobile capital, the non Dixit Stiglitz aggregator and the lower elasticity is consistent with the view that firms reoptimize prices more often than once every three quarters.

References

[1] Altig, Christiano, Eichenbaum and Linde (2003), Monetary Policy and the Diffusion of Technology Shocks, manuscript, Northwestern University.

[2] Burstein, A, 'Inflation and Output Dynamics with State Dependent Pricing Decisions', 2002, mansucript, University of Michigan.

[3] Calvo, Guillermo, 1983, 'Staggered Prices and in a Utility-Maximizing Framework, *Journal of Monetary Economics*, 12(3): 383-98.

[4] Chari, V.V., Kehoe, Patrick and Ellen McGrattan, 'Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?', *Econometrica*, 68(5), September 2000, pages 1151-79.

[5] Clarida, R., Mark Gertler and Jordi Gali, 2001, "Optimal Monetary Policy in Closed versus Open Economies: An Integrated Approach." American Economic Review, vol 91, no. 2.

[6] Christiano, Eichenbaum and Evans (2001), Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy, manuscript, Northwestern University.

[7] Dotsey,Michael, King, Robert, G. and Alexander L. Wolman, 1999, 'State-Dependent Pricing and the General Equilibrium Dynamics of Money and Output', *Quarterly Journal of Economics*, 114(2), May, pages 655-90.

[8] Erceg, Christopher, J., Henderson, Dale, W. and Andrew T. Levin, 2000, 'Optimal Monetary Policy with Staggered Wage and Price Contracts', *Journal of Monetary Economics*, 46(2), October, pages 281-313.

[9] Hansen, Lars P. (1982) "Large Sample Properties of Generalized Method of Moments Estimators," *Econometrica*, Vol. 50, 1029–1054.

[10] Hansen, Lars P. and Kenneth J. Singleton (1982) 'Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models', *Econometrica*, Vol. 50, 1269-1286.

[11] Fuhrer, Jeffrey and Jeffery Moore, Inflation Persistence, *Quarterly Journal of Economics,* 1995.

[12] Gali, Jordi, and Mark Gertler, 1999, 'Inflation dynamics: A structural econometric analysis,' *Journal of Monetary Economics* 44, pp. 195-222.

[13] Gali, Jordi, Mark Gertler and David Lopez-Salido, "European Inflation Dynamics," European Economic Review, 2001.

[14] Taylor, John 'Aggregate Dynamics and Staggered Contracts', Journal of Political Economy, 88, February, 1980.

[15] Ireland, Peter, 1997, ' A Small, Structural, Quarterly Model for Monetary Policy Evaluation, *Carnegie Rochester Conference Series on Public Policy*, 47, pages 83-108.

[16] Kim, Jinill, 2000, 'Constructing and Estimating a Realistic Optimizing Model of Monetary Policy', Journal of Monetary Economics; 45(2), April 2000, pages 329-59.

[17] Mankiw, N.G. and R. Reiss, 'Sticky Information: A Proposal to Replace the New Keynesian Phillips Curve, Quarterly Journal of Economics, 117, Nov. 2002, 1295 - 1328.

[18] Moreno, A, 2003, "Reaching Inflation Stability," manuscript Universidad de Navarra, Spain.

[19] Rotemberg, Julio J. and Michael Woodford, 1997, 'An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy,' National Bureau of Economic Research *Macroeconomics Annual*.

[20] Rotemberg, Julio J. and Michael Woodford, 1999, 'The Cyclical Behavior of Prices and Costs', *Handbook of Monetary Economics*, Vol. 1B, Michael Woodford and John Taylor, Amsterdam; New York and Oxford: Elsevier Science, North-Holland.

[21] Sbordone, Argia, 2001, 'An Optimizing Model of U.S. Wage and Price Dynamics,' Journal of Monetary Economics.

[22] Woodford, Michael, 1996, 'Control of the Public Debt: A Requirement for Price Stability,' NBER Working Paper 5684.

[23] Yun, Tack, 1996, 'Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles,' *Journal of Monetary Economics* 37(2): 345 - 370.

Appendix

In this appendix we describe our data, describe how to interpret the parameters A and D, and provide more detail on the version of the Calvo model with non-Dixit-Stiglitz aggregation and immobile capital.

Data

Our data are from the Haver Analytics database. For each data series below we provide a brief description and, in parenthesis, the Haver codes for the series used.

- Price measures: GDP deflator is the ratio of nominal GDP (GDP) and real chain-weighted GDP (GDPH); personal consumption expenditures deflator (JCBM2).
- Real marginal costs: Share of labor income in nominal output for the non-farm business sector which is proportional to the Bureau of Labor Statistics measure of nominal unit labor costs divided by the non-farm business deflator (LXNFU/LXNFI).
- Adjusted real marginal costs: Per capita hours - hours non-farm business sector (LXNFH) divided by over 16 population (LN16N); Capital-output ratio - annual private fixed capital (EPQ) interpolated with quarterly private fixed investment (FH) divided by GDP (GDPH), all variables in chained 1996 dollars.
- Instruments: Quadratically detrended real GDP is the residual of a linear regression of real GDP (GDPH) on a constant, t and t^2; inflation is the first difference of the log of the price measures; growth rate of nominal wages is the first difference of the log of nominal compensation in the non-farm business sector (LXNFC).

Interpreting Estimates of A

Recall that the elasticity of demand for a given intermediate good is

$$\eta(x) = -\frac{G'(x)}{xG''(x)} \tag{40}$$

where

$$x = \frac{\tilde{Y}}{Y} \tag{41}$$

The coefficient A can be written

$$A = \frac{1 - 1/\bar{\eta}}{2 + G'''(1)/G''(1)} \tag{42}$$

where

$$\bar{\eta} = -\frac{G'(1)}{1 \times G''(1)}$$

is the steady state elasticity of demand. Note that in steady state an intermediate good firm sets price as a markup over marginal cost, where the markup, ζ, is

$$\zeta = \frac{\bar{\eta}}{\bar{\eta} - 1} \tag{43}$$

A variety of authors have considered the value of

$$\epsilon = \left. \frac{\tilde{P}}{\eta(x)} \frac{\partial \eta(x)}{\partial \tilde{P}} \right|_{x=1}$$

This is the percent change in the elasticity of demand due to a one percent change in the own price at the steady state. The value of ϵ can be derived in terms of A and $\bar{\eta}$ (or ζ) using (3), (40), (41), and (42)

$$\begin{aligned} \epsilon &= \left[\frac{\tilde{P}}{\eta(x)} \frac{\partial \eta(x)}{\partial x} \frac{\partial x}{\partial \tilde{Y}} \frac{\partial \tilde{Y}}{\partial \tilde{P}} \right]_{x=1} \\ &= 1 + \bar{\eta} \left[\frac{1 - 1/\bar{\eta}}{A} - 1 \right] \\ &= 1 + \frac{\zeta}{\zeta - 1} \left[\frac{1}{\zeta A} - 1 \right] \end{aligned}$$

Notice that under Dixit-Stiglitz, when $A = 1$, $\epsilon = 0$. This is to be expected: under Dixit-Stiglitz the markup is constant. We can solve this for A

$$A = \frac{1}{(\zeta - 1)\epsilon + 1}$$

Immobile Capital and Non-Dixit-Stiglitz Aggregation[15]

Here we derive the inflation equation under static indexation. The derivation for the dynamic indexation case follows the same basic steps.

Intermediate good firms will not have the same marginal cost if capital is fixed in place and does not reallocate in response to shocks. The crucial feature of the derivation is that log linearized date $t + j$ real marginal costs for an intermediate good producer which implements reoptimized prices at t can be written in terms of $\hat{s}_{t+j}$, which is measured in terms of aggregates, and a firm-specific term. To achieve this result one needs to make the auxilary assumption that firm level capital stocks are proportional to the aggregate capital stock. With a unit measure of firms we have $K_{it} = K_t$ where K_t is the aggregate stock of capital.

[15] We thank Argia Sbordone for correspondence which helped us clarify the analysis in this section.

Real marginal cost at date $t+j$ firms which implement a reoptimized price plan at date t, $s_{t+j,t}$ is

$$s_{t+j,t} = \frac{1}{1-\alpha}\frac{W_{t+j}}{P_{t+j}}\frac{\tilde{L}_{t+j}}{\tilde{Y}_{t+j}} \tag{44}$$

where the tildes denote intermediate good firm choices. Linearizing this yields

$$\hat{s}_{t+j,t} = \hat{W}_{t+j} - \hat{P}_{t+j} + \hat{\tilde{L}}_{t+j} - \hat{\tilde{Y}}_{t+j} \tag{45}$$

The intermediate good firm production function implies,

$$\frac{L_{it+j}}{Y_{it+j}} = \frac{1}{A_{t+j}^{1/(1-\alpha)}}\left(\frac{Y_{it+j}}{K_{t+j}}\right)^{\alpha/(1-\alpha)}$$

Linearizing this and substituting into (45) yields

$$\hat{s}_{t+j,t} = \hat{W}_{t+j} - \hat{P}_{t+j} + \frac{\alpha}{1-\alpha}\hat{\tilde{Y}}_{t+j} - \frac{\alpha}{1-\alpha}\hat{K}_{t+j} - \frac{1}{1-\alpha}\hat{A}_t \tag{46}$$

Recall that the demand for intermediate good i in date $t+j$ under a reoptimized plan implemented at t is

$$\tilde{Y}_{t+j} = Y_{t+j}G'^{-1}\left(\frac{\tilde{P}_t\bar{\pi}^j Y_{t+j}}{\lambda_{t+j}}\right) \tag{47}$$

Linearizing this yields

$$\hat{\tilde{Y}}_{t+j} = \hat{Y}_{t+j} + \hat{\tilde{g}}_{t+j}$$

where $\hat{\tilde{g}}_{t+j}$ is the linearized version of $G'^{-1}\left(\tilde{P}_t\bar{\pi}^j Y_{t+j}/\lambda_{t+j}\right)$. Substituting this last expression for $\hat{\tilde{Y}}_{t+j}$ in (46) implies

$$\begin{aligned} \hat{s}_{t+j,t} &= \hat{W}_{t+j} - \hat{P}_{t+j} + \frac{\alpha}{1-\alpha}\hat{g}_{t+j} \\ &+ \left[\frac{\alpha}{1-\alpha}\hat{Y}_{t+j} - \frac{\alpha}{1-\alpha}\hat{K}_{t+j} - \frac{1}{1-\alpha}\hat{A}_t\right] \end{aligned} \tag{48}$$

The last part of the derivation involves replacing the term in square brackets with the linearized aggregate labor-output ratio. Linearizing the aggregation technology for the final good firm yields

$$\hat{Y}_{t+j} = \int_0^1 \hat{Y}_{it+j}di$$

Substituting from the linearized intermediate good firm's technology and using the definition of aggregate labor input as the arithmetic sum of labor input across intermediate good producers yields

$$\begin{aligned} \hat{Y}_{t+j} &= A_t + \alpha\hat{K}_t + (1-\alpha)\int_0^1 \hat{L}_{it+j}di \\ &= A_t + \alpha\hat{K}_t + (1-\alpha)\hat{L}_{t+j} \end{aligned}$$

Using this we can write

$$\hat{L}_{t+j} - \hat{Y}_{t+j} = \frac{\alpha}{1-\alpha}\hat{Y}_{t+j} - \frac{\alpha}{1-\alpha}\hat{K}_{t+j} - \frac{1}{1-\alpha}\hat{A}_t \tag{49}$$

Notice that the right hand side of this equation is identical to the term in square brackets in equation (48). Using the labor share definition of s_{t+j}

$$\hat{s}_{t+j} = \hat{W}_{t+j} - \widehat{P}_{t+j} + \widehat{L}_{t+j} - \widehat{Y}_{t+j}. \tag{50}$$

After substituting (49) into (48) and using (50) we achieve the desired decomposition of $\hat{s}_{t+j,t}$:

$$\hat{s}_{t+j,t} = \hat{s}_{t+j} + \widehat{\tilde{g}}_{t+j}.$$

The objective of the intermediate firm is

$$\max_{\tilde{P}_t} E_{t-\tau} \sum_{j=0}^{\infty} (\beta\theta)^j \nu_{t+j} \left[\tilde{P}_t \bar{\pi}^j \tilde{Y}_{t+j} - W_{t+j} A_{t+j}^{1/(1-\alpha)} \tilde{Y}_{t+j}^{1/(1-\alpha)}\right]$$

where $\tilde{Y}_{t+j}$ is given by (47) and $A_{t+j}^{1/(1-\alpha)} \tilde{Y}_{t+j}^{1/(1-\alpha)} = \tilde{H}_{t+j}$. Log linearizing the first order condition around the relevant steady state values we obtain:

$$\widehat{\tilde{p}}_t = E_{t-\tau} \sum_{l=1}^{\infty} (\beta\theta)^l \hat{\pi}_{t+l} + A \cdot D \cdot E_{t-\tau} \left[\hat{s}_t + \sum_{l=1}^{\infty} (\beta\theta)^l (\hat{s}_{t+l} - \hat{s}_{t+l-1})\right] \tag{51}$$

where A is the coefficient defined above and D is given by

$$D = \frac{1}{1 + A\frac{\alpha}{1-\alpha}\frac{\zeta}{(\zeta-1)}}$$

Under Dixit-Stiglitz, $A = 1$ so the coefficient on marginal cost is

$$\begin{aligned} D &= \frac{1}{1 + \frac{\alpha}{1-\alpha}\frac{\zeta}{(\zeta-1)}} \\ &= \frac{1}{1 + \frac{\alpha}{1-\alpha}\mu} \\ &= \frac{(1-\alpha)}{1 + \alpha(\mu - 1)} \end{aligned}$$

which is the same coefficient displayed in Sbordone (2001) and Gali, et. al (2001).

Linearizing the zero profit condition for final good firms and combining it with the linearized first order condition yields the aggregate inflation equation under non-Dixit-Stiglitz aggregation and immobile capital:

$$E_{t-\tau}\left\{\hat{\pi}_t - \beta\hat{\pi}_{t+1} - \frac{(1-\beta\theta)(1-\theta)}{\theta} \cdot A \cdot D \cdot \hat{s}_t\right\} = 0$$

Table 1. Estimates of the Standard model with Static Indexation

Inflation Measure	$L = 0$ θ	$L = 0$ J_T	$L = 12$ θ	$L = 12$ J_T
		1959:I-2001:IV		
GDP Deflator	0.90	28.2	0.91	10.2
	(0.05)	[9e-5]	(0.03)	[0.04]
PCE Deflator	0.87	36.9	0.88	11.1
	(0.04)	[2e-6]	(0.02)	[0.03]
		1959:I-1979:II		
GDP Deflator	0.86	12.1	0.87	4.58
	(0.05)	[0.02]	(0.03)	[0.33]
PCE Deflator	0.82	16.8	0.83	5.60
	(0.04)	[0.02]	(0.02)	(0.23)
		1982:III-2001:IV		
GDP Deflator	0.87	15.8	0.90	6.16
	(0.04)	[0.003]	(0.03)	[0.19]
PCE Deflator	0.87	8.89	0.89	4.39
	(0.04)	[0.06]	(0.03)	[0.36]

Notes: The J_T statistics are distributed as χ^2 random variables with 4 degrees of freedom. Standard errors in parenthesis. P-values in brackets. In the $L = 12$ cases the Newey-West correction to the weighting matrix is used.

Table 2. Estimates of the Standard model with Dynamic Indexation

Inflation	$L = 0$		$L = 12$	
Measure	θ	J_T	θ	J_T
		1959:I-2001:IV		
GDP Deflator	0.81	35.0	0.91	10.2
	(0.03)	[6e-7]	(0.02)	[0.04]
PCE Deflator	0.79	47.9	0.88	10.8
	(0.03)	[1e-9]	(0.02)	[0.03]
		1959:I-1979:II		
GDP Deflator	0.76	17.5	0.87	5.59
	(0.05)	[0.002]	(0.04)	[0.23]
PCE Deflator	0.77	18.1	0.88	5.80
	(0.04)	[0.002]	(0.03)	(0.22)
		1982:III-2001:IV		
GDP Deflator	0.68	17.0	0.83	4.41
	(0.04)	[0.002]	(0.08)	[0.35]
PCE Deflator	0.54	14.2	0.77	4.54
	(0.03)	[0.007]	(0.06)	[0.34]

Notes: The J_T statistics are distributed as χ^2 random variables with 3 degrees of freedom. Standard errors in parenthesis. P-values in brackets. In the $L = 12$ cases the Newey-West correction to the weighting matrix is used.

Table 3: Prices Chosen One Period In Advance with Static Indexation

Inflation	Full Sample		1959:I-1979:II		1982:III-2001:IV	
Measure	θ	J_T	θ	J_T	θ	J_T
GDP Deflator	0.89	6.89	0.84	2.96	0.92	3.98
	(0.03)	[0.14]	(0.03)	[0.56]	(0.04)	[0.41]
PCE Deflator	0.90	8.54	0.83	2.95	0.91	3.50
	(0.03)	[0.07]	(0.05)	[0.56]	[0.05]	[0.48]

Notes: The J_T statistics are distributed as χ^2 random variables with 3 degrees of freedom. Standard errors in parenthesis. P-values in brackets.

Table 4: Prices Chosen One Period In Advance with Dynamic Indexation

Inflation	Full Sample		1959:I-1979:II		1982:III-2001:IV	
Measure	θ	J_T	θ	J_T	θ	J_T
GDP Deflator	0.88	2.65	0.86	0.89	0.83	6.33
	(0.05)	[0.62]	(0.09)	[0.93]	(0.05)	[0.18]
PCE Deflator	0.86	4.98	0.84	2.05	0.83	5.61
	(0.05)	[0.29]	(0.08)	[0.73]	(0.06)	[0.23]

Notes: This table considers the case where firms that do not reset their price plans use the updating scheme: $P_{it} = \pi_{t-1}P_{it-1}$. The J_T statistics are distributed as χ^2 random variables with 3 degrees of freedom. Standard errors in parenthesis. P-values in brackets.

Table 5: Prices Chosen One Period In Advance, Static Indexing, and Rule of Thumb Firms

Inflation	Full Sample			1959:I-1979:II			1982:III-2001:IV		
Measure	θ	ω	J_T	θ	ω	J_T	θ	ω	J_T
GDP Deflator	0.85	0.44	0.92	0.88	0.51	0.68	0.85	0.37	0.73
	(0.08)	(0.17)	[0.82]	(0.11)	(0.32)	[0.97]	(0.12)	(0.28)	[0.87]
PCE Deflator	0.96	0.56	1.66	0.97	0.72	0.73	0.48	0.80	0.12
	(0.09)	(0.22)	[0.64]	(0.09)	(0.35)	[0.87]	(0.18)	(0.08)	[0.99]

Notes: Notes: This table considers the case where $(1-\omega)$ of firms that have the opportunity to change prices do so optimally while ω are of the Gali-Gertler type, that is they set prices according to $P_t' = \pi_{t-1}\bar{P}_{t-1}$. where $\bar{P}_t = (1-\omega)\tilde{P}_t + \omega P_t'$. When unable to reset the price plan, all firms use the same updating scheme, $P_{it} = \bar{\pi}P_{it-1}$. The J_T statistics are distributed as χ^2 random variables with 3 degrees of freedom. Standard errors in parenthesis. P-values in brackets.

Table 6: Prices Chosen One Period In Advance,
Dynamic Indexing, and Rule of Thumb Firms

Inflation	Full Sample			1959:I-1979:II			1982:III-2001:IV		
Measure	θ	ω	J_T	θ	ω	J_T	θ	ω	J_T
GDP Deflator	0.87	0.04	2.79	0.83	0.12	0.61	0.82	0.15	6.12
	(0.05)	(0.14)	[0.43]	(0.10)	(0.22)	[0.89]	(0.07)	(0.26)	[0.11]
PCE Deflator	0.88	-0.06	4.79	0.85	-0.02	1.85	0.76	0.40	5.67
	(0.06)	(0.15)	[0.19]	(0.09)	(0.18)	[0.60]	(0.63)	(2.73)	[0.13]

Notes: This table considers the case where $(1-\omega)$ of firms that have the opportunity to change prices do so optimally and using dynamic indexing when they do not have the opportunity to reset the price plan. In additin ω firms are of the exact version Gali-Gertler considered in their paper. That is they set prices P'_{it} according to $P'_{it} = \pi_{t-1}\bar{P}_{t-1}$, where $\bar{P}_t = (1-\omega)\tilde{P}_t + \omega P'_t$ when they have the opportunity to reset their plan, but use $P_{it} = \bar{\pi}P_{it-1}$. The J_T statistics are distributed as χ^2 random variables with 3 degrees of freedom. Standard errors in parenthesis. P-values in brackets.

Table 7: Pass Through and Elasticity (ϵ) with Prices Chosen One Period In Advance and Dynamic Indexing

Panel A: Full Sample

Inflation Measure	Assumed θ	Price Pass Through	Capital Mobile ϵ	Capital Immobile ϵ
GDP Deflator	0.25	0.01	1223.9	1168.9
	0.50	0.04	266.0	211.0
	0.60	0.07	137.9	82.9
	0.75	0.21	36.9	-18.1
PCE Deflator	0.25	0.01	954.7	899.7
	0.50	0.05	205.8	150.8
	0.60	0.09	105.7	50.7
	0.75	0.27	26.7	-28.3

Panel B: 1959:I-1979:II

Inflation Measure	Assumed θ	Price Pass Through	Capital Mobile ϵ	Capital Immobile ϵ
GDP Deflator	0.25	0.01	858.2	803.2
	0.50	0.05	184.2	129.2
	0.60	0.10	94.1	39.1
	0.75	0.30	23.0	-32.0
PCE Deflator	0.25	0.01	727.7	627.7
	0.50	0.06	155.0	100.0
	0.60	0.11	78.4	23.4
	0.75	0.36	18.0	-37.0

Panel C: 1982:III-2001:IV

Inflation Measure	Assumed θ	Price Pass Through	Capital Mobile ϵ	Capital Immobile ϵ
GDP Deflator	0.25	0.02	618.4	563.4
	0.50	0.07	130.6	75.6
	0.60	0.13	55.3	10.3
	0.75	0.42	13.9	-41.1
PCE Deflator	0.25	0.02	613.7	558.7
	0.50	0.07	129.5	74.5
	0.60	0.13	64.8	9.8
	0.75	0.42	13.7	-41.2

Note: Estimates based on with $\alpha = 1/3$ and $\zeta = 1.1$.

Table 8: Frequency of Reoptimization under Benchmark Demand Elasticities (ϵ) with Prices Chosen One Period In Advance and Dynamic Indexing

Panel A: Full Sample

Inflation		Capital			
Measure	Assumed	Mobile		Immobile	
	ϵ	θ	$\frac{1}{1-\theta}$	θ	$\frac{1}{1-\theta}$
GDP Deflator	10	0.83	5.9	0.69	3.3
	33	0.76	4.2	0.66	2.9
PCE Deflator	10	0.81	5.3	0.66	2.9
	33	0.73	3.7	0.63	2.7

Panel B: 1959:I-1979:II

Inflation		Capital			
Measure	Assumed	Mobile		Immobile	
	ϵ	θ	$\frac{1}{1-\theta}$	θ	$\frac{1}{1-\theta}$
GDP Deflator	10	0.80	5.0	0.65	2.9
	33	0.72	3.6	0.61	2.6
PCE Deflator	10	0.78	4.6	0.62	2.6
	33	0.70	3.3	0.58	2.4

Panel C: 1982:III-2001:IV

Inflation		Capital			
Measure	Assumed	Mobile		Immobile	
	ϵ	θ	$\frac{1}{1-\theta}$	θ	$\frac{1}{1-\theta}$
GDP Deflator	10	0.77	4.3	0.60	2.5
	33	0.67	3.0	0.56	2.3
PCE Deflator	10	0.76	4.2	0.62	2.6
	33	0.68	3.1	0.56	2.3

Note: Estimates based on $\alpha = 1/3$ and $\zeta = 1.1$.

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