INFLATION NON-NEUTRALITIES AND THE RESPONSE OF INTEREST RATES TO INFLATION EXPECTATIONS

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Ever since Fisher [1896; 1907; 1930] provided both the theoretical analysis suggesting complete adjustment and the empirical evidence indicating only partial adjustment of the nominal interest rate to anticipated inflation, the relation between interest rates and inflation expectations has been the subject of controversy. The controversy focuses on the magnitude of the total derivative of the nominal interest rate (i) with respect to a change in the expected rate of inflation (π). If this total derivative, $di/d\pi$, equals one, consistent with Fisher's theoretical analysis, nominal rates adjust fully to expected inflation. If $di/d\pi < 1$, consistent with Fisher's empirical findings, nominal rates only partially adjust to inflation expectations.

Fisher rationalized the contradiction between his theoretical and empirical findings as reflecting money illusion on the part of wealth owners. Research on interest rate determination since Fisher's studies initially concentrated on either deriving theoretical results consistent with Fisher's empirical finding of partial adjustment, or demonstrating empirically that nominal rates fully adjust to a change in the expected rate of inflation, consistent with Fisher's theoretical conclusion.

More recently, the controversy was further complicated when Darby [1975] and Feldstein [1976] demonstrated that the taxation of nominal interest income (and/or the tax deductibility of nominal interest payments) implied a more-than-complete adjustment of nominal rates to anticipated inflation, in this case $di/d\pi > 1$. Darby's and Feldstein's analyses were modified by Nielsen [1981] and Gandolfi [1982]. They both introduced capital gains taxation and found that the response of interest rates to anticipated inflation should be greater than the complete response derived by Fisher, but smaller than the result suggested by the Darby-Feldstein analysis.

Feldstein, Green, and Sheshinkski [1978], Feldstein [1980], and Summers [1983] further extended the analysis by demonstrating that other inflation non-neutralities associated with the tax structure —in particular, the use of a historic rather than a replacement basis for depreciation allowances and the use of the FIFO[1] accounting procedure for inventories— tend to reduce the response of the nominal interest rate to inflation expectations. This result, when combined with the Darby-Feldstein analysis, allows for a partial, complete, or more-than-complete adjustment of the nominal rate to anticipated inflation. In this case $di/d\pi$ may be less than, equal to, or greater than one. We are, however, left with a maze of partial and highly specialized models yielding conflicting results.

The diversity of results found in the theoretical literature is mirrored in the empirical findings. While a number of studies, including Feldstein and Eckstein [1970], Gibson [1972] and Fama [1975], found evidence of full adjustment, many others, including Lahiri [1976] and Summers [1983], found evidence of only partial adjustment. Evidence on the Darby-Feldstein hypothesis of more-than-complete adjustment has also been mixed: although several studies, including Carr, Pesando and Smith [1976], Carlson [1979][2] and Tanzi [1980], did not find compelling evidence for the hypothesis, Cargill and Meyer [1980] and Peek [1982] found strong support for more-than-complete adjustment.

The purpose of this paper is to present a general framework employing a familiar IS-LM model within which the various theoretical and empirical findings in the literature hold as special cases. Sahu, Jha and Meyer [1990] used a growth model to reconcile the conflicting results. However, their use of the growth framework did not allow them to distinguish between two key results (Darby and Feldstein effects). The IS-LM model employed in this paper is able to distinguish clearly among the various theoretical findings. In addition, our paper also provides some empirical results to determine the actual magnitude of the impact of inflation expectations on the interest rate.

In the first section, we develop a general framework for analyzing the response of interest rates to anticipated inflation and show how the alternative findings in the theoretical and empirical literature hold under special assumptions about the parameter values of this model. The second section employs estimates of the model parameters extracted from other studies to try to pin down the magnitude of the response of interest rates to anticipated inflation, and provides some independent empirical evidence on this magnitude. The third section then examines the implications of our model in light of the parameter estimates for the divergent response of the real after-tax return to savers and the real cost of capital to firms. The final section is a brief conclusion.

THE MODEL: THE TAX STRUCTURE AND INFLATION NON-NEUTRALITIES

In this section we develop a general model within which the various results obtained in the theoretical and empirical literature hold as special cases, each obtainable for a clearly definable set of parameter values. We employ a modified generalized version of Mundell's [1963] "IS-LM" model adapted to allow for inflation non-neutralities due to the tax structure and to include disposable income as the additional determinant of consumption in the Keynesian tradition. This IS-LM model is augmented with a Phillips Curve and refined to include the real after-tax interest rate as a determinant of both consumption and investment and to incorporate other inflation non-neutralities that affect the real cost to firms of acquiring capital. The model has a unique long-run equilibrium at full employment and the analysis therefore focuses on the long-run equilibrium response of interest rates to a change in the rate of expected inflation.

The output market equilibrium is given by,

$$X = C(Y, r_s, m) + I(c) + G, \tag{1}$$

where X is real output; consumption (C) depends on the after-tax real interest rate to savers (r_s), real disposal income (Y), and real money balances (m)[3]; investment (I) depends on the real cost of capital to firms (c); and real government expenditures (G) are exogenous. The definitions of Y, r_s, and c are required to complete the specification of the real sector. Real disposable income is simply real output minus real tax revenue (T), and real tax revenue is a linear function of real output:

$$Y \equiv X - (T_o + tX) = (1 - t)X - T_o, \tag{2}$$

where t is the marginal personal-income-tax rate and T_o is the constant term in the tax function.

The after-tax real interest rate of consumers (r_s) is,

$$r_s \equiv (1 - t)i - \pi, \tag{3}$$

where i is the nominal rate on bonds and π represents inflation expectations. The real cost of capital to firms (c) is:

$$c \equiv (1 - \tau)i - \pi + \lambda\pi, \tag{4}$$

where τ is the tax rate on corporate income and λ captures the effects of inflation on the real cost of capital due to inflation non-neutralities associated with historic cost depreciation, FIFO inventory accounting, and taxation on nominal capital gains. The term, λ, in turn, can be expressed as,

$$\lambda \equiv \tau\mu + g, \tag{5}$$

where μ represents the nominal increase in profits per unit of capital due to the effect of inflation on the real value of depreciation allowances and on after-tax corporate income associated with the taxation of capital gains on inventories, and g captures the effect of taxation of nominal capital gains. The μ term is based on Feldstein and Summers [1979], and is defined as follows:

$$\mu = [(CCA + IVA)/K]\cdot[1/\pi],$$

where CCA is the capital consumption adjustment, IVA is the inventory valuation adjustment and K is the capital stock.[4]

The money market equilibrium is given by,

$$m = L(X, (1 - t)i), \tag{6}$$

where m is the level of real money balances. Note that the demand for money depends on the nominal interest rate, while consumption and investment depend on the real interest rate.[5]

The expectations-augmented Phillips Curve is employed to tie down the equilibrium value of output at the full employment or "potential" level *(POT)*. Inflation *(p)* depends on demand slack, defined as the difference between actual output and potential output, and on expected inflation:

$$p = \alpha(X - POT) + \pi. \tag{7}$$

To study the long-run effects of inflation one must use either a fixed output or an equilibrium growth approach. Sahu, Jha and Meyer [1990] used an equilibrium growth approach to reconcile the diverse results regarding the response of the nominal interest rate to inflation expectations. Following Sargent [1972], who also used a variant of the IS-LM model to analyze the effect of anticipated inflation on the nominal interest rate, we assume a stationary equilibrium level of income.[6] In our model, price flexibility assures that $X = POT$ in the long run when $p = \pi$. In the long run, then, output is predetermined at the level of potential output and is effectively an exogenous variable in the model. In addition, the rate of inflation and expected inflation can be viewed as predetermined at the rate consistent with the exogenously set rate of growth in the nominal money stock. This leaves the real money supply and the nominal interest rate effectively as the two unknowns in the IS-LM framework.[7] The basic experiment is to vary the rate of expected inflation (by varying the rate of money growth) and to find the response of the nominal interest rate. We can then solve via the identities for the response of the real after-tax rate to savers, and the real cost of capital to firms.

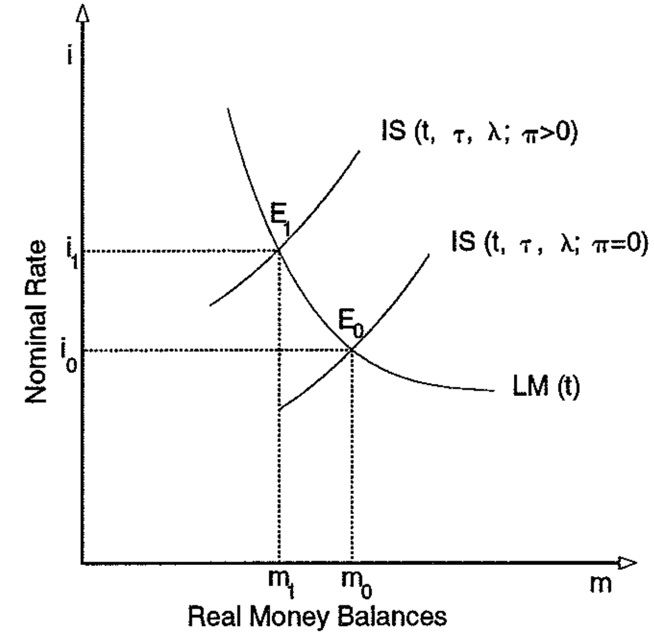
To find the response of the nominal rate, we first set X=POT and substitute Equations (2) through (5) into Equation (1). We then totally differentiate the two-equation system described by (1) and (6) to obtain:

$$\begin{bmatrix} C_r(1-t) + I_c(1-\tau) & C_m \\ L_i(1-t) & -1 \end{bmatrix} \begin{bmatrix} di \\ dm \end{bmatrix} = \begin{bmatrix} C_r + I_c(1-\lambda) \\ 0 \end{bmatrix} d\pi.$$

Application of Cramer's rule to the above system yields the general solution for the response of the nominal rate to anticipated inflation:

$$\frac{di}{d\pi} = \frac{C_r + I_c(1-\lambda)}{C_r(1-t) + I_c(1-\tau) + C_m L_i(1-t)}. \tag{8}$$

FIGURE 1
Nominal Interest Rates and Inflation Expectations



This result can yield values less than, equal to, or greater than one depending on the values of the model parameters. The response of nominal rates to inflation expectations is thus ultimately an empirical question that can be resolved only by pinning down the values of the critical model parameters or by estimating some simple reduced-form relationship between interest rates and expected inflation. The various results in the theoretical literature, outlined above, all can be derived as special cases from this general model.

The response of the nominal interest rate to inflation expectations can be demonstrated using the following "IS-LM" diagram used by Mundell [1963], shown as Figure 1 above. Given the tax parameters, the "IS" schedule plots the locus of pairs of values of real interest rates and real money balances along which saving equals investment. Since a higher interest rate inhibits output demand, creating an excess supply of output, which is eliminated by an increase in real money balances, the IS schedule has a positive slope. The "LM" curve represents the locus of nominal interest rates and real money balances that is consistent with money market equilibrium, *ceteris paribus*. This curve has a negative slope because at high nominal interest rates the demand for real balances is low and, thus, people will be content to hold increased stock of real money balances only at lower money interest rates. At equilibrium point E_0, the nominal interest rate (i_0) is equal to the real interest rate since the expected inflation rate is zero, and the real interest rate is defined as the difference between the nominal interest rate and the anticipated inflation rate $(r = i - \pi)$. However, as inflation expectations increase, the IS curve (which depends on the real interest rate) shifts to the left, raising the nominal interest rate to i_1. The magnitude of the change in the nominal interest rate for any given increase in anticipated inflation will depend on behavioral parameters, I_c, C_r, C_m and L_i, and tax parameters, t, τ and λ. In our model this magnitude is determined by Equation (8).

Below we derive special cases of the general model that explain the differing results that have appeared in the literature on the response of nominal rates to inflation. Specifically, we derive the conditions under which nominal rates adjust completely, partially or more than completely to inflation.

Complete Adjustment

Fisher's theoretical result of complete adjustment holds in either of two cases. In the first case, it holds if $t = \tau = \lambda = 0$ and C_m or $L_i = 0$. In this case, there are no non-neutralities associated with inflation. The IS curve reduces to one equation with one unknown, the real interest rate, r. The real rate is thus independent of the rate of anticipated inflation and the nominal interest rate therefore completely adjusts to anticipated inflation. The second possibility is that, by coincidence, the values of the parameters in the general model are such that $di/d\pi = 1$. The intuition underlying this result will be developed after considering the various non-neutralities in the general model.

Partial Adjustment

We included real money balances as an argument in the consumption function to allow for the partial-adjustment result derived by Mundell [1963]. If we set $t = \tau = \lambda = 0$ but allow $C_m > 0$, the expression for the response of the nominal rate would become:

(9) $$\frac{di}{d\pi} = \frac{1}{1 + [C_m L_i/(C_r + I_c)]} < 1.$$

Hence, if $C_m > 0$, an increase in inflation leads to only a partial adjustment of the nominal rate and a decline in the real rate. In this case, there is no longer a unique real interest rate consistent with output market equilibrium. Instead, there are various combinations of the real interest rate and real money balances consistent with output market equilibrium. The upward sloping IS curve illustrates that equilibrium can be maintained in the output market if a higher real interest rate (which lowers investment) is offset by a higher level of real money balances (which raises consumption). An increase in inflation lowers the equilibrium level of real money balances as wealth owners move to economize on money holdings. The lower level of money balances will then require a lower real interest rate to maintain output market equilibrium. In order to allow the real interest rate to decline with an increase in inflation, the nominal interest rate must less-than-completely adjust to the higher rate of inflation.

Our model, however, also allows for partial adjustment, even if $C_m = 0$. All that is required is that the numerator of Equation (8) is less than its denominator! In particular, the larger is λ relative to t and τ, the more likely is partial adjustment.

If $C_m = 0$, we can rewrite Equation (8) as:

(8') $$\frac{di}{d\pi} = \frac{1+(1-\lambda)\phi}{(1-t)+\phi(1-\tau)}.$$

Here, the critical parameters are the two tax parameters, the parameter for other inflation non-neutralities, and the single behavioral parameter, ϕ, the relative interest responsiveness of investment to consumption.

When $\lambda > 0$, there is no longer a unique level of the real interest rate consistent with output market equilibrium, even if $C_m = 0$. To isolate the role of the inflation non-neutralities summarized by λ, assume that $t = 0$ and that the real rather than the nominal interest rate is deductible in computing corporate taxes. In this case, Equation (8') reduces to,

(8") $$\frac{di}{d\pi} = \frac{1+(1-\lambda)\phi}{(1+\phi)}.$$

When $\lambda > 0$, inflation raises the cost of capital and therefore discourages investment. The real interest rate is the only variable that can move to restore output market equilibrium; the real interest rate must therefore fall by enough to just offset the adverse effect of the inflation non-neutralities summarized by λ. To allow the real interest rate to decline, the nominal interest rate must only partially adjust to an increase in inflation. Note that the expression in (8') also allows for the effect of taxation of nominal interest income to work in the opposite direction. The effect of this modification is developed below.

More-Than-Complete Adjustment

Darby [1975] and Feldstein [1976] demonstrated that integrating the taxation of nominal interest income and the tax deductibility of nominal interest payments into the simple Fisherian analysis implies that nominal interest rates should increase by more than one percentage point for each percentage point increase in the anticipated rate of inflation. However, Darby's and Feldstein's results differed in that the personal tax rate mattered in the Darby analysis and the corporate income tax rate mattered in the Feldstein analysis. Each of their expressions can be derived from the general model by appropriate assumptions about model parameters.

We can derive Darby's expression for the response of the nominal rate to inflation expectations by assuming that $I_c = 0$ and C_m or $L_i = 0$ in Equation (8). Then the IS curve is one equation with one unknown, the real after-tax interest rate to savers (r_s), which, in turn, is independent of the rate of inflation. The expression for the response of the nominal rate to inflation expectations in this case is:

(10a) $$\frac{di}{d\pi} = \frac{1-\lambda}{(1-\tau)} > 1.$$

If $C_m = 0$, and there are no other tax non-neutralities other than taxation of nominal interest $(\lambda = 0)$, there is a unique value of the after-tax real interest rate consistent with output market equilibrium; this equilibrium after-tax interest rate is therefore independent of the inflation rate. When the inflation rate increases the nominal interest rate has to rise enough so that, even allowing for taxation of nominal interest income, the real after-tax interest rate remains unchanged; in the Darby model, it is only the real after-tax interest rate to savers (r_s) that matters. The after-tax nominal rate must increase by an amount equal to the increase in inflation in this case to maintain an unchanged after-tax real interest rate; this will require the before-tax nominal interest rate to increase by more than the rate of inflation — hence there will be more-than-complete adjustment of the nominal interest rate to inflation.

Similarly, Feldstein's result can be obtained by assuming that $C_r = 0$, C_m or $L_i = 0$ and $\lambda = 0$ in Equation (8). In this case:

$$\frac{di}{d\pi} = \frac{1}{(1-\tau)} > 1. \tag{10b}$$

The intuition here is exactly the same as for Darby's expression, except that it is the after-tax real rate to firms that must remain unchanged and therefore it is the corporate income tax rate rather than the personal tax rate that controls the degree of adjustment of the nominal interest rate to inflation.

Finally, we can obtain a generalization of the Darby-Feldstein results by assuming C_m or $L_i = 0$ and $\lambda = 0$; we can rewrite the general expression in this case as:

$$\frac{di}{d\pi} = \frac{1}{[C_r/(C_r+I_c)](1-t)+[I_c/(C_r+I_c)](1-\tau)} > 1. \tag{10c}$$

Here, the response of nominal rates is one over a weighted average of one minus the personal and one minus the corporate tax rates, where the weights are the relative interest responsiveness of consumption and investment.

Of course, our model can also yield more-than-complete adjustment, as long as λ is small enough relative to t and τ.

Nielsen [1981] and Gandolfi [1982] modified the Darby-Feldstein analysis by assuming that there was a single tax rate (t) applying to personal income, corporate income, and capital gains. In addition, they assumed that there were no inflation non-neutralities other than those associated with the taxation of interest income and of nominal capital gains. Hence, in terms of our general model, $C_m = 0$, $t = \tau$, and $\lambda = g = t$. The resulting expression for the response of the nominal interest rate to anticipated inflation can be written as,

$$\frac{di}{d\pi} = \frac{1}{(1-t)} - \frac{t}{1-t}\cdot\frac{1}{1+(C_r/I_c)} > 1. \tag{11}$$

The above expression is greater than one but less than the adjustment predicted in the Darby-Feldstein analysis — a result obtained by Nielsen [1981] and Gandolfi [1982] independently.

***The Implications of Inflation Non-Neutralities*[8]**

Feldstein, Green, and Sheshinkski [1978], Feldstein [1980], and Summers [1983] demonstrated that other inflation non-neutralities associated with the tax structure —in particular, the calculation of depreciation allowances based on the historic rather than replacement value of the capital stock, the FIFO accounting technique for the value of inventories, and the taxation of nominal capital gains— tend to raise the real cost of capital to firms (for a given after-tax real interest rate) as inflation rises. This, in turn, tends to offset, at least in part, the magnified effect of inflation expectations on nominal rates associated with the taxation of interest income and the tax deductibility of interest payments.

Summers [1983] derived a simple expression to demonstrate this. He assumed that $C_m = 0$ and $C_r = 0$. In this case, our IS-LM model reduces to,

$$\frac{di}{d\pi} = \frac{1-\lambda}{(1-\tau)} > 1. \tag{12}$$

This is similar although not identical to Summers' expression. His modeling of investment is different from ours, and he includes in his λ term all the inflation non-neutralities associated with the tax treatment of corporations. Still, the above expression conveys the same point that Summers was making: the λ term might partially or completely offset the effect of the τ term, allowing for the partial adjustment of interest rates in the empirical literature, even though the model allows for the tax deductibility of interest payments and the taxation of interest income.

We discussed the intuition underlying the potential for partial adjustment due to the inflation non-neutralities summarized by λ above. Returning now to the general case, presented in Equation (8), the various forces affecting the adjustment of the nominal interest rate to inflation can be summarized. There is potential for *partial adjustment* via the Mundell effect $(C_m > 0)$ and via the inflation non-neutralities associated with original cost depreciation, FIFO accounting, and taxation of nominal capital gains, as emphasized by Feldstein [1980] and Summers [1983] and summarized in the λ parameter. There is also potential for *more-than-complete adjustment* due to the taxation of nominal interest income, emphasized by Darby [1975] and Feldstein [1976] and captured by the role of the t and τ parameters, respectively. Finally, these two sets of forces could by coincidence just offset, so that nominal interest rates *adjust completely* to a change in the inflation rate.

SOME EVIDENCE ON THE RESPONSE OF NOMINAL RATES TO EXPECTED INFLATION

In this section we employ estimates of model parameters extracted from other empirical studies to pin down the magnitude of the response of nominal interest rates to anticipated inflation, and provide some independent empirical evidence on this response based on a simple reduced-form regression.

The Magnitude of $di/d\pi$ Based on Empirical Parameters From Other Studies

The key empirical parameters in the model are the two tax rates, t and τ, the parameter summarizing other inflation non-neutralities, λ, the responsiveness of consumption to a change in the real after-tax interest rate, C_r, and the response of investment to the real cost of capital to firms, I_c. The latter two parameters sometimes enter in ratio form, $\phi = I_c / C_r$.

Table 1 presents a number of estimates of t, τ, and λ from the literature in order to provide empirically plausible ranges for these parameters (and thus the range for the magnitude of $di/d\pi$). The values for t reported in Table 1 are average marginal tax rates for interest income as estimated by Feldstein and Summers [1979] and Gordon and Malkiel [1979]. The values of τ are either statutory marginal tax rates on corporate income (used by Feldstein [1980]) or an effective marginal tax rate paid by corporations (as estimated by Feldstein [1980]). Estimates of ϕ likely would vary substantially across macroeconometric models, but the ratio is likely to be substantially in excess of unity. Fortunately, the results below are not highly sensitive to values of ϕ. Table 2 computes values of $di/d\pi$ (for $C_m = 0$)[9] for a number of alternative combinations of t, τ and λ for a particular value of ϕ.

The values of $di/d\pi$ in Table 2 fall between 1.1 and 1.4. Varying the value of ϕ between 5 and 1000 does not substantially alter these estimates. Even if $C_r = 0$ the above range is unaffected. Hence, the empirical estimate of $di/d\pi$ appears to lie within the range of 1.1 to 1.4 and the empirical evidence on parameters appears to support a more-than-complete adjustment of the nominal interest rate to expected inflation.

TABLE 1
Some Estimates of t, τ and λ

t	τ	λ[a]
0.42[b]	0.48[c]	0.27[c]
0.33[d]	0.38[c]	0.30[c]

a. Feldstein [1980] estimated the value of $\tau\mu$ at 0.22, assuming an average inflation rate of 7 percent for the five-year period preceding 1977. For a 6 percent rate of inflation, his estimate was 0.256. Feldstein and Summers had earlier estimated the marginal capital gains tax rate (g) at 0.047. The λ is the sum of $\tau\mu$ and g.
b. Feldstein and Summers [1979].
c. Feldstein [1980].
d. Gordon and Malkiel [1979].

TABLE 2
Estimates of $di/d\pi$ based on $\phi = 40$[a]
Combinations of t, τ, λ

t	τ	λ	$di/d\pi$
.42	.48	.27	1.412
.33	.48	.27	1.407
.42	.38	.27	1.190
.33	.38	.30	1.139

a. The estimate of $\phi = 40$ is derived by approximating C_r by -0.5, the coefficient on the government bond rate in the permanent income version of the consumption function estimated by Dolde [1980] and using the value of I_c of -20 from the Washington University Macroeconometric Model (WUMM), a value that seems to approximate the average value encountered in other macroeconometric models. The exact value of I_c used is not of much significance as the magnitude of $di/d\pi$ is not sensitive to values of ϕ.

Independent Empirical Evidence on the Response of the Nominal Interest Rate to Inflation

In this section a simple regression of the nominal interest rate on inflation expectations is used to provide independent evidence on this relation, supporting the conclusion reached in the previous section.[10] For this purpose we use the nominal yield on one-year Treasury bills from Salomon Brothers' *An Analytical Record of Yields and Yield Spreads* and the one-year inflation forecasts from the Livingston series, obtained from the Federal Reserve Bank of Philadelphia, to match the maturity of Treasury bills.

The Livingston survey is conducted semiannually in April and October every year, and the data are published in June and December, respectively. The Livingston inflation forecasts thus reflect inflation expectations formed in April and October. Therefore, we have used only biannual observations on the nominal interest rate (April and October one-year Treasury bill rates) to match the one-year Livingston inflation expectations reported semiannually. The sample period is from 1961 to 1993 (the second quarter). The resulting OLS regression is given by (t-ratios in parentheses):

$$i = \underset{(4.46)}{2.33} + \underset{(10.11)}{1.08}\,\pi \qquad R^2 = 0.62\,. \tag{13}$$

While the above regression suggests that the nominal interest rate adjusts slightly more than point for point to expected inflation, the coefficient on inflation is not significantly different from one (the implied t-statistic for the null hypothesis that the coefficient on inflation equals one is 0.74). This implies that the value of $di/d\pi$ is closer to the bottom of its range of 1.1 to 1.4 from Table 2, and may in fact be equal to one. Thus, the nominal interest rate adjusts either completely or slightly more than completely to a change in anticipated inflation. Thus, the regression result seems to support the Nielsen-Gandolfi effect. However, it is statistically indistinguishable from the Fisher effect when $di/d\pi = 1$.

INFLATION NON-NEUTRALITIES AND THE INCENTIVES TO SAVE AND INVEST

The above analysis can be applied to an analysis of perhaps the most important consequence of inflation non-neutralities in the 1970s —the slowdown in the rate of net capital formation. This is a theme that Feldstein developed and supported in a number of papers. The inflation non-neutralities associated with the tax structure can simultaneously cause the after-tax real interest rate to savers to fall, discouraging saving, and the real cost of capital to firms to rise, discouraging investment. Obtaining such results with our macroeconomic model depends critically on the existence of the inflation non-neutralities summarized by our t, τ and λ terms. In this section we develop the implications of the general model developed in the first section, given the parameter values of the second section, for the response of the real cost of capital to firms and the real after-tax return to savers.

The existence of inflation non-neutralities associated with historic cost depreciation and FIFO inventory accounting may act as a wedge between the return to savers and the cost of capital to firms. These non-neutralities may allow increases in anticipated inflation to reduce the after-tax real interest rate to savers at the same time that it is raising the real cost of capital to firms.

The above result has an interesting interpretation, analogous to the analysis of the incidence of an excise tax between households and firms. In the excise tax case, the excise tax falls disproportionately on the unit that is relatively less sensitive to price changes. In the current case, inflation non-neutralities are like an excise tax, a wedge between the return to savers and the cost to borrowers. If $C_r = 0$, for example, this insensitivity of households to the real after-tax return to saving imposes the entire burden of inflation non-neutralities on households, allowing firms to shift all the effect of the non-neutralities which fall directly on firms to households by lowering the rate of interest they are willing to pay to finance capital accumulation. Alternatively, if $I_c = 0$ the burden can be shifted to firms.

Based on the general model, the response of the real after-tax return to savers and the real cost of capital to firms to a change in anticipated inflation can be expressed as follows:

$$\text{(14a)} \qquad \frac{dr_s}{d\pi} = \frac{[-\lambda(1-t) + (\tau-t)]I_c}{(1-t)C_r + (1-\tau)I_c}.$$

$$\text{(14b)} \qquad \frac{dc}{d\pi} = \frac{[\lambda(1-t) + (\tau-t)]C_r}{(1-t)C_r + (1-\tau)I_c}.$$

Table 3 reports estimates for $dr_s/d\pi$ and $dc/d\pi$ based on the model presented in the first section and the model parameters assumed in the second part. The results

TABLE 3
Estimates of $dr_s/d\pi$ and $dc/d\pi$

$di/d\pi^a$	$dr_s/d\pi$	$dc/d\pi$
1.412	-.1810	.0042
1.407	-.0573	.0016
1.190	-.3098	.0078
1.139	-.2369	.0062

a. Estimates of $di/d\pi$ are taken from Table 2 and associated values of $dr_s/d\pi$ and $dc/d\pi$ are calculated using identities for r_s and c.

provide some support for Feldstein's contention that inflation non-neutralities drive a wedge between the after-tax real return to savers and the cost of capital to firms, simultaneously discouraging saving and capital formation. Thus $dr_s/d\pi < 0$ and $dc/d\pi > 0$. However, the magnitude of the response of the cost of capital to inflation casts doubt on the quantitative significance of this effect. While the real after-tax return to savers falls by 6 to 31 basis points for each one percentage point increase in expected inflation, the cost of capital rises by less than one basis point. The parameter values thus suggest that inflation does not have a serious adverse effect on the cost of capital and hence capital formation.

This conclusion reflects in part the small value assumed for C_r. Recall that $C_r = 0$ would imply no effect of inflation on the cost of capital. A small value of C_r is, however, fully consistent with many empirical studies, including the Dolde [1980] paper from which the value of C_r used in this paper was taken.

CONCLUSION

This paper has developed an IS-LM model of the response of real and nominal interest rates that integrated the role of tax rates and other inflation non-neutralities. This model is theoretically consistent with less-than-complete, complete, or more-than-complete adjustment of nominal interest rates to inflation expectations. Thus, the magnitude of the response of the nominal interest rate is ultimately an empirical question. The empirical evidence suggests that nominal rates adjust either point for point or slightly more than point for point to a change in inflation expectations. This result suggests that the effects of taxation of nominal interest income and of other inflation non-neutralities in the tax system just offset each other.

The model and parameter estimates suggest that inflation reduces the real after-tax return to savers and increases the real cost of capital to firms, simultaneously reducing both the incentives to save and invest. However, the magnitude of the effect of inflation on the cost of capital and hence capital formation appears to be very small. The latter case is consistent with savings being interest inelastic so that the burden of increased inflation falls entirely on households in the form of a decline in the after-tax real return to savings.

NOTES

1. FIFO stands for the "first in, first out" method of evaluating the cost of depleting inventories. Firms which use the FIFO inventory cost method deduct only the acquisition cost, assuming that the first item to come out of inventories was the item that was first put into inventories. In inflationary periods, acquisition cost may be much less than the replacement cost, giving rise to phantom inventory profits. See Feldstein and Summers [1979] for treatment of FIFO inventory cost method in the context of evaluating the effects of inflation on corporate profits.
2. Carlson found that variations in short-term interest rates are attributable to cyclical variations in the degree of capacity utilization and to liquidity effects as well as to changes in expected inflation. His evidence is supportive of the Darby-Feldstein effect for the 1960s, but the support disappears when Carlson extends the period of empirical analysis to include data from the 1970s.
3. The real-balance term in the consumption function represents the effect of net wealth of households on consumption. For simplicity, we have incorporated only real money balances explicitly. But the effect this produces, the decline in real wealth associated with an increase in the price level, is consistent with a more general specification of the wealth variable. Mundell [1963] introduced real money balances in the savings function to derive the partial-adjustment result. It may, however, be noted that the real balance effect is not necessary to obtain the partial-adjustment result in our model.
4. For corporations, the *CCA* is the tax-return-based capital consumption allowances less capital consumption allowances that are based on estimates of uniform service lives, straight line depreciation, and replacement cost. Similar adjustments are applied to proprietors' income and rental income. Thus, the National Accounts concept of *CCA* allows for the countervailing influence of accelerated depreciation provision on the effect of inflation in reducing the real value of depreciation allowances.

   In defining the cost of capital, we have assumed there is no investment tax credit (ITC). The ITC is ignored because its effect on the cost of capital is not influenced by the rate of inflation, i.e., it is not a source of inflation non-neutralities, in contrast with depreciation based on original cost, FIFO inventory accounting, and taxation of nominal capital gains. It is true, however, that the ITC (along with accelerated depreciation) can be used to offset the adverse effect of inflation on the cost of capital and some have indeed argued that this was the intent.
5. In a two-asset model one can consider wealth as being composed of money and bonds. When all capital is debt financed, real value of bonds equals real capital stock. The composition of a wealth-holder's portfolio between these two assets depends on the nominal rate of interest.
6. There is a long-standing tradition of using a fixed-output IS-LM model to study the response of nominal interest rates to inflation. As early as 1963, Mundell used such a model to provide the theoretical justification for the partial adjustment of nominal interest rates to inflation. Sargent [1972] also used a similar framework. An alternative approach, employed by Tobin [1965], Feldstein [1976], and Sahu, Jha and Meyer [1990] is to study the response of nominal interest rates to inflation in a simple growth model, where steady state growth replaces the assumption of a fixed equilibrium level of output.
7. In the "Hicksian IS-LM" model, real output (X) and the nominal interest rate (i) serve as two endogenous variables. We are, however, using a variant of the IS-LM model used by Mundell [1963]. Such an IS-LM model is a full-employment model in which the nominal interest rate (i) and the real money balances (m) serve as the two endogenous variables.
8. It may be noted that the recent changes in the U.S. tax code have not eliminated the inflation non-neutralities associated with the tax structure. An exhaustive analysis of the changes in the tax code is found in Fullerton and Mackie [1989].
9. A partial justification for $C_m=0$ lies in the way money supply is augmented. The usual method employed by the Federal Reserve is the open market operation. This method of augmenting money supply does not affect total private wealth as bonds are exchanged for money. Thus assuming $C_m=0$ simply implies that there is no wealth effect (on consumption) associated with money creation.
10. Following Summers [1983], we have estimated a simple relationship rather than a full, reduced-form equation to provide some idea about the magnitude of $di/d\pi$ involved.

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