Modeling the Effect of Inflation: Growth, Levels, and Tobin*

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Abstract

The negative effect of inflation on the output growth rate has been found in panel studies that avoid biases of previous cross section work. Theoretically this effect is supported qualitatively by endogenous growth exchange economies. Related research examines Tobin-type effects of inflation on the levels of various variables, such as capital usage. A coherent explanation of both growth and level effects theoretically still is lacking. We present a model to do this and find an explanation for both the growth effect and a set of inflation-induced phenomena that can be thought of as a revised Tobin effect. A basic link between the magnitude of the growth and the level effects is the degree to which inflation affects the real wage to real interest rate ratio, and this depends on the magnitude of the interest elasticity of money demand. Inflation acts as a tax on market earnings that raises the real wage rate relative to the real interest rate, lowers the growth rate, and increases the capital/labor intensities across sectors, to a degree inversely dependent on the magnitude of the interest elasticity. In addition our micro-founded exchange technology qualitatively explains some basic postwar monetary facts, and we compare this technology to more standard money/credit exchange technologies. Together the effects of inflation present a candidate monetary explanation for the postwar rise and fall of stagflation, including a wide range of effects that can be described as Tobin-related.

Keywords: Inflation, Growth, Tobin-Effect, Credit Technology

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1 Introduction

Ahmed and Rogers (2000) examine exogenous growth monetary models in search of Tobin (1965)-type effects on the equilibrium variables. They show that none of the four classes of reviewed models, a Sidrauski one, a cash-in-advance constraint on consumption, a cash-in-advance on consumption and investment, and a Tobin model, can explain the level effects that they find in cointegration results for a century of US data: a decrease in the consumption/output ratio, an increase in the investment/output ratio, and an increase in the capital to output ratio as coinciding with an increase in the inflation rate. They suggest that a fall in the real interest rate as the inflation rate rises, as in a Tobin type model, is consistent with their results since a higher capital investment should decrease the real interest rate. Further, models that generate the reverse-Tobin effect appear to be at odds with the data (p.25). And after defining the Tobin effect within the exogenous growth environment, they state that the more modern genre of endogenous growth model with money also generate a reverse-Tobin effect of the type discussed above as well as the additional feature that a once-and for-all rise in inflation has a negative effect on the steady-state *growth rate* of the economy (p.8-9, italics in original). They conclude that "real-business-cycle models and endogenous growth models without money might be useful approximations when analyzing historical US data on real variables, *but only because the unit root in inflation is small"* (p.30, italics in original).

Chari and Manuelli (1996) argue that the endogenous growth monetary models that they present are qualitatively consistent with the negative growth effect of inflation but do not deliver a high enough magnitude of the effect. The Ahmed and Rogers and Chari et al papers are important for forcing a focus on the ability of our standard monetary models to explain the basic facts of the effect of inflation on levels and growth rates along the balanced-growth path, just as the real business cycle papers forced our models to focus on co-movements with output. Getting both level and growth effects put together has still eluded us. For example the Einarsson and Marquis (1999) use Lucas (1988)-type human capital investment in a cash-in-advance framework to study transitional dynamics, but not these level and growth effects along the balanced growth path. They find for example that output can rise transitionally because of an inflation rate increase, as seems to be consistent with Ahmed and Rogers vector error-correction results. In a similar Lucas-type endogenous growth monetary economy, Gomme (1993) includes both growth and some level effects, but focuses on the stochastic properties of the model. He finds for example that the ratio of consumption to human capital goes down with inflation rate increases along the balanced-growth path, as Ahmed and Rogers support empirically. Ireland (1994) AK model has only a transitional effect of inflation on the growth rate, while showing a long run Tobin-type increase in capital because of inflation. However here inflation causes a build-up in capital because the credit sector uses only capital and the agent avoids inflation by using credit and thereby increasing capital usage.

Ahmed and Rogers associate the lack of a Tobin effect with the exogenous growth general equilibrium models that they review, in which the real interest rate and the capital to effective-labor ratio is constant. Our paper shows that endogenous growth theory is in fact consistent with a positive Tobin effect, in terms of a decline in the real interest rate and an increase in capital intensity, and with the Ahmed and Rogers stylized facts on the "great ratios". We show this by presenting a coherent explanation of both growth and level effects of inflation within an endogenous growth monetary economy in which inflation drives down the return to capital. And we provide an explanation of a negative inflation-growth effect, and one that differs marginally for high and low inflation countries because of a non-linearity in this effect that we find theoretically in our model, and that is supported empirically for industrial countries in recent panel studies, adjusted for fixed country and time heterogeneity effects (Khan and Senhadji (2000), Ghosh and Phillips (1998), and Gillman and Matyas (2001)). We further show that Chari and Manuelli (1996) result, that within their models inflation does not have a large enough negative effect on growth to be consistent with evidence, does not hold in general for endogenous growth monetary models. Rather it is because of the way the Chari et al specify their human capital investment function that leads to their low calibrated effect. Using the standard Lucas (1988) and King and Rebelo (1990) human capital investment functions, we show that the magnitude of the inflation-growth effect is sufficiently high even across different specifications of the exchange technology.

We further show that the Lucas type human capital endogenous growth model in an exchange setting can produce the Tobin effect of a greater capital intensity and a lower real interest rate, and a negative inflation growth effect, independent of the exchange technology. So the other main contribution of our paper is that we clarify just what is the role of the exchange constraint, as a way to avoid the inflation tax, in the explanation of both growth and level effects. It turns out that including an explicit credit sector is marginal in explaining the basic real effects of inflation, that is, the non-neutralities. But the addition of a micro-founded credit sector is crucial in explaining certain money and banking features, such as why the magnitude of the interest elasticity of money demand, and the size of the banking sector, both rise with inflation on the balanced-growth path. An explicit credit sector also makes the interest elasticity, and the magnitude and non-linearity of the effect of inflation on both growth and levels of variables, depend on the technology coefficients of credit production. And these additional technology coefficients make for less free parameters in the calibration of the model.

Further our comparison allows us to show not only how the cash-in-advance models perform, but actually how the whole class of exchange-based economies perform in terms of the growth and level effects. The credit sector model that we use is a special case of the McCallum and Goodfriend economy, the exchange technology that both Goodfriend (1997) and Lucas (2000) use to explain certain monetary facts. In these latter papers, the exchange technology is specified so that the interest elasticity of money is constant. Our micro-based specification, which postulates simply that there are diminishing returns to effective labor in producing credit services, implies instead that the interest elasticity of money increases with the inflation rate, which is the main mechanism that generates both growth and level results that are consistent with data.

Thus we use a Lucas type human capital investment within a cash-in-advance economy that includes a micro-founded exchange-credit sector, using Hicksian (1935) banking time , as our baseline model. We include physical capital in both goods and human capital sectors, making the model an extension of Gillman and Kejak (2000). Adding physical capital is not necessary to generate a large enough magnitude for the inflation-growth effect, as well as a non-linearity in this effect, as Gillman and Kejak show with by using only human capital. But with physical capital added, we develop a general equilibrium version of the Tobin effect with respect to inflation and growth, and can capture the level as well as the growth effects. The original Tobin effect, as Walsh (1998) restates it, is taking a Solow growth model with a constant savings rate, adding money as an asset that costs foregone interest (but has no benefit), and assuming that an increase in the nominal interest rate causes substitution from money to physical capital, which lowers the marginal product of capital. An increase in inflation causes an increased capital accumulation and output with no effect on the (exogenous) balanced-growth rate. In a Lucas (1980) cash-in-advance economy without capital, an increase in the inflation rate reduces output. Stockman (1981) points out that with the cash-in-advance constraint also applying to investment, an inflation rate increase can cause a decrease in both capital and output. Ireland (1994) reverses the result on capital with a credit sector that uses only capital, but the growth rate in these models is unaffected in the long run.

The Tobin effect in our model is fundamentally different and quite simple. The inflation-induced substitution towards leisure means less capacity utilization of the human capital, just like a physical plant shut down for holidays. This lowers the return to effective labor in human capital production. Since the return to physical capital must be the same as that of human capital in equilibrium, the return on physical capital must also fall. And this occurs only by increasing capital accumulation. So the capital to effective labor ratio rises, and the growth rate falls because of a lower return on all capital. And the Tobin effect results in the form of a higher capital to effective labor ratio, in each sector and across the sum of all sectors, and a higher real wage to real interest rate ratio, all while there is a lower balanced-path growth rate. We include a full comparison of growth and level effects to more standard cash-in-advance models. We show that both the magnitude of the inflation-growth effect remains in the empirical range that Chari and Manuelli (1996) find in reviewing the literature, and that there exists a non-linear nature of the effect for both growth and level effects. And we argue that these effects are not only consistent with certain evidence and analysis, but also in combination help to characterize the rise and fall of Stagflation, a still unexplained historical experience.

The paper sets out the model in Section 2 and analyzes the basic effect of inflation on the growth rate and the levels of variables and their ratios. We provide a baseline calibration in Section 3, with alternative calibrations for a range of parameters for the credit services technology. We also present calibrations for the alternative technologies of the cash-only (Lucas (1980)) type and the cash-good/credit-good (Lucas and Stokey (1987)) type, and for the inclusion of income taxes as in Chari and Manuelli (1996), and discuss how the model is a special case of McCallum and Goodfriend, in Section 4. A comparison to related results is made in Section 5, and we add conclusions, qualifications, and suggested extensions in Section 6.

2 Three-Sector Economy with Human and Physical Capital

Consumer utility at time T depends on goods, c_t, and leisure, x_t, in the constant elasticity form

$$\bar{U} = \int_0^{\infty} e^{-\rho t} \left[c_t^{1-\theta} x_t^{\alpha(1-\theta)} / (1-\theta) \right] dt. \tag{1}$$

Output of Goods, that can be turned costlessly into physical capital and is denoted by y_t, and Human capital is produced with effective physical capital and effective labor each in Cobb-Douglas fashion, with functions denoted by G and H. Let k_t and h_t denote the stocks of physical capital and human capital, with the fixed depreciation rate of the capital stocks denoted by δ_k and δ_h . Let s_{Gt}, and s_{Ht} denote the fraction of capital that the agent uses in the Goods production and Human capital investment, whereby

$$s_{Gt} + s_{Ht} = 1. \tag{2}$$

The $s_{Gt}k_t$, and $s_{Ht}k_t$ are the amounts of capital used in each sector. Similarly, let l_{Ft}, l_{Gt}, and l_{Ht} denote the shares of human capital that the agent uses in each sector, whereby

$$l_{Ft} + l_{Gt} + l_{Ht} = 1 - x_t, \tag{3}$$

and unity is the total time endowment. Then $l_{Ft}h_t$, $l_{Gt}h_t$, and $l_{Ht}h_t$ are the *effective labor* employed in each sector. The sectoral production functions are then given as

$$y_t = G\left[s_{Gt}k_t, l_{Gt}h_t\right] = A_G \left(s_{Gt}k_t\right)^{1-\beta} \left(l_{Gt}h_t\right)^{\beta}, \tag{4}$$

$$H\left[s_{Ht}k_t, l_{Ht}h_t\right] = A_H \left(s_{Ht}k_t\right)^{1-\delta} \left(l_{Ht}h_t\right)^{\delta}, \tag{5}$$

where $\gamma, \beta, \delta \in [0,1]$ and A_G and A_H are positive shift parameters.

Let the consumption good be denoted c_t by and the price of goods by P_t. The share of goods bought with currency is an endogenous fraction $a_t \in (0,1]$ and the share of goods bought with credit residually is $(1-a_t)$. By the production of credit services, we mean that the share of credit purchases is produced with the effective labor, per unit of consumption. Denoting this function as F, it is specified to have diminishing returns to the effective labor per unit of goods:

$$(1-a_t) = F\left(l_{Ft}h_t/c_t\right) = A_F \left(l_{Ft}h_t/c_t\right)^{\gamma}, \tag{6}$$

with A_F a positive shift parameter and with $\gamma \in (0,1)$. Total credit purchases are given by $c_t(1-a_t)$. This sector is specified implicitly in the sense that the price of the credit services, the wages going to labor working in the sector, and the profit that the agent receives as banker are all left implicit. To see these credit sector output and factor prices derived explicitly, see the appendix in Gillman and Kejak (2000).

Let the nominal money stock by denoted by M_t. The nominal money balances constrain money purchases in a Clower-type constraint of

$$M_t = a_t P_t c_t. \tag{7}$$

Substituting in from equation (6), the Clower constraint can be written as

$$M_t = \left[1 - A_F \left(l_{Ft}h_t/c_t\right)^{\gamma}\right] P_t c_t \tag{8}$$

Money supply is supplemented by the government at a constant rate each period through a lump sum cash transfer to the agent of V_t, so that

$$\dot{M}_t = V_t \equiv \sigma M_t. \tag{9}$$

The total financial wealth, denoted by Q_t, is the sum of the money stock M_t and the nominal value of the physical capital stock :

$$Q_t = M_t + P_t k_t. \tag{10}$$

With goods production defined by equation (4), it is assumed that the output of goods can be converted without cost into physical capital and so is divided between consumption goods and investment net of capital depreciation:

$$c_t + \dot{k}_t + \delta_k k_t = y_t = A_G \left(s_{Gt} k_t \right)^{1-\beta} \left(l_{Gt} h_t \right)^{\beta}. \tag{11}$$

The nominal capital and labor income from goods production is the nominal value of the marginal products factored by the effective capital and effective labor used in output production. Define by r_t the marginal product of effective capital $(s_{Gt} k_t)$, and by w_t the marginal product of effective labor $(l_{Gt} h_t)$. The change over time in the agent's financial capital equals the income net of expenditure and depreciation, plus the term $\dot{P}_t k_t$ to account for the change in nominal value of physical capital:

$$\dot{M}_t + P_t \dot{k}_t + \dot{P}_t k_t = r_t P_t s_{Gt} k_t + w_t P_t l_{Gt} h_t + V_t - P_t c_t - \delta_k P_t k_t + \dot{P}_t k_t. \tag{12}$$

The change over time in the agent's human capital stock equals the human capital stock produced at time t minus the constant depreciation of the existing human capital stock. Following King and Rebelo (1990) modification of the Lucas (1988) human capital investment relation, we include both human and physical capital. With the production of new human capital h_t defined by equation (5), with substitution from equations (2) and (3), and with the depreciation rate on human capital denoted by $\delta_h \in R_+$, the human capital flow constraint is

$$h_t = A_H \left(\left[1 - s_{Gt} \right] k_t \right)^{1-\delta} \left(\left[1 - x_t - l_{Ft} - l_{Gt} \right] h_t \right)^{\delta} - \delta_h h_t. \tag{13}$$

2.1 Equilibrium

The agent maximizes utility in equation (1) subject to the stock constraints (7) and (10) and the flow constraints (12) and (13), with respect to the variables $c_t, x_t, s_{Gt}, l_{Gt}, s_{Ft}, l_{Ft}, M_t, Q_t, k_t$ and h_t. The present value Hamiltonian for the problem is

$$
\begin{aligned}
H &= e^{-\rho t} c_t^{1-\theta} x_t^{\alpha(1-\theta)} / (1-\theta) \\
&+ \phi_t \left(M_t - \left[1 - A_F \left(l_{Ft} h_t / c_t\right)^{\gamma}\right] P_t c_t \right) \\
&+ \varphi_t (Q_t - M_t - P_t c_t) \qquad (14) \\
&+ \lambda_t \left[r_t P_t s_{Gt} k_t + w_t P_t l_{Gt} h_t - P_t c_t + V_t - \delta_k P_t k_t + \dot{P}_t k_t \right] \\
&+ \mu_t \left[A_H \left(\left[1 - s_{Gt}\right] k_t \right)^{1-\delta} \left(\left[1 - x_t - l_{Ft} - l_{Gt}\right] h_t \right)^{\delta} - \delta_h h_t \right]
\end{aligned}
$$

A reduced set of first-order equilibrium conditions that characterize the balanced growth path, dropping time subscripts, are

$$
\begin{aligned}
-\dot{\lambda}/\lambda \equiv R &= r + \dot{P}/P - \delta_k, \qquad (15) \\
R &= \left(w / \left[A_F \gamma \left(l_F h / c_t\right)^{\gamma - 1} \right] \right) \qquad (16) \\
u_c / u_x &= x / (ac) = (1 + aR + whl_F / c) / wh, \qquad (17) \\
w/r &= (s_G k / l_G h) (\beta / [1-\beta]) = (s_H k / l_H h) (\delta / [1-\delta]), \qquad (18) \\
g &\equiv \dot{c}/c = \dot{k}/k = \dot{h}/h = [r - \delta_k - \rho] / \theta \\
&= \left[(1-x) A_H \beta \left(s_H k / l_H h\right)^{1-\beta} - \delta_H - \rho \right] / \theta \qquad (19)
\end{aligned}
$$

2.2 Growth and Level Effects

2.2.1 The Marginal Cost of Credit Services

With the nominal interest rate R defined in equation (15), consider equation (16). The marginal cost in a competitive credit services market is the relative price of credit services. The relative price of the credit services can be derived by making the credit service sector explicit rather than implicit as it is here. Defined as the explicit nominal price of the credit services divided by the nominal price of the consumption good, the relative price of the credit services of this economy equals the nominal interest rate in equilibrium (see Gillman and Kejak (2000)). This means that the marginal cost of credit services is the nominal interest rate R. Therefore equation (16) can be interpreted as setting the marginal cost of credit services, R, equal to the ratio of the marginal factor cost divided by the marginal factor input. This is a standard input price, equilibrium, condition. It is also a general equilibrium analogue of the Baumol (1952) equilibrium since examination of that condition shows that there the marginal cost of money, R, is equal to the marginal cost of banking. Here the marginal cost of money is equal to the marginal cost of credit as the agent equalizes the marginal cost of exchange across the two different means of exchange. In equilibrium a rise in the nominal interest rate due to inflation induces an increase in the marginal cost of credit services. This causes the labor input in the credit services sector to increase as in S. Rao Aiyagari and Eckstein (1998) and Gillman (1993), and the quantity of real money demanded falls. Or put differently, since R is the relative price of credit services, the "Baumol" condition (16) says that the real wage w equals the value of the marginal product of labor in credit services. An increase in R, while w also rises but by less than the increase in R, requires that the marginal product of labor in credit services must fall through an increase in the labor input.

2.2.2 The Revised Tobin Effect

Time Allocation and the Real Wage

An increase in inflation takes away time from goods and human capital production both because of an increase in banking time and an increase in leisure time. Equation (17) shows that when the average shadow exchange cost per unit of goods consumption, $aR+whl_F/c$, rises relative to the shadow price of leisure w, the ratio of c/h relative to x must fall. In calibrations, an increase in R causes c/h to fall and x to rise. This reallocation of the output items that enter the utility function occurs as the input combinations are reallocated in the goods and human capital sectors. Calibration shows that the inflation-induced diversion of time into credit services and into leisure coincides with a decrease in time spent in goods and in human capital production, and with a rise in the real wage w.

Return on Capital and the Real Interest Rate In taxing goods consumption relative to leisure, inflation reduces the return on both the physical and human capital that is used in goods production. *This lower return on all capital* is reflected in a lower real interest rate r (the marginal product of physical capital in goods production). Thus the input price ratio, of the real wage to the real interest rate, rises and the capital to effective labor ratio rises across both sectors. Here the relative Cobb-Douglas coefficients of production in equations (4) and (13) matter because they determine whether there will be an additional effect to the size of output in these sectors due to their relative capital intensities. Beyond any other factors determining the output of these two sectors, the more capital intensive sector will expand relative to the less capital intensive sector when w/r rises, as in equation (18). In addition, the total effective physical capital to effective labor ratio $k/[h(l_G + l_H)]$ rises. Including the labor in the credit services sector, the ratio $k/[(l_G + l_H + l_F)]$ should also rise if the increase in l_F is not too large but it would rise by less than $k/[h\,(l_G + l_H)]$.

Input reallocations because of a higher inflation tax updates/extends the Tobin (1965) effect. This is really a general equilibrium rewriting of the effect. Instead of an asset-motivated decreased return on money that causes capital increases as in Tobin, here the transactions-based avoidance, of an output tax on consumption goods relative to leisure, causes a change in the input price ratio and the capital to effective labor ratios. It is not as in Ireland (1994) a result of more capital being used in banking that causes capital to rise relative to effective labor, as there is no capital in the credit services sector. Rather it is that time is used up in leisure and in banking, causing a higher real wage and lower real interest rate.

2.2.3 Growth Effects along the Balanced-Growth Path

Equation (19) shows that the balanced-growth rate equals the normalized return on physical capital, or the normalized return on human capital net of leisure leakage, minus the normalized subjective rate of time preference. The reduction in the return on capital, as a result of an increased inflation tax, causes a lower growth rate. The Tobin-effect allows some of the burden of inflation avoidance that is on output substitution, from goods to leisure, to be taken over by input substitution, from relatively more expensive labor to less expensive capital. Thus an increase in the inflation rate causes the growth rate to fall. But it falls by a bit less than if there were no physical capital because, with both physical capital and effective labor, inputs can be realigned in response to the higher w/r.

2.3 A Summary of Level Effects on the Balanced Growth Path

It is convenient to categorize the effect of an inflation rate increase on the equilibrium into four groups: Baumol-type exchange effects, output-type effects, Tobin-type input effects, and other aggregate effects.

1. The share of purchases made with money a falls, credit services output rises, and time in credit services l_F rises.

2. Substitution from c/h to x implies that c/h falls and x rises if the substitution effects dominate any income effects. The income effects come from less output when resources are devoted to credit services, a negative effect, and from the inflation tax transfer back to the agent, a positive effect.

3. There are numerous effects that can be categorized in the input reallocation area. First consider that analysis and calibration confirm that w rises, r falls, and the ratio w/r rises. This implies an increase in the capital/effective-labor ratios, of the total economy, $k/[h(l_H + l_H)]$ where $l_G + l_H$ is the productive effective labor that is used in sectors with physical capital, and in these ratios for each sector, $s_G k/l_G h$ and $s_H k/l_H h$. Further, as labor is devoted to leisure and credit services, and as the capital/effective-labor ratio is increased, these effects would both go in the direction of reducing the labor shares l_G and l_H. And with c/h falling, this effect would go in the direction of shifting the share of physical capital from the goods sector to the human capital sector, making s_G fall and s$_H$ rise. And this implies, given that the capital intensity of both sectors must rise, that l_G would have to fall by more than l_H.

Fourth, changes in certain aggregates are the other important set of Tobin-related effects. The savings rate, defined as the investment-output ratio i/y, should rise since the physical capital to effective labor ratio is rising. The ratio of output to physical capital to output y/k should fall since the physical capital to effective labor ratio is rising while the agent is substituting away from consumption goods. Similarly, the ratio of consumption goods to physical capital c/k should fall for the same reasons, and should fall by more that y/k rises. The effect on k/h depends on several factors. For the case of no credit services sector, there is no leakage of human capital outside of goods and human capital production, and the return on both human and physical capital remains equal at a lower rate when inflation increases. Add to this an equal capital intensity in each sector, as we do in the baseline calibration in that we set $\beta = \delta$, then there should be no redistribution of k relative to h because of the input effect, and in this case k/h should stay the same. However with credit services included, some human capital gets diverted to this non-productive activity away from goods and human capital production, requiring more human capital overall in order to keep the ratio of physical capital to productive human capital the same. Thus the overall ratio k/h should decline within the three sector economy for the baseline. Finally are the productivity levels. The ratio of goods output to effective labor in the goods sector is effected by labor falling to a strong degree, because of substitution to credit and leisure, and by y/h falling to a small degree as output gets shifted from consumption towards investment as the capital to effective labor ratios rise. So $y/l_G h$ should rise. Similarly $c/l_G h$ should rise but by less since y/c is rising. In the human capital sector, output should rise relative to the effective labor input since the physical capital to effective labor ratio is rising; this implies $H/l_H h$ increases. Note that the growth rate of output to effective labor, $y/l_g h$, is zero, while the growth rate of output to raw labor is the same as the balanced-path growth rate.

3 Baseline Calibration

The calibration is geared first towards seeing if a high enough magnitude of the inflation-growth effect exists with standard parameter values. Finding this, we choose such a parameter set as our baseline calibration. Second, as the credit services sector is still novel in the literature, we report the model's results with a range of values for the technology parameters of the credit services sector.

3.1 The assumptions

We start the baseline with a growth rate of 2%, as in Chari and Manuelli (1996), an inflation rate of 5%, and a rate of time preference of 4%. Next we set the value for leisure at x=0.7, similar to the 0.69 in Jones and Rossi (1993). We set the intertemporal elasticity of substitution θ equal to 1.5, as in Gomme (1993). This ranges usually between 1 and 2 in the literature. Increasing θ tends to make the negative inflation-growth effect smaller. We set the utility parameter for leisure, α, at 4.69, within the range of estimates in the literature. The depreciation rates of both physical and human capital are 0.1, as in King and Rebelo (1990). The Cobb-Douglas parameters for the effective labor intensity in the goods and human capital sectors are both set equal, at $\beta = \delta$=0.64 as in Gomme (1993), while S. Rao Aiyagari and Eckstein (1998) set these both equal at 0.62. The shift parameters of the sectoral production functions are given at $A_G = 1$, $A_H = 0.58$, and $A_F = 0.80$. For other parameters relating to the exchange technology, the share of cash is a=0.7, similar to Ireland and Lacker (1996). The degree of diminishing returns in the credit services sector is initially set at $\gamma = 0.2$. Values of 0.21 and 0.26 are found by Gillman and Otto (2000) when estimating money demand for the US and Australia using the last quarter of the century quarterly data, based on the same money demand model as in the economy of this paper. We also present the calibration with alternative values of γ. The parameters and baseline variable values, which are used below in Tables 2-6, are summarized in Table 7.

3.2 The Results

The Growth Effect We show results for the baseline calibration for an inflation rate increase from 5 to 15%, from 15 to 25%, and from 25 to 35%, in Tables 2, 3, and 4. The first five data columns of each table show the calibration for alternative values of , at 0.2, 0.3, 0.5, 0.6 and 0.8. First note in Table 2 that for all γ the estimate for the decrease in the balanced-growth rate of g is above 0.20%, the bottom of the Chari and Manuelli (1996) range. For γ=0.2, the baseline, the negative growth effect is -0.23%. This also can be compared to the panel data, econometric, result that Gillman and Matyas (2001) find for OECD countries grouped into three average annual inflation rates for the 1961-1997 period, making adjustment for fixed and period effects. For the range of countries in the low inflation category defined as those with 0 to 10% annual average inflation rates, they find in a regression of the growth rate on the log of one plus the inflation rate, a semi-elasticity coefficient equal to -0.23=$(1 + \pi) \left[dg/d\left(1 + \pi\right)\right]$. Given a sample mean inflation rate of around 4%, the -0.23 estimate corresponds to a 0 to 4% change in the inflation rate. Factoring 0.23 by 0.10/0.4=2.5, gives an approximate estimate of -0.57 for a 0 to 10% increase in the inflation rate, as compared to our calibration of -0.23. The other key feature of the inflation-growth effect in Table 2 is that as the inflation rate rises, the growth effect becomes smaller in magnitude. From -0.23 it drops to -0.20 and to -0.17 for the 10% increases in the inflation rate up to 25% and then up to 35%. Following Khan and Senhadji (2000) non-linearity findings, Gillman and Matyas (2001) find the same type of non-linearity with the three inflation groupings for OECD countries: an inflation-growth semi-elasticity of -0.23 for the low range, -0.15 for the middle range of 11 to 20%, and -0.11 for the high range of over 20%. This kind of non-linearity is a feature characterized in Gillman and Kejak (2000) as coinciding with the increased interest elasticity of money demand (or of tax avoidance more generally) as the inflation tax goes up. Our calibration, given at the bottom of Table 2, is that the magnitude of the interest elasticity rises as the inflation rate goes up, from 0.175, to 0.221, to 0.262. The greater elasticity means less substitution towards leisure and more towards credit instead of money in the purchase of goods. This decreasing substitution towards leisure is also evident in the tables, as leisure first increases by 0.009 in Table 2, and then by 0.008 and 0.007 in Tables 3 and 4.

Finally for the inflation-growth effect note that with increases in the credit sector coefficient γ, the magnitude of the inflation-growth effect becomes bigger. This coefficient is the degree of diminishing returns to labor in the production of credit services, and equally can be shown to be the share of labor in credit services output (see Gillman and Kejak (2000)). Because the profit of credit services production is returned to the agent as a lump sum transfer, while the labor time used in credit services is lost from total resources, the higher is the share of labor relative to entrepreneurial capacity and profits, the more are resources used up. Thus the more negative is the inflation-growth effect. Or viewed from the money demand angle, as the share of labor in credit services increases, credit is more costly, and substitution out of money is less. This is reflected in a lower magnitude of the interest elasticity of money demand, more leisure usage, and a bigger magnitude of the inflation- growth, and the level, effects.

The Level Effects The level effects of inflation go in the direction as indicated in the equilibrium analysis of the Section 3. The goods ratios of c/h and c/k both fall, while leisure rises, the real wage rises, the real interest rate falls, and the physical capital to effective labor ratios rise. The savings rate rises and the output to capital ratio y/k falls. The levels of the productivity of effective labor rise across sectors. The use of money falls relative to credit. As the inflation rate rises, these effects are all smaller in magnitude. This shows the fuller dimensions of the non-linearity described above.

One interesting reallocation is that the output of the human capital sector rises relative to the goods sector. This can be seen in that the human capital sector gets more of the physical capital share and the goods sector less. This is because of the substitution effect of c/h going down as x goes up. Because both sectors have the same capital intensity, in that $\beta = \delta$, there is not an additional Stolper-Samuelson type expansion of the one sector over the other due to the input price changes. The ratio k/h falls in the model with credit services while $k/h[(l_G + l_H)]$ rises; this can be interpreted as being due to the less efficacious use of human capital as a result of more leisure use. Because of the greater unused capacity of human capital, more has to be produced relative to physical capital even while achieving a higher physical capital to effective labor ratio in both goods and human capital sectors.

The Role of Capital Intensity We also provide in Table 5 a calibration with the goods sector more capital intensive than the human capital production sector, in that $\beta < \delta$. The growth and level effects are almost all more pronounced. There is greater substitution away from the human capital sector because now it is more labor intensive than goods production, and because w/r rises with the inflation rate. Less human capital accumulation leads to less growth. Notice again that the level of the magnitude of the interest elasticity falls relative to when $\beta = \delta$, a reflection of more substitution towards leisure and of less growth. A different capital intensity across sectors changes the results for the k/h ratio. With a credit sector, some of the human capital gets used up in credit services, and so k/h may rise or fall if the use of h in credit services is high. In Table 5 the k/h ratio does rise for cases of a high γ when credit is more costly and less used, but there are cases such as with the baseline γ in Table 2 when k/h decreases.

4 Comparison with Alternative Exchange Technologies

4.1 Case 1: Cash-only Economy

The cash-only economy is a special case of the Section 2 model. Setting a=1, rather than making the proportion of cash usage a choice variable, achieves the cash-only economy as first set out in Lucas (1980). For the calibration, the parameters are the same as for the baseline and the results are given in the last column of Table 2. An increase in the inflation rate causes a relatively big change in leisure and in the growth effect. This is because there is no credit available to ease the burden of having to substitute away from goods entirely in order to avoid the inflation tax. The non-linearity in the inflation-growth effect is evident also with the cash- only model, although somewhat less pronounced. This coincides with the interest elasticity of money demand being lower in magnitude for all inflation rates as compared to the baseline model. Also the bigger leisure and growth effect is reflected in a bigger effect on the input price ratio w/r. This establishes a sense in which the cash- only model represents an overstatement of the magnitude of the effect of inflation. For the highest value γ of for which we report results, γ=0.8, the cash-only growth effect is comparable to the credit sector model. But the initial evidence in Gillman and Otto (2000), that finds a γ between 0.2 and 0.3, makes such a high γ less plausible. Table 2 shows that the effects on other variables all go in the same direction as in the Section 2 model, except for k/h, but the magnitudes differ. The effects on the real interest rate, the real wage, the ratio of w/r, the sectoral physical capital to effective labor ratios, and the c/h and c/k ratios are larger than the Section 2 model, for all values of γ presented in the tables. As for k/h with $\beta = \delta$ and with no leakage of h into a credit sector, k/h stays constant as in Gomme (1993) rather than declining as in the model with costly credit. With $\beta < \delta$, k/h increases because of the shift towards the capital intensive sector when the price of capital falls relative to that of labor.

4.2 Case 2: Fixed Cash Good, Credit Good Economy

We find that the Lucas and Stokey version of our economy can yield a large range of results, depending crucially on the utility parameterization for the degree to which the cash good and credit good are substitutes. The more closely are the goods substitutes, then the easier it is to avoid the inflation tax through good to good substitution, rather that through goods to leisure substitution. As a result, a closer substitutability of goods, with no resource cost of making the substitution, makes the effect of inflation on growth of smaller magnitude. Thus the Lucas and Stokey economy is in this sense very versatile in being able to give a strong or a weak effect. Restricting these substitution- related utility parameters requires some beliefs about the interest elasticity of money demand, or some other outside implied value. For this we choose the magnitude of the inflation-growth effect. We calibrate a version of the Lucas and Stokey utility function that Chari and Manuelli (1996) use, so that the inflation-growth effect is -0.22%, close to our baseline and at the bottom of the Chari et al range.

Goods are specified as cash or credit, denoted by c_{1t} and c_{2t}, and there is no resource cost to using credit. Thus l_{Ft} is zero. The Hamiltonian is

$$\begin{aligned} H &= e^{-\rho t}\left\{\left[\left(c_1^{-\lambda}+\eta c_2^{-\lambda}\right)^{-1/\lambda}\right]x^{\alpha(1-\theta)}\right\}/\left[1-\theta\right] \\ &\quad +\phi_t\left(M_t - P_t c_{1t}\right)+\varphi_t(Q_t - M_t - P_t k_t) \\ &\quad +\lambda_t\left[r_t P_t s_{Gt}k_t + w_t P_t l_{Gt}h_t - P_t c_t + V_t - \delta_k k_t + P_t k_t\right] \\ &\quad +\mu_t\left[A_H\left(\left[1-s_{Gt}\right]k_t\right)^{1-\delta}\left(\left[1-x_t-l_{Gt}\right]h_t\right)^{\delta}-\delta_h h_t\right]. \end{aligned} \tag{20}$$

The first-order conditions are largely the same, except for the marginal rates of substitution amongst outputs. The real interest rate still equals the marginal product of effective labor in producing human capital, factored by $(1-x)$. Without time spent in credit services, the shadow exchange cost of the credit good is zero. This yields the marginal rates of substitution $u_{c_1}/u_{c_2} = 1+R$; $u_{c_1}/u_x = (1+R)/wh$; and $u_{c_2}/u_x = 1/wh$. We find for our calibrations that w rises with inflation by less than x. By this, these margins imply that inflation induces substitution from cash to credit goods, from cash goods to leisure, and from leisure to credit goods.

The calibration results are very similar to the baseline model. The additional utility parameters in the calibration are $\alpha = -0.5$ and $\eta = 0.7$. One notable difference is that the effect on the savings rate is much smaller in the Lucas and Stokey model. The reallocation from consumption towards investment, another way to view the Tobin effect of the model, is less than in the baseline or the cash-only models. This may be due to the fact that no resources are being used up in a credit sector, so that less new physical capital is required to adjust the physical capital to effective labor ratios. Also the k/h ratio is constant for equal capital intensities across goods and human capital sectors, and the ratio rises for $\beta < \delta$. This is the same qualitative effect as the cash-only economy because both lack any use of resources in the production of credit services. Also note that the non-linearity of the effects is present in this model as in the baseline and cash-only cases.

4.3 Comparison to the McCallum Goodfriend Economy

Gillman and Kejak (2000) show that the model of section 2, modified so that there is no physical capital, is a special case of the McCallum and Goodfriend (1987) economy. In fact the exact same special case holds for the economy of Section 2 with capital included. The special case results because only effective labor is used in credit services production; if physical capital were also used to produce credit services, it would be more general than McCallum-Goodfriend. The special case is that the shopping time of the McCallum and Goodfriend exchange constraint becomes instead the banking time of an explicit production technology. This gives micro-foundations that switches the burden of calibration away from ubiquitous transaction cost parameters towards the parameters of the credit services technology, especially γ in the Section 2 model.

4.4 Including A Tax on Income

Keeping all parameters the same, while including a small income tax as set up in the Chari and Manuelli (1996) model, causes a slight decrease in the magnitude of the negative inflation-growth effect. With a tax rate of 0.05%, Table 6 shows that the magnitude of the effect, from increasing the inflation rate from 5 to 15%, drops from -0.232 to -0.223. To impose a tax rate of -0.22% as in Chari et al, we are able to still keep most of the parameters and baseline values of variables the

The effect of change in inflation rate on BGP values**							
Model	**c/h**	**k/h***	**i/h**	**$\mathbf{l_G}$**	**c/y**	**i/y**	**k/y**
Sidrauski	0	0	0	0	0	0	0
CIA (c)	0	0	0	-	0	0	0
CIA (c,i)	-	-	-	-			
Tobin	?	+	+	0			
Sect. 2 & 3 Models	-	+	+	-	-	+	+
Data	-	+	+	-	-	+	+

* In the models of Sections 2 and 3, the relevant physical capital to human capital ratio is $k/[h(1-x)]$, since leisure is not indexed by human capital in its usage.
** The table is based on Ahmed and Rogers (2000) and our results.

Table 1: The effect of change in inflation rate on BGP values of variables.

same, and find a growth rate decrease of -0.219 for an inflation rate increase from 5 to 15%.

5 Comparison to Other Findings: Calibrations and Empirics

Ahmed and Rogers (2000) find that c/y falls while i/y rises, as in our results. They compare their results to four other models of exogenous growth of different classes: Sidrauski, cash-in-advance (no credit) applied to consumption goods, cash-in-advance applied to both consumption and investment goods, and Tobin. Their table of the qualitative results of the effect of inflation, is here reproduced in the four rows and three columns; then we extend the table two additional rows and three additional columns that we supply, using the results of our models and the results reported by Ahmed and Rogers:

Table 1 shows that the model of section 2, as well as ones that we supply with alternative exchange technologies in section 3, capture the effects that Ahmed and Rogers focus on but cannot explain with exogenous growth models. With a similar model to our cash-only case, Gomme (1993) finds as in our results that the c/h ratio falls as the inflation rate increases, y/h falls, and that k/h remains the same given that the Cobb-Douglas coefficients for in the goods and human capital sectors are the same. He also has leisure increasing, the share of labor time in goods production decreasing, and the share of capital in goods production decreasing, as in our results. Ahmed and Rogers note the Gomme paper in discussing how the positive Tobin effect does not exist in endogenous growth economies. But the constancy of the k/h ratio is not an indicator of whether the real interest rate changes. It is only the capital to effective labor ratio in each sector that determines this and Gomme does not report this. But we detail how these ratios fall in Tables 2-4.

On growth, Chari and Manuelli (1996), without a Lucas type function for human capital, present an estimate of the inflation- growth effect of -0.009% in increasing the inflation rate from 10 to 20%, compared to our baseline of -0.23, and compared to the -0.2 to -0.7% range that Chari et al find from surveying econometric estimates. Gomme (1993), while studying the effect of stochastic shocks, reports a -0.0139 decrease in the quarterly growth rate from a 0 to 10% inflation rate change along the balanced-growth path. This is -0.0556 on an annual basis as compared to our estimate of -0.23. Gomme's economy along the balanced-growth path is nearly the same as our economy in the cash-only case. However we choose a higher value for α, the preference for leisure, of 4.69 as compared to 3.38 in Gomme.

Employment Rate Note that, although there is no unemployment in the model, the increase in leisure time as a result of an inflation increase is equivalent to a decrease in time spent working. Thus the model offers a monetary type explanation for part of the decrease in working time experienced over the stagflation period, that for example Ljungqvist and Sargent (1998) explain through the disincentive to work because of the welfare systems. Here we instead tie together the decrease in the balanced-growth rate with a decrease in the employment rate through an inflation rate increase.

Productivity Growth Rate Productivity in terms of its growth rate is the same as the output growth rate. Defined as output divided by the raw labor time input, the growth rate equals the growth rate of output minus the zero growth rate of the labor input on the balanced- path. So productivity growth goes down in our model as a result of inflation on the balanced-growth path and there is a lot of empirical support for this. P. (1982) and Ram (1984) finds such a relation for US postwar annual data. Selody (1990) similarly finds for the US and Canada that a 1 percentage point increase in inflation causes a 0.1 to 0.2 percentage point decrease in labor productivity growth. Smyth (1995) finds such a negative relationship, of a slightly larger magnitude, in Germany for the period 1951-1991. Similar findings are in Buck and Fitzroy (1988) for West Germany and Cozier and Selody (1992) for an OECD sample.

A Positive Inflation Effect Some empirical work finds a positive effect of inflation on the growth rate of output. However a careful examination shows that this can result because developing countries are sampled together with developed countries. Khan and Senhadji (2000) test for the existence of a threshold inflation rate, above which the inflation growth effect is negative and below which the effect is positive. They find for the APEC countries in a postwar panel study, after adjusting for fixed and period effects, that the threshold inflation rate is 11%, while for the OECD sample it is 1%. This means that for inflation rates 1% or above there is a negative effect of inflation on growth for the OECD countries. Gillman and Matyas (2001) divide the countries in a similar postwar panel sample into three average inflation rate groupings: from 0 to 10%, from 11 to 20%, above 20%. Also with adjustment for fixed and period effects, they find a strongly significant negative effect of inflation on growth for all three ranges of the OECD countries. Also consistent with Khan and Senhadji (2000), for the APEC countries they find that the effect is positive and insignificant for the 0 to 10% inflation rate range, and negative and with some significance for the higher ranges. As we view our model as explaining the developed countries, we find its results consistent with this evidence. If the model were extended to show that inflation avoidance helps develop capital markets in developing countries, then the model might be able to explain such a positive effect at low inflation rates (See Gillman and Kejak (2000)).

Also it is important to note the difference between cumulative effects of inflation on growth and the marginal effect. Bruno and Easterly (1998) finding that the negative effect of inflation is of large magnitude in high inflation countries is consistent with our model. This is the cumulative effect of a high inflation rate.

The existence of the non-linearity in our model means that the marginal decrease in the growth rate from additional inflation rate increases is smaller the higher is the inflation rate. But the cumulative effect of course is higher in high inflation rate countries than in low inflation rate countries.

Related to this non-linearity, our results and explanation are somewhat counter to that of Dotsey and Sarte (2000). As in Ireland (1994), Dotsey and Sartre find no effect of inflation on growth in a deterministic AK model with a standard cash-only Clower constraint. They state that this model relates to developed countries, citing specifically the US and the OECD for which they suggest that an insignificant growth effect would be consistent with their model. Further they state that such a zero or insignificant inflation-growth effect captures the phenomena of the Chari and Manuelli (1996) model, which as mentioned above yields a very small marginal decrease in the output growth rate from an inflation rate increase from 10 to 20%. Dotsey and Sarte also impose the cash-in-advance constraint on the purchase of capital, a case of their model that they associate with developing countries, and find a negative effect of inflation on growth. Further, they also randomize the money supply process and find that the variability of inflation increases the output growth rate. They reason that the combined negative and positive effects may explain why even in high inflation countries the negative growth effect of inflation is not found. In this argument, the high inflation-mean countries are the high inflation-variance countries, and these are the developing countries that correspond to the added cash constraint on investment. So while their growth rate is more negative from a high level of inflation, the negative effect is offset to some degree by the positive effect of the variability of inflation. By this logic, Dotsey and Sarte suggest that both developed and developing countries may show an insignificant effect. Our model and the panel data evidence cited above go contrary to this characterization, with a strong negative effect of inflation in developed countries, albeit one that gets weaker as the inflation rate rises. Our explanation of the growth effect is also quite different, being based on a King and Rebelo (1990) approach, whereby substitution towards leisure in a human capital setting endogenously determines the growth rate.

Interest Elasticity General equilibrium models of money demand that are matched to evidence include Eckstein and Leiderman (1992), Easterly and Schmidt-Hebell (1995), and Gillman and Otto (2000). In each of these, a rising magnitude of the interest elasticity of money demand, with the inflation rate, is critical in explaining features of the data such as seigniorage or money demand as a percent of income. Similarly, Marty (1999), Mulligan and i Martin (2000), and Hsing (1989) all focus on how the magnitude of the interest elasticity empirically needs to move with the inflation rate in order to explain money demand. In partial equilibrium, this result is similar to the Cagan money demand function, in which a constant semi-interest elasticity implies a total interest elasticity that rises in magnitude with the inflation rate. Lucas (2000) suggests that the constant semi-interest elasticity model better fits recent decades of US experience than the constant elasticity model. In our model, total elasticity rises and the semi-interest elasticity actually falls slightly in calibrations as the inflation rate rises. However, this slightly falling semi-interest elasticity with a rising total elasticity is a result supported specifically by Petrovic, Zorica, and Mladenovic (2000).

6 Qualifications and Conclusions

The exchange technology approach is advantageous to the task because it includes a basic distortion of the inflation-growth effect that Chari and Manuelli (1996) emphasize: the substitution from inflation-taxed exchange to non-exchange goods, or simply from goods to leisure in some models. This distortion causes both level effects on the "great ratios" and growth rate effects when framed in an endogenous growth setting. With an investment process that requires costs of adjusting the stock, as in Lucas (1988), this inflation-growth effect is of a sufficiently high magnitude to fall within the range of the evidence, because inflation-induced leisure use significantly decreases the return to human capital. Is leisure a realistic channel through which inflation works in part? If it is then the employment rate should fall when inflation is accelerating and should rise when inflation is decelerating. Our postwar stagflation experience certainly does not contradict this. Other explanations are possible, such as Ljundqvist and Sargent's focus on the welfare state. But certainly a monetary explanation such as ours cannot yet be ruled out and deserves further study. The leisure increase from inflation is another dimension of this analysis, a kind of flip-side to the increase in the real-wage to real interest rate, and the increase in capital intensity.

The negative effect of an increase in the inflation rate on the balanced-growth rate is perhaps the most prominent part of our model, and one that recent panel data supports, but still just one of many interrelated effects. The growth rate effect coincides with the effect of inflation on the rest of the variables of the equilibrium. Since Friedman and Schwartz (1963) emphasized the negative effects of unexpected inflation changes, and Cooley and Hansen (1989) found little such evidence in calibrations, whether inflation can have a seriously detrimental effect has continued to be examined. Lucas (1996) reviews how inflation can cause transitory effects in a business cycle model, in his Nobel Lecture, and he suggests a fuller examination of the effect of changes in stationary inflation rates. The inflation and growth literature examines this empirically with cross-section and panel work, and theoretically with calibration.

Our findings in this paper show a range of phenomena effected by inflation on the balanced- growth path, whereby both growth and level effects, qualitatively and to some degree quantitatively, appear consistent with the empirical evidence so far. We categorize these effects into output-type effects, Tobin-type inputs realignments, and Baumol-type exchange effects. Together, they imply a high inflation, low growth, low employment rate environment similar to the stagflation of the 1970s and 1980s. And in reverse, the model may help explain the lower inflation, higher growth, higher employment period of the 1990s, in industrial nations. The consistency of the model with other empirical findings, such as the relation between inflation and the investment/output ratio, shows a wider set of related effects that emerge as a candidate for defining more broadly the stagflation experience. And we find that the magnitudes of the various effects from inflation are closely interrelated. The strength of the changes depends on the degree of substitution towards leisure that an increase in the inflation rate induces. The bigger is the leisure substitution, the bigger the growth effect, and the changes in input prices and in capital to effective labor ratios. And the more non-linear is the inflation-growth effect, the more non-linear are the changes in the levels of variables and in the ratios of the variables, growing weaker as the inflation rate rises and the substitution towards leisure lessons.

We also show in the paper that although calibration of the estimate of the inflation-growth effect is not highly sensitive to the nature of the exchange technology, alternative exchange technologies do in general cause differences in the magnitude of the effect on ratios and growth rates. But the microfoundations of a credit sector exchange technology help resolve issues that the standard models cannot address. These are an explanation of the interest elasticity of money demand, the degree of substitution towards leisure and towards banking, and the magnitude of the growth and level effects, in terms of the parameters of the credit production function. Further research can explore with this model how the degree of financial development effects the level and growth effects, which here we leave mostly unexplored. And the relation of the credit productivity shift parameter, to the shift parameters of the goods and human capital sectors, was left free in our model and should be able to be better pinned down with empirical evidence.

Studying the transition path and the relation of growth and level effects along it remains fertile ground, as Einarsson and Marquis (1999) show. For example, it would be useful to see whether the transition to a lower productivity growth rate implies a big drop initially in productivity. If so, this may offer a monetary approach that helps explain the 1970s productivity slowdown described in a non-monetary fashion in "1974" (Greenwood and Mehmet (1997)). And it may be useful in explaining the drop in output that transition countries experienced after the dramatic 1989 political changes that swept Soviet regimes out of power. However, here the productivity drop would likely have to be combined with a large increase in the inflation rate since these countries mostly had to resort initially to printing money in order to cover their deficits; both of these could be encompassed in the model of the paper.

Quantitative research could further investigate whether internationally, during the Stagflation period, the inflation rate increase caused pressure towards a falling real interest rate to real wage ratio and rising capital intensities as the Tobin feature of the model predicts. It also could investigate other monetary dimensions internationally, such as the relation of the bank sector and the interest elasticity to the inflation rate. Extension of the model to a stochastic, business cycle, setting within endogenous growth, with shocks to the credit sector technology along as well as to inflation and productivity, may be useful for developing the financial crisis literature such as that of Kiyotaki (1998). And it would be useful to sort out the link between the effect of inflation variability on the average growth rate in our Gomme (1993) - type endogenous growth economy, as do Dotsey and Sarte (2000) in their Ireland (1994)-type AK economy.

Extending our model to include capital in the credit services sector proves difficult in the current model because of an inability of a well-defined ratio of capital to effective labor in the banking sector as the nominal interest rate approaches the Friedman optimum at a zero interest rate. We view this less as a failing of the model and more as a consequence of the agents inability to earn a competitive return on capital that provides a service that competes with a zero-cost commodity, being cash. We speculate that should the model be extended so as to include the costly supply of government money, then capital in banking can be included in the model and can earn the real rate of interest in the optimum. The lack of capital in the credit services sector introduces certain asymmetries into the model because only labor is used in banking, and lost to society, while the profits of banking are not lost to society but rather returned to the consumer as banker as a lump sum income transfer. With a CRS production function of credit services with capital and labor, both inputs are used up in the credit services activity and this seems a more appealing analysis. A further extension that gives the credit value for intertemporal smoothing purposes could capture the tradeoff between the waste from avoiding inflation and the benefit of establishing capital markets.

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The effect of increasing the inflation rate from 5% to 15%							
	Section 2 Model					**L&S**	**CIA**
5%-15%	$\gamma = 0.2$	$\gamma = 0.3$	$\gamma = 0.5$	$\gamma = 0.6$	$\gamma = 0.8$		
g	-0.00232	-0.00271	-0.00336	-0.00360	-0.00380	-0.00221	-0.00367
x	0.00879	0.01025	0.01272	0.01366	0.01442	0.00884	0.01535
r	-0.00321	-0.00376	-0.00469	-0.00504	-0.00533	-0.00322	-0.00572
w	0.01055	0.01251	0.01586	0.01712	0.01813	0.01052	0.01985
w/r	0.83588	1.01986	1.34289	1.46516	1.56149	0.82203	1.79918
a	-0.04204	-0.04482	-0.02770	-0.01422	-0.00025	-0.03853	0.00000
s_H	0.00196	0.00215	0.00172	0.00131	0.00085	0.00048	0.00093
s_G	-0.00196	-0.00215	-0.00172	-0.00131	-0.00085	-0.00048	-0.00093
I_F	0.00090	0.00095	0.00059	0.00031	0.00001	0.00000	0.00000
I_H	-0.00383	-0.00447	-0.00555	-0.00596	-0.00629	-0.00385	-0.00670
I_G	-0.00587	-0.00674	-0.00777	-0.00801	-0.00814	-0.00499	-0.00866
c/k	-0.00364	-0.00419	-0.00478	-0.00490	-0.00494	-0.00298	-0.00529
c/h	-0.00393	-0.00449	-0.00491	-0.00489	-0.00479	-0.00289	-0.00513
M/Ph	-0.00816	-0.00940	-0.00822	-0.00663	-0.00482	-0.00687	-0.00513
$y/I_G h$	0.01649	0.01955	0.02477	0.02675	0.02834	0.01644	0.03102
$H/I_H h$	0.00957	0.01135	0.01438	0.01553	0.01645	0.00955	0.01801
F	0.00725	0.00771	0.00478	0.00247	0.00005	0.00000	0.00000
c/y	-0.00217	-0.00243	-0.00222	-0.00193	-0.00159	-0.00090	-0.00174
s=i/y	0.00217	0.00243	0.00222	0.00193	0.00159	0.00090	0.00174
$s_G k/y$	0.04091	0.04866	0.06195	0.06697	0.07098	0.04073	0.07816
k/y	0.08909	0.10482	0.12595	0.13199	0.13590	0.07774	0.14975
$i/l_G h$	0.01102	0.01287	0.01499	0.01545	0.01565	0.00901	0.01718
$c/l_G h$	0.00547	0.00668	0.00979	0.01131	0.01269	0.00743	0.01385
$G/l_G h$	0.01649	0.01955	0.02477	0.02675	0.02834	0.01644	0.03102
$H/l_h h$	0.00957	0.01135	0.01438	0.01553	0.01645	0.00955	0.01801
$s_G k/l_G h$	0.09812	0.11722	0.15007	0.16249	0.17238	0.09747	0.19121
$s_H k/l_H h$	0.09812	0.11722	0.15007	0.16249	0.17238	0.09747	0.19121
k/h	-0.00312	-0.00334	-0.00210	-0.00110	-0.00002	0.00000	0.00000
K/h[1-x]	0.08701	0.10518	0.14238	0.15848	0.17231	0.09747	0.19121
$k/[h(l_G + l_H)]$	0.09812	0.11722	0.15007	0.16249	0.17238	0.09747	0.19121
Level of ε	-0.1751	-0.17206	-0.12739	-0.09909	-0.07059	-0.15376	-0.08335

Table 2: The effect of increasing the inflation rate from 5% to 15%.

The effect of increasing the inflation rate from 15% to 25%							
	Section 2 Model					**L&S**	**CIA**
15%-25%	$\gamma = 0.2$	$\gamma = 0.3$	$\gamma = 0.5$	$\gamma = 0.6$	$\gamma = 0.8$		
g	-0.00199	-0.00228	-0.00286	-0.00314	-0.00348	-0.00183	-0.00350
x	0.00825	0.00942	0.01173	0.01289	0.01430	0.00758	0.01370
r	-0.00304	-0.00350	-0.00439	-0.00484	-0.00538	-0.00279	-0.00520
w	0.01031	0.01204	0.01552	0.01724	0.01930	0.00937	0.01906
w/r	0.87546	1.06697	1.46524	1.66316	1.89484	0.78198	1.98486
a	-0.03319	-0.03821	-0.03005	-0.01897	-0.00090	-0.03850	0.00000
s_H	0.00228	0.00263	0.00237	0.00186	0.00096	0.00043	0.00090
s_G	-0.00228	-0.0263	-0.00237	-0.00186	-0.00096	-0.00043	-0.00090
l_F	0.00104	0.00118	0.00092	0.00059	0.00003	0.00000	0.00000
l_H	-0.00360	-0.00411	-0.00512	-0.00562	-0.00624	-0.00330	-0.00598
l_G	-0.00570	-0.00649	-0.00754	-0.00786	-0.00809	-0.00427	-0.00772
c/k	-0.00361	-0.00414	-0.00477	-0.00493	-0.00501	-0.00258	-0.00482
c/h	-0.00397	-0.00454	-0.00505	-0.00505	-0.00487	-0.00250	-0.00467
M/Ph	-0.00675	-0.00822	-0.00837	-0.00723	-0.00497	-0.00643	-0.00467
$y/l_G h$	0.01610	0.01881	0.02424	0.02693	0.03015	0.01464	0.02977
$H/l_H h$	0.00935	0.01092	0.01408	0.01564	0.01750	0.00850	0.01729
F	0.00882	0.01009	0.00789	0.00499	0.00024	0.00000	0.00000
c/y	-0.00246	-0.00285	-0.00279	-0.00243	-0.00175	-0.00081	-0.00170
s=i/y	0.00246	0.00285	0.00279	0.00243	0.00175	0.00081	0.00170
$s_G k/y$	0.04028	0.04728	0.06136	0.06833	0.07663	0.03654	0.07615
k/y	0.09094	0.10673	0.13069	0.13939	0.14751	0.06986	0.14638
$i/l_G h$	0.01135	0.01327	0.01575	0.01643	0.01685	0.00806	0.01664
$c/l_G h$	0.00475	0.00554	0.00849	0.01050	0.01330	0.00658	0.01314
$G/l_G h$	0.01610	0.01881	0.02424	0.02693	0.03015	0.01464	0.02977
$H/l_h h$	0.00935	0.01092	0.01408	0.01564	0.01750	0.00850	0.01729
$s_G k/l_G h$	0.09762	0.11531	0.15101	0.16866	0.18960	0.08833	0.18991
$s_H k/l_H h$	0.09762	0.11531	0.15101	0.16866	0.18960	0.08833	0.18991
k/h	-0.00378	-0.00434	-0.00348	-0.00223	-0.00011	0.00000	0.00000
$K/h[1\text{-}x]$	0.08357	0.09886	0.13755	0.16001	0.18918	0.08833	0.18991
$k/[h(l_G + l_H)]$	0.09762	0.11531	0.15101	0.16866	0.1896	0.08833	0.18991
Level of ε	-0.2214	-0.22938	-0.19209	-0.15717	-0.1043	-0.23329	-0.09796

Table 3: The effect of increasing the inflation rate from 15% to 25%.

The effect of increasing the inflation rate from 25% to 35%							
	Section 2 Model					**L&S**	**CIA**
25%-35%	$\gamma = 0.2$	$\gamma = 0.3$	$\gamma = 0.5$	$\gamma = 0.6$	$\gamma = 0.8$		
g	-0.00173	-0.00194	-0.00241	-0.00269	-0.00318	-0.00152	-0.00325
x	0.00706	0.00784	0.00962	0.01074	0.01148	0.00586	0.00631
r	-0.00263	-0.00294	-0.00365	-0.00410	-0.00440	-0.00218	-0.00243
w	0.00915	0.01045	0.01342	0.01525	0.01656	0.00749	0.00925
w/r	0.83100	1.00227	1.40693	1.65677	1.85542	0.66204	1.07055
a	-0.02591	-0.03153	-0.02949	-0.02157	-0.00183	-0.03445	0.00000
s_H	0.00234	0.00281	0.00283	0.00235	0.00093	0.00035	0.00044
s_G	-0.00234	-0.00281	-0.00283	-0.00235	-0.00093	-0.00035	-0.00044
l_F	0.00105	0.00125	0.00116	0.00086	0.00007	0.00000	0.00000
l_H	-0.00308	-0.00342	-0.00420	-0.00469	-0.00501	-0.00256	-0.00276
l_G	-0.00504	-0.00567	-0.00658	-0.00691	-0.00654	-0.00331	-0.00356
c/k	-0.00326	-0.00370	-0.00429	-0.00446	-0.00413	-0.00201	-0.00225
c/h	-0.00363	-0.00415	-0.00469	-0.00472	-0.00404	-0.00195	-0.00218
M/Ph	-0.00540	-0.00681	-0.00768	-0.00704	-0.00425	-0.00545	-0.00218
$y/l_G h$	0.01429	0.01633	0.02097	0.02383	0.02587	0.01170	0.01445
$H/l_H h$	0.00830	0.00948	0.01218	0.01384	0.01502	0.00679	0.00839
F	0.00940	0.01134	0.01048	0.00764	0.00064	0.00000	0.00000
c/y	-0.00248	-0.00296	-0.00312	-0.00278	-0.00161	-0.00065	-0.00084
s=i/y	0.00248	0.00296	0.00312	0.00278	0.00161	0.00065	0.00084
$s_G k/y$	0.03603	0.04141	0.05367	0.06122	0.06667	0.02940	0.03736
k/y	0.08434	0.09828	0.12122	0.13111	0.12949	0.05629	0.07200
$i/l_G h$	0.01062	0.01239	0.01487	0.01567	0.01472	0.00647	0.00813
$c/l_G h$	0.00368	0.00395	0.00610	0.00816	0.01116	0.00523	0.00632
$G/l_G h$	0.01429	0.01633	0.02097	0.02383	0.02587	0.01170	0.01445
$H/l_h h$	0.00830	0.00948	0.01218	0.01384	0.01502	0.00679	0.00839
$s_G k/l_G h$	0.08818	0.10212	0.13398	0.15352	0.16786	0.07168	0.09446
$s_H k/l_H h$	0.08818	0.10212	0.13398	0.15352	0.16786	0.07168	0.09446
k/h	-0.00398	-0.00481	-0.00458	-0.00341	-0.00029	0.00000	0.00000
$K/h[1\text{-}x]$	0.07276	0.08309	0.11537	0.13956	0.16667	0.07168	0.09446
$k/[h(l_G + l_H)]$	0.08818	0.10212	0.13398	0.15352	0.16786	0.07168	0.09446
Level of ε	-0.26272	-0.28287	-0.25975	-0.22228	-0.13897	-0.30855	-0.12752

Table 4: The effect of increasing the inflation rate from 25% to 35%.

The effect of increasing the inflation rate with $\beta < \delta$							
	Costly Credit Model					**L&S**	**CIA**
5%-15%	$\gamma = \mathbf{0.2}$	$\gamma = \mathbf{0.3}$	$\gamma = \mathbf{0.5}$	$\gamma = \mathbf{0.6}$	$\gamma = \mathbf{0.8}$		
g	-0.00271	-0.00315	-0.00389	-0.00417	-0.00439	-0.00257	-0.00423
x	0.00866	0.01010	0.01252	0.01344	0.01417	0.00870	0.01508
r	-0.00376	-0.00439	0.00546	0.00587	0.00619	-0.00377	-0.00662
w	0.01239	0.01469	0.01861	0.02009	0.02126	0.01233	0.02329
w/r	0.98798	1.21235	.60672	.75514	1.87077	0.96816	2.17838
$s_G k/_G h$	0.11538	0.13809	0.17705	0.19166	0.20320	.11438	0.22607
$s_H k/l_H h$	0.05128	0.06137	0.07869	.08518	0.09031	0.05084	0.10048
k/h	0.00056	0.00097	0.00311	0.00440	0.00566	0.00334	0.00618
$K/h[1\text{-}x]$	0.06794	0.08240	0.11252	0.12565	0.13689	0.07719	0.15226
$k/[h(l_G + l_H)]$	0.0747	0.08973	0.11719	0.12807	0.13693	0.07719	0.15226
Level of ε	-0.17122	-0.16741	-0.12176	-0.09331	-0.06496	-0.15071	-0.07683
15%-25%							
g	-0.00232	-0.00265	-0.00331	-0.00363	-0.00400	-0.00213	-0.00407
x	0.00814	0.00929	0.01157	0.01270	0.01406	0.00746	0.00692
r	-0.00355	-0.00407	-0.00510	-0.00561	-0.00622	-0.00325	-0.00307
w	0.01212	0.01418	0.01829	0.02030	0.02267	0.01100	0.01131
w/r	1.05031	1.29189	1.79644	2.04575	2.33269	0.93338	1.19694
$s_G k/l_G h$	0.11543	0.13676	0.17969	0.20071	0.22527	0.10415	0.11313
$s_H k/l_H h$	0.0513	0.06078	0.07986	0.0892	0.10012	0.04629	0.05028
k/h	-0.00016	-0.00014	0.00171	0.00336	0.00586	0.00295	0.00296
$K/h[1\text{-}x]$	0.06518	0.07736	0.10893	0.12739	0.1512	0.07022	0.07609
$k/[h(l_G + l_H)]$	0.07377	0.08741	0.11713	0.13263	0.15145	0.07022	0.07609
Level of ε	-0.21598	-0.22276	-0.1836	-0.14828	-0.09592	-0.22878	-0.08764
25%-35%							
g	-0.00201	-0.00225	-0.00278	-0.00312	-0.00364	-0.00176	-0.00366
x	0.00697	0.00774	0.00951	0.00963	0.01129	0.00577	0.01274
r	-0.00306	-0.00342	-0.00423	-0.00430	-0.00505	-0.00253	-0.00570
w	0.01078	0.01235	0.01589	0.01635	0.01950	0.00880	0.02198
w/r	1.01188	1.23611	1.77008	1.88771	2.35236	0.79966	2.64368
$s_G k/l_G h$	0.1048	0.12191	0.16086	0.16683	0.20097	0.08484	0.22634
$s_H k/l_H h$	0.04658	0.05418	0.07149	.07415	0.08932	0.0377	0.1006
k/h	-0.00075	-0.00111	0.00001	0.00154	0.00478	0.00234	0.00567
$K/h[1\text{-}x]$	0.05665	0.06485	0.09141	0.10113	0.13396	.05716	0.15203
$k/[h(l_G + l_H)]$	0.06609	0.07648	0.10276	0.1086	0.13466	0.05716	0.15203
Level of ε	-0.25587	-0.27454	-0.24867	-0.20759	-0.12798	-0.30318	-0.12242

Table 5: The effect of increasing the inflation rate with $\beta < \delta$.

The effect of increasing the inflation with a 0.05 Income Tax							
	Section 2 Model					**L&S**	**CIA**
15%-25%	$\gamma = \mathbf{0.2}$	$\gamma = \mathbf{0.3}$	$\gamma = \mathbf{0.5}$	$\gamma = \mathbf{0.6}$	$\gamma = \mathbf{0.8}$		
g	-0.00223	-0.00260	-0.00327	-0.00351	-0.00371	-0.00218	-0.00364
x	0.01302	0.01515	0.01711	0.01838	0.01942	0.00917	0.00762
r	-0.00342	-0.00401	-0.00457	-0.00492	-0.00520	-0.00335	-0.00283
w	0.01216	0.01439	0.01656	0.01789	0.01896	0.01101	0.00980
w/r	0.07255	0.08726	0.10231	0.11140	0.11868	1.06460	1.08469
a	-0.07001	-0.06347	-0.03037	-0.01501	-0.00025	-0.04078	0.00000
s_H	0.00522	0.00574	0.00410	0.00311	0.00204	0.00056	0.00051
s_G	-0.00436	-0.00479	-0.00341	-0.00258	-0.00169	-0.00056	-0.00051
l_F	1.04759	1.26156	1.88665	2.78511	13.80497		
l_H	-0.03179	-0.03745	-0.04291	-0.04626	-0.04893	-0.00400	-0.00333
l_G	-0.04102	-0.04753	-0.05007	-0.05168	-0.05247	-0.00517	-0.00429
c/k	-0.02993	-0.03466	-0.03609	-0.03701	-0.03735	-0.00338	-0.00286
c/h	-0.03374	-0.03872	-0.03834	-0.03817	-0.03737	-0.00311	-0.00263
M/Ph	-0.10139	-0.09973	-0.06754	-0.05261	-0.03761	-0.00720	-0.00263
$y/l_G h$	0.01216	0.01439	0.01656	0.01789	0.01896	0.01811	0.01612
$H/l_H h$	0.01216	0.01439	0.01656	0.01789	0.01896	0.01051	0.00936
F	1.11908	1.35265	2.00174	2.93533	14.37965		
c/y	-0.00452	-0.00507	-0.00414	-0.00359	-0.00296	-0.00100	-0.00091
s=i/y	0.00565	0.00634	0.00518	0.00450	0.00372	0.00100	0.00091
$s_G k/y$	0.02172	0.02572	0.02962	0.03203	0.03396	0.04494	0.04494
k/y	0.02619	0.03066	0.03315	0.03471	0.03572	0.08623	0.07808
$i/l_G h$	0.01788	0.02081	0.02183	0.02247	0.02275	0.00957	0.00859
$c/l_G h$	0.00759	0.00925	0.01235	0.01424	0.01594	0.00854	0.00753
$G/l_G h$	0.01216	0.01439	0.01656	0.01789	0.01896	0.01811	0.01612
$H/I_h h$	0.01216	0.01439	0.01656	0.01789	0.01896	0.01051	0.00936
$s_G k/l_G h$	0.03415	0.04048	0.04667	0.05050	0.05357	0.10779	0.09906
$s_H k/l_H h$	0.03415	0.04048	0.04667	0.05050	0.05357	0.10779	0.09906
k/h	-0.00393	-0.00420	-0.00233	-0.00121	-0.00002	0.00000	0.00000
$K/h[1\text{-}x]$	0.03009	0.03610	0.04423	0.04923	0.05355	0.10779	0.09906
$k/[h(l_G + l_H)]$	0.11117	0.13294	0.15492	0.16802	0.17842	0.10779	0.09906
Level of ε	-0.17443	-0.17135	-0.12355	-0.09553	-0.0678	-0.0678	-0.07611

Table 6: The effect of increasing the inflation rate with a 0.55 income tax.

Parameters used in Calibrations		
	Tables 2,3,4,6	**Table 5**
Parameter Values		
ρ	0.04	0.04
δ_{H}	0.1	0.1
δ_{K}	0.1	0.1
θ	1.5	1.5
β	0.64	0.64
δ	0.64	0.8
α	4.692	5.289
A_{G}	1	1
A_{H}	0.581	0.659
A_{F}	0.801	0.801
λ	-0.5	-0.5
η	0.7	0.7
γ		0.2
Benchmark Calibrated Variables		
a	0.7	0.7
x	0.7	0.7
g	0.02	0.02
π	0.05	0.05
l_G	0.1635	0.129
l_H	0.1355	0.169
l_F	0.00098	0.0009

Table 7: Parameters used in calibrations.