Inflation Uncertainty and the Disappearance of Financial Markets:
The Mexican Example*

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The following paper looks at the effect of very high levels of inflation uncertainty on the length of the term structure. A general equilibrium model is presented which shows how markets for assets at the long end of the term structure disappears as inflation uncertainty becomes very great. The negative relationship between inflation uncertainty and asset length is illustrated using the market for Mexican treasury bills as an example.

I. Introduction

As inflation uncertainty increases, the length of contracts with fixed nominal terms shortens. This issue has received much attention in the labour literature for wage contracts. Gray (1978) shows that when the degree of wage indexation is optimal,[1] contract length is inversely related to the amount of uncertainty in the system (i.e. monetary variability) and positively related to the cost of re-contracting. Canzoneri (1980) derives a similar result in a set-up where risk averse labour unions impose labour contracts on competitive firms. In that model, firms choose the length of labour contracts in such a way that balances the costs of recontracting with the "premium" that they must pay to workers for the greater real wage uncertainty assumed from longer contracts. Finally, Christofides and Wilton(1983) show for the Canadian economy, that the length of labour

contracts depends inversely on inflation uncertainty.

The negative correlation between inflation uncertainty and contract length is not restricted to labour markets. Financial markets also exhibit this shortening of contract length when inflation uncertainty becomes very great. The German hyperinflation provides the clearest example of this phenomenon. Assets at the long end of the term structure simply disappeared as inflation uncertainty became very great. Indeed, in the midst of that hyperinflation, the longest asset traded with a fixed nominal return was an over-night deposit.[2]

While much has been said about the effect of inflation uncertainty on the slope of the term structure (Fama (1976), Brealey & Schaefer (1977), and Miller (1989)), very little has been said about the effect of inflation uncertainty on the length of the term structure. In this paper we present a simple general equilibrium model which illustrates how the maturity of financial assets with nominally fixed returns shrinks as inflation uncertainty increases. To phrase it differently, we show that as inflation uncertainty becomes very large, the market for assets at the long end of the term structure disappears. We also illustrate the negative relationship between inflation uncertainty and contract length using the example of the market for Mexcian Treasury Certificates.

This paper proceeds in five parts. In section 1 we present the model which illustrates how the market for assets at the long end of the term structure disappears as inflation uncertainty becomes too great. We also show that maturity is positively related to the cost of refinancing. In section 2 we relate this model to the Mexican Treasury bill market (CETES) experience from 1986 until present. There we will outline the events which contributed to uncertainty and argue that the percentage of new Treasury bills issued in the form of the longer term asset fell as uncertainty increased. In section 3 we proxy inflation uncertainty to illustrate the inverse relationship between it and contract length. We propose a direction for further research in section 4. Finally in section 5 we conclude.

II. The Model

In this section we present a simple two-period general equilibrium model which illustrates how the market for assets with long maturities and fixed nominal returns shrinks as inflation uncertainty increases. The

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[2] Other countries such as Israel and to a lesser extent Brazil, partially avoided the problem of missing markets by indexing their bonds.

following model is similar to that derived in Brealey & Schaefer (1977) and extended in Miller (1988).

The notation that we employ follows:

$_tF_{t+1}$: the one period forward rate which is locked in at time t on the spot contract which lasts from $t+1$ to $t+2$.

R_t : the spot rate at time t for the spot contract which lasts from t to $t+1$.

r   : the equilibrium real rate of interest at time t.

π_t : the rate of inflation from t–1 to t.

x_i : the proportion of investor i's portfolio which is invested in a two-period nominally risk-free asset.

B_i : the amount individual i chooses to lend for two periods given the real rate of r.

Et(.) : the expectation operator conditional upon the information available at time t.

$V_t(.)$: the variance conditional upon information available at time t.

$_k\varepsilon_t$: the information which arrives at time k about the rate of inflation from t–1 to t.

T   : the percentage transactions cost of recontracting.

The assumptions that we employ are the following:

A.1) The government is risk neutral; has a perfectly inelastic demand to borrow a real amount B for two periods; and seeks to minimize the expected real cost of borrowing.

A.2) The one period spot rate is equal to a constant ex-ante real rate of interest plus the rate of inflation expected to prevail over the period to which the spot contract applies.

A.3) The only securities in the economy are one and two-period assets that have fixed nominal interest rates.

A.4) Markets are perfect and competitive.

A.5) All individuals are risk averse and seek to mximize expected utility. Expected utility is defined to be a function of the mean and variance of the real return on the portfolio at the end of the second market period.[3]

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[3] Since the only source of uncertainty in our model is inflation uncertainty, there is an issue of asymmetric information. This is because the government can determine the outcome

A.6) Investors have homogeneous probability beliefs about infla-
tion and their forecasts of inflation are unbiased and effi-
cient.

A.7) Inflation has positive autocorrelation.

Since the government has a perfectly inelastic real demand for funds
(A.1), the equilibrium real rate of interest is completely supply determin-
ed and fixed for the two periods in which the government borrows. The
spot rate of interest is then equal to the supply determined real rate plus
expectations of inflation (A.2). Assumptions A.3 and A.4 are self ex-
planatory. Assumption A.5 allows us to abstract from the issue of timing
preferences. Given A.6, inflation from t–1 to t can be written as the sum
of passed innovations:

$$\pi_t = {}_t\varepsilon_t + \mathrm{E}_{t-1}(\pi_t)$$

$$= {}_t\varepsilon_t + {}_{t-1}\varepsilon_t + \mathrm{E}_{t-2}(\pi_t)$$

$$\ldots$$

$$= {}_t\varepsilon_t + {}_{t-1}\varepsilon_t + \ldots + {}_{t-k}\varepsilon_t + \ldots$$

Unbiasedness tells us that $\mathrm{E}({}_{t-k}\varepsilon_t) = 0$ for all k, and efficiency implies that
$\mathrm{COV}({}_{t-k}\varepsilon_t,\ {}_{t-j}\varepsilon_t) = 0$ for all k and j.

We assume stationarity in the sense that the covariance between infor-
mation at time t about the realization of inflation in two different periods
hence, depends solely upon the difference between the periods to which
this information refers. That is:

$$\mathrm{COV}({}_t\varepsilon_{t+k},\ {}_t\varepsilon_{t+j}) = \mathrm{COV}({}_s\varepsilon_{s+k},\ {}_s\varepsilon_{s+j}) > 0, \text{ for all s, t, j, k.}$$

A.7 implies that a higher than expected inflation rate causes expectations
of inflation for all future periods to be revised upwards. Therefore the
above covariances are positive.

Transforming the process of information about inflation so that the
innovations have a constant variance, we have:

$$\pi_t = {}_t\zeta_t + \Theta_1\ {}_{t-1}\zeta_t + \Theta_2\ {}_{t-2}\zeta_t + \ldots + \Theta_k\ {}_{t-k}\zeta_t + \ldots$$

of inflation. Assuming the investor to be risk averse and the government to be risk neutral,
we effectively introduce this asymmetry into our model. As we will see, the government will
have to pay the lender for inflation uncertainty which is similar to the outcome that we
would expect from a model of asymmetric information.

where

$$\text{Var}(_t\zeta_t) = \text{Var}(_{t-1}\zeta_t) = \ldots = \text{Var}(_{t-k}\zeta_t) = \sigma^2$$

$$\Theta_k = \text{sd}(_{t-k}\varepsilon_t)/\sigma^2, \quad \Theta_k \;_{t-k}\zeta_t = _{t-k}\varepsilon_t$$

$$\text{and } 1 > \Theta_1 > \Theta_2 > \ldots > \Theta_k > \ldots > 0$$

Finally we denote the correlation coefficient between $_t\zeta_{t+k}$ and $_t\zeta_{t+j}$ as ρ_{kj}. Assumption A.7 implies that ρ_{kj} is positive.

To solve for the equilibrium percentage of loans in the form of the two-period bond, we begin with the investor's problem. This will enable us to define a relationship between the supply of these loans and the risk premium. Then given this supply relation, the government chooses the premium (forward rate) that minimizes the real cost of borrowing.

We begin with the investor's protfolio decision. Given a real rate r, investor i decides to lend an amount B_i for two periods. Investor i then decides how much of B_i to lend in two one-period installments, and how much to lend in one two-period installment. We refer to the first alternative as the "rolling" alternative and the second as the two-period asset. Suppose that the proportion of the portfolio that investor i devotes to the "rolling" alternative is $(1-x_i)$; x_i is then dedicated to the two-period asset. Investor i's nominal wealth at the end of the second market period is then:

$$(1.1) \quad B_i[(1-x_i)(1 + R_t + R_{t+1}) + x_i(1 + {_t}F_{t+1} + R_t)]$$

Substracting the relevant inflation rates from (1.1) yields investor i's real wealth at the end of the second market period (1.2):

$$(1.2) \quad B_i[(1-x_i)(1 + R_t + R_{t+1} - \pi_{t+1} - \pi_{t+2})$$
$$+ x_i(1 + {_t}F_{t+1} + R_t - \pi_{t+1} - \pi_{t+2})]$$

The real return is then:

$$(1.3) \quad (1-x_i)(R_t + R_{t+1} - \pi_{t+1} - \pi_{t+2}) + x_i(F_{t+1} + R_t - \pi_{t+1} - \pi_{t+2})$$

This reduces to:

$$(R_t + R_{t+1} - \pi_{t+1} - \pi_{t+2}) + x_i({_t}F_{t+1} - R_{t+2})$$
$$= 2r + E_t(\pi_{t+1}) - \pi_{t+1} + E_{t+1}(\pi_{t+2}) - \pi_{t+2}$$
$$+ x_i[{_t}F_{t+1} - r - E_{t+1}(\pi_{t+2})]$$

$$= 2r_{-_{t+1}}\zeta_{t+1} {-_{t+2}}\zeta_{t+2} + x_i \left[{}_tF_{t+1} - r - E_{t+1}(\pi_{t+2}) \right]$$

Given the above assumptions, investor i chooses x_i so as to maximize the following utility function:

$$\max_{x_i} E_t(\text{real return}) - \frac{\lambda_i}{2} V_t(\text{real return})$$

where

$$E_t(\text{real return}) = 2r = 2r + x_i \left[{}_tF_{t+1} - r - E_t(\pi_{t+2}) \right]$$

$$V_t(\text{real return}) = 2\sigma^2 + x_i^2 \theta_1^2 \sigma^2 + 2x_i \theta_1 \rho_{01} \sigma^2$$

Taking the derivative with respect to x_i and setting the quantity equal to zero yields invstor i's proportional supply function of the two-period asset:

(1.4) $x_i = ({}_tF_{t+1} - E_t(R_{t+1})) / \theta_{12} \sigma^2 \lambda_t - \rho_{01} / \theta_1$

Multiplying x_i by the total amount individual i is going to lend, aggregating over all investors and dividing by the total supply of loans yields X, the aggregate proportion of loans supplied in the form of the two-period asset:

(1.5) $X = ({}_tF_{t+1} - E_t(R_{t+1})) / \theta_{12} \sigma^2 \lambda_m \, \rho_{01} / \theta_1$

or

(1.6) ${}_tF_{t+1} - E_t(R_{t+1}) = X \theta_{12} \sigma^2 \lambda_m + \rho_{01} \theta_1 \sigma^2 \lambda_m$

Where $1/\lambda_m = \Sigma(B_i/\lambda_i) / \Sigma B_i$ and $0 \leq X = \Sigma(x_i B_i) / \Sigma B_i \leq 1$

(1.5) shows that X is an increasing function of the risk premium and a decreasing function of inflation uncertainty. This relationship is illustrated in fugure 1. The porportion of loans in the form of the two-period asset is measured along the vertical axis. The horizontal axis measures the size of the expected premium. AB denotes the proportional supply curve and is drawn for a given level of inflation uncertainty. Since X must be positive, only that part of the AB schedule which lies above the horizontal axis is feasible. As we can see, for a given level of uncertainty, the percentage of loans in the form of the two-period asset increases with the risk premium. An increase in uncertainty causes AB to rotate clockwise

Figure 1
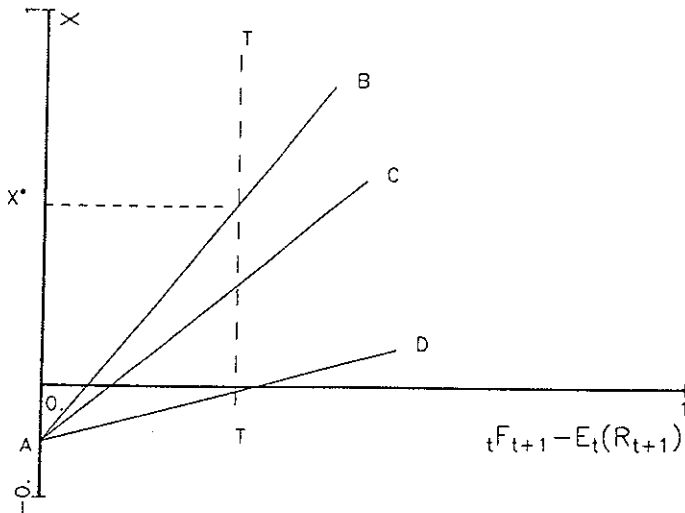
(to AC for example). This rotation shows that for a given X, lenders require greater compensation for greater inflation uncertainty.

The proportional supply curve also shows that X is decreasing in ρ_{01}. An increase in ρ_{01} causes AB to shift down. This means that the more one period's inflation rate reveals about the next period's rate, the better off an investor is in the rolling alternative. This is because in the rolling alternative, an investor can use new information to update expectations of inflation and hence obtain a fair return through the Fisher equation. This explains the vertical intercept in figure 1. Since X must be positive, an increase Θ_1 decreases the proportion of loans which take the two-period form. That is, the larger new innovations to the inflation process may be, the more inclined an investor is to lend by rolling over two one-period assets. Finally, since there is only uncertainty about inflation, the higher is the coefficient of risk aversion, the less lenders will be inclined to purchase the two-period asset.

We now turn to the government's problem. The government seeks to minimize the real expected cost of borrowing for the two periods which begin at time t. It faces the following tradeoff: For a given real of inflation uncertainty, the government must offer a higher premium to obtain a larger X (This is the relationship defined by the proportional supply curve). However, the more the government borrows in the form of the

two-period asset, the smaller is the total transactions cost that it must pay
to refinance in the rolling alternative. Thus the cost minimizing X is that
which sets the marginal cost of borrowing in the form of the two-period
asset just equal to the marginal cost of borrowing in the form of the roll-
ing alternative (the transactions cost). If the government takes the
premium as given, the cost minimizing X will be that at which the
premium is equal to the transactions cost. This case is illustrated in figure
1. The vertical line labelled TT represents the refinancing cost. The point
at which the AB line intersects the transactions cost line, determines the
cost minimizing X for a government which is a price taker. An increase in
inflation uncertainty causes the AB line to rotate clockwise. As we can see
an increase in uncertainty results in a smaller proportion of loans in the
form of the two-period asset. If uncertainy becomes very large, AD, then
the two-period asset disappears and the term structure shrinks. An in-
crease in the transactions cost will cause the TT schedule to shift to the
right and a larger percentage of the government's borrowing will be done
through issuing two-period assets.

The results do not change significantly for the case in which the
government is a price "maker" (i.e. relaxing assumption A.4). The only
difference is that the government's marginal cost is given by (1.7) rather
than constant and given.

(1.7) $MC = \rho_{01}\theta_1\sigma^2\lambda_m + 2\lambda_m\theta_{12}\sigma^2 X$

The problem for a price making government follows. The government
can choose either the forward rate, $_tF_{t+1}$ or the proportion of loans in the
two-period asset, X. Choosing one of these variables necessarily determines
the other, through the aggregate investor proportional supply function.
All other variables are predetermined. The real cost of borrowing is given
by:

$$(1-X)\ [R_t + R_{t+1} + T - \pi_{t+1} - \pi_{t+2}]\ + X\ [_tF_{t+1} + R_t - \pi_{t+1} - \pi_{t+2}]$$
$$[R_t + R_{t+1} + T - \pi_{t+1} - \pi_{t+2}]\ + X\ [_tF_{t+1} - R_{t+1} - T]$$

The real expected cost of borrowing is then

$$[R_t + E_t(R_{t+1}) + T - E_t(\pi_{t+1}) - E_t(\pi_{t+2})]\ + X\ [_tF_{t+1} - E_t(R_{t+1}) - T]$$

or

(1.8) $2r + T + X\ [_tF_{t+1} - r - E_t(\pi_{t+2}) - T]$

Substituting (1.5) into (1.8) for X and having the government choose the forward rate (which determines the premium), the government faces the following problem:

$$\min_{t F_{t+1}} \left[2r + T + \frac{({}_t F_{t+1} - E_t(R_{t+1}) - \rho_{01}\theta_1\sigma^2\lambda_m)}{\theta_1^2\sigma^2\lambda_m} \; ({}_t F_{t+1} - r - E_t(\pi_{t+1}) - T) \right]$$

Taking the derivative of the above expression with respect to the forward rate and setting it equal to zero yields the equilibrium forward rate:

$${}_t F_{t+1} = E_t(R_{t+1}) + \frac{(\rho_{01}\theta_1\sigma^2\lambda_m + T)}{2}$$

The second derivative is positive ensuring us that we have a minimum. Now substituting the equilibrium forward rate into (1.5) we can find the equilibrium proportion of loans in the form of the two-period asset:

$$X^* = \frac{(\rho_{01}\theta_1\sigma^2\lambda_m + T)}{2\theta_1^2\sigma^2\lambda_m} - \frac{\rho_{01}}{\theta_1}$$

$$= \frac{T}{2\theta_1^2\sigma^2\lambda_m} - \frac{\rho_{01}}{2\theta_1}$$

This is exactly the X^* that results from setting the marginal cost (1.7) equal to the transactions cost.

Comparative statics on X^* confirms our intuition:

i) $dX^*/d\sigma^2 < 0$
ii) $dX^*/dT > 0$

i) shows that the equilibrium proportion of the total market value accounted for by the two-period asset falls as inflation uncertainty increases. Indeed as inflation uncertainty becomes too great, the two-period asset disappears. ii) shows that the proportion of borrowing in the form of the two-period asset increases with the transactions cost.

III. The Mexican Treasury Bill Market and Mexican Uncertainty

Figure 2 shows the percentage of new one- and three-month Mexican Certificates of the Federal Treasury (CETES) issued each month that are three month bills. The period covered is from January of 1986 until February of 1989 (1986:1-1989:2). Longer maturity CETES did exist before this time but that market disappeared as inflation uncertainty became too great. The government also began to issue shorter maturity CETES in December of 1987. However those assets account for a very small proportion of the total Treasury certificate market value and so we disregard them here. Therefore we only consider CETES issued of the one- or three-month variety.

Figure 2 is broken up into two regions. Each region represents a different issuing policy for CETES. From the first auctions of CETES in October of 1982,[4] until September of 1985, the Government fixed the quantity of CETES to be auctioned and let the market determine the rate. In September of 1985 the Ministry of Finance changed this operating policy. Instead of fixing the quantity, the government began to fix the rate and let the market determine the quantity sold. This change in policy came about because financial disintermediation gave way to monopsonization of the bid market and the government responded to the lack of competition. As this policy was not a very successful one, the government reverted to its original operating policy on July 10, 1986 with the amendment that it could reduce the quantity of CETES for sale if it felt that yields were too high. Indeed no three month CETES were issued from July 10 until the end of September in 1986 for precisely this reason.

To understand the uncertainty in the Mexican economy from January of 1986 until present, we provide a brief history of the factors which contributed to it. From 1950 until 1974 the Mexican economy was characterized by low inflation, high growth and a moderate external debt. In the early seventies part of this high growth was due to an expansionary fiscal policy.[5] However because the increased government expenditures were not met by an increase in revenues, inflation and external borrowing was used to finance the deficit.[6] This financing scheme resulted in a

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[4] CETES were first issued in January of 1978. This was the first time that the central bank was able to perform open market operations and they were created for precisely this reason. Like U.S. Treasury bills they are obligations of the Treasury. However, unlike our T-bills, CETES can be used by commercial banks to satisfy reserve requirements even though they are not liabilities of the central bank.

[5] These increased expenditures continued until they had to be reduced in 1982.

[6] These deficits had to be financed externally because a decrease in real interest rates caused a decline in the quantity of savings supplied.

Figure 2

% Issued for 91 Days
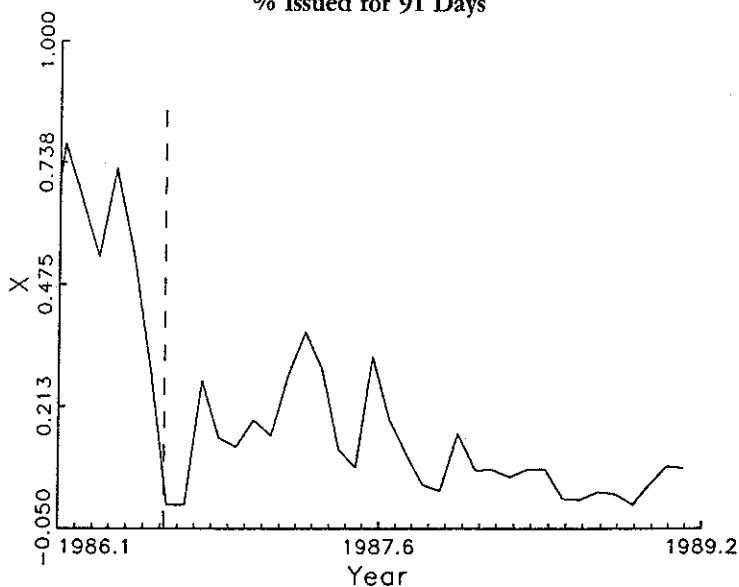
sizable devaluation in 1976.

Major oil discoveries in the late seventies along with an increase in world oil prices, prevented the devaluation from weighing heavily on the economy. Thereafter Mexico became increasingly dependent on its oil revenues. This in addition to a continued expansionary fiscal policy and an overvalued currency made Mexico extremely vulnerable to the shocks which began the eighties.[7] Consequently the economy became increasingly unstable, devaluation became inevitable[8] and so inflation soared to 100%.

The de la Madrid administration which began its sexennio[9] in December of 1982, instituted a comprehensive three-year stabilization plan.[10] This program was very successful for the first two years.[11] However,

[7] In the beginning of the eighties world interest rate and hence debt payments increased; a world recession led to a reduced demand for Mexico's exports; and the price of oil started its downturn. In addition a negative real interest rate on Mexican deposits combined with the overvalued currency to produce capital flight.

[8] The peso was devalued 69% in February of 1982.

[9] A ''sexennio'' is a six-year presidential term.

[10] In December the peso was devalued 112%.

[11] This plan called for a structural reform of public finances, a moderate wage policy, a

towards the end of 1984 a rebound in domestic demand[12] and a slight increase in government expenditures gave way to new inflationary pressures. In addition, a loss of external competitiveness along with a capital account deficit led to a deterioration of the balance of payments,[13] a loss of international reserves and consequently renewed pressure on the exchange rate. As a result, a new set of adjustment measures was adopted in the early part of 1985,[14] and then further measures were instituted later that year.[15] These measures included a more rapid depreciation of the peso which added inertia to the inflation process.

The sharp decline in oil prices in February of 1986, led to a modification of the economic plan for that year. Then in June the government announced the "Program for Recovery and Growth" (PAC). The main objective of PAC was economic growth in a framework of financial stability. In exchange for monetary and fiscal austerity, the plan called for a concerted financing effort from Mexico's creditors. In addition, the plan continued the trade reforms which had already begun and instituted a more rapid daily depreciation of the controlled exchange rate to avoid the depletion of international reserves.[16] Figure 2 shows a fall in the percentage of the three month CETES in June and July of 1986.[17] Presumably the announcement of the PAC signalled a change in regime and hence an increase in inflation uncertainty. We will see in section 3 that inflation uncertainty does exhibit an increase at this time.

From August of 1986 until September of 1987, the Mexican economy was relatively calm.[18] However after October, uncertainty increased and the percentage of CETES issued of the three-month variety fell after this time. In October the Mexican stock market crashed. The crash along with a temporary opportunity for private debt buy backs[19] led to a flight from

tight money policy, flexible exchange rate and interest rate policies and the liberalization of trade and exchange controls. The immediate objectives of this program were to reduce inflation and to strengthen public finances and the balance of payments.

[12] This was a response to the improved economic conditions.

[13] Which was partially due to a drop in oil prices.

[14] The set of adjustment measures included: 1) the cancellation of all public sector vacancies and a sizable reduction in the number of public sector employees, 2) a large increase in domestic interest rates; and 3) a special issue of monetary bonds to absorb excess liquidity.

[15] The further measures included a tight money and credit policy, trade liberalization and a more active exchange rate policy. We remark that the tight stance on credit combined with the lack of external credit strained the credit markets. This gave way to faster depreciation of the peso, higher interest rates and therefore more inflation.

[16] Which had been falling since March.

[17] We cannot make comparisons over times of different auctioning policies for CETES.

[18] Also the price of oil increases from its low in 1986:7 until 1987:7.

[19] This evolved from the 1987 debt rescheduling.

the peso and hence a devaluation in November.[20] This devaluation no doubt fuelled expectations of future inflation and exchange rate devaluations.

On December 1, the Pacto de Solidaridad Economica began. Initially intended to expire in December of 1988, the Pacto was extended on November 15 to July of 1989. The Pacto is a stabilization plan with the objective of slowly reducing inflation rather than bringing it immediately to zero.[21,22] Under the plan, the government controls the path of prices. Each month the government announces an expected inflation rate which is smaller than the rate announced for the previous month.[23] Existing Pacto terms were modified on the first day of March, April, June, and September. Approximately two weeks before each of these dates, a meeting was held to decide what the new terms would be. These new terms were announced about one week before they took effect. Thus since the public could never completely anticipate what the new Pacto arrangements were going to be, there was always uncertainty for the one to three weeks preceding the beginning of a new arrangement. This explains (in part) the low percentage of three-month CETES issued over this period.

In addition to the economic events outlined above, the presidential election of 1988 also constituted a source of uncertainty. In October of 1987, Carlos Salinas de Gortari was nominated as the candidate for the Partito Revolucionario Institucional (PRI) and on July 6, 1988 he was elected president. Usually there is a drop in uncertainty before these elections and an increase after. This is because existing presidents want their parties to be re-elected and so few unanticipated events ever occur before an election. However, after an election, an existing president no longer has an incentive to maintain a reputation, and so uncertainty increases. In figure 2 we see that the CETES market exhibits less uncertainty before July of 1988 than between July and December 1, when Salinas took office (the percentage of three month CETES is higher before than after). Yet we would expect a distinct drop in the percentage of new three-months CETES issued after March. For after this time, new three month bills expired beyond the election and hence during the period of greatest uncertainty. The small quantity of three month CETES before March suggests

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[20] The devaluation shows up in our dataset in December.

[21] Inflation had reached 160% per year at this time.

[22] In addition, the Pacto was intended to keep the market free of the influence of the upcoming election.

[23] Initially these announcements were to occur every month but eventually they were extended to every three months.

that speculators chose to remain highly liquid as a precaution to an expected devaluation. In the event of an expected devaluation, speculators would want to fly from the peso before a devaluation is realized. Indeed, although capital began to return to Mexico in March, the loss of reserves after April suggests that speculators were anticipating a devaluation. We will return to the issue of capital flight in section 4.

Figure 2 indicates that uncertainty peaked right before Salinas took office, as the three-month CETES market completely dried up in November. Then after Salinas stepped into office, the percentage of long CETES inceased. This reflects the drop in political uncertainty and the adoption of a crawling peg in January of 1989.[24]

IV. Estimation of Inflation Uncertainty

In this section we derive proxies for Mexican inflation uncertainty from January of 1986 until September of 1988.[25] We do this to illustrate the negative relationship between inflation uncertainty and the percentage of new CETES issued of the three-month variety. We first estimate predicted inflation. This enables us to estimate the unaiticipated component of inflation and hence to proxy uncertainty. Here we model expectations of inflation in two ways: Adaptively and structurally (rationally).

If expectations are formed adpatively then the best prediction of inflation is based solely on past information. Since uncertainty is especially great in 1988 it is difficult to obtain a good model of inflation if we include this year in our sample. Thus we use data from 1983 until November of 1987 to choose the best structural model for inflation. We then re-estimate this model for each month from 1986:1 until 1988:8, assuming that agents have a memory of two years.[26] The standard errors from such a rolling regression provide good proxies of inflation uncertainty. The prediction equation that we found to fit the data best is (3.1):

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[24] In December, President Salinas de Gortari made a commitment to make Mexico financially strong. As part of this commitment the exchange rate was to be depreciated by one peso each day starting January 1, 1989 until July. The intention of this policy was to further reduce inflation uncertainty in addition to increasing Mexico's competitiveness on the world market.

[25] Unfortunately our dataset only enables estimation of uncertainty until this time.

[26] We tried memory sets of 12, 16, 24 and 30 months. (30 months was the longest memory that our short data set would allow). We found that the proxy of uncertainty which results from an information set which contains two years (24 months) of data, is the best at inversely explaining the amount of three-months CETES shown in figure 2.

$$(3.1) \quad \dot{P} = \alpha_1 + \alpha_2 \dot{P}_{-1} + \alpha_3 \dot{W}_{-1} + \alpha_4 \dot{W}_{-2} + \alpha_5 e_{-1} + \alpha_6 d_1 + \alpha_7 d_2 + \alpha_8 t$$
$$+ \alpha_9 \Delta R_{-1} + \varepsilon$$

$\dot{P}$ and $\dot{W}$ are price and wage inflation respectively. e is the natural logarithm of the exchange rate. d_1 and d_2 are dummies. d_1 accounts for December of every year and d_2 is one for September in which the presidential address occurs. Wage increases are announced in September and take place in December. Thus prices are likely to occur at both times. t is a time trend and ΔR is the change in the level of reserves. The results from estimating this prediction equation for the period 1983:1-1987:11 are presented below (standard errors are in parenthesis).

$$\dot{P} = -.117 + .337\dot{P}_{-1} + .057\dot{W}_{-1} + .026\dot{W}_{-2} + .032e_{-1} + .001d_1$$
$$\quad\ \ (.034) \quad (.121) \quad\ (.012) \qquad (.012) \qquad (.008) \qquad (.005)$$
$$- .011d_2 - .001t - .004\Delta R_{-1}$$
$$\ \ (.004) \quad (.0004) \quad (.002)$$
$$R^2 = .797; \qquad \sigma = .009$$

This equation was estimated under the assumption that the errors are white noise and have a constant variance. However, if uncertainty changes over time, as we will show below, then the homoscedasticity assumption will be violated and the standard errors will be incorrect. The inconsistency of the standard errors is irrelevant for prediction purposes. In spite of a non-constant variance the parameter estimates will still be consistent as will be the R^2 and standard error of the regression. We chose our prediction equation (3.1) on the basis of the adjusted R^2 which is similarly unaffected by heteroscedastic errors.

In figure 3, we present the standard errors from the rolling regression from 1986:1 to 1988:8.[27] A comparison of figure 3 to figure 2 reveals a very strong negative relationship between this measure of uncertainty and the percentage of new CETES issued of the three-month form.[28] This uncertainty proxy exhibits a slight increase when the PAC was announced and a dramatic increase after the maxi-devaluation in 1987:11. The standard error then grows larger during the first months of the Pacto, falls slightly before the July election and then increases again in August.

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[27] The standard error for 1986:1 for example is from the sample 1984:1-1986:1.

[28] As the information set is two-years, the implication is that agents take two years to change their beliefs about uncertainty. The reluctance to immediately modify beliefs about uncertainty is as we would expect in a situation where government crediblity is a problem.

Figure 3

S.D. — Rolling Reg.
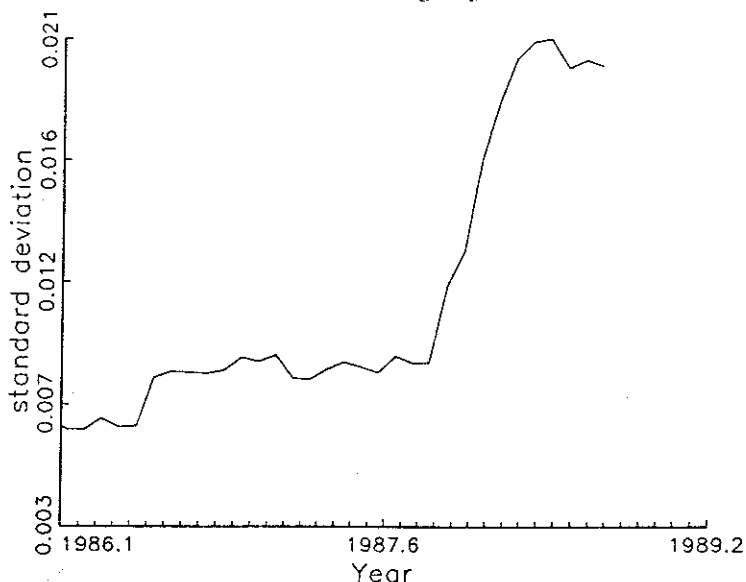
A comparison of figure 2 to figure 3 should convince the reader of the negative relationship between inflation uncertainty and the percentage of the new CETES issued in the long asset. However we present the following regression to drive the point home:

$$(3.2) \quad X = \delta_0 + \delta_1 \text{dum1} + \delta_2 \text{dum2} + \delta_3 \log(\tilde{\sigma}_\pi^2) + \varepsilon$$

Here dum1 is a dummy which accounts for the change in the CETES auctioning policy. It is one for the period 1986:1-1986:7. dum2 equals one for the months 1986:7-1986:9. It captures the period in which the government chose not to issue any CETES because yields were deemed excessively high. Finally, σ_π^2 is our proxy of inflation uncertainty shown in figure 3. The results from running (3.2) are presented below:

$$X = -.717 + .370\text{dum1} - .223\text{dum2} - .193\log(\tilde{\sigma}_\pi^2)$$
$$\quad\quad (.199) \ (.042) \quad\quad (.051) \quad\quad (.045)$$

$$R^2 = .873, \quad\quad \sigma = .083$$

The negative and highly significant coefficient on the uncertainty proxy indicates that inflation uncertaintly is indeed negatively correlated with asset length, as we would expect.

A criticism of the above inflation model is that it may not accurately capture the expectations of Mexican investors, for Mexicans are more "rational" in forming their beliefs. In an attempt to capture this rationality, we impose more structure on the inflation equation. Again, we first identify the relationship which explains inflation the best. However, unlike above, we allow variables to have contemporaneous as well as lagged influences on inflation. Then we estimate structural equations for those variables which have significant contemporaneous effects on inflation using only lagged information. Finally, assuming equations to be stable throughout the sample, we estimate predicted inflation based on the information available at the time that the prediction is formed and on the estimated parameters.

The equation that we found to explain inflation the best is (3.3):

$$(3.3) \quad \dot{P} = \alpha_1 + \alpha_2 \dot{W} + \alpha_3 e + \alpha_4 e_{-1} + \alpha_5 d_1 + \alpha_6 d_2 + \alpha_7 t + \varepsilon$$

All variables are as previously defined. The results from estimating (3.3) over the stable period (1983:1-1987:11) yields the following:

$$\dot{P} = -.181 - .066\dot{W} + .110e - .059e_{-1} + .026d_1 - .009d_2 - .002t$$
$$\quad\;\; (.025)\;(.012)\quad(.050)\;(.049)\quad\;\;(.005)\quad(.004)\quad(.0003)$$
$$R^2 = .798, \quad \sigma = .008$$

As before the standard errors have not been corrected for heteroscedasticity.

Now since the level of the exchange rate and the percentage change in wages have a significant contemporaneous effect on inflation, we must predict these variables. We found the rate of change of the exchange rate to be best explained by its lagged value, and lags of oil prices and changes in reserves.[29]

$$(3.4) \quad \dot{e} = \tau_0 + \tau_1 \dot{e}_{-1} + \tau_2 P_{oil,-1} + \tau_3 \Delta R_{-1} + \zeta$$

Estimating (3.4) over the stable sample we obtain:

$$\dot{e} = .075 + .396\dot{e}_{-1} - .0006P_{oil,-1} - .01\Delta R_{-1}$$
$$\quad\;\; (.021)(.155)\quad(.0002)\quad\quad(.005)$$
$$R^2 = .42$$

[29] We regressed the first difference of the level rather than the level because the exchange rate has a unit root. This procedure allows us to identify those variables which significantly determine the next-period exchange rate besides the exchange rate itself.

The next-period expected exchange rate is then:[30]

$$E_0(e_{+1}) = \hat{\tau}_0 + \hat{\tau}_1 e + \hat{\tau}_2 P_{oil} + \hat{\tau}_3 \Delta R + \varepsilon$$

Finally, we assume the following wage setting equation:

$$(3.5) \qquad \dot{W} = \beta_0 + \beta_1(\omega^* - \omega_{-1})$$

ω denotes the natural logarithm of the real wage and ω^* is its long-run equilibrium value. (3.5) defines a relationship in which nominal wages are adjusted to maintain a long run equilibrium real value. If the real wage is above (below) its long run equilibrium value then the nominal wage will be adjusted downwards (upwards). Assuming a constant ω^* and including a dummy for December we estimate (3.6):

$$(3.6) \qquad \dot{W} = \beta_0 + \beta_1 \omega_{-1} + \beta_2 d_1 + \varepsilon$$

Estimation of (3.6) over the stable sample yields:

$$\dot{W} = -.188 - .704\omega_{-1} + .274d_1$$
$$\quad (.030)\,(.077) \qquad (.030)$$
$$R^2 = .758$$

The next-period expected percentage change in the nominal wage is then:

$$E_0(W_{+1}) = \hat{\beta}_0 + \hat{\beta}_1 \omega + \hat{\beta}_2 d_{1,+1}$$

Finally, our predicted inflation rate has the following form:

$$E_0(\dot{P}_{+1}) = \hat{\alpha}_1 + \hat{\alpha}_2 E_0(\dot{W}_{+1}) + \hat{\alpha}_3 E_0(e_{+1}) + \hat{\alpha}_4 e + \hat{\alpha}_5 d_{1,+1}$$
$$+ \hat{\alpha}_6 d_{2,+1} + \hat{\alpha}_7 t$$

The error of forecast for time $t + 1$ is then $\dot{P}_{+1} - \dot{E}_0(P_{+1})$. All parameter estimates are presented above, are derived using the 1983:1-1987:11 sample and assumed to be stable.

A two year moving average of the squared forecast errors from this structural model are presented in figure 4.[31] As we may expect, these results are quite similar to those obtained from the adaptive model (figure

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[30] The predicted coefficients are those in the above regression.

[31] As in the adaptive model, we found that an information set of two years is best at inversely explaining the percentage of new three-month CETES issued.

Figure 4
Structural Model
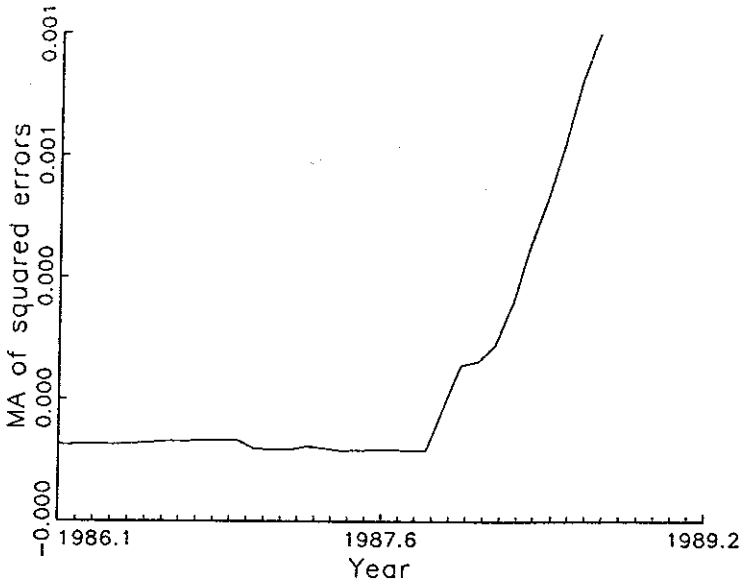
3).[32] Estimation of regression (3.2) with the uncertainty proxy developed above results in the following:[33]

$$X = -.444 + .428\text{dum1} - .221\text{dum2} - .134\log(\tilde{\sigma}_{\pi2})$$
$$\quad\;\;(.158)\quad(.039)\qquad(.054)\qquad(.036)$$
$$R^2 = .859, \qquad \sigma = .087$$

The estimated coefficient on the log of this proxy again indicates the negative relationship which is the focus of this study: The length (and quantity) of assets with fixed nominal terms shrinks as inflation uncertainty increases.

Although the infrequency of our data prevents us from asserting that our measures of uncertainty exactly capture certain events, our proxies in-

[32] It should be no surprise that the forecast errors from our adaptive model and rational model are quite similar. As Benjamin Friedman shows in "Rational Expectations are Really Adaptive After All," unpublished, Harvard, February 1975, rational expectations can be closely approximated by an adaptive expectations mechanism of the kind discussed here.
[33] We take the log of the square root of average of squared forecast errors. We do this to be consistent with the same regression presented above which used the log of the standard deviation.

dicate the following general trend for uncertainty: Uncertainty increased after the maxi-devaluation in November of 1987 and then remained high during the first months of the Pacto. Uncertainty then eased slightly before March when capital returned from abroad and a commitment was made to peg the exchange rate. In addition, impending Pacto modifications and the election seem to have also contributed to uncertainty.

Finally, we remark that although the length of our sample does not enable us to proxy uncertainty up to the point at which the three-month CETES market actually disappeared (November 1988), it is reasonable that the political uncertainty which precedes a change of post could alone explain the disappearance of this market.

V. Suggested Extension

An alternative way to view the disappearance of the long CETES market is by focusing on exchange rate rather than inflation rate risk. If there is uncertainty about whether or not a devaluation will be expected in the near future, then speculators will choose to remain highly liquid so that they can fly from the domestic currency should the need arise. An expectation of devaluation will be reflected by an actual flight from the domestic currency. Therefore, as expectations of devaluation increase we should expect a drop in the percentage of long domestic assets as speculators ready themselves for flight from the currency and an increase in capital flight as those investors who assign a higher probability to devaluation actually take their capital abroad. This suggests reformulating the model in section 1 to include exchange risk and foreign assets, and then estimatng the following seemingly unrelated system:

$$(4.1) \quad X = \delta_0 + \delta_1 dum1 + \delta_2 dum2 + \delta_3 \sigma_e^2 + \delta_4 E(\dot{e}_{+1}) + \varepsilon_1$$

$$(4.2) \quad K = \beta_0 + \beta_1 E(\dot{e}_{+1}) + \varepsilon_2$$

Here K denotes capital flight, $E(\dot{e}_{+1})$ is an expectation of a devaluation and σ_e^2 denotes exchange risk. All other variables are as previously defined. Since capital flight will be correlated (negatively) with the percentage of the CETES market value which is dedicated to the longer asset, the errors too should be correlated. Thus there will be a gain in efficiency by estimating (4.1) and (4.2) as a system.

VI. Conclusion

While it is clear that inflation uncertainty is inversely related to contract length, (when contracts have fixed nominal terms) this seemingly obvious finding has received surprisingly little attention in the academic literature for financial markets. In this paper we developed a simple two-period general equilibrium model which illustrates this negative relationship for financial assets. We also showed that contract length is positively related to the transactions cost of refinancing. We then illustrated this fact for the Mexican Treasury bill market (CETES). By estimating a proxy for inflation uncertainty we were able to show that the percentage of CETES with the longest maturity shrinks as inflation uncertainty increases. Although our dataset was not long enough to estimate inflation uncertainty upto the point at which this market actually disappeared (November 1988), we were able to argue that the uncertainty due to a president's leave of office could alone explain the disappearance.

Finally we suggested that the disappearance of the long end of the term structure could be linked to exchange risk and capital flight. We also proposed a direction for further research along this line.

Data Appendix and Definition of Variables

All data are monthly and come from the following sources:
  R: Reserves net of gold. Measured in billions of U.S. dollars.
    Source: *International Financial Statistics*. International Monetary Fund. various issues.
  P_{oil}: Producer Price Index of Crude oil. source: Citybase.

The following data is from Banco de Mexico: indicadores Economicos:
  e: Nominal exchange rate
  P: Mexican price index. 1978 = 100
  i: CPP: Interest rate index.
  W: Nominal wage index. 1978 = 100

Definitions of variables:
  $\dot{e} = \log(e) - \log(e_{-1})$
  $\dot{P} = \log(P) - \log(P_{-1})$
  $\dot{W} = \log(W) - \log(W_{-1})$
  $i = i - i_{-1}$
  $\Delta R = R - R_{-1}$
  $\omega = \log(W/P)$

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