

**MONETARY INSTABILITY, THE PREDICTABILITY OF PRICES AND  
THE ALLOCATION OF INVESTMENT: An Empirical Investigation Using  
UK Panel Data\***

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\* We would like to thank C. Baum, C. Canavan, M. Devereux, R. Murphy and seminar participants at the World Bank, the Federal Reserve Bank of Boston, Boston College, Northeastern University, University of Victoria, and the Finance Department at UBC for useful comments.

## ABSTRACT

In this paper, we propose a framework aimed at giving empirical content to the idea that monetary instability adversely affects the allocation of investment. To this end, we develop a simple macro model to illustrate the impact of monetary instability on the allocation of investment. In particular, we show that as monetary policy becomes more predictable and, as a consequence, individual relative prices become easier to forecast, the cross-sectional distribution of investment should widen. The reason is that better quality information should lead to a more unequal distribution of investment across firms as the market takes advantage of more precise knowledge of different investment opportunities. When firm specific differences in profit opportunities are, instead, hard to predict, we should observe less cross-sectional variations in investment rates. Therefore, our framework predicts a negative association between the cross-sectional variance of investment and nominal (aggregate demand) uncertainty. In accordance with this observation, our empirical strategy consists of examining whether different measures of nominal uncertainty help in explaining the time-variation in the cross-sectional distribution of investment. In our empirical work, we exploit a panel data set covering a large number of quoted UK companies over the period 1970-1990, and we make use of both macro and micro based measures of uncertainty.

## 1. Introduction

A major goal of macroeconomic policy throughout industrialized countries is to achieve low and stable inflation. There are many reasons advanced in defense of this goal. One reason often given is that lowering and stabilizing inflation improves the informational content of the price system and thereby favors a more efficient allocation of resources.<sup>1</sup> In this view, price stability allows investments to be more effectively channeled towards projects with the highest returns since the best opportunities are more easily identified. Although such a belief is widely shared, to our knowledge it has not been subject to close empirical scrutiny.

In this paper, we propose a framework aimed at giving empirical content to the idea that monetary instability adversely affects the allocation of investment. To this end, we develop a simple macro model to illustrate the impact of monetary instability on the allocation of investment. In particular, we show that as monetary policy becomes more predictable and, as a consequence, individual relative prices become easier to forecast, the cross-sectional distribution of investment should widen. The reason is that better quality information should lead to a more unequal distribution of investment across firms as the market takes advantage of more precise knowledge of different investment opportunities. When firm specific differences in profit opportunities are, instead, hard to predict, we should observe less cross-sectional variations in investment rates. Therefore, our framework predicts a negative association between the cross-sectional variance of investment and nominal (aggregate demand) uncertainty. In accordance with this observation, our empirical strategy consists of examining whether different measures of nominal uncertainty help in explaining the time-variation in the cross-sectional distribution

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<sup>1</sup>See, for instance, Friedman (1977).

of investment. Clearly, monetary policy is not the only source of uncertainty in the economy and, for this reason, our model should be taken as a stylized account of the way in which general macroeconomic instability may affect the allocation of investment.

Our empirical work exploits a panel data set covering a large number of quoted UK companies over the period 1970-1990. We first document that there were substantial variations in the cross-sectional distribution of investment over this period. More specifically, the distribution of investment rates narrowed significantly during the 1970's and then widened anew in the 1980's. Moreover, the dispersion displays procyclical movements, in the sense that the distribution narrows during recessions and widens during booms. The macroeconomic history of the UK, characterized by greater turbulence in the 1970's with frequent changes in monetary policy induced by adverse supply shocks, followed by a greater stability in the 1980's, provides some *prima facie* evidence in favor of our story. We supplement this informal evidence with two formal tests. The first test investigates the association between the cross-sectional variance of investment and macro measures of nominal uncertainty. These measures are based on estimates of the conditional variances of money and inflation derived from ARCH models. The second test is based entirely on panel data and uses the model's prediction that there should be a negative association between the cross-sectional variance of investment and the cross-sectional variance of the log of the profit rate. The reason for this negative association is quite intuitive. By reducing the information content of prices, monetary instability reduces the capacity of investment flows to equate profit rates across firms. Therefore, a lower cross-sectional variance in investment should be associated with a higher cross-sectional variance of profit rates. This second test of the model is perhaps the more attractive of the two since it more easily differentiates our story from plausible alternatives.

The overall evidence is supportive of the framework we propose to explain the relationship between nominal uncertainty, the informational content of prices, and the time

variations in the cross-sectional distribution of investment. Hence, we conclude that the data is consistent with the view that monetary instability may affect the process of investment allocation through its effect on the predictability of prices. The theoretical and empirical emphasis on the effect of the informational content of market signals on the distribution of investment is the distinguishing and unique feature of our paper. However, its general objective is related to that of numerous contributions that have studied the effects of inflation on relative price volatility and on the optimality of resource allocation.<sup>2</sup> Although we do not provide an analysis of the welfare consequences of uncertainty in this paper, it is clear that the link we outline between nominal uncertainty and the allocation of investment may be one of the important elements in such an analysis.

The remainder of the paper is organized as follows. In Section 2, we extend a Lucas (1973) model to show how variations in the predictability of monetary policy can lead to changes in the distribution of investment. Section 3 documents the nature of the time variation in the cross-sectional distribution of investment in our data. Section 4 discusses how this observed time-variation accords with the macro evidence on inflation and money growth uncertainty, while Section 5 presents micro evidence on the link between the cross-sectional variance of profits and of investment. Section 6 concludes the paper.

## **2. The Model**

In this section we develop a simple model to illustrate how macroeconomic uncertainty can affect the allocation of investment through its effect on the informational content of prices. In the model, we focus on variations in the predictability of monetary policy as a source of changes in the informational content of market signals. The environment we consider modifies the island model used by Lucas (1973) in a manner that

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<sup>2</sup>The emphasis on the ability to predict future prices on the basis of current information (in particular price information) is also the distinguishing feature of the recent theoretical contributions by Ball and Romer (1993) and Tommasi (1994a).

emphasizes the implications for investment as opposed to employment. Firms in the model are assumed to operate in competitive markets that are subject to both relative demand and aggregate monetary shocks. Investment in physical capital is assumed to have a one period delivery lag and, therefore, investment decisions must be based on firms' expectations of the relative prices to prevail next period. In order to form such expectations, firms have access to all observations on prices in their own market as well as past information in all other markets. They use this information to extract signals about the future demand. However, because of the time variation in the predictability of monetary policy, the informational content of these market signals may vary over time. The question we want to address is what are the observable implications for investment of changes in the time variation of the informational content of prices.

Consider an economy where there is a continuum of markets indexed by  $z$ , and  $z$  is uniformly distributed over the unit interval. The demand for goods in market  $z$  depends both on relative prices and on the state of aggregate demand. For simplicity, the logarithm of the demand for goods produced in market  $z$  is given by equation (1), and aggregate demand is assumed to satisfy the quantity theory as in (2):

$$y_t^d = y_t^D - \gamma(p_t(z) - p_t) + \varepsilon_t(z), \quad (1)$$

$$y_t^D = m_t - p_t, \quad (2)$$

where:

$y_t^d(z)$ : log of real demand in market  $z$ ,

$y_t^D$ : log of real aggregate demand,

$p_t(z)$ : log of price in market  $z$ ,

$p_t$ : price index defined by  $\int_0^1 p_t(z) dz$ ,

$\gamma$ : price elasticity of demand,

$\varepsilon_t(z)$ : exogenous relative demand component,

$m_t$ : log of the money supply.

Equations (1) and (2) together reflect the fact that demand can be perturbed by both real demand factors through  $\varepsilon_t(z)$ , and nominal factors through  $m_t$ . However, because the origin of a shock is not readily identifiable, firms need to solve a signal extraction problem in order to predict real factors affecting the future demand. The exact nature of this signal extraction problem will become clear shortly.

The supply of output in the economy is determined by representative firms, one of which exists in each market. The production of output is assumed to depend only on capital. Therefore, at any given point in time, the supply of output in market  $z$  can be represented by (3) where the (log) capital stock in each market,  $k_t(z)$ , is determined one period ahead:

$$y_t^S = \theta k_t(z) \quad (3)$$

Because of a one period delivery lag, the representative firm in market  $z$  determines the next period's capital stock by setting the expected marginal product of capital for next period equal to the user cost of capital, which we denote by  $c_t$ . When making such an investment decision, the firm does not know next period's marginal revenue product of capital since it does not know the real price that will prevail. However, the firm can form an expectation of the real price of good  $z$  based on its observation of the current price of the good and all past information on the economy (which we denote by  $\Omega_{t-1}$ ). Notice that this informational structure implies, as in Lucas (1973), that aggregate information is revealed to the firm with a one period lag. Therefore, assuming prices are log-normally distributed (which in equilibrium will be valid), the determination of period  $t+1$  capital stock in each market is given by equation (4):

$$k_{t+1}(z) = \frac{1}{1-\theta} E[p_{t+1}(z) - p_{t+1} / p_t(z), \Omega_{t-1}] + \text{Var}_{z,t}(p_{t+1}(z) - p_{t+1}) - \log(c_t), \quad (4)$$

where:

$$Var_{z,t}(p_{t+1}(z) - p_{t+1}) = \int_0^1 \left\{ (p_{t+1}(z) - p_{t+1}) E[(p_{t+1}(z) - p_{t+1}) / p_t, \Omega_{t-1}] \right\}^2 dz.$$

Equation (4) states that the (log) capital stock in a market increases with the expected real (log) price of the good and decreases with the (log) user cost of capital. It also indicates that the (log) capital stock increases with the conditional variance of the real price of good  $z$ . This last effect reflects Jensen's inequality and can essentially be disregarded in our discussion since in equilibrium this conditional variance is constant. Moreover, in all that follows, we assume that the user cost of capital,  $c_t$ , is constant over time.<sup>3</sup> Hence, the only effective source of time variation in market-specific capital is due to changes in the expected real prices of goods.

The nature of the informational problem faced by firms is now made clear by equation (4). In particular, a firm would like to know the current state of relative demand in its market in order to most appropriately determine investment. However, firms do not have this information. Instead, each firm must extract, from both its current observation on its market-specific price and its knowledge of the past state of the economy, a prediction of the future relative price of its goods. The conditional expectation in equation (4) precisely reflects this information processing problem. However, solving this conditional expectation problem is complicated by general equilibrium interactions.

In order to solve for an equilibrium, we need to specify the properties of the two driving forces. First, let the exogenous money supply process be represented by the (possibly-non stationary) autoregressive and heteroscedastic process given in (5):

$$m_t = A(L)m_{t-1} + \mu_t. \tag{5}$$

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<sup>3</sup>This could be formally justified by the explicit inclusion of risk neutral agents in the economy.



In equation (5), the monetary innovation  $\mu_t$  is an independent and normally distributed random variable with mean zero and conditional variance  $\tau_t^2$ , and  $A(L)$  is a polynomial in the lag operator. The important element to notice in (5) is that the money supply process is characterized by time-variation in its predictability since the variance of  $\mu_t$  is not constant. In fact, it is precisely the implications of such "monetary instability" that we are trying to explore--that is, the implications for investment of variations in  $\tau_t^2$ . Obviously, we are not claiming here that only variations in uncertainty associated with monetary policy are important. This model should be taken as a stylized account of the consequences for the distribution of investment of an increase in macroeconomic policy uncertainty in general.

The other driving forces in this economy are the relative demand components. These exogenous forces are assumed to be stationary (in order for real prices to be stationary) and are assumed to obey the first-order autoregressive process given by (6):

$$\varepsilon_t(z) = \rho \varepsilon_{t-1}(z) + v_t(z), \quad 0 < \rho < 1. \quad (6)$$

In (6), the innovation in relative demand,  $v_t(z)$ , is assumed to be independently and normally distributed with mean zero, constant variance,  $\sigma^2$ , and with  $\int_0^1 v_t(z) dz = 0$ .

Assuming that all markets are Walrasian, an equilibrium for this economy is characterized by a pair of market-specific stochastic processes for capital and prices, such that: (a) given the allocation of capital, prices ensure the equality of supply and demand in each market; and (b) given prices, the allocation of capital satisfies equation (4).

Using the method of undetermined coefficients, it is straightforward (but somewhat tedious) to show that the following pair of stochastic processes for capital and the aggregate price level constitute an equilibrium.<sup>4</sup>

$$k_{t+1}(z) = \phi_I \varepsilon_t(z) + (\phi_{2,t} - \phi_I) v_t(z) + \phi_{2,t} \mu_t, \quad (7)$$

$$P_t(z) = m_t + \frac{1}{\gamma} \varepsilon_t(z) - \frac{\theta}{\gamma} \phi_I \varepsilon_{t-1}(z) + \frac{\theta}{\gamma} (\phi_{2,t-1} - \phi_I) v_{t-1}(z) - \theta \phi_{2,t-1} \mu_{t-1}, \quad (8)$$

where  $\phi_I = \frac{\rho}{\theta + (1 - \theta)\gamma}$

and  $\phi_{2,t} = \frac{\rho \sigma^2}{(\sigma^2 + \tau_t^2 \gamma^2) \gamma (1 - \theta) + \theta \sigma^2}$ .

There are several features of the capital stock equation to which we want to attract attention. First, equation (7) states that capital stocks depend both on real factors, affecting relative demand, and on monetary innovations. Monetary innovations affect the capital stocks because of the confusion between real and nominal factors as in Lucas (1972 and 1973). A positive monetary innovation increases investment because it leads the firm to infer from an increase in nominal demand that relative demand has increased (since the firm is solving a signal extraction problem). The second element to note from equation (7) is that the sensitivity of capital expenditures to monetary innovations depends on the stability of monetary policy. In particular, an increase in monetary instability, as represented by an increase in  $\tau_t^2$ , leads to a fall in  $\phi_{2,t}$ . This change in  $\phi_{2,t}$  reflects the fact that when monetary policy is less predictable, firms interpret observed increases in demand as reflecting mainly monetary factors (as opposed to real factors). A final aspect to note from (7) is that an increase in monetary instability also leads firms to adjust less to

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<sup>4</sup>In order to verify that these equations constitute an equilibrium behavior; first, postulate that capital expenditure decisions are of the form specified in equation (7); second, use this conjecture to derive the behavior of prices that would equate supply and demand and note that it corresponds to equation (8); third, use the resulting price behavior in conjunction with equation (4) to derive optimal capital expenditure decisions (which requires the solution to be a signal extraction problem); finally, verify that the resulting capital expenditure decisions are equal to those initially postulated.

innovations in relative demand. Hence, when monetary policy is more unstable, productive capacity will be less effectively targeted towards the sectors with high demand. We find that this latter feature of the model nicely captures the notion that monetary instability may reduce the efficient allocation of investment by reducing the informational content of prices.

In order to render the above observations empirically testable, it is helpful to examine the implication of equation (7) for the variance of the cross-sectional distribution of the investment rate. Using the fact that the investment rate can be approximated as the log difference of the capital stock, equation (7) implies that the cross-sectional distribution of investment rate can be written as:

$$Var_z(I_{t+1}(z)/K_t(z)) = \phi_1^2 \rho^2 \frac{(1-\rho)^2}{(1-\rho^2)} \sigma^2 + \phi_{2,t}^2 \sigma^2 + (\phi_{2,t-1} - \phi_1 \rho)^2 \sigma^2 \quad (9)$$

From equation (9), it can be seen that cross-sectional distribution of the rates of investment is related to both the variance of  $v_t(z)$  and the variance of  $\mu_t$  (through  $\phi_{2,t}$ ). Note that for our purpose, it is the effects of the time-variation in the variance of  $\mu_t$  which is of interest since it is this variance that reflects the effects of monetary instability. In fact, equation (9) implies that the cross-sectional variance of the investment rate depends upon the contemporaneous and once lagged variance of monetary innovations with the following partial derivatives:

$$\frac{\partial Var_z(I_{t+1}(z)/K_t(z))}{\partial \tau_t^2} < 0, \quad (10)$$

$$\frac{\partial Var_z(I_{t+1}(z)/K_t(z))}{\partial \tau_{t-1}^2} < or > 0 \quad (11)$$

As stated in (10) and (11), an increase in  $\tau_t^2$  leads to a decrease in the variance of the investment rate, while the effect of  $\tau_{t-1}^2$  is ambiguous. (Note that as long as  $\rho$  is not too large, the effect of  $\tau_{t-1}^2$  will also be negative.) Therefore, the main insight we draw

from (8) is that, when monetary policy becomes more stable and the predictability of prices improves, cross-sectional distribution of the rates of investment widens. This arises because investment is distributed more unevenly across firms as each of them responds more accurately to differences in the profitability of investment. Conversely, when prices become harder to predict, the cross-sectional distribution of investment rates will contemporaneously tend to narrow. In order to make this prediction easily implementable empirically, it is useful to consider the linear approximation of equation (8) as given below:

$$\text{Var}_z\left(\frac{I(z)_{t+1}}{K(z)_t}\right) = \beta_0 + \beta_1\sigma^2 + \beta_2\tau_t^2 + \beta_3\tau_{t-1}^2, \quad (12)$$

with  $\beta_2 < 0$ .

Equation (9), which forms the basis of part of our empirical investigation, states that holding  $\sigma^2$  and  $\tau_{t-1}^2$  constant, an increase in  $\tau_t^2$  should be associated with a reduction in the cross-sectional variance of the investment rate.

The model we have developed provides one interpretation of how a change in the informational content of market signals can effect the variance of the investment rate over time. Obviously, other rationales may exist. Potential candidates include explanations based on risk aversion, asymmetric information, and costly contract enforcement problems.<sup>5</sup> However, we believe that the above model manages to capture an uncertainty-based explanation in a very simple manner, and therefore, we think it is appropriate to adopt it as a base from which to empirically investigate changes in the variance of

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<sup>5</sup> For instance it may be argued that in bad times lenders find high debt to asset ratios less acceptable because they are perceived as being associated with greater risks of bankruptcy. If this leads to higher interest rates or rationing for firms characterized by high leverage, we could observe, for each level of internal funds, a decrease both in the mean value of the investment rate and a compression from the top of the distribution in bad times. In a sense this argument is related with the "flight to quality" story that emphasizes how credit may concentrate on the safer firms in bad times (see Bernanke, Blinder and Gilchrist (1994)). Nevertheless, existing models do not address the distributional issue directly and the arguments presented above is highly speculative at this stage. It goes beyond the purpose of this paper to produce a model based on capital market imperfections, although this is certainly a fertile topic for future research. We will therefore continue to focus on the role of uncertainty in the context of a perfect capital market.

investment. Moreover, this model provides a clear example of how macro uncertainty can hinder the efficient allocation of investment, and therefore growth, independently of its effect on the average rate of investment.

### **3. Trend and Cyclical Distributional Changes of the Investment Rate**

The model presented in Section 2 suggests analyzing the time-variation in the distribution of investment as a means of examining the effects of time-variation in the predictability of prices. This section begins by discussing the empirical evidence on the evolution of the cross-sectional distribution of UK firms' investment rate over the period 1970-1990. The objective of this exercise is to document both the trend and cyclical movements that occurred during the 1970's and the 1980's. The empirical analysis is based on an unbalanced sample of 963 quoted UK companies for which complete and consistent balance sheet data are available for at least three consecutive years. The source of the data is the DATASTREAM file.

In order to provide a summary of the distributional changes that have occurred, we report in Table 1 the standard deviation, the coefficient of variation, the 1st decile, the 1st quartile, the median, the 3rd quartile and the 9th decile of the investment rate. Figure 1a contains plots of the percentiles, while in Figure 1b we plot the inter-quartile (inter-decile) range to provide a better picture of changes in the dispersion of the distribution.

Three main features are revealed. First, concentrating on trend movements, it is evident that investment rates decreased during the 1970's. Second, the decrease was, however, greater for the 9th decile and for the 3rd quartile, so that we detect a substantial narrowing from the top of the distribution of investment rate over the 1970's. Both the 9th decile and the 3rd quartile dropped by approximately 45% comparing the investment rate in 1970 with that of 1980. During the 1980's we observe the opposite phenomenon with the dispersion of the distribution of the degree of leverage gradually increasing starting from

1983 and, more dramatically, between 1986 and 1988. This is because of a faster increase in the investment rate for the 9th decile, and also for the 3rd quartile than that of the median up to 1988. Comparing 1981 with 1988, we observe that the 9th decile and the third quartile increased, respectively, by 180% and 140%. Finally, at a cyclical frequency, we observe a decrease in investment rates for firms in periods corresponding to most of the recessionary episodes, leading to a decrease in dispersion. This is true for the recession of 1971, 1974-1975, 1980-1982 and the recession starting in 1990.

In order to make certain that these are genuine changes and do not only reflect the variation in the composition of the sample, we partition the whole sample into two sub-periods: 1970-1980 and 1980-1990. For each sub-period, we present graphs on four samples that differ for the conditions imposed on firms' entry and exit in the panel. In the first sample, we allow for both entry and exit (fully unbalanced). In the second, we allow entry but not exit by choosing only the firms that survived until the final year (1980 in one case and 1990 in the other). In the third sample, we do not allow entry but we allow exit choosing only the firms that were in existence in the initial year (1970 and 1980 respectively). Finally in the fourth sample, we allow neither entry nor exit by considering firms with observations for all the years in each sub-sample (fully balanced within each sub-period). This breakdown allows us to investigate whether and how the evolution of the investment rate differs for different categories of firms (new entrants, exiting firms, survivors). Table 2a gives the number of firms in each sample in each year, while Table 2b provides the number of entering and exiting firms for the different samples. The plots of the relevant percentiles in deviation from the median for each sub-period are given in Figures 2 a, b, c, d and 3 a, b, c, d.

For all four samples in the 1970's, we see a reduction of the dispersion of the distribution because of the greater fall in the investment rate for the top decile (quartile). Perhaps it would not be surprising to see such reduction of the dispersion in a sample

which allows firms to exit, since as the time passes surviving firms become more alike. However, we obtain the same results when we do not allow for exit. Similarly, the widening of the distribution between 1987 and 1989 is common to all four samples. However, the increase in dispersion from 1983 to 1988 is more marked for the samples that allow for new entrants, compared to the samples in which entry is not allowed. The decrease in dispersion starting in 1989 is also more pronounced. This says that new entrants contribute in an important way to the changes in dispersion. From the point of view of this paper, however, the important thing is that our general qualitative conclusions about the evolution of dispersion of the investment rate hold for all four sampling criteria.

#### **4. Macroeconomic Evidence on the Effect of Uncertainty on the Variance of Investment.**

Our model predicts that a more unstable and uncertain macroeconomic environment, because of its adverse effect on the informational content of prices, should lead to a cross-sectional distribution of the investment rate characterized by less dispersion. The panel data evidence for the UK suggest that there was an overall decrease in the dispersion in the 1970's and an increase in the 1980's. Dispersion also appears to have moved procyclically, falling in recessions and rising in during expansions. In order to assess whether our model can provide a satisfactory explanation of these changes, we need to define appropriate measures of uncertainty and assess the nature of their correlation with the variance of the investment rate. We will start from an anecdotal approach and argue that the main macroeconomic developments in the UK during the periods covered by our panel are indeed consistent with the changes in the cross-sectional distribution of investment. The main theme we want to emphasize is that the 1970's were characterized by a high and increasing degree of macro volatility while the 1980's saw a return to a more stable environment, particularly with regard to the inflation rate. Clearly the two oil price shocks were very important in giving rise to the initial upward pressure on prices in the

1970's. However, the increase in inflation is intimately related to the macroeconomic policy response adopted by the government in its attempt to keep unemployment from rising in the context of wage resistance by unions. We focus on this policy response and, in particular, on the consequences of an increase in the uncertainty that characterizes such response in the wake of the adverse supply shocks. In order to test our model more formally, we complement the descriptive evidence on macroeconomic developments in the UK with the econometric results obtained from estimating ARCH models for prices and money, and analyze the direction, strength and significance of the association between the conditional variances of inflation and money with the variance of the investment rate. Finally, in the next section we develop a test of our model using a panel data based measure of uncertainty. Although we regard the latter test as the most convincing and innovative one, we find the macro evidence informative as well.

#### *4.1 Anecdotal Evidence*

The decade of the 1970's was characterized by the rise in international commodities prices that generated periods of crisis in which all OECD economies suffered from high inflation, balance of payment problems, an increase in unemployment, and a general slow down of growth. The UK was one of the countries for which the adjustment to the adverse supply shock was particularly difficult. The annual rate of inflation in the UK was in the double digits for most of the 1970's and exceeded 20% for 1974 and 1975. Moreover, the inflation rate in the 1970's was not only higher on average than in the 1980's but also more variable. Neither the policies of the Conservative governments, between 1970-1974, nor the Labour governments, between 1974-1979, were successful in controlling inflation, although different strategies were attempted, including statutory and voluntary incomes policies during some of the periods.<sup>6</sup> Over this period there were frequent changes of economic policy strategies by both sets of administrations, which may have contributed to

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<sup>6</sup>See Cairncross (1992) for a detailed overview of the macro developments and of the policy responses.



uncertainty about the evolution of prices and other macro aggregates. The overall lack of permanent success in the struggle to control inflation was due in part to the real wage resistance exhibited by the unions, to which incomes policy brought only temporary relief. It also reflected the post war political consensus in the attempt by the governments to maintain high levels of employment. This commitment, shared, for the most part, by all political parties, gave both fiscal and monetary policy a stop-and-go quality as the governments tried to navigate among slow-downs in economic activity with the attending unemployment problem, the occurrence of balance of payment crises, and the resurgence of inflation. We have already commented about inflation. The two main contractionary episodes followed the oil price shocks at the end of 1973 and in 1979 and the contemporaneous slow-down of world trade. There was also a significant contraction in 1971.

The victory by the Conservative party in the 1979 elections changed the rules of the game in terms of economic policy. Following the collapse of the previous Labour government income policy during the winter of discontent of 1978-1979, the new Conservative government led by Mrs. Thatcher pursued a restrictive monetary and fiscal policy, that in addition to the effect of the oil price increase and the slow-down in world demand, created a very severe contraction that lasted until 1982. It has been debated how restrictive monetary policy actually was during that period, since the growth rate of M3 often overshoot the target ranges set by the government. However, the behavior of narrower money aggregates, like M0, and the appreciation of the pound sterling suggests that monetary policy was indeed tight. Moreover, the fiscal policy stance was also contractionary, and indeed the control of the Public Sector Borrowing Requirement was the main instrument through which the government attempted to reduce the rate of growth of money.<sup>7</sup> Whatever the final judgment on how the initial contraction was achieved and on

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<sup>7</sup>See Buiter and Miller (1981) and (1983) for a detailed description and evaluation of Mrs. Thatcher's policies.

possible initial mistakes,<sup>8</sup> it is clear that the government eventually succeeded in establishing its credibility in the anti-inflation strategy, whatever the cost in terms of unemployment was. The willingness to live with high levels of unemployment was a departure from the post-war consensus and, together with legislation aimed at decreasing the power of the unions, succeeded in achieving low and steady inflation rates. By 1982 the rate of inflation was down to 5.4%, and reached its lowest value (3%) in 1986. The years between 1982 and 1989 were a period of steady expansion in output.<sup>9</sup> The evolution of the money growth rate suggests that monetary policy was not particularly expansionary for most of the 1980's. Finally, the period of expansion came to a close at the end of the 1980's and was followed by the beginning of another severe (and long) recession, starting in 1990, that was reflected in a negative growth rate of GDP for manufacturing in that year. The change in the volatility and predictability of the economic environment that occurred over the 1970's and 1980's, as suggested by our brief summary of the macroeconomic developments in the UK, fits together nicely with the observed variations in the dispersion of the investment rate if one is ready to associate the overall turbulence with (nominal) monetary instability.

#### 4.2 *Arch Results*

The anecdotal approach provides some *prima facie* evidence that is consistent with the predictions of our simple model. However, in order to provide a more formal test, we need to derive quantitative measures of the degree of nominal uncertainty. For this reason, we have estimated ARCH models for inflation and money supply growth.<sup>10</sup> ARCH models allow for the conditional variance of an economic time series to change over time

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<sup>8</sup>The inflationary increase in VAT and the initial wage increases accorded to public sector employees have been mentioned in this respect.

<sup>9</sup>Productivity also increased, though the unemployment performance of the UK was rather disappointing in absolute terms and relative to other OECD countries. See Bean and Symons (1989), and Matthews and Minford (1987) for an evaluation of the Thatcher years.

<sup>10</sup>See Engle (1982).

and are appropriate to model its behavior when the series displays periods of high volatility followed by periods of tranquillity. The conditional variance is the variance of the forecast error conditioned on the available information set and provides us a measure of the precision with which forecasts can be made. In our empirical application, we have used monthly data over the period 1960 to 1990 for the log difference of the CPI and quarterly data for M4.<sup>11</sup> The choice of a meaningful monetary aggregate covering a two decades period is fraught with conceptual and data difficulties. Since money supply in the model is the only determinant of aggregate demand, we have used quarterly M4 which is the only wide money aggregate continuously available over the entire period.<sup>12</sup> For both series we first test for the presence of ARCH effects using the Lagrange Multiplier (LM) test. We then estimate an ARCH model by maximum likelihood (ML), with linearly declining weights for the conditional variance for each of the two variables. Use of linearly declining weights makes it easier to ensure that the conditional variance is always positive. The estimated model is:

$$y_t = \sum_{i=1}^p \beta_i y_{t-i} + \varepsilon_t, \quad (13)$$

where  $y_t$  denotes either the CPI or the index of manufacturing production and  $\varepsilon_t = \mu_t \sqrt{h_t}$ .  $\mu_t$  is a zero mean, unit variance white noise process and  $h_t$  is defined as:

$$h_t = \alpha_0 + \alpha_1 \sum_{i=1}^q a_i \varepsilon_{t-i}^2, \quad (14)$$

where  $a_i = (q+1-i) / \sum_{i=1}^q i$ . After some experimentation and testing we have set  $p = 6$

and  $q = 8$  for the inflation rate, while for the logarithmic growth rate of M4 we have set

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<sup>11</sup>The data for M4 is seasonally adjusted. Since that the CPI data is not seasonally adjusted, we include seasonal dummies in estimating the inflation equation.

<sup>12</sup>Monthly M4 is only available from August 1982, while the only other continuously available series, M0, is more weakly linked to aggregate demand.

$p=4$  and  $q=1$ .<sup>13</sup> The results of the LM tests are reported in Part A of Table 3, with the ML estimates in Part B. The LM tests suggest that the hypothesis of constant conditional variance can be rejected at the 1% significance level.  $\alpha_1$  is significantly different from zero in a one-sided test at the 1% level in the inflation equation and at the 5% level in the money growth equation. The estimated conditional variances for inflation and for money growth rate suggest that the 1970s were turbulent years compared to the 1980s (see figures 4a and 4b).<sup>14</sup> These results confirm and complement those obtained for UK inflation by Engle (1982) who finds significant ARCH effects during the 1960's and 1970's.<sup>15</sup>

The consistency of macroeconomic developments with the prediction of our theoretical model can now be investigated formally by analyzing the direction and significance of the association between the estimate of the conditional variances obtained from the ARCH model with the estimate of the variance of the investment rate obtained from the panel. Such a test is based on the linearized version of equation (9) (see (12)).<sup>16</sup> Since the ARCH model for inflation is estimated using monthly data, we have taken twelve-month averages of the estimated conditional variances. Similarly, we have taken four-quarter averages of the estimated conditional variances for money growth. In Table 4a we present the results of the OLS regression of the investment variance on the contemporaneous and once lagged estimated conditional variance of inflation, denoted by  $CVCPI_t$  and  $CVCPI_{t-1}$  respectively.<sup>17</sup> In this and the following regressions, we have

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<sup>13</sup> In both cases  $\alpha_0$  is positive and  $\alpha_1$  is between zero and one, guaranteeing positive variance for any value of  $\varepsilon_t$ .

<sup>14</sup> We also estimated ARCH models with longer lags on  $p$  and  $q$  for both models. The chosen specifications cannot be rejected against the more general models on the basis of likelihood ratio tests.

<sup>15</sup> On a related topic, see also Ball and Cecchetti (1990) who provide evidence that high levels of inflation are accompanied by greater uncertainty about future inflation, especially at long horizons. Moreover, Tommasi (1994b) finds that higher inflation is associated with greater difficulties in predicting relative prices.

<sup>16</sup> Huizinga (1993) presents interesting empirical evidence for the US on the relationship between inflation and real price uncertainty, and on their effect on the level of investment. The emphasis in our paper is, instead, on the effect of uncertainty on the cross-sectional variance of investment.

<sup>17</sup> In calculating the variance of the investment rates we have used only firms with at least seven years of observation. This leaves us with 721 firms. We have made this choice in order to strike a balance between maintaining a large number of firms in the calculation, while avoiding the drawbacks

allowed for an intercept shift between the 1970's and 1980's. This is meant to capture any decade long shifts in the variance  $\sigma^2$ . The important result to note for our purposes is that both the coefficients on  $CVCPI_t$  and  $CVCPI_{t-1}$  are negative and are jointly significantly different from zero, with a marginal significance level of less than 1% ( $F_{2,15} = 7.85$ ).<sup>18</sup> Although the theory presented in section 2 has a definite prediction only for the coefficient associated with  $CVCPI_{t-1}$ , the estimates presented in Table 4 suggest that lagged nominal uncertainty also has a negative effect. To gain some intuition about the magnitude of the effects, consider that these results imply that, starting from their mean values, a 50% increase in the (conditional) standard deviation of the inflation rate generates approximately a cumulative 20% increase in the standard deviation of the investment rate after three periods. In Table 4b, we report the results obtained when the conditional variance of M4 (denoted by  $CVM4_t$ ) is used as our measure of nominal uncertainty. The sign of the coefficients are consistent with the prediction of our model (both of them are negative), but their significance is not as sharp as for the proxy of uncertainty derived from the inflation equation ( $F_{2,15} = 2.75$ ). However, the magnitude of the effect is similar. In this case a 50% increase in the (conditional) standard deviation of the money growth rate leads, approximately, to a 25% increase in the standard deviation of the investment rate after three periods. This may be the result of the very stylized nature of the model (that relies, for instance, on a stable velocity of money) and the difficulty in identifying a single monetary aggregate bearing a stable relationship with aggregate demand over a two decades period.

Before exploring the evidence on time-variation in price predictability based on micro data, it is relevant to ask whether the results reported to date could alternatively be interpreted as reflecting time-variation in fundamental uncertainty (as captured by  $\sigma_t^2$ ) as opposed to variation in noise (as captured by  $\tau_t^2$ ). As can be inferred from equation (8),

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deriving from changes in the composition of the sample in each year. However, the basic results hold for different choices of the firms included in the calculation of the variance.

<sup>18</sup>Although the conditional variance of inflation is a generated regressor, as shown in Pagan (1984) the joint test of significance is perfectly valid (while the individual  $t$  statistics are not).

the contemporaneous effect of an increase in  $\sigma_i^2$  on the variance of the investment rate (holding  $\tau_i^2$  constant) is positive, since it is efficient to distribute investment more unevenly when there is more divergence in profitable opportunities. Therefore, to explain the narrowing of the distribution of investment rates observed in the late 1970s and early 1980s by changes in the variance of fundamental shocks, it would be necessary to argue that this period was a period of relative tranquillity. This explanation seems implausible to us.

The previous discussion is relevant also in understanding whether adverse supply shocks may explain the observed movements in the cross-sectional variance of investment. Supply shocks can be modeled by inserting a firm and time specific additive stochastic term in the (logarithmic) production function summarized by equation (3). Different values of the shock across firms may reflect differences in energy needs. The 1974 and 1979 oil price shocks could be interpreted as lowering the mean of this term and increasing its variance. However, it can be easily shown that in the absence of a signal extraction problem, an increase in such variance would lead to an increase in the variance of the investment rate. The effect of a supply shock is therefore similar to the one caused by an increase in the variance of the real demand shocks,  $\sigma^2$ , and it leads to the counterfactual implication that an oil price shock should increase the cross-sectional variance of investment.

## **5. Panel Data Evidence on the Effect of Uncertainty.**

We now adopt a different and novel approach to test our model. In the previous sections, we focused on the pattern of co-movement between the cross-sectional distribution of investment and aggregate measures of nominal uncertainty. In contrast, in this section we want to examine the relationship between the cross-sectional variance of the profit rate and the cross-sectional variance of the investment rate implied by our model.

An advantage of this change of focus is that it allows us to develop a test that exclusively uses information drawn from our panel data set. Moreover, this alternative focus is methodologically attractive since it provides an example in which panel data is used to test a model's prediction regarding the co-movement of second moments.

The intuition behind our alternative test is quite simple. In the case of increased nominal uncertainty, we showed in Section 2 that investments will be less efficiently channeled towards the most profitable investment opportunities. Correspondingly, increased nominal uncertainty should lead to an increased dispersion of the *ex post* profit rates since investment flows are *de facto* less likely to equalize profit rates. Hence, these two observations imply that an increase in the cross-sectional variance of the *ex post* profit rates should be associated with a decrease in the variance of the investment rate. Before empirically exploring this idea, it is valuable to show formally that such a prediction is implied by the model presented in Section 2.

Based on the notation introduced in Section 2, the log of the real profit rate in market  $z$  can be expressed as in equation (15).

$$\log \frac{\pi(z)_{t+1}}{K(z)_{t+1}} = p(z)_{t+1} - p_{t+1} - (1 - \theta)k(z)_{t+1} \quad (15)$$

$\pi(z)_{t+1}$  is the real operating profit at time  $t+1$ , and  $K(z)_{t+1}$  is the level of the capital stock. Using the specification of equilibrium prices given by equation (8) in conjunction with equation (15), the cross-sectional variance of the (log) profit rate can then be expressed as in (16):

$$\text{Var}_z \left( \log \frac{\pi(z)_{t+1}}{K(z)_{t+1}} \right) = \frac{\sigma^2}{\gamma} + \left( \frac{\rho\sigma^2}{\gamma} - \phi_{2,t} \left( \frac{\theta}{\gamma} (1 - \theta) \right) \right)^2 \sigma^2 \quad (16)$$

The main element to notice from equation (16) is that, through  $\phi_{2,t}$ , the cross-sectional variance of the profit rate is positively related to monetary instability. In other

words, the partial derivative of  $Var_z\left(\log\frac{\pi(z)_{t+1}}{K(z)_{t+1}}\right)$  with respect to  $\tau_t$  is positive.

Therefore, using linear approximation of (16), equation (12) can be rewritten to express the relationship between cross-sectional variance of the investment rate and the cross-sectional variance of the profit rate. This relationship is given by equation (17):

$$Var_z\left(\frac{I(z)_{t+1}}{K(z)_t}\right) = \beta_0' + \beta_1'\sigma^2 + \beta_2'Var_z\left(\log\frac{\pi(z)_{t+1}}{K(z)_{t+1}}\right) + \beta_3'Var_z\left(\log\frac{\pi(z)_t}{K(z)_t}\right) \quad (17)$$

with  $\beta_2' < 0$ .

Equation (17) indicates that an increase in the cross-sectional variance of the profit rate should be associated with a contemporaneous decrease in the cross-sectional variance of the investment rate. This partial correlation prediction reflects the fact that as the informational content of prices goes down, the investment flows should be less effective in equating profit rates across firms. In order to test this prediction, we therefore need to extract an estimate of the cross-sectional distribution of the profit rate using our panel data.<sup>19</sup>

The results of regressing the variance of the investment rate on the contemporaneous and lagged variance of operating profits ( $VARPR_t$ ) are presented in Table 5. The coefficients are both negative and jointly significantly different from zero at the 5% level ( $F_{2,15} = 3.77$ ). Note that the coefficient of  $VARPR_t$  is more than twice as large than the coefficient of  $VARPR_{t-1}$ . In this case, a 50% increase in the standard deviation of the log profit rate leads, approximately, to a 70% cumulative increase in the standard deviation of the investment rate after two periods. These results are again supportive of the predictions of our theoretical model.

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<sup>19</sup>Profits are defined here as gross of depreciation and interest payments and are therefore equal to total revenue minus labor and material costs.



It is worth noting that the results presented in table 5 are particularly supportive of the imperfect information story we are advocating as opposed to a credit rationing view. For example, if the alternative hypothesis is that time-variation in the cross-sectional distribution of investment is due mostly to changes in the importance of credit rationing, then we would expect the cross-sectional variance of the profit rate (which reflects availability of internal funds for investment) to be positively related to the cross-sectional variance of the investment rate. As seen in Table 5, this is not the case.

## **5. Conclusions**

This paper has focused on the effect of the informational content of prices on the distribution of investment across firms. In order to explain the distributional movements in the investment rate, we have developed a simple model whose objective is to formalize how monetary uncertainty may affect the allocation of investment. The model implies that as the money supply process becomes more predictable, the firm's own relative price, and hence its profit opportunities, become easier to forecast. This should cause the cross-sectional distribution of investment to widen, since improved information allows firms to channel investment towards most profitable opportunities. Correspondingly, our empirical work has concentrated on explaining the changes in the dispersion of the investment rate in the UK over the period 1970-90, where we have documented that dispersion decreased in the 1970's, at times of greater uncertainty, and widened in the 1980's. We have also documented that the variance of the investment rate moved procyclically.

Formal support for the model comes both from panel data analysis and from more macro-level evidence. First, both the anecdotal approach and simple ARCH models for aggregate prices and money suggests that the 1970's were a period of greater price uncertainty, following adverse supply shocks and the frequent changes in macroeconomic policy. Furthermore, econometric estimation shows that the conditional variance of

inflation is inversely related to the variance of the investment rate. The direction of the effect of the conditional variance of money growth is also consistent with our model but is not statistically significant. The implications of the model also receive empirical support from the significant negative correlation between the variance of the investment rate and the variance of the log of profit rate calculated using panel data. We have shown that the latter is positively related to the conditional variance of the money supply process in our model. Hence, we believe that this paper provides some clear and intuitive evidence in support of the view that monetary instability, through its effect on the predictability of prices, may hinder the efficient allocation of investment.

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