# UNCERTAINTY AND INVESTMENT OF DUTCH FIRMS:

# AN EMPIRICAL ANALYSIS USING STOCK MARKET DATA

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**Abstract**

This paper examines the investment-uncertainty relationship for a panel of Dutch firms. The uncertainty proxy is derived from daily stock market prices of individual firms. We show that some macro indicators, in combination with firm fixed effects, are able to give a reasonable explanation of the uncertainty a firm is faced with, and hence can be used to extract the exogenous component of uncertainty. The investment-uncertainty relationship appears to be non-linear: for low levels of uncertainty there is a positive effect on investment, whereas for high levels of uncertainty the effect becomes negative.

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## 1. Introduction

The relationship between uncertainty and investment has been examined quite extensively in the last decade. The investment-uncertainty relationship now seems to be clear from a theoretical point of view. However, empirical studies are lagging behind. Empirical researchers on the investment–uncertainty relationship are confronted with two basic problems. First, uncertainty is unobservable so that a proxy for uncertainty has to be developed. Second, the uncertainty proxy is a constructed, endogenous variable, which makes least-squares estimates biased and inconsistent.

This paper analyses the investment-uncertainty relationship for a panel of Dutch firms. There are two special features. First, a firm-level uncertainty proxy is derived from conditional variances of a model of generalised autoregressive conditional heteroscedasticity  (GARCH) applied to daily stock market prices of Dutch firms. The volatility in stock markets is a general measure of uncertainty and is probably the best indicator for the variability of future expected cash flows. The GARCH model is used since daily stock market prices probably display clustering effects. Second, in order to circumvent the problem of biased least-squares estimates for a constructed variable, the technique of instrumental variable estimation is used. The paper pays considerable attention to the selection of appropriate instruments for firm-level uncertainty.

The paper shows that some macro (policy) indicators are appropriate instruments for the volatility of firm stock prices.  Moreover, the analysis suggests that the investment-uncertainty relationship is non-linear. The investment-uncertainty relationship is positive for low values of uncertainty, but negative for high values of uncertainty. To our knowledge, this has not been documented before in the empirical literature on investment under uncertainty. However, it is a well-known phenomenon in the inflation-growth literature.

The paper is organised as follows. Section 2 presents a survey of the literature on investment under uncertainty. In Section 3 the method to measure uncertainty is explained. This section also justifies the set of instruments. In Section 4 the regression results are presented. Section 5 explains the regression results. Section 6 concludes.

## 2. Literature Survey

There are extensive surveys available on investment under uncertainty, see *e.g.* Nickell (1978), Dixit and Pindyck (1994) and Lensink, Bo and Sterken (2000). Therefore, we are deliberately brief in this paper and refer

the reader willing to have a more complete overview to one of these references.

Economic theories do not succeed in predicting a clear-cut relationship between business investment and uncertainty. There are several characteristics that influence the sign of the investment-uncertainty relationship. The following list contains the most important factors:

**(1)** The risk attitude of the firm. Most studies assume that the managers of the firm are risk-neutral. Nickell (1978) considers alternative assumptions regarding risk behaviour of firms. More recently, Aizenman and Marion (1999), in an empirical cross-country study, pay attention to risk averse behaviour. By modifying the standard expected utility analysis with the concepts of disappointment aversion (Gul, 1991) and Knightian uncertainty, they show that the effect of uncertainty on investment is negative. In general, one can conclude that the probability of a negative effect of uncertainty on investment increases the more risk-averse the firm is.

(2) The degree of irreversibility and the option value of investment opportunities. Dixit and Pindyk (1994) emphasise the consequences of irreversibility and the possibility to wait for the investment-uncertainty relationship. They introduce uncertainty in the investment decision rule through the threshold value that triggers investment and show that uncertainty increases the investment trigger. Alternatively, Abel and Eberly (1999) argue that even in the case of irreversible investment, uncertainty may have a positive effect in the long-run due to a so called "hangover" effect. Bar-Ilan and Strange (1999) also point out that uncertainty may have a positive effect on irreversible investment. This might be the case when the intensity of investment is taken into account. However, in general the probability of a negative effect of uncertainty on investment increases the higher the degree of irreversibility.

(3) The degree of financial constraints. Ghosal and Loungani (2000) document that the uncertainty-investment relationship probably depends on the degree of capital market imperfections based on the reasoning given by Greenwald and Stiglitz (1990). This indicates that a well-developed financial system can manage risks more efficiently. In the case of stock markets, the risk diversification will be direct, whereas it is indirect in the case of commercial banks. Indeed Lensink (2000), in a cross-country study, finds strong evidence that countries with a more developed financial sector are better able to nullify the negative effects of uncertainty. Therefore a firm facing an increase in uncertainty will more likely cut investment in the case where it suffers from financial constraints.

(4) The competitiveness in product markets in combination with the production technology. Cabellero (1991)

shows that the effect of an increase in uncertainty on irreversible investment is always positive if the firm is operating in a perfect competitive product market using a constant returns to scale production technology. The reason for this positive effect is that in this case the marginal product of capital is a convex function of the uncertainty variable, and hence by means of Jensen's inequality an increase in uncertainty will positively affect investment. For similar analyses, see Hartman (1972) and Abel (1983).

Empirical studies are rather mixed with respect to the sign of the investment-uncertainty relationship. A large amount of empirical papers report a negative effect of uncertainty on investment. However, the sign of the investment–uncertainty relationship seems to be subject to many issues, such as the technique used to quantify uncertainty, the dataset and the source of uncertainty (see Lensink, Bo and Sterken, 2000, Ch.6). More empirical research is necessary to improve empirical knowledge.

## 3. The Proxy for Uncertainty

### 3.1 Pros and Cons of Using Stock Market Data to Proxy for Uncertainty

The change in the value of an investment project is caused by changes in the underlying variables, such as prices, wages and sales, which are probably affected by *e.g.* government policies. Preferably, the modelling of investment decisions should explicitly consider the sources of the value fluctuations. Hence, indicators that are able to pinpoint the exact source of uncertainty have to be developed. However, this would make the analysis extremely time consuming and complicated, among others since the different sources of uncertainty are probably interconnected with each other. In order to come around this problem, we follow Leahy and Whited (1996) by using information on the volatility of an individual firm's stock market prices.[1] Pindyck (1986, 1991) use stock market data to obtain an uncertainty proxy for a study on aggregate investment. Stock returns reflect any aspect of a firm's environment, which makes it possible to derive a general measure of uncertainty. Another advantage of using stock market data to proxy for uncertainty is that the proxy is probably the least influenced by measurement problems since stock market data provide a one-catch proxy for uncertainty.

Some authors criticise the use of stock market data since the volatility in stock market returns may be caused by speculative bubbles in stead of fundamentals (Ferderer, 1993). Stock market volatility may contain an additional component of uncertainty as compared with other sources of uncertainty, such as sales and net profit. If stock markets work efficiently, the changes in stock market prices reflect only the changes in the expected discounted

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value of future dividend of the firm (fundamentals). However, theoretical and empirical studies have shown that often there are deviations of the stock market value of the firm from fundamentals. There is a literature that examines whether such deviations are relevant to capital investment. Some studies, based on US data, find that only fundamentals are important (e.g. Blanchard, Rhee, and Summers, 1993; Mork, Shleifer, and Vishny, 1990). Recently, Chirinko and Schaller (1999) test the impact of the deviation of the stock market value from the expected discounted value of the firm (bubbles) on business investment for the case of Japan. They find that the bubbles boost business fixed investment by means of a lowering of the cost of capital. The volatility of stock market prices contain bubbles. Hence, testing the effect of uncertainty on firm investment using stock market volatility is in fact a joint test of the fundamental uncertainty on investment and the impact of stock market bubbles. This requires some caution in interpreting the empirical results. Nevertheless, the volatility in stock market returns is probably the best indicator for cash flow uncertainty, which has induced us to derive the uncertainty proxy from daily information on stock market prices for individual firms.

*3.2 The Method*

Lensink, Bo and Sterken (2000, Ch6.) distinguish five methods to construct an uncertainty proxy:

1) The standard deviation of the variable under consideration;

2) The standard deviation of the unpredictable part of a stochastic process;

3) The standard deviation from a geometric Brownian process;

4) The General AutoRegressive Conditional Heteroskedastic (GARCH) model of volatility

5) The standard deviation derived from Survey Data.

For the problem at hand, the fourth method is most appropriate. A GARCH model assumes that the variance of the error terms is not constant over time, which is often documented to be the case for stock market data. The GARCH (1,1) technique is used in this paper. It comes down to jointly estimating a mean equation for the firm stock market price and an additional equation for the conditional variance which depends on a lagged value of the squared error terms and a lagged value of the conditional variance. The mean equation for each firm $i$ is specified as follows:

$$SI_{i,t} = \beta_{i,1} + \beta_{i,2}\, SI_{i,t-1} + \varepsilon_{i,t} \tag{1}$$

where $SI$ is the stock market price for firm $i$. $t$ refers to daily time periods. In total there are 56 firms in the sample. The equation for the conditional variance ($\sigma^2$) is specified as:

$$\sigma^2_{i,t} = \alpha_{i,0} + \alpha_{i,1}\varepsilon^2_{i,t-1} + \alpha_{i,2}\, \sigma^2_{i,t-1} \tag{2}$$

Since the uncertainty measure is determined per firm, the most appropriate mean equation as well as the most appropriate specification of the conditional variance may be different per firm. In other words, the specification of the GARCH model may be accurate for some firms in the data set, whereas a slightly different specification would be preferred for other firms. In order to keep the analysis tractable we decided to use a uniform specification for all firms in the sample. However, we tested some slightly different specifications of the mean equation. More specifically, in alternative specifications we included a trend (*T)*, and a second-order autoregressive term, respectively. The uncertainty proxies constructed by using these mean equations appeared to be highly correlated with the uncertainty proxy constructed by using the mean equation as specified above (correlation coefficients above 0.95), so that qualitatively and quantitatively the same results were obtained using these specifications. For reasons of space, the detailed estimation results per firm are not presented.

The mean equation and the conditional variance equation are estimated for all 56 firms, firm by firm, in the data set for each sub-period of a year, using daily information on stock market prices. This gives daily conditional variances. Since investment data are only available on a yearly basis, we can not proxy uncertainty directly by the conditional variances. Therefore, we proxy the uncertainty measure per firm for each sub-period by the average conditional variance (*AGAR*) over the sub-period. We divide *AGAR* by the mean of the stock market price (*MEAN*) of the individual firm to get a sort of a coefficient of variation, defined here as *AGARM*. Hence,

$$AGARM_{i,h} = (AGAR \: / \: MEAN) = (\Sigma_t \sigma^2_{i,t}/n)/ \: (\Sigma_t \: SI_{i,t} \: /n) = \Sigma_t \sigma^2_{i,t}/\Sigma_t \: SI_{i,t} \tag{3}$$

where the subscript *h* is a time index referring to the yearly sub-period; *n* is the amount of observations in the sub-period. We also constructed an uncertainty measure by using the median of the conditional variances over the sample period. This did not change the qualitative results since the correlation coefficient between the different measures appears to be very high (above 0.9).

*3.3 Using Instruments for the Uncertainty Proxy*

The uncertainty proxy *AGARM* is a constructed variable that may suffer from measurement problems, even though measurement problems are probably the least when using stock market data. Moreover, and more importantly, uncertainty is an endogenous variable. This implies that least-squares estimates of the regression parameters are biased. The technique of instrumental variable estimation can be used to solve this problem.

However, finding appropriate instruments at the firm-level is a difficult task. In fact, it comes down to partly pinpointing the exact source of uncertainty, which we wanted to avoid in the first place. Nevertheless, a first attempt is made to find appropriate instruments for the uncertainty proxy.

The problem is approached as follows. We start by deriving instruments from aggregate macro-level information on the stock market in the Netherlands. More specifically, for each year the standard deviation of the Morgan Stanley monthly country index for the Netherlands (*STDMSCI*) is calculated. Note that the Morgan Stanley country index is not available on a daily or weekly basis for the entire estimation period, so that we had to use monthly information. The instrument we use is defined as *STDMSCI* over its mean (*MEANMSCI*). This allows to account for the correlation between the stock market volatility of individual firms and the average stock market volatility. In addition, *MEANMSCI*, as well as the lagged value of *AGARM* are used as instruments. Equation 1 in Table 1, presents the regression results.

INSERT TABLE 1 ABOUT HERE

The regression result is reasonable, indicating that the firm-level stock market volatility is highly correlated with the aggregate stock market volatility. Assuming that the market is atomistic and hence that for individual firms the aggregate market volatility is exogenous, the market volatility can be used as one instrument. Therefore, we derive from this regression a fitted variable of *AGARM*, defined as *FITTEDA*, which will be used in the next section in the investment regressions.

There are a few problems with equation 1 in Table 1. First, *STDMSCIM* is a constructed (endogenous) variable itself, and preferably should be instrumented. Second, besides $AGARM_{t-1}$ and the firm fixed effects, the instruments do not allow for differences at the firm-level. *STDMSCIM* is a macro variable with the same value for all firms. Moreover, all firms are implicitly assumed to react similarly to changes in *STDMSCIM*.

We try to come around the first problem by replacing $STDMSCIM_t$ and $MEANMSCI_t$ by different macro variables that are highly correlated with $STDMSCIM_t$ and $MEANMSCI_t$ and hence may indirectly be a source of uncertainty for firms. A set of possible instruments is selected from the following group of macro variables that may proxy for sales uncertainty, cost uncertainty and uncertainty with regard to government policies:

*CONG*: the growth rate of total consumption; *CPI*: the consumer price index; *CPS*: credit to the private sector as a percentage of GDP; *CPSG*: growth rate of *CPS*; *EXCHR*: the real exchange rate; *GGCG*: the growth rate of government general consumption; *INFL*: the inflation rate; *DINFL*: the change in the inflation rate; *INTERESTR:* the deposit rate; *OBD:* the overall budget deficit as a percentage of GDP; *OBDG* : the growth rate of *OBD*; *TAX*: taxes on income, profits and capital gain as a percentage of current revenue; *TAXG:* the growth rate of *TAX*; *TAXR*: tax revenue as a percentage of GDP; *TAXRG*: the growth rate of *TAXR*; *WAGE*: wages and salaries as a percentage of total expenditure; *WAGEG*: the growth rate of *WAGE*; *POPG:* the growth rate of population; *REALR*: the real interest rate; *REALRG*: the growth rate of *REALR*; *SPREAD*: the interest spread (lending rate minus LIBOR); *SPREADG*: the growth rate of *SPREAD*; *SUBS*: subsidies and other current transfers as a percentage of total expenditure and *SUBSG*: the growth rate of *SUBS*.

Most variables in the presented pool of variables appear to be highly correlated.[2] In order to avoid multicollinearity problems, we consider different groups of instruments for which the correlations are not too high, but perform well in the regressions concerning the instruments. After trying many combinations, we come up with the following group of appropriate instruments: *EXCHR; POPG; TAXG; OBD* and *DINFL*. From this regression we obtain another fitted variable of *AGARM*, called *FITTEDB*, which will also be used in the investment regressions in the next section. Note that, since some of the variables are highly correlated, other combinations of variables can as well be used to instrument *AGARM*. For instance, replacing *TAXG* by *GGCG,* or *EXCHR* by *INFL* gives qualitatively the same results.

We tried to solve the second problem by searching for firm-level variables that can be used to instrument *AGARM*. Due to data limitations, however, there are not many candidates. We tested the relevance of the growth of sales (*SALESG*), the change in debt (*DDEBT*), the interest coverage (*IC*) and the change in the interest coverage (*DIC*). We tested these variables individually, in some combinations with each other, as well as together with (different combinations of) the five macro instruments. In none of the estimates, the firm-level variables appeared to be significant. Some examples are given by equations 3, 4 and 5 in Table 1. In alternative estimates we also allowed for differences in firm responses to the macro uncertainty instruments. This has been done by testing for firm-level and hence non-common slope parameters for one of the macro variables *DINFL, EXCHR, POPG, TAXG* or *OBD*. However, since the degrees of freedom decrease enormously when all firms are

allowed to react differently to one of the macro instruments and since the results were not very promising we decided to stick to *FITTEDA* and *FITTEDB*. Table 2 presents a correlation matrix for *AGARM, FITTEDA* and *FITTEDB*.

INSERT TABLE 2 ABOUT HERE

Theoretically, it is better to take account of firm-level variables in order to extract the exogenous component of firm-level uncertainty. However, given the available data, we have not much of a choice. It is interesting to see, though, that the macro variables outperform the firm-level variables we have tested. The irrelevance of firm-level variables in explaining firm stock market volatility may be explained by the fact that changes in stock market prices mainly reflect the movement of markets that are common to all firms.[3] Our estimates suggest that a substantial part of firm-level uncertainty can be explained by government policies as reflected in *TAXG* and *OBG*. If it is taken into account that government policies indirectly have an important impact on the value of the real exchange rate and the change in the inflation rate, the importance of government policies for the uncertainty Dutch firms are confronted with becomes clear. The significance of the rate of population growth is somewhat more difficult to explain. We have included *POPG* because it appears to be highly significant, but from alternative estimates it appears that ignoring *POPG* does not qualitatively affect the results.

## *4.* **Estimation Results**

### *4.1 Linear effects of uncertainty*

We proceed by estimating three standard investment models extended with an uncertainty term. The aim is not to examine the significance of these three standard models per se, but to examine whether the uncertainty term is sensitive to the specification of the investment model. The first model is a simple accelerator type of investment model. The basic determinant of investment behaviour is the growth rate in total sales (*SALESG*), or alternatively the change in sales. A positive relationship between investment and the sales variable is expected if it is assumed that investment decisions are based on observed patterns of past demand for output. Next, we estimate a cash-flow type of model, in which in addition to *SALESG* a measure of internal sources is added to the model. We add the net profits after taxes divided by the capital stock (*PFK)*. Many investment studies include a measure of internal sources to test for possible financial constraints. The idea is that controlling for the growth opportunity of the firm investment is only sensitive to internal funds if the firm is facing financial constraints. Hence, a

significant coefficient for *PFK* will suggest that Dutch firms suffer from financial constraints.[4] Finally, we estimate a *q*-type investment model. The *q* theory of investment states that all fluctuations of investment are related to *q*, *i.e.* the ratio of the market value of installed capital to the replacement cost of installed capital. An increase in *q* should have a positive effect on investment. However, because of measurement problems the *q* model performs badly in empirical research. To come around this problem, Barro (1990) proposes to use stock market prices in stead of imperfect proxies for *q* in investment studies. The reason is that, according to his study, movements in the market value of equity dominate changes in *q*. We follow Barro (1990) and proxy *q* by the ratio of the mean value of the stock market price to the capital stock (*MEANK*) for individual firms.

Before presenting the regression results, Table 3 gives some descriptive statistics of the variables used in the estimates.

INSERT TABLE 3 ABOUT HERE

It should be noted that none of the variables is normally distributed. For all variables the distribution has thicker tails than does the normal distribution since the kurtosis is above 3. Moreover, since the values of the skewness are above 0 for all variables but *GIK*, the upper tail of the distributions are probably thicker than the lower tail. The non-normality of the variables is a well-known phenomenon in panel studies. Note that the value of the kurtosis and the skewness of *FITTEDA* and *FITTEDB* are much more in line with a normally distributed variable than the corresponding values for *AGARM*.

Although we prefer to use instruments for the uncertainty proxy, we start the analysis by presenting regression results for the case where uncertainty is proxied by *AGARM*. These results are presented in Table 4.

INSERT TABLE 4 ABOUT HERE

Next, Table 5 presents estimation results in which *AGARM* is replaced by *FITTEDA* and *FITTEDB,* respectively.

INSERT TABLE 5 ABOUT HERE

The regression results show a consistent picture. In all regressions *SALESG* is highly significant, indicating the relevance of the accelerator model. Alternatively, *PFK* is never significant. In other regressions, not presented for reasons of space, we replaced *PFK* by cash flow scaled by the capital stock. These regressions gave the same result: cash flow appeared to be insignificant in all regressions. This suggests that, on average, the Dutch firms in the sample are not suffering from financing constraints. Of course, it may well be the case that some groups of firms may suffer from financing constraints, but we refrain from such an analysis here since an *a priori* classification of firms has many drawbacks (see Lensink, Bo and Sterken, 2000, Ch. 3). Moreover, this paper does not primarily aim to examine the degree of financing constraints of Dutch firms.

Most importantly for the subject matter of this paper, the uncertainty proxy is significant in all regressions. Both *AGARM* and the exogenous component of uncertainty the firm is confronted with, given by either *FITTEDA* or *FITTEDB,* appear to have a significant impact on investment behaviour. This result appears to be robust to different specifications of the investment model. The most important result concerns that the sign of the coefficient for uncertainty is positive in all cases. The literature survey presented in Section 2 shows that this result is theoretically easy to explain. However, since most empirical evidence suggests that uncertainty has a negative effect on investment, the result is at the least remarkable.

*4.2 Non-linear Effects of Uncertainty*

We proceed the analysis by examining whether there are non-linearities in the investment-uncertainty relationship. The reason is that the values of uncertainty vary considerable across observations. In this situation, a non-linear specification would probably yield a specification with more plausible properties than the standard linear relationship.

The proposition to be tested is that low levels of uncertainty have favourable effects on investment, whereas for high levels of uncertainty the investment-uncertainty relationship becomes negative. In order to test this, a quadratic term is added to the investment model. The augmented equation has been estimated for the three investment models, using *AGARM*, *FITTEDA* and *FITTEDB*. For all cases the results appear to be qualitatively the same in the sense that the linear uncertainty term is significantly positive, and the quadratic uncertainty term

is significantly negative. For reasons of space, Table 6 presents only the estimation results for the augmented accelerator model.

INSERT TABLE 6 ABOUT HERE

The regression results clearly indicates that low levels of uncertainty display positive effects, but that above some level of uncertainty, uncertainty starts to have negative effects.

By taking the first derivative with respect to the uncertainty proxy, and setting it equal to zero, the turning point above which uncertainty starts to have a negative effect on investment curve can be estimated. Using *AGARM* as the proxy for uncertainty, the turning point is 3.9618. Using *FITTEDA* as the proxy for uncertainty, the turning point of 0.7225. In the case where *FITTEDB* is used, the turning point equals 0.7224.

*4.3 Sensitivity Analysis*

It may be the case that the results are highly sensitive to the inclusion of some high-uncertainty firms. For that reason, some attention to the possibility of outliers is highly important. The sensitivity analysis starts by considering the amount and percentage of observations that are on the right-hand side of the top. For the three uncertainty proxies, *AGARM, FITTEDA* and *FITTEDB* the amount of observations on the right-hands side equals 1, 7 and 7, respectively. In percentages of the total amount of observations, this equals 0.2, 1, and 1 percent, respectively. Hence, although the regressions support the notion of a negative uncertainty effect on investment for high levels of uncertainty, most observations are on the left-hand side of the top, and hence, in general, uncertainty has a positive effect on investment.

Since only a few observations are on the right-hand side of the turning point for each uncertainty measure, it is important to know what happens if these possible "outliers" are ignored in the estimates. So in the first set of sensitivity tests we repeat the estimations in Table 6 after cutting the observations on the right hand side of the turning points for each uncertainty measure. Equation 1, 2, and 3 in Table 7 present estimation results.

INSERT TABLE 7 HERE

The regression outcome still confirms the relevance of the model with a positive linear term and a negative quadratic term, even when the possible outliers are ignored. The threshold value implied by these model, however, differ from the model estimated on the entire sample. The turning point now equals 1.2175, 0.6791, and 0.6481 respectively for *AGARM*, *FITTEDA*, and *FITTEDB* and hence seems to be sensitive to the sample used in the estimates, especially concerning *AGARM*.

As a final sensitivity analysis, the regressions are redone for a sample in which, quite arbitrarily, the 6 highest values, as well as the 6 lowest values of the uncertainty proxy are ignored. In total, about 2 percent of the observations are then deleted. The equations 4, 5 and 6 in Table 7 present the results. It appears that qualitative results remain. For low values of uncertainty there is a positive effect on investment, whereas for high values of uncertainty this effect becomes negative. The value of the turning point equals 1.7261, 0.6461, and 0.6359 for *AGARM*, *FITTEDA* and *FITTEDB*, respectively. These values are somewhat lower than the values of the turning points based on regressions using the entire sample, but are still quite comparable.

## 5. Explaining the Results

How can it be explained that for not too high levels of uncertainty, the investment-uncertainty relationship is positive for Dutch firms and that for high values of uncertainty the relationship is negative? We do not present a formal model, but present several reasons as to why this may occur. Before doing that, two possible caveats are noteworthy. First, although the regressions suggest that on average not too high values of uncertainty have positive effects on investment, it may be the case that the sign of the effect is different for alternative groups of firms. For instance, small firms may display a positive effect of uncertainty whereas large firms may display a negative effect.[5] We have experimented with different possibilities to classify firms on the basis of size criteria, such as employment and sales, but could not find significant differences concerning the investment-uncertainty relationship per group. The reason might be that the sample of firms is relatively homogeneous *e.g.* since the sample only consists of listed firms. However, it may also be the case that the classification of firms is incorrect. Since *a priori* classifications of firms have many drawbacks, we have not further elaborated on this.[6] Second, the positive sign may be related to econometric issues, such as the quantifying of uncertainty, or the measurement of uncertainty. For instance, as has been mentioned before, there exist some literature that suggests that stock market volatility positively affects investment. (e.g. Chirinko and Schaller,1999). If this is the case, uncertainty measured by using stock market volatility will probably also display positive effects on investment.

The question then is whether our uncertainty measure really picks up uncertainty firms are faced with, or whether it is e.g. merely driven by speculative bubbles. A definitive answer can not be given before the effects of different uncertainty measures are compared to each other.

A positive relationship between investment and uncertainty for low values of uncertainty and a negative relationship for high values of uncertainty has, to our knowledge, not been documented before by the investment literature. However, we can at least think of two explanations as why this might be so. The first explanation is related to the literature on inflation and growth. The second relates to corporate governance arguments.

There is a vast literature on inflation and economic growth that shows that the inflation-economic growth relationship is non-linear. Uncertainty partly results from the variability in inflation rates, as has been confirmed by the estimates presented in Section 3. Moreover, the value of the rate of inflation and the variability in the inflation rate are probably highly positively correlated (see Chowdhury, 1991 and the cited literature there). Therefore, it may be relevant to consider the inflation-economic growth literature in more detail. A good survey is given by Temple (1999). Some theoretical inflation studies argue that moderate inflation rates may be positive for economic growth. A possible explanation for this is the existence of sticky nominal wages. In many (unionised) industries, nominal wages are set by wage contracts, and hence can not be changed immediately. A rise in the price level due to a positive inflation rate lowers the real wage, making labour cheaper and hence induces firms to invest more. There are also empirical inflation studies showing that inflation only becomes problematic for economic growth at higher rates. Some empirical studies conclude that there is not a strong negative relationship between inflation and economic growth across countries, or that the relationship is positive (Karras, 1993; Stanners ,1993). Other studies, such as Barro (1996, 1997) show that for low inflation rates (below 20 percent a year) there is little evidence for negative effects on growth. However, these studies also show that for higher inflation rates there is a clear connection with lower economic growth. Hence, if the uncertainty a firm is faced with mainly comes from volatility in prices, our result can be explained by referring to the literature on inflation and economic growth.

The hump-shaped pattern of the investment-uncertainty relationship may also be explained from corporate governance point of view. In general, corporate governance arguments favour management protection, which would lead to less risk-taking. A manager is concerned with his job market chances. However, it might be so

that inside ownership makes it optimal for management to take more risk. But inside ownership is substantial but not overruling, so controlling power by banks takes over after a certain level. Moreover, managers are rewarded by stock market increases. So in general incentive schemes are made to make managers more risk taking. Of course this will only hold to a certain level.

It is relevant to consider whether there are specific reasons as to why we may expect a positive investment-uncertainty relationship for firms in the Netherlands in addition to the general arguments supplied above. The literature survey in Section 2 gives some possible explanations for a positive sign. Confronting this with the situation in the Netherlands may improve the understanding of our results. First, theoretically the positive sign may be explained by risk-loving behaviour of Dutch firms. However, we do not think that this is the case for the firms in the sample. The firms in the sample are relatively large, and one would expect a risk-loving behaviour especially for small (and young) firms. Moreover, corporate governance in the Netherlands can be characterised as a system of cooption. In this system, new members of the supervisory board are elected by the current members of the supervisory board. In practice it appears that the management board strongly influences the composition of the supervisory board. The system of cooption reduces the corporate governance role of shareholders in general. This implies that the relative importance of monitoring by creditors (banks) increases, which probably reduces risk-taking activities of firms. Second, the positive sign might also be caused by perfect competition of the firms in the sample, in combination with a constant returns to scale production technology. This is, in our opinion, also not a convincing explanation since the data set contains many large-old firms, such as Philips electronics, Heineken and KLM, which probably are monopolistic or operate under oligopolistic circumstances. In our view, the positive sign for most observations in the sample probably is related to the fact that capital markets in the Netherlands are highly developed. The Netherlands has a well-organised and fully developed stock market and banking sector. Moreover, due to capital funding Dutch pension funds are relatively big institutions, driving the Netherlands in financial terms to the top-8 countries of the world (Garretsen, Lensink and Sterken, 2000). It is also the case that creditors and shareholders have long-term credit relationships with firms so that long-term projects can be carried out. This probably reduces the information asymmetry between banks or shareholders on the one hand and management on the other hand. Moreover, almost no firms in the Netherlands seem to be financed constrained. This is suggested by a recent interview study among Dutch firms by Lensink, van Steen and Sterken (2000). In the questionnaire firms were asked whether it was difficult to obtain external funds in the case where investments were partly financed externally. It appears that for only 6 of

the 930 firms it was difficult to obtain external funds. The regression results presented in Section 4 of this paper also suggest that Dutch firms are not finance constrained since the coefficient for *PFK* is insignificant after the growth opportunity is controlled. In Section 2 some arguments are given as to why a better developed capital market may lower the probability of a negative uncertainty-investment relationship. In addition, it is likely that a highly developed capital market makes it much easier to sell used capital goods, and hence the degree of irreversibility becomes lower the better developed the capital market. In Section 2 it has been argued that the probability of a negative sign for the investment-uncertainty relationship increases the higher the degree of irreversibility of capital goods. Hence, if better developed capital markets increase the reversibility of capital goods, the probability of a positive investment-uncertainty sign increases the better the capital markets are developed.

## 6. Conclusions

This paper examines the investment-uncertainty relationship for a panel of Dutch firms. The uncertainty proxy is derived from daily stock market prices of individual firms. We show that some macro (policy) indicators, such as the growth in profit taxes, the overall budget deficit, the real exchange rate and the change in the rate of inflation, in combination with firm fixed effects are able to give a reasonable explanation of the uncertainty a firm is faced with, and hence can be used to extract the exogenous component of uncertainty. The investment-uncertainty relationship appears to be non-linear for the firms in the sample: for low levels of uncertainty there is a positive effect on investment, whereas for high levels of uncertainty the effect becomes negative. Since most observations are on the left-hand side of the turning point the positive sign seems to hold in general. A reason for this positive sign might be the well-developed capital markets in the Netherlands, which may make irreversibility problems of the investment decision less severe. However, due to a lack of data, our study can not as yet give a definitive explanation of the results. We hope that our results are interesting enough to stimulate more empirical research on the investment-uncertainty relationship. In our view, it is relevant that future empirical research pays special attention to the possible relationship between capital market (im)perfections on the one hand and the sign of the investment-uncertainty relationship on the other hand.

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**Appendix: List of Variables and Data Sources**

(1) Information on investment, capital stock, profit, and sales is taken from the *Jaarboek van Nederlandse Ondernemingen*. The firms in the data set are listed on the Amsterdam stock exchange over the period 1984 –1996. The data set refers to an unbalanced panel of 56 manufacturing firms. From this data set we obtain:

*DEBT*: the book value of debt, which includes short and long term debt

*DDEBT*: the change in *DEBT*

*DIC*: the change in interest coverage

*GI*: gross capital investment, defined as the change in the capital stock plus depreciation

*GIK*: *GI/K*

*IC*: interest coverage, the ratio of interest payments to cash flow

*K*: the book value of the capital stock

*PF* : operating profits after tax and before interest payments

*PFK: PF/K*

*SALES* : the product of the output price and the amount of product sold

*SALESG*: the growth rate of *SALES*


(2) The stock market data come from *DATASTREAM*. From *DATASTREAM* daily stock market prices, we calculate:

*AGAR*: the average conditional variance of a firm's stock market price derived from a GARCH(1,1) process Conditional variances are on a daily basis. Averages are calculated over years

*MEAN*: the mean of the (daily) stock market price of the individual firm

*MEANMSCI*: the yearly mean of the Morgan Stanley monthly country index for the Netherlands

*SI*: the daily stock market price for firms

*STDMSCI*: the yearly standard deviation of the Morgan Stanley monthly country index for the Netherlands

*STDMSCIM = STDMSCI/ MEANMSCI*


(3) The macro-level variables used to instrument the stock market volatility are from World Bank (1999). from this data set we derive:

*CONG*: the growth rate of total consumption

*CPI*: the consumer price index

*CPS*: credit to the private sector as a percentage of GDP

*CPSG*: growth rate of *CPS*

*DINFL*: the change in the inflation rate

*EXCHR*: the real exchange rate

*GGCG*: growth rate of government  general consumption

*INTERESTR:* the deposit rate

*INFL*: the inflation rate

*OBD:* the overall budget deficit as a percentage of GDP

*OBDG* : the growth rate of *OBD*

*POPG:* the growth rate of population

*REALR*: the real interest rate

*REALRG*: the growth rate of *REALR*

*SPREAD*: the interest spread (lending rate minus LIBOR)

*SPREADG*: the growth rate of *SPREAD*

*SUBS*: subsidies and other current transfers as a percentage of total expenditure

*SUBSG*: the growth rate of *SUBS*

*TAX*: taxes on income, profits and capital gain as a percentage of current revenue

*TAXG:* the growth rate of *TAX*

*TAXR*: tax revenue as a percentage of GDP

*TAXRG*: the growth rate of *TAXR*

*WAGE*: wages and salaries as a percentage of total expenditure

*WAGEG*: the growth rate of *WAGE*


 (4) The constructed uncertainty measures based on the above-mentioned data sets are:

*AGARM*: *AGAR/MEAN*.  It is the coefficient of variation of the stock market prices

*FITTEDA*: a fitted variable of *AGARM*, derived from a regression in which *STDMSCIM, MEANMSCI,* the lagged value of *AGARM*, time dummies and firm level constants are used as instruments

*FITTEDB*: a fitted variable of *AGARM*, derived from a regression in which *DINFL, EXCHR, OBD, POPG, TAXG*, the lagged value of *AGARM*, time dummies and firm level constants are used as instruments

**Table 1: Instruments of the proxy for uncertainty**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| *STDMSCIM* | 0.5337 (1.73) | | | | |
| *MEANMSCI* | 0.00068 (3.97) | | | | |
| *DINFL* | | 0.0348 (2.24) | | | |
| *EXCHR* | | 0.0084 (3.21) | | | |
| *POPG* | | -0.9713 (-3.35) | | | |
| *TAXG* | | 0.2396 (1.82) | | | |
| *OBD* | | 0.042 (4.05) | | | |
| *SALESG* | | | 0.040 (1.01) | 0.030 (0.86) | 0.039 (0.98) |
| *DDEBT* | | | | 4.42E –08 (0.80) | |
| *DIC* | | | | | -1.16E–05 (-0.43) |
| *AGARM$_{t-1}$* | 0.1875 (1.97) | 0.1761 (1.74) | 0.1748 (1.67) | 0.1670 (1.61) | 0.1753 (1.67) |
| | | | | | |
| adj. $R^2$ | 0.29 | 0.31 | | 0.25 | 0.24 |
| F | 41.17 | 32.83 | | 34.52 | 32.94 |

Note: the dependent variable is *AGARM. STDMSCIM = STDMSCI/ MEANMSCI*. White Heteroskedasticity-Consistent t-values are between brackets. All equations are estimated with the fixed effects panel estimator to account for firm-level differences in the constant. The equation is estimated for the 1985-1996 period.

Significant time dummies for 1986, 1987, 1989, 1990, 1991 and 1992 are included. The amount of observations equals 647.

**Table 2: The correlation matrix of the uncertainty measures**

|          | AGARM | FITTEDA | FITTEDB |
|----------|-------|---------|---------|
| AGARM    | 1     |         |         |
| FITTEDA  | 0.60  | 1       |         |
| FITTEDB  | 0.62  | 0.97    | 1       |

**Table 3: Descriptive statistics for main variables**

|  | MEAN | MEDIAN | STAND DEV. | KURTOSIS | SKEWNESS |
|---|---|---|---|---|---|
| *GIK* | 0.2027 | 0.1998 | 0.2478 | 54.3961 | -4.7516 |
| *SALESG* | 0.0892 | 0.05963 | 0.2072 | 31.2493 | 3.3311 |
| *PFK* | 0.2242 | 0.1514 | 0.3853 | 19.7337 | 2.2058 |
| *MEANK* | 0.0226 | 0.0038 | 0.0802 | 118.8507 | 9.6479 |
| *AGARM* | 0.2099 | 0.1317 | 0.3109 | 83.6677 | 7.1578 |
| *FITTEDA* | 0.2129 | 0.1749 | 0.1796 | 3.6126 | 0.9661 |
| *FITTEDB* | 0.2094 | 0.1679 | 0.1881 | 3.6372 | 1.0098 |

Note: *GIK* is the dependent variable in the estimates, it is defined as gross investment over the capital stock.

STAND DEV. is the standard deviation.

**Table 4: The linear effect of uncertainty on investment**

|         | 1       | 2       | 3      |
|---------|---------|---------|--------|
| *SALESG* | 0.435   | 0.437   |        |
|         | (32.60) | (33.19) |        |
| *PFK*   |         | 0.011   |        |
|         |         | (0.38)  |        |
| *MEANK* |         |         | 0.037  |
|         |         |         | (0.62) |
| *AGARM* | 0.035   | 0.034   | 0.051  |
|         | (6.61)  | (6.48)  | (8.62) |
|         |         |         |        |
| Adj. R$^2$ | 0.81 | 0.81    | 0.6    |
| F       | 264     | 242     | 107    |
| Obs.    | 604     | 604     | 652    |

Note: The dependent variable is *GIK*. Time dummies for 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993 and 1994 are included. The estimates refer to a panel estimation technique with fixed effects. Cross-section weights are used in the estimates. The t-values (between brackets) are based on White heteroskedasticity-consistent standard errors. The estimation period is 1986-1996. This also applies to Table 5, Table 6 and Table 7.

**Table 5: The linear effect of uncertainty on investment : using instruments**

|          | 1       | 2       | 3       | 4       | 5       | 6       |
|----------|---------|---------|---------|---------|---------|---------|
| *SALESG* | 0.436   | 0.437   |         | 0.427   | 0.427   |         |
|          | (31.77) | (31.78) |         | (30.84) | (29.97) |         |
| *PFK*    |         | 0.013   |         |         | 0.005   |         |
|          |         | (0.43)  |         |         | (0.16)  |         |
| *MEANK*  |         |         | 0.049   |         |         | 0.030   |
|          |         |         | (0.85)  |         |         | (0.56)  |
| *FITTEDA*| 0.097   | 0.089   | 0.107   |         |         |         |
|          | (3.48)  | (3.11)  | (4.46)  |         |         |         |
| *FITTEDB*|         |         |         | 0.137   | 0.136   | 0.154   |
|          |         |         |         | (8.67)  | (8.48)  | (7.69)  |
|          |         |         |         |         |         |         |
| Adj. $R^2$ | 0.82  | 0.84    | 0.61    | 0.85    | 0.84    | 0.63    |
| F        | 284     | 256     | 110     | 336     | 303     | 116     |
| Obs.     | 604     | 604     | 652     | 604     | 604     | 652     |

**Table 6: Non-linear effects of uncertainty on investment**

|  | 1 | 2 | 3 |
|---|---|---|---|
| *SALESG* | 0.433 (32.03) | 0.433 (31.27) | 0.419 (30.31) |
| *AGARM* | 0.057 (5.11) |  |  |
| *FITTEDA* |  | 0.153 (4.23) |  |
| *FITTEDB* |  |  | 0.236 (9.57) |
| $UNCERT^2$ | -0.007 (-2.41) | -0.106 (-2.41) | -0.163 (-4.87) |
|  |  |  |  |
| Adj. $R^2$ | 0.81 | 0.82 | 0.86 |
| F | 238 | 262 | 340 |
| Obs. | 604 | 604 | 604 |

Note: $UNCERT^2$ is the quadratic uncertainty term. It equals $AGARM^2$, $FITTEDA^2$, and $FITTEDB^2$, respectively. This also applies to Table 7.

**Table 7: Sensitivity Analysis of non-linear effects of uncertainty on investment**

|  | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| *SALESG* | 0.427 (31.51) | 0.432 (31.31) | 0.418 (30.29) | 0.430 (31.80) | 0.434 (31.47) | 0.420 (30.37) |
| *AGARM* | 0.121 (8.65) |  |  | 0.105 (5.02) |  |  |
| *FITTEDA* |  | 0.166 (4.49) |  |  | 0.168 (4.58) |  |
| *FITTEDB* |  |  | 0.252 (9.061) |  |  | 0.254 (9.29) |
| $UNCERT^2$ | -0.049 (-8.04) | -0.122 (-2.24) | -0.195 (-4.21) | -0.030 (-1.69) | -0.130 (-2.47) | -0.199 (-4.45) |
|  |  |  |  |  |  |  |
| Adj. $R^2$ | 0.81 | 0.82 | 0.86 | 0.81 | 0.83 | 0.86 |
| F | 237 | 259 | 335 | 238 | 262 | 343 |
| Obs. | 603 | 597 | 597 | 592 | 592 | 592 |

**Endnote**

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[1] Leahy and Whited (1996) assume that the variance of the stock returns follows a stationary process with a finite-order autoregressive representation. By taking expectations and applying the law of iterated expectations, they obtain an ex-ante measure of uncertainty.

[2] The correlation matrix for the entire pool of possible instruments can be obtained on request.

[3] Schankerman (1991) finds that factors that are common across firms are much more important determinants of the stock market return.

[4] Note that in the cash-flow type of studies, following the seminal paper by Fazzari, Habbard and Petersen (1998), it is common to divide firms into groups for which it may be expected *ex ante* that differences exist with respect to the extent of financial constraints. For a survey of this type of studies, see Lensink, Bo and Sterken (2000).

[5] For a totally different sample of Dutch firms, the study of Lensink, van Steen and Sterken (2000) suggests this to be the case. Ghosal and Loungani (2000), on the other hand, suggest the opposite: the increase in uncertainty is more negative in small firm dominated industries in comparison to the effect on large firm dominated industries.

[6] Hansen (1999) proposes to use a threshold regression method to classify firms. This may be a promising direction of future research.