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INVESTMENT, UNCERTAINTY AND IRREVERSIBILITY: EVIDENCE FROM BELGIAN ACCOUNTING DATA

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The views expressed in this paper are those of the authors and do not necessarily reflect the views of the National Bank of Belgium.

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Editorial

On May 27-28, 2002 the National Bank of Belgium hosted a Conference on *"New views on firms' investment and finance decisions"*. Papers presented at this conference are made available to a broader audience in the NBB Working Papers no 21 to 33.

Abstract

This paper investigates the effects of uncertainty on the investment behaviour using firm-level data for a sample of Belgian manufacturing firms. In general, the results confirm former analysis at the aggregate level, stating that uncertainty does matter but that the sign of the effect and its magnitude largely depend on which proxies are used and how they are defined. It is shown that uncertainty has mainly an impact on the decision to invest and to a much lesser extent on the amount invested. Furthermore, the difference between reversible and irreversible investment is crucial. The impact of volatility on irreversible investment is far more larger than on reversible investment. In some cases, the amount of reversible investment will increase with higher volatility.

JEL Codes: D81, D92, C23
Key words: investment, uncertainty, irreversibility

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INTRODUCTION

Understanding investment is of major importance for economic policy makers because fluctuations in investment are not without consequences for the rest of the economy. Especially in times of recession they reappear on the research agenda because of their link with the overall performance of the economy and hence with employment and growth. The major question is to find efficient levers to stimulate investment when needed.

Although investment has always been an important research topic, both theoretically as well as empirically, the results in the latter domain are not very satisfying. A survey of Chirinko (1993) gives a clear insight in the different ways researchers have tried to come to a better understanding of investment, and more specific of business fixed investment. One of his important conclusions is that “the weight of the evidence clearly points to a modest response of investment to prices and a much greater response to output″ (p.1898). This has important policy consequences because it implies that the level of prices and interest rates is of minor importance for stimulating investment.

One interesting explanation for this minor role of the interest rate level as such and the more prominent role of the volatility of economic variables, is given in the work of a.o. Dixit and Pindyck (1994). Their analysis is based on the simultaneous existence of three phenomena: uncertainty, irreversibility of investment and some freedom of choice on the timing of investment. The decision to invest in an irreversible project can be seen as the decision to kill a real option. Basically, one will decide to invest when the marginal profitability of capital reaches a certain threshold value which depends upon the volatility of the expected demand and profitability. Uncertainty about future economic evolutions may increase the threshold resulting in postponing investment decisions. Hence, in their view, reducing volatility in the economy may give an important impulse to investment. Allthough the basic idea is rather straightforward, translating it into empirically-verifiable specifications is far from self-evident.

In this paper we focuss on the relation between uncertainty and investment for manufacturing sector firms in Belgium[1]. We use information from the annual accounts of companies that employ more than fifty persons for the period 1991-2000. It is the only information that publicly available on a company-level. The ideal situation would have been to combine them with specific survey data, in which companies are asked a number of questions specifically related to their view on the uncertainty they are facing and on the degree of irreversibility of the investment projects they are planning. Part of this information is gathered in the surveys of the European Commission and the National Bank of Belgium (NBB). However, due to confidentiality regulations, it is not possible to link the results directly to the companies in the sample we used.

We focus on the manufacturing sector because the investment projects in this sector are often characterized as showing a certain extent of irreversibility. Furthermore, the amount invested is related to firm size. The problem that an investment is a 'sunk cost' which can hardly be reversed or recovered, predominantly becomes a problem when large sums are involved, which is more often the case for large companies.

The first part of this paper gives a brief description of the real option approach of irreversible investment projects and which introduces the role of uncertainty and volatility of the economic environment on investment decisions. It also presents some empirical results based on aggregate data. Especially, indicators for economy-wide uncertainty are considered because this type of uncertainty should have the largest impact on investment, in contrast to idiosyncratic uncertainty. The following two sections of the paper present the analysis of investment and uncertainty using Belgian firm-level data. Section 2 of the paper presents the model and hypotheses to be tested, and describes the sample and defines variables used. Section 3 presents the empirical results. First, a cross section-type analysis of companies in the manufacturing sector presents some indicative results. The problem, however, is that in a cross section approach, especially for the data considered, it is not clear whether the volatility indicators which can be constructed from the data relate to idiosyncratic or to aggregate uncertainty. Therefore, section three of the paper continues by using pooled data for a period of ten years.

[1] Other aspects which may result in a better understanding of the evolution of investments in Belgium are treated in other papers during this conference.

This allows us to consider not only company-specific elements, but also more aggregate uncertainty indicators. Section 4 concludes.

1. INVESTMENT AND UNCERTAINTY: THEORY AND SOME AGGREGATE EMPIRICS

1.1 Recent theoretical advances: the real option approach

Discussing the importance of uncertainty of the economic environment on the decision to invest is not new. Traditionally, taking into account uncertainty in investment analysis was done by introducing expectations on a set of variables in the investment function, varying from simple adaptive expectations to more complex models with rational expectations. In empirical investment functions, one focused on capturing the dynamics underlying not only the formation of expectations, but also the delays between the decision and the actual realization of the investment.

During the last two decades, a new stand of theory linking uncertainty and investments, has emerged. This theory is based on the simultaneous existence of three phenomena: uncertainty, irreversibility of investment and some freedom of choice on the timing of investment. It starts from the fact that investment decisions are to a large extent irreversible, i.e. cannot be reversed except at a high cost (the cost is largely 'sunk'). Combining irreversibility with the existence of uncertainty over the future behaviour of variables that affect the value of the investment (such as future output prices) leads to the following intuitive reasoning: suppose there is some leeway in delaying investment until more information about the uncertain future becomes available; it may then be optimal to wait some time before investing. It is clear that waiting to invest implies risks (e.g. entry of competitors) and foregone profits, but it may prevent from being trapped in an irreversible investment project which turns out to be very costly when the adverse future materializes.

The theory states that an investment project which satisfies these three characteristics is best treated analogous to holding an (American-type) financial call option: for some specific time period, an investor (a firm) has the right, but not the obligation, to pay a certain price (the investment cost) in return for an asset (an investment project) that has some value; when the investment decision is made, the option is exercised, which is an irreversible decision. Like a financial option, the option itself has some (non-negative) value, denoted as F_0 in the following, a.o. because of uncertainty over the future value of the investment project. As a consequence, option pricing theory can be used to 'price' investment decisions and decide on optimal timing of exercise. This gave rise to a large body of new literature, and a new class of models usually referred to as 'real options' models[2].

The basic consequence of viewing the investment decision as exercising an investment option is straightforward, and can be illustrated most simply by referring to the conventional NPV-rule. The direct pay-off from investing is given by V-I, where V is the present value of the investment project and I the investment cost (the classical NPV-criterium). When this pay-off is positive, it is worthwhile to invest. However, once the investment is made, the option is gone, so the value of the option today (F_0) must be considered as an opportunity cost of investing, and hence must be added to the investment cost (I). Hence the optimal investment criterion is modified into:

$$V < I + F_0 : \text{wait to invest} \qquad [1]$$

$$V \geq I + F_0 : \text{invest}$$

Another way of indicating the same criterion is stating that the value of the project, V, must exceed the investment cost, I, by at least the value of the option, F_0, in order to decide to invest now. This minimum-acceptable project value is generally called the 'threshold value' of investment, in the following denoted as V^*.

In option pricing jargon, the option is said to be 'out of the money' in the first case (waiting) and 'in the money' when the underlying value of the investment (V) exceeds the option value (price) plus the investment cost. The basic new insight is in fact that one should wait until the orthodox NPV is 'very large', with F putting an exact value to it[3]. As such, the basic investment decision to take is not *whether or not* to invest (as indicated by the orthodox NPV-rule), but rather when

[2] See e.g. McDonald & Siegel (1986), Caballero & Dixit (1992), Pindyck & Solimano (1993), Bertola and Caballero (1994). A comprehensive theoretical treatment is given in Dixit and Pindyck (1994). A recent extensive review of theory and empirics is presented in Carruth et.al (2000).

[3] In fact, this is what is often happening in pratice, with investment decisions taken by applying the orthodox NPV criterion, but using 'hurdle' required rates of return that are much larger than the orthodox discount rate (see e.g. Poterba and Summers, 1991).

to invest, i.e. determining the optimal moment of exercising the investment option[4]. This intuitive reasoning is graphically represented in figure 1.

<insert figure 1 here>

From the viewpoint of the subject of this paper, the most important consequence resulting from this model solution is that uncertainty (and irreversibility) introduces a difference between the minimum-acceptable value of the project in order to invest (V^*) and the cost of investment (I). More important even, the greater the level of uncertainty, the more the value of the investment opportunity must exceed its cost before investment is indeed taking place. As such, the individual investment decision is, in theory, very dependent on the level of uncertainty.

Extending the analysis from the individual firm to the country level, introduces the aggregation problem which is treated in detail by Bertola & Caballero (1994). Starting from the behaviour of the individual firm, they try to come to a relation between aggregate investment and two types of uncertainty: idiosyncratic or firm-related uncertainty on the one hand, and aggregate or overall uncertainty on the other. The importance of this distinction is further stressed by Caballero & Pindyck (1992). Whether changes in uncertainty will or will not affect investment depends upon the distribution of the future values of the marginal revenue product of capital. Only when this distribution is asymmetric, higher volatility will result in less investment. In a competitive market, only aggregate shocks will lead to an asymmetric distribution for the marginal revenue product and might, in combination with irreversibility of the investment, lead to a negative relation between uncertainty and aggregate investment. The exact analysis of the interaction between aggregate and firm-specific shocks and irreversibility can be found in Caballero & Pindyck (1992) and Pindyck & Solimano (1993).

Crucial in the analysis is the assumption which is made concerning the behaviour of the marginal revenue product of capital. When the returns are concave the relation between uncertainty and investment is negative. This relation is reversed when the returns are a convex

[4] From the previous paragraphs, it is clear that the orthodox NPV criterium is no longer valid for 'real option' investments. But whether this must be considered as a new theory of investment or a correction of the old paradigm remains open and is in fact less important, as indicated also by Dixit and Pindyck (1994, p.8).

function. The problem is that there are no sound theoretical arguments to favour one of the two possibilities. As a consequence empirical studies of investment and uncertainty or volatility will have to clear the issue.

1.2 Aggregate empirical results

Former analysis of the authors, as summarized predominantly in Meersman & Cassimon (1995;1997), focused on exploring the relation between different types and measures of uncertainty on the investment decision from an aggregate macro-economic point of view.

The crucial variable for capturing the effect of volatility (and uncertainty) on the investment decision is the threshold value for the marginal profitability of capital. The most obvious way to get information on this value, is to start from information on the level of an individual firm (or even investment project). However, for an aggregate investment function which is suitable for economic policy recommendations at country level, there is no straightforward way to introduce this threshold value. Therefore, one has to rely on approximating indicators for uncertainty and volatility; obvious candidates are the fluctuations in effective exchange rates, real interest rates, inflation rates and real wage rates.

In order to have a first global indication of the magnitude of the effect of some of these volatility variables on investment, an approach similar to Pindyck and Solimano (1993) was applied to annual data for a pooled sample of 14 European countries[5]. The results are presented in table 1. The major conclusion is that, apart from the traditional role of accelerator and cost components (as represented by the level of the real interest rate) volatility as measured by the standard deviation of the effective exchange rate and the real interest rate, is an additional determinant of the total investment level. Especially fluctuations of the effective exchange rate have a strong negative impact.

<insert table 1 here>

[5] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Spain, Sweden and the United Kingdom. The sample period was 1971-1992.

When concentrating on business fixed investment (as in the right column of table 1), the results are even more pronounced and in addition, the impact of the level of the real interest rate disappears. These results confirm the theory of Dixit & Pindyck in as much as they support the negative relation between volatility and investment. However, the rather 'global' empirical approach is not without any criticism because it masks the country-specific aspects which might affect the investment behaviour.

This becomes clear when empirical analysis for individual countries is considered, as shown in table 2. The most striking issue of these results is that there are considerable differences between the countries in the way business investments react to changes in volatility. Although there is evidence for the presence of such effects in the short run for most countries, it is not always clear that the effects work in the same direction. Not only is there a difference in the direction in which the volatility indicators affect investment, but there is even a difference between countries in the contribution of the different volatility indicators. As a consequence it is hard to conclude that for Europe there is evidence for the negative relation between investment and uncertainty. Although there might be some indication, it should be treated with the utmost care.

<insert table 2 here>

For most of the countries, the volatility of the real interest rates has a significant negative impact on investments which is in line with the global results. For the Belgian case, the results are mixed with short-term rates indicating a negative effect, and long-term rates indicating the opposite.

The effect of fluctuations in the real effective exchange rate are less pronounced and illustrate that the global results indeed require a carefully balanced appraisal. In a European context, the policy consequences are that the reduction of the volatility of the exchange rates will not have a large impact on investment; for the Belgian case, however, these preliminary results seem to indicate that it does. If, however, this reduction requires frequent adjustments of the interest rates, the final effect on investment might be negative.

Quite remarkable is the effect of wage volatility on investment. For the majority of the countries, larger wage variation results in higher investments. This indicates that a flexible wage formation process which allows for larger fluctuations in wages, might be advantageous for investment. A possible explanation for these findings might be that the stickiness of the European labour markets makes labour a quasi-fixed production factor. In order to adjust production costs in the short run, firms cannot instantaneously change the number of workers. If, however, they have more flexibility in adjusting the wage costs, this might increase their short-run profitability. These general tendency is not witnessed so far for the Belgian results.

2. FIRM-LEVEL ANALYSIS ON INVESTMENT AND UNCERTAINTY IN THE BELGIAN MANUFACTURING SECTOR: THE EMPIRICAL MODEL

It is clear that the tentative results emerging from this aggregate analysis are too unstable to be relied on for use in hard policy advice. For this, we need additional analysis using more large-scale, micro-economic data. It is the major scope of this paper to replicate what has been done so far using the available firm-level, a.o. coming from the data base assembled by the NBB, for the Belgian case, in a panel data approach. As such, we can confront these findings not only with our former aggregate findings, but also with comparable studies already executed for other countries (see e.g. Leahy & Whited (1996) on US data).

The use of panel data often allows the examination of issues that can not be studied in either cross-sectional or time-series settings alone. The advantage is that there is more flexibility in modelling differences in behaviour across sectors or even across companies. One can formally model the heterogeneity across groups that is typical in micro data at the company level.

As already discussed before, when investigating the impact of uncertainty on firm investment decisions, it is important to consider idiosyncratic (firm-related) and aggregate uncertainty. Whether changes in uncertainty will or will not affect investment depends upon the distribution of the future values of the marginal revenue product of capital. Only when this distribution is asymmetric, higher volatility will result in less investment. In a competitive market, only aggregate shocks will lead to an asymmetric distribution for the marginal revenue product and might, in combination with irreversibility of the investment, lead to a negative relation between uncertainty and aggregate investment. By their nature, panel data are the ideal setting for studying this difference.

In firm-level models of investment under uncertainty, investment depends on the expected value and conditional variance of variables such as demand for the firm's product(s), profitability, factor costs, capital costs, or technology, in addition to other variables. These are clearly all subjective projections conditional on information available to the firm's investment decision makers. Empirical work along these lines has evolved around two lines of thought. One borrows from the aggregate investment analysis the use of uncertainty proxies such as the standard deviation of (changes in) variables such as inflation, real exchange rates, interest rates, wage rates, or even the parallel premium (Federer, 1993) or stock market prices. Among the studies using this approach on firm- or sector-level data are Ghosal & Loungani (1996) and Whited & Leahy (1996). These are valid proxies to the extent that indeed firms forecast future volatility based on past trends and that the aggregate volatility trends are part of their information set (Patillo, 1998).

More recently, empirical research tries to directly measure the firm's investment decision maker perception of uncertainty and risk by relying on (or combining this with information of the first type) information from surveys of a panel of firms that include questions on the person's subjective future expectations (and their subjective probability distribution) of key variables such as demand for the firms' product(s), from where uncertainty measures of these variables can be constructed (Patillo, 1998; Guiso & Parigi, 1999).

The model presented here will focus on the first line of thought, as the second approach is followed by another contribution to the project (Butzen et al., 2002).

2.1 Theoretical model and hypotheses

The model starts from a derivation of the firms' optimal investment rule stating that investment is undertaken only when the marginal revenue product of capital (MRPK) reaches a certain trigger level: the first-order condition says that the firm waits to undertake an irreversible investment decision until the expected present value of MRPK exceeds the cost of the investment (P) by the multiple ϖ, where ϖ, among other factors, is increasing in the variance of indicators for business conditions, and as such, uncertainty increases the (firm-specific) investment trigger point.

So company i will invest a certain amount if it decides to invest ($INVD_i$=1) which will be the case if $MRPK_i/P_i \geq trigger_i$. The company will not invest ($INVD_i$=0) if $MRPK_i/P_i < trigger_i$. The decision to invest will depend upon the change in real value added, DY_i, profitability, $PROF_i$, the user cost of capital, UC_i, the marginal revenue product of capital, $MRPK_i$, expected demand growth, DD_i, firm characteristics, $CHAR_i$, and, indirectly, on uncertainty indicators, UNC_i, and irreversibility indicators, IRR_i.

If the company decides to invest, the company's investment rate, I_i, is only function of the change in real value added, DY_i, profitability, $PROF_i$, the user cost of capital, UC_i, and the firm characteristics, $CHAR_i$. The uncertainty indicators, UNC_i, and irreversibility indicators, IRR_i should not have an impact on the amount invested.

Traditionally in empirical studies of investment, the decision whether or not to invest and the decision on the amount invested are not considered seperately. Most of the time a reduced-form investment function is estimated. This type of investment function contains the variables which have an impact on the amount invested and, indirectly, also the variables which have an impact on the decision to invest. This gives the traditional investment function augmented with the marginal revenue product of capital and the uncertainty indicators, or

$$I_i = Z_i' a + u_i \qquad [2]$$

where Z_i contains the variables which have an impact on the investment and the investment decision (DY_i, $PROF_i$, UC_i, $CHAR_i$, UNC_i, IRR_i).

The coefficients of this equation can be estimated with OLS. However, one has to take into account the fact that, given the definition of I, one cannot observe negative investment. Therefore the investment function is better represented by a standard Tobit model.

$$I_i^* = Z_i' a + u_i \qquad [3]$$

$$I_i = \begin{cases} I_i^* & \text{if} \quad I_i^* > 0 \\ 0 & \text{if} \quad I_i^* \leq 0 \end{cases} \qquad [4]$$

However, the sample of companies that invest, is not necessarily a random sample. On the contrary, in this case companies will invest if the real marginal revenue product of capital reaches the trigger. When the decision to invest is correlated to the investment function, the traditional Tobit-model should be expanded to a sample selection or tobit II model

$$INVD_i = X'_{1i}ß_1 + u_{1i} \quad [5]$$

$$I_i = X'_{2i}ß_2 + u_{2i} \quad [6]$$

where we have the following observation rule

$$I_i = X'_{2i}ß_2 + u_{2i}\ ,\ INVD_i=1 \text{ if } X'_{1i}ß_1 + u_{1i} \leq 0 \quad (\text{trigger}_i\text{-MRPK}_i/P_i\leq 0) \quad [7]$$

$$I_i \text{ not observed, } INVD_i=0 \text{ if } X'_{1i}ß_1 + u_{1i} > 0 \quad (\text{trigger}_i\text{-MRPK}_i/P_i>0) \quad [8]$$

and I_i is the investment ratio of company i, $INVD_i$ is a binary variable indicating whether the company is investing ($INVD_i$=1) or not investing ($INVD_i$=0), and X_{1i} and X_{2i} are vectors containing exogenous variables, where X_{1i} may differ from X_{2i}. It is assumed that the disturbance terms (u_{1i},u_{2i}) are normally distributed with expectations zero, variances s_1^2, s_2^2 and covariance σ_{12}.

The conditional expected investments, given that the company has decided to invest, is given by:

$$E(I_i \mid INVD_i = 1) = X'_{2i}ß_2 + s_{12}\frac{f(X'_{1i}ß_1)}{F(X'_{1i}ß_1)} \quad [9]$$

where the last term is the conditional expectation of a standard normal distribution given that company i has decided to invest. The ratio f(.)/F(.) is sometimes referred to as Heckman's lambda, following the analysis of sample selection models by Heckman (1979). If the disturbances u_{1i} and u_{2i} are uncorrelated, the investment equation could be estimated consistently by ordinary least squares. However, if the covariance between u_{1i} and u_{2i} (σ_{12}) differs significantly from zero, the OLS estimates of the investment equation will be vulnerable to a sample selection bias.

In this case, both equations should be estimated simultaneously taking into account the correlation between the decision to invest and the investment function. The loglikelihood function can be written as

$$\ln L = \sum_{H_0} \ln(1 - F(X'_{1i}ß_1)) + \sum_{H_1}\left[(\text{-}1/2)\ln(2?\,s_2^2) - \frac{(I_i - X'_{2i}ß_2)^2}{2s_2^2} + \ln F\left(\frac{X'_{1i}ß_1 + (s_{12}/s_2^2)(I_i - X'_{2i}ß_2)}{\sqrt{1 - s_{12}/s_2^2}}\right)\right] \quad [10]$$

with

H_0 = {i: $trigger_i$-$MRPK_i/P_i$>0} and H_1={i: $trigger_i$-$MRPK_i/P_i \leq 0$}

and

F(.) is the value of a standard normal cumulative distribution.

For the estimation, one can use the Heckman's two-step procedure (Heckman, 1979). In the first step the selection model is estimated using a probit maximum likelihood. The estimates, $\hat{ß}_1$, are used to calculate Heckman's lambda, which enters the investment function:

$$I_i = X'_{2i}ß_2 + s_{12}\frac{f(X'_{1i}\hat{ß}_1)}{F(X'_{1i}\hat{ß}_1)} + e_i \quad \text{and} \quad e_i = u_{2i} - E(u_{2i} \mid INVD_i = 1) \quad [11]$$

that is estimated in the second step with ordinary least squares. The estimates are concistent but not efficient. The major problem with this two-step-procedure is that the traditional OLS standard errors are incorrect if $\sigma_{12} \neq 0$. Heckman (1979) has shown how the OLS covariance matrix can be appropriately corrected to give reliable standard errors.

2.2 Sample description

Our sample includes all Belgian manufacturing companies from NACE-code 3, which reported unconsolidated complete annual accounts for the last ten years and that have at least 50 employees in the last year of reporting (2001). Data are obtained from BelFirst. In this way we obtain data for 462 companies. Table 3 describes our sample. As can be seen from panel A the average age of the companies in our sample is 27 years. The sample is equally split over medium companies (30-99 employees) and large companies (more than 100 employees). Panel C through E report the 25%, 50% and 75% percentiles and the mean in thousand BEF for turnover, total assets and return on capital employed respectively for the last year.

<insert table 3 here>

2.3 *Definition of variables*

The definition of the variables is given in table 4. For the investment ratio's three alternatives were considered, of which only I1 was actually used for estimation. As a consequence there are no disinvestments and $I1 \geq 0$. From the four alternative profitability indicators, only net profit over turnover (PROF2) gave the most reliable results. Assuming perfect competition, the marginal revenue product of capital is set equal to the ratio of profit to capital.

Theoretically, uncertainty should enter the model through the variance of expected demand. However, information on demand expectations is not available directly from company accounting data. Therefore we had to consider some alternative indicators. A number of variables were considered, but finally the 4-year-variance of the profitability was used. It combines the volatility of a number of factors, such as prices, sellings, wages, capital costs, etc. It is clear that this indicator has its limitations, but it seemed to perform well as an approximation of the uncertainty the companies are facing.

In general uncertainty will have an impact mainly on large, irreversible investments. The problem however is, that it is not straightforward to define ‘large’ and ‘irreversible’. We consider as an indicator of reversibility the fact that part of the capital stock is leased and use a dummy variable, REV, which is 1 for reversible investments and 0 otherwise. The impact of uncertainty is represented by the following component:

$$(\alpha + \beta REV_i)VARPROF_i = \alpha VARPROF_i + \beta\ (REV_i)(VARPROF_i) \qquad [12]$$

We expect the variance of the profit rate to have a negative impact on the decision to invest and to have no impact on the amount invested, once it is decided to invest. For reversible projects one expects that the value of β offsets the value of α, in the decision to invest.

To account for investments being ‘large’, we split up the sample in two parts. The trigger is the first quartile of the investment rate. Values above the trigger are considered as 'large', for values below the trigger it is assumed that the investment is too small to be relevant for this study and those companies are considered not investing.

3. FIRM-LEVEL ANALYSIS OF INVESTMENT AND UNCERTAINTY IN BELGIAN MANUFACTURING: EMPIRICAL RESULTS

This section presents the empirical results of firm-level analysis for the Belgian manufacturing sector using the model as described in section 2. As a first approximation, the model is applied using cross-sectional data for 1999. We then move on to presenting results from pooled firm-level data for the 1991-2000 period in order to be able to study the impact of aggregate uncertainty.

3.1 Empirical results from a cross-sectional approach

As a first exploration, the model was estimated with cross section data for Belgian manufacturing companies and using OLS, a Tobit and the two-step-sample selection procedure. Estimating simultaneously the probit and the investment function failed due to the fact that the procedure did not converge.

The results are presented in table 5. In general, the explanatory power of the models is rather low compared to the aggregate time series models, but this is hardly surprising for cross-section analysis on the firm level.

< insert table 5 here >

The impact of uncertainty, measured by the 4-year variance of net profit over turnover, has clearly an impact on the decision to invest or not. Higher uncertainty reduces the probability to invest when the investment is characterised by a higher degree of irreversibility, but it has clearly no impact on the amount invested. When investments are reversible, uncertainty has no longer an impact on the decision to invest (α does not differ significantly from $-\beta$). However, the amount invested will increase as uncertainty increases under the condition that the investments can easily be reversed.

Company size has an impact on the decision to invest, with a higher probability to invest for larger firms. No significant impact of company size on the amount invested could be found. Additionally, we could not find any significant sector-specific impact.

The results for the cross-sectional data do provide some indication, albeit not a very convincing one, of the existence of sample selection. A positive innovation in the probability to invest will also increase the amount invested. However, one should be careful with this interpretation because in the two-step procedure Heckman's λ may also capture the impact of missing variables, such as aggregate uncertainty. In order to capture this effect of aggregate uncertainty in a more direct way, we move on to a pooled analysis.

3.2 Investment and aggregate uncertainty: empirical results using pooled firm-level data

One of the shortcomings of using cross-section data is the fact that it is not possible to introduce the volatitility of a number of macro-economic policy variables, such as interest rates, inflation rates, exchange rates, etc. Therefore we decided to pool data, in order to be able to study the impact of aggregate uncertainty.

The basic underlying model remains the same. The difference is that, apart from company-specific data, general uncertainty indicators are introduced. They are the same for all the companies under consideration, but vary over time.

Inspired by our former work (Meersman & Cassimon, 1995;1997), we use as an approximation for the volatility in the economy the variance of the long term interest rate and the effective exchange rate. The variances are estimated using three different approaches. In the first approach the variance of the change of the long term interest rate (VDIRL) and of the real effective exchange rate (VDREER) is calculated as the variance of the monthly data in the year under consideration. For the second approach an ARIMA- model is estimated for the interest rate and for the effective exchange rate with annual data from 1975 to 2000. The variance of the resulting residuals are calculated over different time spans but the best results were obtained with a time span of five years. For the long term interest rate this results in the indicator V5DIRL. For the effective exchange rate two ARIMA specifications are withheld resulting in the indicators V5DREER1 and V5DREER2. Finally, the ARIMA-models were combined with a GARCH specification which was used to calculate estimations of the variances VDIRLGARCH, VDREER1GARCH and VDREER2GARCH.

Table 6 gives an overview of the correlations between the different uncertainty indicators. It is remarkable that there is only little correlation between the indicators which questions some of the approximations of volatility and which might have severe consequences for the estimation of the investment model.

< insert table 6 here >

The results of the OLS-estimation results with the full sample are reported in table 7, the Tobit estimation results in table 8. The Probit estimation results for the probability to invest are given in table 9. They were used to calculate Heckman's lambda which is used in the sample selection estimation of the investment function, the results of which are given in table 10.

< insert table 7 here >
< insert table 8 here >
< insert table 9 here >
< insert table 10 here >

The results confirm to a large extent the conclusions of the cross-section estimations. However, there are some remarkable differences and additional elements to discuss. In this pooled sample, the coefficient of Heckman's lambda differs significantly from zero which implies that the Tobit-II estimates of the investment function are the most reliable ones. There is a positive correlation between the probability to invest and the amount invested. Innovations which will result in a higher probability to invest, will increase the amount invested by those firms which decided to invest.

Changes in value added have no significant impact on the probability to invest, but have a strong impact on the amount invested. The distributed lags are spread over three years with the strongest impact in the year of the investment. Net profit over turnover has a very strong impact on the probability to invest as well as on the amount invested. The higher the profit rate, the higher the probability to invest and the higher the amount invested. If the profit rate is considered as a proxy for liquidity of the company, this implies that we may conclude that the degree of liquidity is an important factor in the investment decision process.

The probability to invest increases clearly with company size but we could not find a significant impact of the company size on the amount invested. This result may be biased due to the fact that we did not consider small size companies in our sample. We tried to introduce sector specific dummy variables but we could not find any significant impact. This might be partly due to the fact that the sample is restricted to the manufacturing sector.

The marginal revenue product of capital has a positive and significant impact on the probability to invest, but has no significant impact on the magnitude of the investment. This is in line with the theory, which states that the firm will decide to invest if the MRPK/P is equal to or bigger than the trigger. If this is not the case the company will postpone the investment (independent of the amount they wish to invest) until the moment that the trigger is reached.

The impact of uncertainty has to be considered in somewhat more detail. In the cross sectional analysis it was clear that the volatility of the profitability has a negative impact on the probability to invest when investment is irreversible. The amount invested will increase with volatility for reversible investment. These results are confirmed by the estimations on a pooled data set when the uncertainty is measured solely by the variance of the profitability.

The introduction of aggregate measures of volatility does not add much to the explanatory power of the models. One explanation for this may be found in the rather short time series horizon and the fact that in the period considered here fluctuations of the effective exchange rate and the long term interest rate were rather small.

As could be expected from the correlation matrix of the volatility measures, the impact of the proxies for aggregate uncertainty differs considerably depending on the method of calculation of the volatility used. The most convincing results are those where the variance of the profitability are combined with the variance from the GARCH estimations of the long run interest rates and the effective exchange rates. Contrary to the impact of the volatility of the profitability, the variance of the long run interest rate and the effective exchange rate have an impact on the amount invested of the companies which decided to invest. Higher volatilities reduce irreversible investment much stronger than reversible investment.

4. CONCLUSIONS

The analysis in this paper has shown that uncertainty does matter for firm investment, but that the sign of the effect, and the exact magnitude largely depends on the way in which the proxies for uncertainty are defined.

The results from aggregate macro-economic analysis point at the negative impact of uncertainty as proxied by the volatility of effective exchange rates or interest rates; on the other hand, proxies such as wage volatility showed in general a positive effect. However, country-specific estimation results showed a lot of variation between (European) countries.

According to theory, the uncertainty has mainly an impact on the decision to invest and only to a much lesser extent on the amount invested. This is clearly confirmed by the empirical analysis based firm-specific data for the Belgian manufacturing sector using both cross-sectional as well as pooled data.

Furthermore, the difference between reversible and irreversible investment is crucial. The impact of volatility on irreversible investment is far more larger than on reversible investment. In some cases, the amount of reversible investment will even increase – and significantly so, with higher volatility.

In our analysis, introducing indicators for macro-economic volatility, such as real interest rate and effective exchange rate volatility, in the firm-specific investment data analysis does not seem to add significantly to the explanatory power of the models. One of the reasons might be the short time series used to capture the aggregate volatility.

Uncertainty is approximated by the volatility of a number of variables, but it is clear that a lot more factors are present once one descends to the level of micro-data. Part of the uncertainty can be captured by it, but the non-systematic, white noise volatitlity will not be incorporated in this type of models. Using longer time series and modelling simultaneously all the uncertainty elements involved might help to come to more robust results, and can be the basis for future work.

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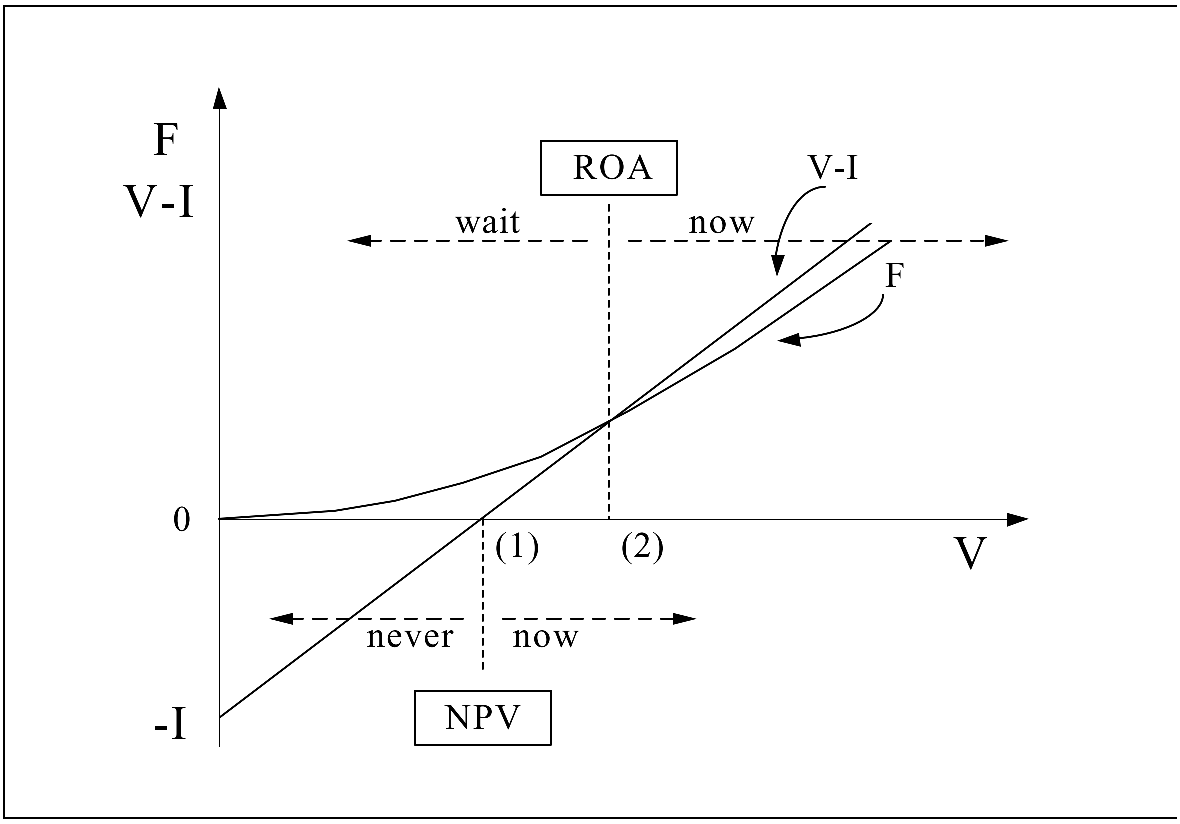
Figure 1. Real option analysis (ROA) versus the net present value rule (NPV)



Source: Cassimon & Meersman (1997, p.6).

Table 1. Investment and Macroeconomic Volatility Indicators: Global Results

Explan. Variables	Dependent variable	
	lnI	LnIB
Constant	-1.233 (.130)	-1.933 (.202)
lnY	0.980 (.008)	0.982 (.012)
dlnY	7.613 (1.783)	10.748 (2.774)
RR	-.024 (.006)	-.008 (.009)
SdEFER	-2.131 (.552)	-2.084 (.859)
sdRR	-0.029 (.012)	-.025 (.019)
R^2	0.997	0.994
DW	1.97	1.92
Sum u^2	0.337	0.816
# obs	42	42

Legend: Values between brackets are standard errors. The data used for estimation are from the OECD Economic Outlook Historical Series from 1971 to 1992 for the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, and the United Kingdom.
Y = Gross Domestic Product, volume; I = Total Fixed Investment, volume; IB = Investment by the business sector, volume; RR = Real interest rate, Long-term; EFER = Effective Exchange Rate, BOP definition; sd refers to standard deviations of the variables, as proxies for volatility; and d refers to changes from the previous year

Table 2. Investment and Macroeconomic Volatility Indicators: Country-specific Results

Explan. Variable: d(lnIB)	Countries											
	Austria	Belgium	Finland	France	Germany	Ireland	Italy	Netherlands	Norway	Spain	Sweden	UK
Constant	6.432 (1.944)	-	-	-	-	-	-	-	-	-	-	-
d(lnY)	2.079 (.529)	2.751 (.519)	3.108 (.482)	1.764 (.173)	1.782 (.363)	1.289 (.52)	2.491 (.393)	2.849 (.835)	1.686 (1.679)	4.425 (.728)	4.598 (.859)	1.035 (.902)
d(lnRCC)	.025 (.007)	-.002 (.007)	-.007 (.008)	.006 (.003)	-.008 (.007)	.04 (.009)	.006 (.003)	-.025 (.013)	-.082 (.035)	.001 (.008)	.011 (.011)	-.016 (.013)
d(lnRLC)	1.638 (.573)	-.320 (.846)	2.146 (.592)	-1.684 (.61)	.703 (.597)	-1.726 (.662)	1.756 (.649)	2.268 (.618)	2.539 (1.098)	1.289 (.858)	1.153 (.682)	.118 (.949)
d(lnRCU)	.002 (.001)	-	.002 (.002)	-	.007 (.003)	-	-	.025 (.01)	-	-	-	.005 (.002)
sdINFL	-	-	-	-	-	-	.05 (.014)	-	.216 (.093)	-.067 (.02)	-	-
sdRLC	.024 (.006)	.011 (.007)	.044 (.021)	-	.014 (.012)	-.07 (.021)	.003 (.001)	.106 (.045)	-.056 (.043)	-.04 (.018)	.027 (.019)	.077 (.012)
sdREER	-.015 (.012)	-.017 (.010)	-	-	-	.043 (.011)	.002 (.004)	-	-.051 (.043)	.026 (.012)	0.015 (.008)	-.005 (.007)
sdRRlt	.048 (.03)	.007 (.004)	-	-.042 (.01)	-	.033 (.019)	-.088 (.016)	-.034 (.014)	-	-	-.117 (.024)	-.025 (.019)
sdRRst	-	-.035 (.014)	-	-	-	-	-	-.001 (.0004)	-	-	-	.037 (.019)
ECM	-.215 (.06)	-.218 (.10)	-.005 (.001)	-	-.002 (.001)	-	-	-.001 (.001)	-	-	-	-.002 (.001)
lnY(-1)	-1.311	1.346	-.973	-2.584	-1.157	-3.491	-1.5	-1.309	-1.309		-2.266	-3.134
RCC(-1)	.019	-.003	.011	.001	.014	.031	.003	.016	.016		-.015	0.003
RLC(-1)	-1.027	-1.859	-1.885	3.782	.058	-1.755	3.058	-.988	-.988		.947	1.215
RCU(-1)	-.003		-.007	.003	-.018	.032	-.03	-.017	-.017		-0.005	-.006

Legend: Values between brackets are standard errors. The data used for estimation are from the OECD Economic Outlook Historical Series from 1971 to 1992 for the following countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, and the United Kingdom. Y = Gross Domestic Product, volume; IB = Investment by the business sector, volume; RRlt = Real interest rate, Long-term; RRst = Real interest rate, Short-term; REER = Real Effective Exchange Rate, BOP definition; INFL = Inflation; RCC = Real Cost of Capital; RLC = Real Unit Labor Cost; RCU = Measure of Capacity Utilization; ECM refers to the impact of the long-term relationship of the Error Correction Model; sd refers to standard deviations of the variables, as proxies for volatility; d refers to changes from the previous year

Table 3. Sample Characteristics (Number of firms in the sample: 462)

Panel A. Age in 2001	
average	27
< 6 years	4
6-10 years	56
11-20 years	161
21-30 years	72
31-40 years	63
41-50 years	48
51-60 years	23
>60 years	34
Panel B. Size	
average	277
Medium (30-99 employees)	224
Large (≥ 100 employees)	238
Panel C. Turnover	
M25	442504
M50	812477
M75	1731868
Mean	2803585
Panel D. Total assets	
M25	310132
M50	567588
M75	1307924
Mean	2098211
Panel E. Return on capital employed	
M25	2.51
M50	11.05
M75	22.93
Mean	12.26

Table 4. Definition of variables

General variables	
Y	Value added
K	Tangible assets
L	Number of employees
size	Total assets
w	Labour cost per employee
RK	return on capital
CF	Cashflow
TO	Turnover
Investment ratio's	
I1	New tangible assets/K_{-1}
I2	New tangible assets/Y
I3	Investment/K_{-1} (Investment calculated using NBB prefered definition: codes 8169+8179+8229+8309)
Profitability indicators	
PROF1	CF/K
PROF2	Net profit/TO
PROF3	Gross operating marge
PROF4	Net operating marge
Uncertainty indicators	
VARPROFi	4-year variance of PROFi (i=1,...,4)
Reversibility measure	
REV	=1 if part of the capital stock is leased =0 otherwise
MRPK-proxy	
PK	operating profit/K (assuming perfect comp.)

Table 5. Estimation of investment functions using cross-section data

	OLS	**TOBIT**	**(I)**	**(II)**
constant	39.66 (3.461)	46.03 (4.635)	-1.243 (0.786)	-28.83 (57.29)
DY	1.730 (.654)	12.463 (1.946)		12.93 (7.567)
DY_{-2}	2.714 (1.047)		0.119 (0.0506)	
PROF2		-.751 (.578)		
$PROF2_{-1}$			0.018 (0.0116)	
$PROF2_{-2}$	1.260 (.455)	1.905 (.676)		2.253 (1.167)
ln(SIZE)			0.140 (0.0587)	
PK			0.204 (0.0856)	
VARPROF2 (α)	-.0143 (.0227)	.0199 (.0666)	-0.0012 (0.00065)	0.00416 (0.0698)
VARPROF2 *REVERS (β)	.241 (.0531)	0.214 (0.0808)	0.0016 (0.00091)	0.250 (0.0892)
Heckman's λ				192.82 (144.625)
# Observations	452	451	451	343
lnL	-2532.7	-1934	-228.17	-1933
χ^2 for $\alpha+\beta=0$ (Prob)			0.416 (p=0.52)	15.55 (p=0.00008)
Adj. R^2	.061	.144		.15
% correctly predicted			75.83	

(I) Reduced form Probit, INVD=1 if any investments, 0 otherwise
(II) Investment selection model voor I

Number between brackets are heteroscedastic robust standard errors and for (II) corrected for sample selection

Table 6. Correlationmatrix of uncertainty indicators within the sample (1991-2000)

	VDIRL	VDREER	V5DIRL	V5DREER1	V5DREER2	VDIRL GARCH	VDREER1 GARCH	VDREER2 GARCH
VDIRL	1.000	0.177	0.056	-0.524	-0.436	0.016	0.575	0.387
VDREER	0.177	1.000	0.344	-0.238	-0.106	0.298	0.271	-0.444
V5DIRL	0.056	0.344	1.000	0.087	-0.095	-0.132	0.704	0.374
V5DREER1	-0.524	-0.238	0.087	1.000	0.865	-0.664	-0.507	-0.269
V5DREER2	-0.436	-0.106	-0.095	0.865	1.000	-0.483	-0.649	-0.492
VDIRLGARCH	0.016	0.298	-0.132	-0.664	-0.483	1.000	0.247	-0.279
VDREER1GARCH	0.575	0.271	0.704	-0.507	-0.649	0.247	1.000	0.608
VDREER2GARCH	0.387	-0.444	0.374	-0.269	-0.492	-0.279	0.608	1.000

Table 7. Unrestricted OLS estimation for different uncertainty indicators (full sample)

constant	39.01 (1.201)	53.86 (12.65)	39.21 (2.608)	42.38 (2.513)	22.84 (6.037)
DY	5.934 (1.491)	5.892 (1.486)	5.930 (.517)	5.922 (1.487)	5.890 (1.483)
DY_{-2}	1.465 (.907)	1.463 (.905)	1.465 (.293)	1.463 (.904)	1.470 (.906)
$PROF2_{-1}$	.455 (.224)	.453 (.227)	.456 (.167)	.450 (.225)	.440 (.226)
$PROF2_{-2}$	.576 (.244)	.600 (.240)	.578 (.174)	.565 (.242)	.618 (.241)
VAR4PROF2 (α)	.00196 (.0082)	.00372 (.0081)	.00214 (.0093)	.00203 (.0081)	.00387 (.0081)
VAR4PROF2 *REV(β)	.0682 (.0446)	.0615 (.0464)	.0675 (.0197)	.0663 (.0463)	.0610 (.0467)
VDIRL (δ)		-714.60 (575.59)			
VDIRL *REV (γ)		138.68 (129.54)			
VDREER (δ)			-6002.58 (49008.8)		
VDREER *REV(γ)			7114.13 (50211.7)		
V5DIRL (δ)				-4.689 (2.960)	
V5DIRL *REV (γ)				1.366 (3.080)	
V5DREER1(δ)					1.351 (.539)
V5DREER1 *REV(γ)					.302 (.262)
# Observations	2841	2841	2841	2841	2841
R^2adjusted	.0667	.0669	.0660	.0668	.0687
lnL	-15617.5	-15616.1	-15617.4	-15616.3	-15613.4

Constant	12.37 (9.709)	66.37 (18.95)	44.76 (2.754)	79.49 (13.81)
DY	5.913 (1.485)	5.905 (1.490)	5.898 (1.482)	5.900 (1.479)
DY_{-2}	1.462 (.905)	1.471 (.906)	1.464 (.907)	1.456 (.905)
$PROF2_{-1}$	.430 (.227)	.459 (.225)	.430 (.227)	.428 (.228)
$PROF2_{-2}$	.612 (.240)	.608 (.242)	.576 (.239)	.601 (.240)
VAR4PROF2 (α)	.00348 (.0081)	.00367 (.0082)	.00232 (.0080)	.00324 (.0080)
VAR4PROF2 *REV(β)	.0616 (.0467)	.0625 (.0465)	.0648 (.0462)	.062 (.0462)
V5DREER2(δ)	2.661 (1.014)			
V5DREER2 *REV(γ)	.330 (.299)			
VDIRLGARCH (δ)		-57.23 (38.35)		
VDIRLGARCH *REV (γ)		5.818 (5.661)		
VDREER1GARCH (δ)			-1.220 (.501)	
VDREER1GARCH *REV(γ)			.294 (.479)	
VDREER2GARCH (δ)				-6.060 (2.002)
VDREER2GARCH *REV(γ)				.452 (.414)
# Observations	2841	2841	2841	2841
R^2adjusted	.0687	.0671	.0679	.0685
LnL	-15613.3	-15615.8	-15614.6	-15613.6

Legend: Number between brackets are heteroscedastic robust standard errors

Tabel 8. Tobit1 estimates for different uncertainty indicators

constant	50.48 (1.50)	68.21 (15.16)	50.98 (3.39)	54.54 (3.09)	30.44 (7.45))
DY	6.231 (1.448)	6.200 (1.444)	6.246 (1.449)	6.224 (1.449)	6.191 (1.443)
DY_{-2}	2.330 (1.202)	2.324 (1.211)	2.340 (1.208)	2.324 (1.210)	2.337 (1.211)
$PROF2_{-2}$	.527 (.252)	.530 (.250)	.508 (.253)	.488 (.255)	.547 (.250)
VAR4PROF2 (α)	.00528 (.0115)	.00537 (.0113)	.00422 (.0114)	.00368 (.0113)	.00581 (.0115)
VAR4PROF2 *REV(β)	.0915 (.0554)	.0903 (.0568)	.0946 (.0565)	.0936 (.0566)	.0894 (.0574)
VDIRL (δ)		-816.16 (695.3)			
VDIRL *REV (γ)		20.419 (153.97)			
VDREER (δ)			-574.54 (65809)		
VDREER *REV(γ)			-37367 (55779)		
V5DIRL (δ)				-4.794 (3.639)	
V5DIRL *REV (γ)				-1.474 (3.577)	
V5DREER1(δ)					1.750 (.663)
V5DREER1 *REV(γ)					.0619 (.311)
# Observations	2938	2938	2938	2938	2938
R^2adjusted	.0723	.0720	.0716	.0723	.0742
lnL	-11895.4	-11894.7	-11895.2	-11894.3	-11892.1

Constant	18.23 (11.84)	86.22 (23.96)	57.37 (3.25)	98.43 (15.85)
DY	6.216 (1.447)	6.218 (1.446)	6.191 (1.444)	6.188 (1.443)
DY_{-2}	2.327 (1.207)	2.343 (1.206)	2.317 (1.217)	2.313 (1.208)
$PROF2_{-2}$	.535 (.249)	.548 (.252)	.491 (.250)	.520 (.250)
VAR4PROF2 (α)	.00487 (.0115)	.00607 (.0115)	.00349 (.0111)	.00469 (.0112)
VAR4PROF2 *REV(β)	.0904 (.0575)	.0903 (.0571)	.0926 (.0598)	.0904 (.0565)
V5DREER2(δ)	3.304 (1.234)			
V5DREER2 *REV(γ)	.0580 (.356)			
VDIRLGARCH (δ)		-73.037 (47.913)		
VDIRLGARCH *REV (γ)		.675 (6.724)		
VDREER1GARCH (δ)			-1.324 (.598)	
VDREER1GARCH *REV(γ)			-.159 (.564)	
VDREER2GARCH (δ)				-7.065 (2.304)
VDREER2GARCH *REV(γ)				.0853 (.494)
# Observations	2938	2938	2938	2938
R^2adjusted	.0742	.0724	.0736	.0739
LnL	-11892.1	-11894.2	-11892.8	-11892.5

Legend: Number between brackets are heteroscedastic robust standard errors

Table 9. Reduced Probit estimation results for different uncertainty indicators

constant	-.658 (0.293)	-.785 (.416)	-.682 (.299)	-.748 (.304)	-.593 (.330)	Constant	-.521 (.372)	-.492 (.522)	-.737 (.304)	-.927 (.483)
DY_{-1}	.00607 (.0082)	.00623 (.0082)	.00623 (.0083)	.00612 (.0081)	.00621 (.0083)	DY_{-1}	.00630 (.0083)	.00622 (.0082)	.00623 (.0082)	.00630 (.0082)
PROF2	.00868 (.0043)	.00906 (.0043)	.00901 (.0043)	.00880 (.0043)	.00887 (.0043)	PROF2	.00889 (.0043)	.00885 (.0043)	.00911 (.0043)	.00893 (.0043)
$PROF2_{-1}$	.0217 (.0045)	.0220 (.0045)	.0218 (.0045)	.0222 (.0045)	.0222 (.0045)	$PROF2_{-1}$	.0222 (.0045)	.0222 (.0045)	.0222 (.0045)	.0222 (.0045)
$PROF2_{-2}$	.00814 (.0041)	.00917 (.0041)	.00906 (.0041)	.00916 (.0041)	.00921 (.0041)	$PROF2_{-2}$	.00918 (.0041)	.00927 (.0041)	.00895 (.0041)	.00915 (.0041)
ln(SIZE)	.0969 (.022)	.0947 (.022)	.0957 (.022)	.0980 (.022)	.0944 (.022)	ln(SIZE)	.0949 (.022)	.0952 (.022)	.0973 (.022)	.0957 (.022)
PK	.0503 (.0189)	.0505 (.0189)	.0504 (.0189)	.0505 (.0189)	.0505 (.0189)	PK	.0503 (.0189)	.0505 (.0189)	.0504 (.0189)	.0504 (.0189)
VAR4PROF2 (α)	-.00032 (.00021)	-.00023 (.00022)	-.000258 (.00022)	-.000255 (.00022)	-.000232 (.00022)	VAR4PROF2 (α)	-.000233 (.00022)	-.000237 (.00022)	-.000256 (.00022)	-.000237 (.00022)
VAR4PROF2 *REV(β)	.00037 (.00042)	.000082 (.000437)	.000178 (.000433)	.000165 (.000434)	.000050 (.000436)	VAR4PROF2 *REV(β)	.000059 (.000438)	.000074 (.000437)	.000175 (.000433)	.000072 (.000436)
VDIRL (δ)		5.263 (13.41)				V5DREER2(δ)	-.0156 (.0244)			
VDIRL *REV (γ)		7.176 (2.912)				V5DREER2 *REV(γ)	.0165 (.00657)			
VDREER (δ)			245.79 (1144.38)			VDIRLGARCH (δ)		-.3700 (.908)		
VDREER *REV(γ)			2272.6 (1190.1)			VDIRLGARCH *REV (γ)		.3078 (.130)		
V5DIRL (δ)				.0629 (.0714)		VDREER1GARCH (δ)			.00907 (.0117)	
V5DIRL *REV (γ)				1307 (0.0734)		VDREER1GARCH *REV(γ)			.0219 (.0114)	
V5DREER1(δ)					-.0065 (.0132)	VDREER2GARCH (δ)				.0360 (.0537)
V5DREER1 *REV(γ)					.0145 (.0056)	VDREER2GARCH *REV(γ)				.0224 (.0093)
# Observations	2938	2938	2938	2938	2938	# Observations	2938	2938	2938	2938
lnL	-1579.7	-1576.4	-1578.02	-1577.09	-1576.14	LnL	-1576.28	-1576.72	-1576.90	-1576.37
χ^2 for $\alpha+\beta=0$ and $\delta+\gamma=0$ (prob)	0.018 (p=0.89)	1.006 (p=0.604)	3.033 (p=0.22)	4.696 (p=0.096)	0.516 (p=0.773)	χ^2 for $\alpha+\beta=0$ and $\delta+\gamma=0$ (prob)	.201 (p=.904)	.181 (p=.913)	4.745 (p=.093)	1.324 (p=.516)
% correctly predicted	75.49	75.43	75.43	75.43	75.39	% correctly predicted	75.46	75.39	75.46	75.49

Legend: Number between brackets are heteroscedastic robust standard errors

Table 10. Sample selection estimates for different uncertainty indicators

constant	-33.38 (26.10)	-13.62 (28.15)	-31.78 (25.55)	-60.66 (28.91)	-80.66 (31.60)	Constant	-90.58 (32.75)	-13.76 (30.81)	-59.08 (28.64)	-18.54 (31.81)
DY	6.734 (1.575)	6.682 (1.570)	6.741 (1.578)	6.831 (1.573)	6.780 (1.567)	DY	6.801 (1.572)	6.801 (1.572)	6.800 (1.568)	6.799 (1.572)
DY_{-1}	.525 (.503)	.529 (.496)	.522 (.502)	.446 (.447)	.465 (.433)	DY_{-1}	.450 (.433)	.468 (.439)	.445 (.441)	.435 (.439)
DY_{-2}	1.678 (1.028)	1.665 (1.042)	1.684 (1.039)	1.815 (1.034)	1.816 (1.032)	DY_{-2}	1.805 (1.026)	1.828 (1.027)	1.803 (1.042)	1.791 (1.027)
$PROF2_{-1}$	.959 (.415)	.943 (.410)	.943 (.415)	1.319 (.402)	1.274 (.398)	$PROF2_{-1}$	1.269 (.400)	1.273 (.401)	1.313 (.397)	1.274 (.401)
$PROF2_{-2}$	.773 (.375)	.817 (.379)	.781 (.377)	.796 (.373)	.864 (.375)	$PROF2_{-2}$	.853 (.373)	.845 (.375)	.813 (.368)	.841 (.371)
VAR4PROF2 (α)	-.0072 (.0134)	-.0037 (.0131)	-.0058 (.0132)	-.013 (.0126)	-.0094 (.0128)	VAR4PROF2 (α)	-.0104 (.0128)	-.0093 (.0128)	-.013 (.0123)	-.0108 (.0125)
VAR4PROF2 *REV(β)	.095 (.0573)	.0815 (.0589)	.090 (.0587)	.099 (.0594)	.090 (.0606)	VAR4PROF2 *REV(β)	.091 (.0606)	.092 (.0602)	.098 (.0595)	.091 (.0594)
VDIRL (δ)		-898.32 (709.07)				V5DREER2(δ)	2.954 (1.205)			
VDIRL *REV (γ)		273.03 (171.00)				V5DREER2 *REV(γ)	0.723 (0.396)			
VDREER (δ)			1663.6 (65784)			VDIRLGARCH (δ)		-93.328 (48.89)		
VDREER *REV(γ)			40830 (59117)			VDIRLGARCH *REV (γ)		12.957 (7.394)		
V5DIRL (δ)				-2.958 (3.648)		VDREER1GARCH (δ)			-1.205 (.583)	
V5DIRL *REV (γ)				4.171 (3.841)		VDREER1GARCH *REV(γ)			.796 (.605)	
V5DREER1(δ)					1.629 (.657)	VDREER2GARCH (δ)				-6.485 (2.290)
V5DREER1 *REV(γ)					.644 (.347)	VDREER2GARCH *REV(γ)				1.0056 (.541)
Heckman's λ	211.18 (67.137)	206.97 (64.795)	205.68 (65.183)	284.63 (73.140)	280.00 (73.523)	Heckman's λ	279.43 (73.30)	273.84 (73.11)	289.73 (73.71)	281.61 (73.14)
# Observations	2128	2128	2128	2128	2128	# Observations	2128	2128	2128	2128
R^2adjusted	.0748	.0746	.0739	.0775	.0794	R^2adjusted	.0794	.0771	.0794	.0793
lnL	-11830.8	-11830.1	-11830.8	-11826.7	-11824.5	LnL	-11824.5	-11827.2	-11824.5	-11824.7
χ^2 for α+β=0 and δ+γ=0 (prob)	2.322 (p=.128)	2.422 (p=.298)		2.370 (p=.306)		χ^2 for α+β=0 and δ+γ=0 (prob)		4.868 (p=0.088)	2.102 (p=.350)	6.794 (p=.033)

Legend: Number between brackets are heteroscedastic robust standard errors corrected for the estimation of Heckman's λ

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