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THE IMPACT OF UNCERTAINTY ON INVESTMENT PLANS

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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

In this paper we investigate how demand and output price uncertainty affect investment plans of Belgian manufacturing firms. We obtain time-varying uncertainty measures at the firm and industry level from the Belgian monthly business cycle survey and investment plans from the half-yearly investment survey. Using investment plans instead of realised investment data, e.g. annual accounts data, is, from an informative point of view, superior since it is more likely to reveal the features of the decision formation process and, therefore, it is most closely related to economic theory. Business investment is normally planned well in advance, because it involves time and costs to implement, and theory describes the behaviour of firms at the moment of their decision, which can be assumed to be fully captured in survey data. In order to find robust predictions we estimate three different specifications, each of which can be considered as a benchmark in the literature: two reduced form equations and a structural Euler equation. Our results show that uncertainty depresses investment. These results hold for industry- as well as for firm-specific demand uncertainty. Moreover, referring to Euler equation, uncertainty postpones investment today in favour of investment tomorrow. This effect is stronger for firms with more irreversible investment. Hence, our results seem to confirm to predictions of the real option theory.

Keywords: investment, uncertainty, irreversibility, real options, survey data
JEL Classification: D92, E22, D82, C23.

TABLE OF CONTENTS

1. INTRODUCTION

In this paper, we investigate how demand and output price uncertainty affect the investment behaviour of a panel of Belgian manufacturing firms. A number of studies have recently analysed the investment behaviour of Belgian manufacturing firms using accounting data[1]. Only three studies (Cassimon et al, 2002, Gérard and Verschueren, 2002, and Peeters, 2001), however, investigate the effect of uncertainty on investment for Belgian manufacturing firms. Peeters (2001) estimates an Euler equation augmented with uncertainty. She finds that output price uncertainty depresses investment, but she detects no effects of demand uncertainty. Gérard and Verschueren (2002) use both an Euler equation and a reduced form framework. Their results show little empirical support for the role of investment price uncertainty. Cassimon et al (2002), on the contrary, obtain that uncertainty with respect to profitability has an impact on the decision to invest. When investment is irreversible, uncertainty also reduces the amount invested.

To reveal the role of uncertainty in the investment decision process, the amount of the investment planned, rather than the actual amount of investment is the relevant variable. Investment is usually planned well in advance, because it involves time and costs to implement. Since firms take into account all available information and the uncertainty surrounding this information at the moment of their decision, all information should be measured as closely as possible to that moment. Hence, planned investment is, from an informative point of view, superior to actual investment, and is most closely related to economic theory. Therefore, we use investment survey data in which managers reveal their planned investment expenditures. We are aware of only two other research papers that make use of planned investment data in order to investigate the effect of uncertainty on investment (Guiso and Parigi, 1999, and Patillo, 1998). All other studies, instead, analyse realised data, i.e. firm-level actual investment from annual accounts.

We further employ the business cycle survey conducted every month by the National Bank of Belgium (NBB), to construct measures of demand and price uncertainty at the industry and firm level. Our uncertainty measures are at the same time industry- or firm-specific, time-varying and forward-looking; further they are derived from directly observable firms' expectations rather than being based on an assumption about the firms' expectation formation model. We relate planned investment to its neoclassical fundamentals, uncertainty and financial constraints measures. Fundamentals and cash flow, which is commonly considered as a proxy for financial constraints, are constructed from annual accounts.

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1 Barran and Peeters (1998), Bond et al. (1997), Butzen et al (2001), Cassimon et al (2002), Deloof (1998), Gérard and Verschueren (2002), Peeters (2001), Vermeulen (1998) and other papers presented at this conference.

In order to find robust predictions we estimate three different specifications, each of which can be considered as a benchmark in the literature. First, we estimate an error correction model augmented with uncertainty, as in Bloom et al. (2001). Second, we apply a variant of the specification used in Guiso and Parigi (1999). Third, for comparability with the existing evidence on Belgian firms, we estimate an Euler equation as in Gérard and Verschueren (2002) and Peeters (2001).

These regressions allow us to test the predictions of what has become in the last decade one of the major strands in the investment literature: the real options theory. According to this theory, when investment is irreversible, i.e. investment is a sunk cost, and if there exists some time flexibility to postpone investment, firms might optimally wait to invest until more is know. So the main conclusion of real option theory is that uncertainty depresses current irreversible investment and postpones investment projects. Although all specifications we estimate, contain dynamics, primarily, the investment Euler equation, which explicitly explains the intertemporal substitution of investment expenditures, can verify this hypothesis. The real option literature yields more ambiguous predictions with respect to the impact of uncertainty on the optimal amount of investment and on the long-run capital stock. Several papers have indicated that the production and market environment in which the firm operates matters and that a slightly different mix of various parameters can substantially alter the conclusions (Bertola, 1988, Caballero, 1991, Pindyck, 1993, and Abel et al, 1996). The total picture is even further blurred when one takes into account the findings of an older strand of research (Hartman, 1972, and Abel, 1983), according to which increased uncertainty will stimulate investment. Therefore, the sign of the long-run relationship between uncertainty and investment needs to be determined on empirical grounds. All three specifications can help to shed some light on this aspect.

This paper is organised as follows. Section 2 gives a brief overview of the prevailing theoretical reflections and empirical approaches to the investment-uncertainty relationship. Section 3 describes our data. Here, we put emphasis on our contribution using survey data and how we construct our uncertainty measures. The various model specifications are presented in Section 4 and our empirical findings in Section 5. Section 6 summarises our main conclusions.

2. THE INVESTMENT-UNCERTAINTY NEXUS IN THE LITERATURE

2.1. Theoretical reflections

The seminal book of Dixit and Pindyck (1994) and the recent survey by Carruth et al (2000) have summarised the renewed attention in the literature for the analysis of firms' behaviour under uncertainty when investment expenditures are irreversible. Their key insight is that, under irreversibility, there exists an option to postpone investment in order to obtain further information about future market conditions. This option to wait has a value (the opportunity cost of investing today) and, subsequently, firms will only invest when the net present value of the investment project covers also this value. Therefore, irreversibility increases the hurdle that triggers investment compared to the reversibility case (the irreversibility effect), and, moreover, this hurdle increases with uncertainty (the uncertainty effect). So, real option theory predicts that uncertainty and irreversibility depress *current* investment and delay investment projects. In linking option pricing theory to investment behaviour the contribution of the real option hypothesis primary brings insights into the *timing* of investment (e.g. the model of Mc Donald and Siegel, 1986).

Real option theory is less conclusive with respect to the optimal amount of investment and long-run capital stock. Several papers have shown that the sign and the magnitude of the effect of uncertainty on the optimal investment policy rule depends on the precise mix of characteristics such as the degree of irreversibility, the competitiveness of product markets, the production process (substitutability, returns to scale) and manager's attitude towards risk (Bertola, 1988, Caballero, 1991, Pindyck, 1993, and Abel et al, 1996). Moreover, Abel and Eberly (1999) prove that one should add to this ambiguity a so-called 'hangover' effect, i.e. the discrepancy between the firm's current capital stock, which reflects the firm's optimal behaviour to favourable circumstances in the past, and the lower level that it optimally would like to hold due to the occurrence of a slacking demand, but is unable to reach because of the irreversibility constraint. The 'hangover' effect makes current investment function of past events, and so, it introduces hysteresis.

The total picture becomes even further confused when one takes into account the findings of an older strand of research (Hartman, 1972, and Abel, 1983), which neglects the role of irreversibility. According to this theory increased uncertainty will stimulate investment of a risk-neutral, competitive firm with a constant returns to scale production process. Under these features the marginal product of capital is a convex function in the variables whose evolution is uncertain. In that case, Jensen's inequality applies: a higher, but mean-preserving, volatility, increases the optimal capital stock. To sum up, there exists no theoretical consensus regarding the long-run investment-uncertainty nexus. Hence, the sign of this relationship needs to be determined on empirical grounds. On the contrary, it is acknowledged that irreversibility and uncertainty affect the timing of investment by delaying investment.

2.2. Empirical methodology

There are several complications involved with the empirical investigation of the investment-uncertainty relationship. Neither is there consensus on the most suitable measure to proxy uncertainty (see next section), nor on the empirical specification.

Following the theoretical ambiguity of the long-run investment-uncertainty relationship, as described in the previous section, a majority of studies have tried to settle it empirically[2]. In our paper we will not only assess this feature but also the other prominent feature of the real option hypothesis: i.e. irreversibility and uncertainty affect the timing of investment. The existence of threshold effects above which investment is triggered and below which the option to delay is exercised has implications for the dynamics of investment resulting in periods of inaction. Irreversibility will change, at least at the project-level, the investment behaviour of firms from being smooth and continuous (the reversibility case) to one that is lumpy and frequently zero.

Several empirical papers have focused on this aspect of real option models. One approach, which deals with the short run dynamics, tries to identify the factors, which affect the trigger values of investment (Pindyck and Solimano, 1993, Patillo, 1998, Cassimon et al, 2002). This method, however, has a number of drawbacks. First, one needs to impose a considerable amount of structure (a particular production technology, competitive markets, etc.) in order to calculate the marginal revenue product of capital (MRPK), which needs to be compared to the marginal cost of capital adjusted for uncertainty. Second and more importantly, the value that triggers investment is not directly observable. Commonly, one has to assume that the theory is correct and that firms with a positive investment rate have just hit the trigger. Under this assumption, one can take the measured MRPK as a proxy for the unobserved trigger. Of course, the condition that the MRPK will never rise above the trigger, is rather severe and will not always hold empirically. Finally, although lumpy and zero investment behaviour has been observed with plant-level data (Doms and Dunne, 1998), aggregation, even at the firm-level, across multiple investment decisions (project, plants) will smooth away much of the lumpiness. In our data set, the frequency of zero investment is much

[2] Among many others are Bloom et al (2001), Driver and Moreton (1992), Driver et al. (1996), Ferderer (1993a, b), Ghosal and Lougani (2000), Guiso and Parigi (1999), Meersman and Cassimon (1995), Peeters (2001), Patillo (1998), Price (1995), von Kalckreuth (2000).

lower for large firms (1%) than for small firms (7.4%), consistently with the fact that aggregation across plants and projects smoothes investment.

Therefore, other approaches put less emphasis on the rare zero investment observations and incorporate some weaker form of lumpy dynamics. They introduce non-quadratic adjustment costs where the relationship between investment and its fundamentals becomes non-linear (Abel and Eberly, 1994, and Eberly, 1997). Still other papers follow a more ad hoc approach and specify a traditional error correction model (ECM) to capture the dynamics (Price, 1995, and Bloom et al, 2001). The advantage of this model is that it can capture a wide variety of relatively complex adjustment processes. On the other hand, as for every reduced form approach, the Lucas critique applies.

In our paper we specify not only a reduced form ECM, but we also estimate an Euler type of equation. Directly derived from the first order conditions of a dynamic optimisation problem, the Euler equation most naturally embodies the intertemporal nature of the investment decision. It offers the advantage that deep structural parameter can be obtained. The disadvantage is that one needs to put some structure on the model (choice of production and adjustment cost technology), which makes the results conditional upon this structure.

2.3. Measuring uncertainty

Investment depends on the expected future returns and the uncertainty surrounding these expectations. The stochastic processes of the underlying variables determine expectations about future returns. We concentrate our analysis on demand and output price uncertainty, because we have firm-subjective expectations of these variables. Further, we believe that macroeconomic variables may be less relevant than firm-specific factors as they can explain only time series variations and not cross-firms variations.

Data on firm-specific uncertainty are rarely readily available. To our knowledge, within the field of business investment research only two papers (Guiso and Parigi, 1999, and Patillo, 1998) refer to such directly available measures of firm-specific uncertainty. Both papers obtain a measure for demand uncertainty from a single survey, which reports the entrepreneur's subjective probability distribution of expected future demand. Most other papers construct a proxy for uncertainty based on the volatility of some variable or on the variance of errors of some forecasting model[3]. Uncertainty measured in this way is based on a parametric assumption about the firms' process of expectations formation. This implies that one assumes, first, that the econometrician knows the true model of expectations formation, and, second, that all firms have the same model.

On the contrary, we construct our measure of uncertainty from observed firms' expectations, a strategy that few papers have followed. When firms' subjective expectations are available, one can construct both aggregate and firm-specific measures of uncertainty. This is the approach we follow. Since future forecasts which are reported in surveys, are often strictly qualitative in nature, they need a special treatment to generate quantitative measures. In the literature, several methods have been suggested to construct measures of aggregate or industry-level uncertainty from individual answers[4]. The intuition behind all these measures is that they are larger as more respondents disagree about the future. We use the monthly business survey, conducted by the National Bank of Belgium, which reports qualitative information on firm's expected demand growth and on firm's expected price growth. We measure uncertainty by the disconformity of expectations across firms and across the twelve months of the year.

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3 See, among others, Bulan (2000), Gérard and Verschueren (2002), Ghosal and Lougani (2000), Meersman and Cassimon (1997), Peeters (2001), Price (1995), von Kalckreuth (2000).

4 For instance, Theil (1952), Caselli et al (2000), Carlson and Parkin (1975), Driver and Moreton (1992).

3. DESCRIPTION OF THE DATA

In order to test the theoretical hypotheses, we match three different data sets. The NBB investment survey provides us with data about planned investment. The NBB annual accounts database is used to construct the required firm-specific control variables such as the capital stock, sales, cash flow, etc. The NBB business survey is used to construct sector-specific and firm-specific measures of demand and output price uncertainty.

The NBB investment survey is conducted twice a year, once during the month of May (Spring Survey) and once during the month of November (Autumn survey). Since the mid eighties the questionnaire did not change and the results are comparable from 1986 onwards. The survey provides *quantitative* information (i.e. in euros) about the firm's investment expenditures in the previous year, the plans for the current year, and the firm's investment plans for the next year. The questionnaire explicitly states that the firm is only presumed to provide a value for investment planned when a sure decision in this respect has been made. From 1986 to 2001 in total 2515 firms of 22 different industries have participated in this survey for one or several years, and they did so rather seriously[5]. We estimate our investment regressions using both the Autumn and Spring surveys. First, we use firm's planned investment for the year t+1 from the Autumn survey conducted in year t. Second, we use the firm's planned investment for the year t+1 from the Spring survey in year t+1 (both are denoted I^P_{it+1}). In the second case, part of the planned investment is therefore already realised. Realised investment over the previous year is also revealed in the survey.

Annual accounting data of Belgian firms are collected by the National Bank of Belgium[6]. They are used to construct a number of control variables, which, according to theory, should appear in our analysis. First, the real capital stock is obtained as the book accounting value of the capital stock, deflated by the industry investment price index[7] corrected for the average age (using the formulae as in Bond et al, 1997, or Chatelain et Teurlai, 2000). Sales are proxied by value added, due to data

5 The actual investment of the previous year reported in the Spring survey coincided with the annual accounts data nearly perfectly for 85% of the firms.

6 Almost every non-financial firm reports annual accounts, by legal obligation. All accounts are submitted to substantial accounting and logical consistency controls, and, if necessary, corrections are made. The data therefore satisfy the highest quality standards.

7 Firm-specific investment prices are not available. We use 2-digit NACE codes for investment and value-added prices. The construction of the capital stock is explained in the appendix.

availability[8]. Cash flow is defined as net profits plus depreciation[9]. The wage sum is directly reported in the annual accounts.

The NBB business survey is used to construct measures of uncertainty and expected future sales growth. This monthly survey reports *qualitative* information about the firm's demand and price conditions. We focus on the answers to the following question: '*For the next three months, the demand of your customers for this product, will according to you be: (a) stronger, (b) unchanged, (c) weaker, than is usual in the period of the year*." The term usual includes normal seasonal fluctuations, and therefore the question really asks for changes relative to "normal business". A similar question is asked for prices. This survey allows us to construct a measure of uncertainty, which is at the same time forward-looking, firm- (or sector-) specific and time varying, and not based on a priori assumption about the firm's expectation formation process. Rather, the measure is based on firm's subjective expectations about future demand and price conditions. We proxy uncertainty by Theil (1952) 's disconformity index, i.e.: $\sigma_t = [(\%_{up}+\%_{down}) - (\%_{up}-\%_{down})^2]$, with $\%_{up}$ and $\%_{down}$, the percentage of observations of expectations of positive growth and negative growth, respectively. The index ranges from 0 to 1. When the answers are all identical, the index is equal to zero. The higher the disconformity index, the more different the answers during the year. The sector-specific index, σ_{st}, is based on the percentage over all months of the year and all firms of the same industry[10]. The firm-specific uncertainty index, σ_{it}, is constructed by computing the percentage over the 12 surveys of the year[11].

We also use this survey to construct a measure of observed firm's subjective expectations of future demand growth, $E_t(\Delta y_{it+1})$, which appears in the ECM as well as in the Guiso and Parigi (1999) specification. This is simply equal to $(\%_{up}-\%_{down})$. This gives an index of the direction of demand expectations. The index ranges from -1 to 1; if the index is 1. The firm has expected all 12 months a stronger demand than usual, if the index is –1 the firm has expected weaker demand for 12 months. This allows us to take into our analysis firm's subjective expectation about future market

8 Small firms do not provide as detailed information as large firms do, and among other things do not have to report sales. A company is regarded as "large", in 1999. either when the yearly average of its workforce is at least 100 or when at least two of the following thresholds were exceeded: (1) yearly average of workforce: 50. (2) turnover (excluding VAT) : EUR 6.250.000. (3) balance sheet total : EUR 3.125.000. In general, the values of the latter two thresholds are altered every four years in order to take account of inflation.

9 Again the definition differs for small and large firms according to data availability.

10 In order to match the business survey with the investment survey, and in order to guarantee a sufficiently large number of firms per sector, we focus on seven (aggregated) sectors: food, textiles, wood, paper, chemicals, non-metal and metal.

11 Not all firms answer to each survey, but restricting to firms that have answered all 12 months leads to a much more precise and reliable measure of the uncertainty index.

conditions. We additionally compare the results including this measure with those based on a rational expectations hypothesis.

We do not have at our disposal a first best data set, i.e. a data set containing a direct measure of the entrepreneur's subjective probability distribution of expected future demand, as in Guiso and Parigi (1999), and Patillo (1998), but we are still able to construct uncertainty measures using the firm's subjective expectations on future demand (or output prices). This procedure, at least, is second best, since it releases us from postulating an implicit process for the formation of expectations (e.g. as in Gérard and Verschueren, 2002, Ghosal and Lougani, 2000, Peeters, 2001, or von Kalckreuth, 2000) and, moreover, provides us with a forward-looking measure. Furthermore, since the business survey is conducted on a higher frequency than the investment survey (monthly versus half-yearly), the final uncertainty measure can be at the same time firm (or sector) specific and time-varying. Of course, there are some caveats. First, quantifying information contained in a qualitative survey is never an easy and exempt-of-error task (see for example the analysis of Batchelor, 1986). Second, there is a time-horizon mismatch between the questions in both surveys. The investment survey asks for the firm's investment intentions for the next year, whereas in the business survey firms have to reveal their demand and output price prospects for the coming three months.

The data appendix gives extensive information about the precise definition of the variables and the trimming procedure, and also provides some descriptive statistics of our sample and its representativity.

4. THE EMPIRICAL MODEL

We attempt to obtain rather robust conclusions on the effect of uncertainty on investment. Therefore, we estimate three different specifications, which can be considered being the benchmark in the current empirical investment literature. The first two specifications are in reduced form, so they are not explicitly derived from a particular optimising behaviour of a firm, but rather they represent an empirical approximation to some complex underlying process that generates the data. The justification behind these specifications is that, starting from a formal intertemporal optimisation problem of a representative firm and taking into account elements of irreversibility and/or adjustment costs, results in closed-form solutions that are highly non-linear and often unmanageable without making some simple linear approximation. With this approach we actually follow the procedure adopted by many authors, who prefer to treat the item of irreversible investment, in a more pragmatic way.

Because we use reduced-form equations, we try different specifications as a robustness check. The firm plans its investment in the next period if it expects good opportunities (sales growth) and it expects to collect the necessary financing funds (internally or externally)[12]. If adjustment to the optimal capital stock is not immediate, it may consider current values of the above variable, realised investment and deviations from its long-run equilibrium. Finally, uncertainty about the future may lead the firm to postpone investment decisions until new information is available, this would imply lower investment plans which may be revised upwards in case of good news in the next period[13].

The first specification is an accelerator model, which controls for demand by entering sales growth (Δy_{it}) as in von Kalckreuth (2000)[14]. We also include an error correction term and assume, as in Bloom et al (2001), that in the long-run, the capital output-ratio is constant, so that deviations from the long-run equilibrium simplify to (k_{it-1}- y_{it-1})[15]. We also include expectations on future market conditions in the equation. However, future sales growth partly captures future cash flow.

12 We use fixed effects and time dummies. These variables can, among other things, be seen as a proxy for the user cost of capital. Since the user cost of capital is not the focus of our paper, we do not think that this strategy would be harmful to the results.

13 Bloom et al (2001) have argued that uncertainty may also reduce the sensitivity of the firm to sales growth. We tested for such effect but it turned out to be non-significant.

14 von Kalckreuth enters multiple lags of sales growth. We prefer to enter the lagged investment ratio together with one lag of sales growth, which implicitly is like entering an infinite number of lags of sales growth with restrictions on the coefficients of these lags. The advantage of this parsimonious specification is that less observations are lost due to constructing lagged variables.

15 Preliminary analysis shows that imposing this restriction substantially improves the results, in terms of both specification and significance of the coefficients. It also prevents from obtaining aberrant values for the returns to scale parameter, as so often is seen in the literature. So, imposing this restriction reflects current best practices. Moreover, it enhances comparability with the Euler specification, in which this assumption is made in order to calculate the MRPK.

Thereby to avoid multicollinearity problems, we do not include future cash flow together with future sales growth, current sales growth and cash flow (CF_{it}/K_{it}). Finally, time dummies (δ_t) capture macroeconomic fluctuations. Small cases represent logs. Our first specification is then

$$(1) \qquad I^P_{it+1}/K_{it} = \delta_t + \alpha\, I_{it}/K_{it-1} + \gamma.E_t(\Delta y_{it+1}) + \beta.\Delta y_{it} + \varphi.CF_{it}/K_{it} + \theta.\sigma_{st} - \lambda.(k_{it-1} - y_{it-1}) + \varepsilon_{it+1}$$

with σ_{st} representing industry-specific demand or output price uncertainty (whereby the subscript s is replaced by i when firm-specific uncertainty is used).

The second specification controls for demand by including the current value added capital ratio (Y_{it}/K_{it}) rather than current sales growth. By doing, one obtains a similar specification as in Guiso and Parigi (1999). The major difference with the first specification is the omission of the error correction term :

$$(2) \qquad I^P_{it+1}/K_{it} = \delta_t + \alpha\, I_{it}/K_{it-1} + \gamma.E_t(\Delta y_{it+1}) + \beta.\, Y_{it}/K_{it} + \varphi.CF_{it}/K_{it} + \theta.\sigma_{st} + \varepsilon_{it+1}$$

The third specification is the classical Euler equation. This equation, in particular, allows us to investigate the intertemporal properties of the investment decision process, since it examines the choice between investing today or tomorrow. Hence, this specification is most interesting to test the real option theory, which prominent feature refers to the timing of investment. A complete derivation of the Euler equation can be found in the Appendix. Our Euler equation becomes (with F_{it} representing the production function, $w_{it}L_{it}$ the wage sum, β_{t+1} the discount rate, δ_i the depreciation rate and the p^I 's the investment price):

(3)

$$(1-\delta_i)\beta_{it+1}E_t(p^I_{t+1}I_{it+1}/p^I_t K_{it+1}) - (I_{it}/K_{it}) + \frac{1}{2}(I_{it}/K_{it})^2 = \frac{-(1-\frac{1}{\varepsilon})}{\alpha}\left(\frac{p_{it}}{p^I_t}\frac{F_{it}}{K_{it}}\right) + \frac{1}{\alpha}\left(\frac{w_{it}}{p^I_{it}}\frac{L_{it}}{K_{it}}\right) + \frac{\theta}{\alpha}*\sigma_{st} +$$
$$+\frac{1}{\alpha}[\phi^2\frac{\alpha}{2} + 1 - \alpha\phi + (\alpha\phi - 1)(1-\delta_i)\beta_{it+1}E_{it}(p^I_{t+1})/p^I_t]$$

The adjustment cost parameter is α and ε represents the absolute value of the price elasticity of the firm's output demand. Under monopolistic competition, one expects for the latter parameter a value close to, but greater than one. An important feature of the data is that we can replace expected investment, $E_t(p^I_{t+1}\, I_{it+1})$, with the observed investment plans of the survey, $p^I_{t+1}\, I^P_{it+1}$. So, we do not need to make an explicit assumption with respect to the firm's expectations formation process. Most studies assume rational expectations and replace expected values by realised ones. This practice introduces a forecast error in the equation and makes regressors correlated with the error term.

Note that the interpretation of the coefficient on uncertainty for the Euler equation is different from the interpretation for the reduced form regressions. The reduced form regressions estimate the effect of uncertainty during year t on the investment planned for year t+1 (where the planning happens in Autumn of year t or Spring in year t+1), conditional on year t investment. The Euler equation describes the effect of uncertainty on the intertemporal substitution between actual investment in year t and planned investment for the year t+1. Uncertainty will have a negative effect on the level of investment in year t when the coefficient on uncertainty is positive (note that I/K_t enters on the left hand side with a negative sign), but also, by forward substitution, on investment rates in the future. Only, a positive coefficient for uncertainty, in addition, implies a shift of investment from year t to year t+1. Hence, the negative effect of future investment will be tempered compared to current investment.

5. THE RESULTS

5.1. Reduced form specifications

We first present our estimates of the reduced-form equations (1) and (2). In this section, we use investment plans as reported in the Autumn survey. Some robustness checks with respect to the Spring survey are reported in appendix B. We assume that all variables in period t are predetermined. We believe that our uncertainty measure is truly exogenous for the plans made during t for year t+1. Clearly, it would be hard to find a reason why e.g. increased demand expected in August year t for Sept-Nov year t could be influenced by the planned investment for year t+1. We assume therefore that the direction of causation can only go from uncertainty to investment plans and not the other way around. We also use the firm-specific measure for future growth described in the above section, and assume for the same reason that it is predetermined.

Estimating both reduced form equations, several assumptions can be made, which determine the use of a particular estimator. Assuming no fixed effects and using our measure of future sales growth, equation (1) can be consistently estimated by OLS. Otherwise, there exist two endogeneity problems. The first is related to the inclusion of fixed effects. These effects capture various unobserved firm-specific factors such as the firm-specific component of the user cost, productivity growth, depreciation rate, etc. The model must then be transformed to get rid of the fixed effects and instrumented because the transformation (e.g. within or first differences are often used) creates a correlation between the transformed error term and the transformed regressors. The second endogeneity problem is related to proxying expected future sales growth by its realisation, i.e. assuming that firms are rational in forming their expectations. This practice, however, introduces a forecast error in the equation and, in this case, the model also needs to be estimated by some instrumental variable technique. We include all variables of the equation in t and t-1 in the instrument set.

We compare our results using sector-specific and firm-specific uncertainty. Assessing the effect of industry-specific uncertainty on investment behaviour, leaves us with a fairly large amount of the degrees of freedom which allows us to include an adequate dynamical path. In this case, we allow for fixed effects and estimate equation (1) with Arellano and Bond (1991) first difference GMM estimator. Although we control for a number of firm-specific variables (such as sales and cash-flow), the fact that we consider sector-specific uncertainty rather than firm-specific uncertainty may introduce the firm-specific component of uncertainty in the error term, calling for a fixed effect estimation[16]. We investigate below whether the results change when taking into account firm-specific uncertainty.

Table 1 below reports the first difference Arellano-Bond GMM estimates of equation (1) with sector-specific uncertainty. We compare a purely backward-looking specification, without future sales growth, with two forward-looking specifications. In the first, we assume rational expectations. In the second, we used our sector-specific proxy of observed expectations for future sales growth, $E_t(\Delta y_{it+1})$. The model is correctly estimated, as evidenced by the Sargan, m1 ad m2 statistics.

The results show that firms smooth investment (the coefficient on realised investment is significantly positive and around 0.09). This may be due to the fact that investment is aggregated over projects and plants, and that investment projects may run over several years.

Including expected future sales growth, there is evidence of accelerator effects. In the rational expectation specification, future sales growth and current sales growth are both significant. However, in the case of observed expectations with demand uncertainty, future sales growth is significant at the 16% level only and current sales growth becomes insignificant. This may indicate that our proxy for observed expectations is poor, which may be due to the fact that it is based on qualitative information with a short forecast horizon (3-months) or to the fact that it is sector-specific. Estimates with firm-specific observed expectations, discussed below, also show that this variable is not significant. Using a similar proxy based on three-month forecast horizon, Houbedine (2001) also finds no effect of future growth on investment plans. On the contrary, using a measure of one-year ahead expected future growth, Patillo (1998) finds that this variable has a significant effect on (positive) investment. This suggests that, because of a short-time horizon, our proxy of observed expectations is a poor indicator of the true firm's expectations of next year growth, and that the latter may be better proxied assuming rational expectation.

The coefficient on cash flow is never significant. This may be due to the fact that the interpretation of cash flow is ambiguous; it has been interpreted as evidence of financial constraints, but may also proxy for future sales growth opportunities (see, for example, the discussion in Kaplan and Zingales, 1997).

The error correction term is significant and correctly signed. This indicates at the same time that firms adjust their investment plans to deviations of their capital stock from long-run

[16] Indeed, preliminary estimates (available on request) show that the omission of fixed effects generates very poor results and lead to misspecification problems.

equilibrium, and that there are long-run constant returns to scale. The value of the adjustment parameter, between 0.06 and 0.08 suggests a slow speed of adjustment towards long-run equilibrium, as is generally found in the literature.

Finally, although price uncertainty is never significant, demand uncertainty is significantly negative across all three specifications. The coefficient of demand uncertainty lies between -0.15 and -0.16. This implies that a one standard deviation increase in sector demand uncertainty (i.e. 0.05) reduces the rate of investment plans by 3% of its mean. Although non-negligible, the effect is not very large, as has been found elsewhere in the literature.

Table 1: GMM estimation in first difference with fixed effects and sector-specific uncertainty

	demand uncertainty						**price uncertainty**					
	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
I_{it}/K_{it-1}	0.09	2.41	0.09	2.38	0.08	2.20	0.09	2.46	0.09	2.40	0.09	2.36
$E_t(\Delta y_{st+1})$					0.08	1.41					0.12	2.14
Δy_{it+1}			0.07	1.62					0.09	1.91		
Δy_{it}	0.03	0.75	0.07	1.51	0.03	0.79	0.03	0.84	0.09	1.74	0.03	0.78
CF_{it}/K_{it-1}	0.01	0.38	0.01	0.50	0.01	0.27	0.01	0.31	0.01	0.44	0.01	0.48
σ^D_{st}	-0.15	-2.21	-0.15	-2.30	-0.16	-2.29						
σ^P_{st}							-0.03	-0.27	-0.02	-0.15	0.04	0.37
$k_{it-1}-y_{it-1}$	-0.07	-2.36	-0.08	-2.62	-0.06	-2.33	-0.07	-2.29	-0.08	-2.61	-0.06	-2.11
# obs – firms	1303	256	1303	256	1303	256	1303	256	1303	256	1303	256
Sargan-p-value	378.48	0.07	375.81	0.08	454.22	0.06	360.91	0.21	356.72	0.24	445.25	0.10
m1 - p-value	-6.59	0.00	-6.68	0.00	-6.58	0.00	-6.52	0.00	-6.62	0.00	-6.56	0.00
m2 - p-value	0.55	0.58	0.60	0.55	0.64	0.52	0.53	0.60	0.55	0.58	0.69	0.49

Instrument set: lags of I_{it}/K_{it-1} ,I_{it-1}/K_{it-2} ,y_{it}, y_{it-1} ,CF_{it}/K_{it-1} ,$CF_{it}-1/K_{it-2}$,σ_{st}, σ_{st-1} ,σ_{st-2} ,k_{it}, ,k_{it-1} ,$E_t(\Delta y_{st+1})$, $E_{t-1}(\Delta y_{st})$, $E_{t-2}(\Delta y_{st-1})$,
All regressions include time dummies, first step robust results

We now investigate the effect of firm-specific demand uncertainty on investment plans. The requirement to obtain a meaningful measure of firm-specific uncertainty, i.e. we restrict ourselves to firms that answered the question regarding their demand prospects every single month, reduces severely the number of firms. We have 473 firm-observations on 249 firms after removing outliers. The data set is unbalanced with most firms having only 1 or very few observations, i.e. with an average of 1.9 observations per firm. Given the size of the sample the best strategy is to stick to OLS estimates rather than using methods which require a larger number of observations, but to include controlling variables to reduce the potential importance of potential firm-specific effects and diminish the potential correlation of uncertainty with the firm specific effect. Among others, the inclusion of firm specific uncertainty, rather than sector specific uncertainty, should diminishes potential fixed effects problems.

We estimate both with and without the expected demand growth and cash flow variables. The results of the estimation of specification (1) are presented in Table 2. In the upper panel of Table 2, , we estimate a sales accelerator specification without error correction term, as in von Kalckreuth (2000). Demand uncertainty is significantly negative and the point estimate (between -0.10 and -0.08) does practically not change when controlling for expected demand and the cash flow capital ratio. Also, the investment rate is significantly positive, as expected from the above results and the fact that firms smooth investment plans. There is evidence of an accelerator effect when cash flow is not included in the equation. Indeed, the expected demand growth variable is always insignificant, but current sales growth is significantly positive. As explained above, the cash flow capital ratio might very well proxy for value added growth or future value added growth. The uncertainty estimate, however, remains quite robust upon entering those variables in the regression implying that our demand uncertainty measure does not proxy for these variables and is robust to the inclusion of other control variables.

Table 2 : The effect of firm specific demand uncertainty on planned investment - OLS estimates of equation (1)

	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
accelerator model												
I_{it}/K_{it-1}			0.12	3.13	0.09	2.19			0.12	3.05	0.08	2.15
Δy_{it}	0.13	2.02	0.08	1.30	0.03	0.46	0.14	2.23	0.09	1.44	0.03	0.51
$E_t(\Delta y_{it+1})$							-0.03	-1.07	-0.02	-0.76	-0.01	-0.33
CF_{it}/K_{it-1}			0.11	5.52							0.11	5.41
σ^D_{it}	-0.10	-2.12	-0.10	-2.08	-0.09	-1.86	-0.10	-1.92	-0.10	-1.93	-0.08	-1.77
# obs	463		463		463		463		463		463	
R^2	0.07		0.10		0.15		0.07		0.10		0.15	
ECM model												
I_{it}/K_{it-1}	0.10	2.50	0.09	2.16	0.10	2.47	0.09	2.14				
Δy_{it}	0.09	1.67	0.02	0.27	0.09	1.74	0.02	0.30				
$k_{it-1}-y_{it-1}$	-0.05	-4.53	-0.02	-1.57	-0.05	-4.43	-0.02	-1.56				
$E_t(\Delta y_{it+1})$					-0.01	-0.34	0.00	0.17				
CF_{it}/K_{it-1}			0.09	3.91			0.09	3.88				
σ^D_{it}	-0.10	-2.06	-0.09	-1.94	-0.10	-1.97	-0.09	-1.87				
# obs	461		461		461		461					
R^2	0.11		0.14		0.11		0.14					

All regressions include time dummies, robust t-stat

Next, we estimated a sales accelerator specification with an error correction term, as in Bloom et al (2001). The second part of Table 2 presents the results. The error correction term is significant and of the correct sign, when the cash flow capital ratio is not present in the regression. The uncertainty coefficient however remains negative and significant and of the same order of magnitude as in the accelerator specification, confirming again the negative effect of demand uncertainty on planned investment.

Finally, we estimated a sales accelerator specification with valued added over capital and no error correction term, as in Guiso and Parigi (1999). Table 3 presents our estimates of equation (2). Uncertainty is significantly negative and the point estimate is practically identical to the one found above. It does practically not change when controlling for the value added capital ratio and the cash flow capital ratio. Again, cash flow seems to dominate the planning decision rendering value added insignificant. Because cash flow might proxy for value added or future value added, this should not be interpreted as if value added is irrelevant for the investment decision, as it results from multicollinearity between value added and cash flow. The uncertainty estimate remains significantly negative, indicating that our results provide robust evidence of a quite independent effect from the other factors determining investment. The results of estimating the same regressions including the expected demand variable indicate, as before, that the expected demand variable is always insignificant. The coefficient of firm-specific demand uncertainty again implies a small response of investment to uncertainty. A one standard deviation increase in firm-specific demand uncertainty (i.e. 0.19) reduces the rate of investment plans rates by 7.5%.

Table 3: The effect of firm specific demand uncertainty on planned investment - OLS estimates of equation (2)

	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
I_{it}/K_{it-1}	0.08	2.28	0.11	3.00	0.13	3.44	0.08	2.26	0.11	2.98	0.13	3.4
Y_{it}/K_{it}	0.001	0.41	0.01	4.89			0,00	0.38	0.01	4.79		
$E_t(\Delta y_{it+1})$							-0.01	-0.29	-0.006	-0.24	-0.01	-0.49
CF_{it}/K_{it-1}	0.11	4.71					0.11	4.71				
σ^D_{it}	-0.09	-1.94	-0.10	-2.05	-0.10	-2.15	–0,09	-1.87	-0.10	-1.98	-0.10	-2.04
# obs	473		473		473		473		473		473	
R^2	0.15		0.11		0.09		0.15		0.11		0.09	

All regressions include time dummies, robust t-stat

In sum, from the estimations with sector-specific uncertainty and those with firm-specific uncertainty, there is robust evidence that demand uncertainty reduces investment plans, although the size of this effect may be of limited magnitude. A one standard deviation increase in demand uncertainty reduces the rate of investment by 3% to 7.5% of its mean. For comparison, von Kalckreuth (2002) find an effect of the same order of magnitude (6.5%). Further, firms smooth investment and there is evidence of an accelerator effect, although these results are sometimes blurred by the inclusion of cash-flow.

5.2. Euler equation

The next two tables present the Euler equation estimates. These were obtained by using the OLS-estimator on orthogonal deviations (an alternative transformation to the within transformation suggested by Arellano and Bover, 1995). In order for the OLS estimates to be consistent, this transformation only requires that the regressors be non-contemporaneously correlated with the error term. The more traditional transformations to eliminate the fixed effects, i.e. within and first differences, need the more severe requirement that the regressors are strictly exogenous. Of course, the current investment rate to some extent determines current sales and the wage sum. One might, however, expect that endogeneity is only weak, since current investment is only a minor fraction of the capital stock, which enters the production function. In addition, we can reasonably expect that the investment rate determines sales growth, as in the accelerator specification, more than the levels of sales. So, in fact there is a trade-off between using simple OLS and accepting a weak endogeneity bias, or using an instrumental variable estimator and accepting the danger of weak instruments. We prefer the former option. Moreover, since we use observed investment plans, we can avoid a forecast error bias, which is introduced by assuming rational expectations and replacing unobserved expectations by realised values. Especially, the presence of this forecast error explains why instrumental variable techniques are common practice in the literature. This practice is less inevitable with our data set.

For the Autumn survey, the results in table 4 indicate that the adjustment cost parameter is significant and that output price uncertainty depresses current investment. Demand uncertainty, however, is not significant. Although a similar result was obtained by Peeters (2001) for a sample of large Belgian manufacturing firms, it does not confirm our previous results. We obtain reasonable estimates (1.22) of the price elasticity of demand, which point to monopolistic forces being present. This coefficient is, however, not significant.

For the Spring survey, the adjustment cost parameter is again significant. We obtain a similar estimate for the price elasticity of demand (1.33) as in the Autumn survey, but now the coefficient is significant at the 15% level. Both demand and output price uncertainty depress current investment, although the latter effect is not significant, when both uncertainty terms are simultaneously entered in the equation. The demand uncertainty effect clearly dominates. This corresponds to the results of the other specifications in this paper. To summarise, demand uncertainty has a negative impact on investment in t (or on the level of investment in any period, when solving the model forward). The impact of demand uncertainty on the gap between future and current investment (the LHS variable), however, is positive. This implies that uncertainty depresses current investment more than future investment. This confirms the timing feature of the real option theory: uncertainty delays investment decisions.

Table 4 : Euler equation estimates

	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
Autumn Survey								
$w_{it}L_{it}/p^{I}_{it}K_{it}$	0.07	4.91	0.04	2.70	0.04	2.68	0.04	2.70
$P_{it}Y_{it}/P^{I}_{it}K_{it}$	-0.02	-0.63	-0.01	-0.62	-0.01	-0.60	-0.01	-0.61
$E_t(P^{I}_{it+1}/P^{I}_{it})$	-0.31	-1.85	-0.31	-1.80	-0.31	-1.83	-0.31	-1.80
σ^{D}_{it}	.		-0.02	-0.12	0.10	0.81	.	
σ^{P}_{it}	.		0.37	2.02	.		0.36	2.18
α	24.45		24.51		24.75		24.56	
ε	1.23		1.22		1.22		1.22	
# obs - #firms	5885	1349	5885	1349	5885	1349	5885	1349
R^2_{adj}	0.01		0.01		0.01		0.01	
Spring Survey								
	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
$w_{it}L_{it}/p^{I}_{it}K_{it}$	0.07	4.91	0.07	4.88	0.07	4.87	0.07	4.92
$P_{it}Y_{it}/P^{I}_{it}K_{it}$	-0.02	-1.51	-0.02	-1.47	-0.02	-1.46	-0.02	-1.50
$E_t(P^{I}_{it+1}/P^{I}_{it})$	0.04	0.22	0.05	0.31	0.05	0.29	0.05	0.29
σ^{D}_{it}	.		0.33	2.29	0.42	3.24	.	
σ^{P}_{it}	.		0.25	1.38	.		0.44	2.68
α	13.77		13.86		13.90		13.75	
ε	1.33		1.32		1.32		1.32	
# obs - #firms	7459	1549	7459	1549	7459	1549	7459	1549
R^2_{adj}	0.01		0.01		0.01		0.01	

All regressions include time dummies

Next, we investigate the effect of irreversibility. The Spring survey contains information on the type of investment: buildings or machines. One can reasonably consider buildings to be more multi purpose, hence more reversible, and machines to be more firm-specific made, hence more irreversible. According to the real option theory, the effect of uncertainty on the former type of investment should be weaker than on the latter type. To analyse this, we include in our equation interaction terms between uncertainty and a measure for the relative importance of a particular type of investment, i.e. its share in total investment. Our results, shown in table 5, confirm the priors. The more a firm invests in buildings, the smaller is the impact of uncertainty. The reverse applies for machine investments. For leased equipment, which in the literature is often regarded as being less irreversible (Cassimon et al, 2002, Guiso and Parigi, 1999) and, thus, being less sensible to uncertainty, we find rather puzzling the opposite effect. This may perhaps be due to the fact that only a limited number of firms use this method of financing, so that this variables may not provide a relevant proxy of the degree of irreversibility.

We additionally performed an estimate including the leverage ratio. These results, which are available on request, confirm the results presented in tables 4 and 5. Guiso and Parigi (1999) argue that omitting a proxy for financial constraints effects, could bias the estimates for the uncertainty parameters, since uncertainty could be capturing the latter effects. Obviously, this does not happen, our results are robust to the inclusion of this variable.

Table 5 : Euler equation estimates including interaction terms – Spring survey

	investment in buildings						investment in machinery					
	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	Coeff	t-stat
$w_{it}L_{it}/p^I_{it}K_{it}$	0.07	4.83	0.07	4.81	0.07	4.88	0.07	4.86	0.07	4.84	0.07	4.90
$P_{it}Y_{it}/P^I_{it}K_{it}$	-0.02	-1.54	-0.02	-1.53	-0.02	-1.58	-0.02	-1.55	-0.02	-1.55	-0.02	-1.59
$E_t(P^I_{it+1}/P^I_{it})$	0.08	0.45	0.07	0.43	0.07	0.42	0.08	0.45	0.07	0.43	0.07	0.41
σ^D_{it}	0.39	2.49	0.48	3.64	.		0.01	0.04	0.07	0.46	.	
σ^P_{it}	0.25	1.27	.		0.50	3.03	0.21	0.42	.		0.00	0.02
σ^D_{it}*ratio	-0.39	-0.88	-0.43	-3.67	.		0.38	0.91	0.41	3.68	.	
σ^P_{it}*ratio	-0.05	-0.08	.		-0.53	-3.52	0.03	0.06	.		0.49	3.48
α	14.01		14.05		13.85		13.93		13.97		13.80	
ε	1.34		1.34		1.35		1.34		1.34		1.35	
# obs - #firms	7459	1549	7459	1549	7459	1549	7459	1549	7459	1549	7459	1549
R^2_{adj}	0.02		0.02		0.02		0.02		0.02		0.02	

	leased investment					
	coeff	t-stat	coeff	t-stat	coeff	t-stat
$w_{it}L_{it}/p^I_{it}K_{it}$	0.07	4.85	0.07	4.81	0.07	4.88
$P_{it}Y_{it}/P^I_{it}K_{it}$	-0.02	-1.46	-0.02	-1.44	-0.02	-1.49
$E_t(P^I_{it+1}/P^I_{it})$	0.05	0.30	0.05	0.27	0.05	0.28
σ^D_{it}	0.33	2.24	0.41	3.10	.	
σ^P_{it}	0.25	1.33	.		0.44	2.65
σ^D_{it}*ratio	-0.07	-0.11	0.46	2.68	.	
σ^P_{it}*ratio	0.73	0.92	.		0.65	2.90
α	13.95		14.07		13.85	
ε	1.32		1.31		1.32	
# obs - #firms	7459	1549	7459	1549	7459	1549
R^2_{adj}	0.02		0.02		0.02	

All regressions include time dummies

The estimations of the reduced forms equations with sector-specific uncertainty and with firm-specific uncertainty show robust evidence that demand uncertainty reduces investment plans. These results are consistent with aggregate evidence showing that uncertainty reduces investment in the US (see, for example, Driver and Moreton, 1992. for output and price uncertainty, Ferderer, 1993a, b) and in Europe (for example, Meersman and Cassimon, 1995 analyse the volatility of the marginal profitability of capital). It is also consistent with firm-level evidence. In the US, Driver et al (1996) show that demand uncertainty reduces investment at the plant level. Bulan (2000) finds that both industry-specific and firm-specific uncertainty of equity returns reduce and delay investment. Ghosal and Lougani (2000) show that profit uncertainty depress investment. In Europe and other countries, Guiso and Parigi (1999), for Italy, von Kalckreuth (2000), for Germany, and Patillo (1998), for Ghana, all find that demand uncertainty depress investment. For Belgium, the results of Peeters (2001) suggest that price uncertainty reduces investment of large firms, but not demand uncertainty. Gérard and Verschueren (2002) also find little empirical support for an effect of investment price uncertainty on investment in a sample of Belgian firms. This may be due to the type of uncertainty (investment prices) they consider, and to the way uncertainty was measured; both Peeters and Gérard and Verschueren use a time-invariant volatility measure interacted with a time-varying assets to equity ratio. On the contrary, Cassimon et al (2002) show that uncertainty of profitability diminishes the probability and amount of investment. Finally, consistently with Cassimon et al (2002), Guiso and Parigi (1999) and Patillo (1998), we also find that the effect of uncertainty on investment is larger for firms with more irreversible investment.

6. CONCLUSIONS

In this paper we investigate how demand and output price uncertainty affect investment plans of Belgian manufacturing firms. We obtain time-varying uncertainty measures at the firm and industry level from the Belgian monthly business cycle survey and investment plans from the half-yearly investment survey. Using investment plans instead of realised investment data, e.g. annual accounts data, is from an informative point of view superior, since it is more likely to reveal the features of the decision formation process and therefore is most closely related to economic theory. Business investment is normally planned well in advance, because it involves time and costs to implement, and theory describes the behaviour of firms at the moment of their decision, which can be assumed to be fully captured in survey data. In order to find robust predictions we estimate three different specifications, each of which can be considered as a benchmark in the literature: two reduced form equations and a structural Euler equation.

Our results show that uncertainty depresses investment. These results hold for industry- as well as for firm-specific demand uncertainty. Our time-varying uncertainty measures at the firm and industry level enter significantly in three different investment specifications. The reduced form estimates for both industry- and firm- specific uncertainty point to the same conclusion. We find that industry- and firm-specific demand uncertainty negatively effects investment plans, where industry- and firm-specific price uncertainty does not effect investment plans. The Euler equation results however show a slightly different picture. Where sector price uncertainty is both significant for the Spring and Autumn survey, we find demand uncertainty only to be significant in the Spring survey. Moreover, the estimation of an Euler equation provides additional insight on the investment-uncertainty relationship. Our results indicate that increased uncertainty induces firms to postpone investment today in favour of investment tomorrow, and that this effect is stronger for more irreversible capital. Hence, our results seem to confirm to predictions of the real option theory.

Our results show that unresolved specification issues in the uncertainty-investment literature remain important. Where papers in this literature usually test for robustness within specifications (by removing or entering extra variables to the regression or using different estimators), we test the robustness of the effect of uncertainty across different specifications (Euler equation and reduced form equation) and across data sets (Spring and Autumn survey, firm and sector uncertainty).

For policy purpose, the relevant question is whether aggregate uncertainty reduces realised investment, and if so what is the best way to reduce the uncertainty of the economic environment. By investigating the effect of uncertainty on planned investment, we really focus on the effect of an uncertain environment on the decision of the firm about its investment projects. The realisation of these projects may be subject to some discrepancies when new information arrives, but the project is defined the period before. Concerning the type of uncertainty our results clearly show that uncertainty reduces investment plans, but our analysis did not fully disentangle between firm-specific or sector-specific and aggregate uncertainty, except to the extent that time dummies control for common aggregate fluctuations in any variables. At least our results with sector-specific uncertainty indicate that aggregate uncertainty matters for investment.

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A. Data appendix

A.1. Data definitions

The real capital stock at time t is constructed by adjusting the book value of the capital stock at time t by its average age. The book value of the capital stock at time t is defined as the sum of the acquisition value of total tangible assets (code 8159) and revaluation gains (code 8209) minus accumulated depreciation and amounts written down (code 8269), all at the end of the preceding period. As in Chatelain and Teurlai (2000), the average age of the capital stock (A) is computed from the share of the capital stock that has already been depreciated with the following formula:

$$A=15*(depr/book)-4 \text{ if } 15*(depr/book)>8$$
$$A=15*(depr/book)*(1/2) \text{ if } 15*(depr/book)<=8.$$

Where depr is accumulated depreciation (code 8269). The variable book is measured by the acquisition value of total tangible assets (code 8159). To obtain the real capital stock at time t, the book value at time t (code 8159 + code 8209 - code 8269) is divided by the investment price index of t-A.

This method has two major advantages over the perpetual inventory method. First, it treats the construction of the real capital stock equally in the beginning of the sample and at the end of the sample. Second, where gaps in the data in terms of missing investment rates lead to breakage of the perpetual inventory method, they do not lead to breaks for this method.

A.2. Data cleaning

The disconformity index lies between 0 and 1 by construction, and therefore cannot contain outliers. So, we remove outliers of the other variables only.

For the estimates of the ECM equation with sector-specific uncertainty, investment rates are trimmed by dropping the first and last decile[17]. This yields investment rates that are not too much above 100%. Sales growth and the cash-flow capital ratio are trimmed by dropping the first 5% and

[17] Preliminary results (not reported here for the sake of brevity) show that less severe trimming leads to identical qualitative conclusions, but the quality of the estimates (in particular the value of the Sargan test) dramatically deteriorates. This may be due to remaining outliers. We therefore use a sample trimmed by the first and last decile.

last 5%. All trimmings are done year by year and for small and large firms separately. Table A.1 in appendix shows some descriptive statistics after cleaning. Initially, the investment survey matched with annual accounts and sector-specific prices yield a sample of 10162 observations and 1992 firms. The maximum values of investment rates clearly indicates the presence of outliers. After trimming and first differencing, our sample has 3090 observations and 930 firms with at least one year of observation. Finally, in order to perform the first difference GMM estimations, we have to restrict this sample by keeping only those firms, which have at least 5 surveys and 6 annual accounts. We end up with a sample of 1303 observations and 256 firms. All variables lie in reasonable ranges. In the final sample, more than 85% of the firms are large. Clearly our sample suffers from a severe selection bias towards large firms, as the percentage of large firms in the whole economy is around 7.5%. Further our sample does not cover all sectors of the economy, since the investment survey focus on manufacturing industries.

Table A.1. Descriptive statistics of the ECM sector-specific uncertainty model

	# obs	mean	std, dev	min	max
Initial sample (1987-2000) - 1992 firms					
I^P_{it+1}/K_{it}	10162	2.65	107.09	0.00	9713.49
I_{it}/K_{it-1}	10162	0.84	15.56	0.00	1075.25
After matching trimmed investment plans with trimmed variables (1987-1999) - 930 firms					
I^P_{it+1}/K_{it}	3090	0.26	0.15	0.04	0.97
I_{it}/K_{it-1}	3090	0.26	0.17	0.03	1.32
Δy_{it}	3090	0.01	0.14	-0.54	0.44
CF_{it}/K_{it}	3090	0.48	0.38	-0.30	3.43
y_{it}	3090	15.72	1.65	10.71	20.92
k_{it-1}	3090	14.90	1.86	9.51	20.82
σ^D_{st}	3090	0.34	0.06	0.09	0.54
σ^P_{st}	3090	0.26	0.05	0.04	0.46
$E_t(\Delta y_{it+1})$	3090	-0.07	0.14	-0.47	0.19
Sample of firms with at least 5 surveys and 6 annual accounts - 256 firms					
I^P_{it+1}/K_{it}	1303	0.26	0.14	0.04	0.72
I_{it}/K_{it-1}	1303	0.26	0.15	0.03	0.87
Δy_{it}	1303	0.01	0.13	-0.39	0.40
CF_{it}/K_{it}	1303	0.47	0.34	-0.30	2.59
y_{it}	1303	16.14	1.59	11.98	20.59
k_{it-1}	1303	15.33	1.74	10.40	20.78
σ^D_{st}	1303	0.35	0.05	0.09	0.54
σ^P_{st}	1303	0.26	0.05	0.05	0.37
$E_t(\Delta y_{it+1})$	1303	-0.09	0.14	-0.47	0.16

For the estimates with firm-specific uncertainty, we restrict our sample to firms for which we have a firm-specific uncertainty measure (that is for firms, which answered the NBB business, survey every month). We remove the first and last percentiles of the variables in the regression, except for the investment and planned investment ratio for which we use the first and 95th percentile. Our final data set contains 473 firm-year observations[18]. Table A.2 reports descriptive statistics for this sample. The data set is unbalanced with most firms having only a few observations.

Table A.2. Descriptive statistics of the firm-specific uncertainty model

	# obs	mean	std, dev	min	Max
I^P_{it+1}/K_{it}	473	0.25	0.20	0.01	1.03
σ^D_{it}	473	0.22	0.19	0.00	0.91
I_{it}/K_{it-1}	473	0.30	0.27	0.01	1.44
Y_{it}/K_{it-1}	473	2.60	2.60	0.23	23.73
Δy_{it}	463	-0.003	0.16	-0.77	0.71
$E_t(\Delta y_{it+1})$	473	-0.11	0.39	-1.00	0.92
CF_{it}/K_{it-1}	473	0.50	0.45	-1.13	2.93

18 However most regressions contain fewer observations due to the fact that not all control variables are available for all firms. For the Spring survey and actual investment data we have a few less observations, since not all firms answered both Spring and Autumn survey.

B. Robustness of the results of equations (1) and (2) with firm-specific uncertainty with respect to the Spring survey

In this section we present the results of the estimation using Spring investment plans. Essentially the same results with respect to uncertainty are obtained as with the Autumn plans. The point estimates of the uncertainty measure are somewhat more imprecisely estimated, however they are very close to the Autumn plan estimates.

Table B.1 : The effect of firm specific demand uncertainty on Spring planned investment - OLS estimates of equation (1)

	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
accelerator model												
I_{it}/K_{it-1}			0.14	2.90	0.09	2.01			0.13	2.8	0.09	1.95
Δy_{it}	0.10	1.39	0.06	0.76	0.01	0.11	0.12	1.66	0.07	1.00	0.02	0.28
$E_t(\Delta y_{it+1})$							-0.05	-1.69	-0.04	-1.41	-0.03	-0.95
CF_{it}/K_{it-1}					0.11	4.14					0.11	4.01
σ^D_{it}	-0.13	-2.64	-0.12	-2.49	-0.11	-2.30	-0.12	-2.32	-0.11	-2.23	-0.10	-2.12
# obs	409		409		409		409		409		409	
R^2_{adj}	0.07		0.10		0.15		0.08		0.10		0.16	
ECM model												
I_{it}/K_{it-1}	0.10	2.08	0.08	1.72	0.09	2.02	0.08	1.67				
Δy_{it}	0.15	1.95	0.08	1.04	0.16	2.11	0.09	1.18				
$k_{it-1}-y_{it-1}$	-0.06	-3.91	-0.03	-1.95	-0.06	-3.80	-0.03	-1.91				
$E_t(\Delta y_{it+1})$					-0.03	-1.09	-0.03	0.90				
CF_{it}/K_{it-1}			0.09	3.12			0.09	3.04				
σ^D_{it}	-0.12	-2.38	-0.11	-2.28	-0.11	-2.18	-0.10	-2.11				
# obs	407		407		407		407					
R^2	0.14		0.16		0.14		0.17					

All regressions contain time dummies, robust t-stats

Table B.2: The effect of firm specific demand uncertainty on Spring planned investment - OLS estimates of equation (2)

	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat	coeff	t-stat
I_{it}/K_{it-1}	0.10	2.19	0.13	2.73	0.15	3.16	0.10	2.15	0.12	2.68	0.14	3.09
Y_{it}/K_{it}	0.01	1.09	0.02	2.85			0,01	1.05	0.02	2.77		
$E_t(\Delta y_{it+1})$							-0.03	-1.14	-0.04	-1.20	-0.04	-1.47
CF_{it}/K_{it-1}	0.08	2.69					0.08	2.66				
σ^D_{it}	-0.12	-2.49	-0.13	-2.56	-0.13	-2.63	–0,11	-2.30	-0.12	-2.36	-0.12	-2.38
# obs	419		419		419		419		419		419	
R^2_{adj}	0.15		0.13		0.09		0.15		0.13		0.1	

All regressions contain time dummies, robust t-stats

C. The derivation of the Euler equation

1. Dividends at any given time t+s (s going from 0 to infinite) are given by

$$D_{t+s} = p_{t+s}F(K_{t+s}, N_{t+s}) - \theta * \sigma * p^I_{t+s}K_{t+s} - w_{t+s}N_{t+s} - p^I_{t+s}I_{t+s} - p^I_{t+s}\Phi(K_{t+s}, I_{t+s})$$

with the last term being the adjustment cost function. We allow for imperfect competition (downward sloping demand curve) by letting the price being a function of output. Uncertainty enters as a cost for the firm if $\theta > 0$. Let the adjustment cost function be the traditional quadratic adjustment cost $\Phi(K_t, I_t) = \frac{\alpha}{2}[\frac{I_t}{K_t} - \phi]^2 K_t$.

2. the firm is at time t and has to maximise its future and current (at time t) dividends i.e. the following objective

$$E_t \sum_{s=0}^{\infty} (\prod_{j=0}^{s} \beta_{t+j}) D_{t+s}$$

where the βs are the discount factors assumed as being given an certain. (One should also assume β_t=1. since contemporaneous dividend should be discounted at 1)

3. capital accumulation is given by

$$K_t = (1-\delta)K_{t-1} + I_t$$

A solution of the maximisation problem can be found by writing down the problem as a Lagrangian Problem:

L=

$$E_t \sum_{s=0}^{\infty} (\prod_{j=0}^{s} \beta_{t+j})[p_{t+s}(F)F(K_{t+s}, N_{t+s}) - w_{t+s}N_{t+s} - \sigma p^I_{it+s}K_{it+s}\theta + p^I_{t+s}I_{t+s} - p^I_{t+s}\Phi(K_{t+s}, I_{t+s})]$$

$$- E_t \sum_{s=0}^{\infty} (\prod_{j=0}^{s} \beta_{t+j})\lambda_{t+s}[K_t - (1-\delta)K_{t-1} - I_t]$$

With λ_{t+s} a Lagrange multiplier

The first order conditions of this problem are the following:

1) FOC w.r.t K_t : $[(1-\frac{1}{\varepsilon})p_t F_K(K_t,N_t)-\theta^* p_t^I \sigma_{st}-p_t^I \Phi_K(K_t,I_t)]-\lambda_t+(1-\delta)E_t\beta_{t+1}\lambda_{t+1}=0$

2) FOC w.r.t. N_t : $(1-\frac{1}{\varepsilon})p_t F_K(K_t,N_t)-w_t=0$

3) FOC w.r.t. I_t : $[-p_t^I-p_t^I\Phi_I(K_t,I_t)]+\lambda_t=0$

4) FOC w.r.t. I_{t+1} : $E_t\beta_{t+1}[-p_{t+1}^I-p_{t+1}^I\Phi_I(K_{t+1},I_{t+1})]+E_t\beta_{t+1}\lambda_{t+1}=0$

The investment equation can then be found by replacing in 1) the λ_t by using 3) and $E_t\beta_{t+1}\lambda_t$ by using 4). We get:

$$E_t(\frac{I_{t+1}}{K_{t+1}})=\frac{-1(1-\frac{1}{\varepsilon})}{(1-\delta)\beta_{t+1}\alpha}\frac{p_t}{p_{t+1}^I}F_K(K_t,N_t)+\frac{1}{(1-\delta)\beta_{t+1}}\frac{\theta}{\alpha}*\frac{p_t^I}{p_{t+1}^I}\sigma_{st}+\frac{-1}{2(1-\delta)\beta_{t+1}}\frac{p_t^I}{p_{t+1}^I}(\frac{I_t}{K_t})^2+\frac{1}{(1-\delta)\beta_{t+1}}\frac{p_t^I}{p_{t+1}^I}(\frac{I_t}{K_t})$$
$$+\frac{1}{(1-\delta)\beta_{t+1}\alpha}\frac{p_t^I}{p_{t+1}^I}[\phi^2\frac{\alpha}{2}-\alpha\phi+(1-\delta)\beta_{t+1}\alpha\phi\frac{p_{t+1}^I}{p_t^I}]+\frac{1}{(1-\delta)\beta_{t+1}\alpha}[\frac{p_t^I}{p_{t+1}^I}-(1-\delta)\beta_{t+1}E_t\frac{p_{t+1}^I}{p_{t+1}^I}]$$

or , after assuming constant returns to scale and applying Euler's theorem to proxy the MRPK

$$(1-\delta_i)\beta_{it+1}E_t(p_{t+1}^I I_{it+1}/p_t^I K_{it+1})-(I_{it}/K_{it})+\frac{1}{2}(I_{it}/K_{it})^2=\frac{-(1-\frac{1}{\varepsilon})}{\alpha}(\frac{p_{it}}{p_t^I}\frac{F_{it}}{K_{it}})+\frac{1}{\alpha}(\frac{w_{it}}{p_{it}^I}\frac{L_{it}}{K_{it}})+\frac{\theta}{\alpha}*\sigma_{st}+$$
$$+\frac{1}{\alpha}[\phi^2\frac{\alpha}{2}+1-\alpha\phi+(\alpha\phi-1)(1-\delta_i)\beta_{it+1}E_{it}(p_{t+1}^I)/p_t^I]$$

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