FIRMS' INVESTMENT DECISIONS IN RESPONSE TO DEMAND AND PRICE UNCERTAINTY

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Abstract

We estimate the effect of demand and price uncertainty on firms' investment decisions from a panel of manufacturing firms. Our uncertainty measures are derived from firms' subjective qualitative expectations and are very close to their theoretical counterparts. We find that demand uncertainty depresses planned and realized investment, while price uncertainty is not significant. This is consistent with the investment behaviour of monopolistic firms under demand uncertainty, as developed in Caballero (1991). In addition, investment plans are for a large part irreversible and firms revise their investment decisions in response to new information on sales growth, but not in response to resolved uncertainty.

* The opinions expressed in this paper are solely our own and do not necessarily reflect the opinion of the National Bank of Belgium or the European Central Bank. E-mail Catherine.fuss@nbb.be. Philip.Vermeulen@ecb.int. We want to thank Patrick Sevestre Anders Warne and Rafael Wouters for useful discussions. We thank Frank Windmeijer for providing us with the codes for the Windmeijer correction in dynamic panels.
I. Introduction

Many theoretical papers investigate the investment response of individual firms to uncertainty. This literature has not led to conclusive agreement on the direction of the investment-uncertainty relationship. Empirical investigation of this question is therefore warranted. However, it is extremely hard to find empirical proxies for uncertainty that are close to those used in the theory. Indeed, in the theoretical literature, uncertainty is usually defined as the variance of a shock to some firm’s fundamental, which is difficult to observe. For example, demand uncertainty refers to the volatility of (unobserved) future demand shocks. In this paper, we investigate the effect of demand and price uncertainty on investment using a panel of manufacturing firms. We are able to construct measures of uncertainty that are as close as possible to their theoretical counterparts.

Our measure of output price uncertainty is a proxy for the variance of future output price shocks. This should be especially relevant to test the investment-uncertainty relationship for the perfectly competitive firm. For such a firm the demand curve is perfectly flat and price uncertainty coincides with demand uncertainty. Abel (1983) shows that a perfectly competitive firm raises investment under increasing price uncertainty, where price uncertainty is defined as the variance of the output price. This counterintuitive result, which is also found in Hartman (1972) and Abel and Eberly (1997), is due to combination of expected profit maximization, a profit function convex in the output price and Jensen’s inequality. Higher uncertainty increases expected profits.

We also construct a proxy for the variance of the future shock to the firm’s demand curve. This should be a more relevant measure of uncertainty than price uncertainty in the case of imperfect competition. For imperfectly competitive firms, price variance, as well as sales variance, is a mix of the variance of demand shocks and the variance of supply shocks. The theoretical literature for the imperfectly competitive firm contains results for the relationship between demand shocks and investment. Caballero (1991) derives the investment-uncertainty relationship for a firm under imperfect competition. The level of demand uncertainty is defined as the variance of the shock to the firm’s downward sloping demand curve. Caballero (1991) shows that the direction of the investment-demand uncertainty relationship depends on the combination of the slope of the demand curve, the asymmetry of adjustment costs (i.e. the degree of irreversibility) and the degree of returns to scale. More market power, more decreasing returns to scale, and more irreversibility all make it more likely that the investment-uncertainty relationship is negative.

Since we have no prior information on whether firms in our sample operate in rather imperfect or close to perfectly competitive markets, we test both demand and price uncertainty on the same firms. Doing so, we investigate the predictions made in Hartman (1972) and Abel (1983) for perfectly competitive firms, and in Caballero (1991) for imperfectly competitive firms.
Our proxies of uncertainty are directly derived from firms' subjective expectations rather than indirectly derived from some ad hoc forecasting regression model. We use a business survey of Belgian manufacturing firms in which they report their qualitative expectations about future demand and price developments. We measure uncertainty by the dispersion of expectations across firms within a year. Our investment data contains information on both actual investment and planned investment. This allows us to investigate the effect of uncertainty on investment from three viewpoints. First, as in Guiso and Parigi (1999) we consider the effect of uncertainty on investment plans. We believe that it is important to relate uncertainty at a particular time to the investment decision (the plans) at that time. Second, we test for the effect of uncertainty on actual investment. On the one hand, we believe that planned investment is the most relevant variable to understand the firm ’s decision process, and thereby test the theory by its closest empirical counterpart. On the other hand, realized investment is the variable that ultimately affects growth and the business cycle. For policy purposes, it is important to understand what influences firms decisions (plans), but also what will affect macroeconomic conditions (realizations). Third, we investigate the effect of new information on investment revisions, defined as the difference between actual and planned investment. This way we analyze the predictions of another strand of the literature, the Real Option theory, which focuses on the effect of uncertainty on the timing of investment (See McDonald and Siegel, 1986). According to this literature, when investment is irreversible and there is some flexibility in the timing of the investment realization, there is a positive-value option to wait. In fact, waiting allows firms to acquire more information about the uncertain future, hence (partly) resolving uncertainty. In this paper we test whether firms modify their investment plans due to news in their fundamentals or due to partly resolved uncertainty.

This paper is an extension of a previous analysis (Butzen et al, 2003). Here we analyze both planned and realized investment, and we evaluate the determinants of investment revisions. Our results show that demand uncertainty has a negative effect on investment plans and actual investment. These results confirm the prediction of the literature on uncertainty for imperfectly competitive firms. We find no effect of price uncertainty. We argue that our measure of price uncertainty is ill-suited for imperfectly competitive firms, because future price changes may be known rather than uncertain for price-setting firms. In addition, we find that firms make very small revisions of their investment plans. This suggests that investment decisions are for a large part irreversible. In addition, our estimates suggest that firms adjust their investment decisions to new information about sales growth, but they do not modify their investment due to changes in uncertainty.

The rest of the paper is structured as follows. In section II, we briefly describe the related literature. In section III, we describe our measures of uncertainty. In Section IV we develop the empirical framework. Section V contains the empirical results and Section VI concludes.

1 Also, we use other estimation techniques, so that this paper may be seen as a robustness check of our previous results.
II. Related literature

The literature on the relationship between uncertainty and investment is relatively large. A new impetus to this literature has been given by Dixit and Pindyck (1994). A recent detailed survey is given by Carruth et al (2000). Three types of firm-level uncertainty are recurrent in this literature. First, the relationship between investment and output price uncertainty for the perfectly competitive firm is developed in Hartman (1972), Abel (1983) and Abel and Eberly (1997). In this literature, uncertainty is defined as uncertainty about future output price changes and is formally defined as its variance. Second, the relationship between investment and demand uncertainty for the imperfectly competitive firm is developed in Caballero (1991). He defines uncertainty as the variance of a shock to the demand curve. Third, the relationship between investment and profit uncertainty is developed in Abel and Eberly (1994). Uncertainty in this model is defined as the variance of a shock to the profit function. The advantage of this modeling approach is that the shock to the profit function incorporates all possible shocks stemming from both demand and supply side factors: i.e. changes in tastes, technology, output prices and input prices. Using industry data, Ghosal and Loungani (2000) consider the standard deviation of the residuals of a profit-forecasting equation on the industry level to measure profit uncertainty, and hence are close to the theoretical uncertainty measure. They find that profit uncertainty reduces industry investment.

In contrast to a large part of the empirical literature that uses aggregate investment data we focus on firm individual investment. We only know of a few other papers that investigate the relationship between firm-specific investment and uncertainty. Most of these papers however use measures of uncertainty that are difficult to interpret in light of the theory. In a seminal paper, Leahy and Whited (1996) use a forecast of the variance of the daily stock return as their measure of uncertainty, in a panel of US manufacturing firms. They find that it negatively affects investment. Although they argue that stock return volatility captures all forms of uncertainty that are relevant for the firm ’s investor, it remains that their measure has no direct theoretical counterpart. In addition stock returns are quite noisy. In the same spirit, Bulan (2000) measures total firm uncertainty as the realized volatility of the firm’s equity returns. She finds that uncertainty reduces investment. Bloom et al. (2003) also use the variance of stock returns to measure uncertainty and again find that uncertainty depresses investment.

Output price volatility may be measured at the industry level only. Ghosal and Loungani (1996) and Henley et al (2003) test the effect of price uncertainty on investment at the industry-level. They find a negative effect of price uncertainty on investment. The magnitude of the effect may depend on the degree of competition. For Ghosal and Loungani (1996) the effect is significant only in competitive industries. For Henley et al (2003), the effect is stronger in concentrated industries.

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2 A branch of this literature focuses on aggregate or industry-level uncertainty see e.g. Pindyck (1993).
Few papers use the volatility of unpredictable sales shocks to construct measures of output uncertainty. Von Kalckreuth (2003) uses the variance of the errors of a sales forecasting equation. Bo (2002) relies on forecast errors of sales derived from a state space model. They both find that output uncertainty negatively affects investment. However, sales uncertainty measures are difficult to interpret. Since sales changes are the result of both demand and supply shocks, sales volatility is caused both by demand uncertainty and the volatility of supply shocks. As such sales volatility is not directly related to any theoretical counterpart. Arguably, if demand shocks are a dominant cause of sales variation, measures based on sales volatility should contain information on demand uncertainty. In contrast to these papers, we use a measure of demand uncertainty rather than a measure of output volatility.

In all the papers mentioned above, the uncertainty measures are based on observable variables. At best, forward-looking measures are obtained from forecasting equations. By doing so, the econometrician implicitly assumes that all firms form their forecasts according to this particular forecasting model. A small number of papers have used survey data to measure directly firms' perceived uncertainty. Guiso and Parigi (1999) and Patillo (1998) use surveys in which the respondents give their subjective probability distribution of their own demand changes. Thus, they are able to construct firm-specific measures of future demand growth variance. This measure is clearly the closest to the variance of the shock to the demand curve as in Caballero (1991). Guiso and Parigi (1999) find that increased demand uncertainty reduces investment and more so for firms with more market power and a more irreversible capital stock. For Ghanian firms, Patillo (1998) finds that uncertainty raises the trigger value at which firms invest. Temple et al (2001) use a survey in which firm must report whether demand uncertainty limits their capital expenditure, but they do not construct a measure of uncertainty. As in our paper, Driver et al (2002) rely on a survey in which firms give their qualitative expectations about future developments to construct a measure of uncertainty. They find that uncertainty about future business conditions depress investment authorisations at the industry-level.

III. The dataset and measuring uncertainty

We combine three data sources to construct our dataset: the Investment Survey database, the Annual Accounts database, and the Business Cycle Survey database. All those three databases are held at the National Bank of Belgium. The Investment Survey database contains quantitative data.

3 To illustrate this, consider the following simplified demand and supply functions for a single firm (1) \( P_d = C_d e^{\psi d} Q^\psi \) with \( \psi = 0 \) (\( \psi = 0 \) for a perfectly competitive firm), and (2) \( P_s = C_s e^{\phi s} Q^\phi \) with \( \phi > 0 \), where \( \epsilon_d \) and \( \xi_s \) are, respectively, demand and supply shocks independent of each other and with respective variance \( \sigma^2_d \) and \( \sigma^2_s \). From the equilibrium on the goods market one can easily show that the variances for (the log of) output, \( \epsilon \), and prices, \( \phi \), depend on both demand and supply shocks:

\[
\text{var}[q] = \sigma^2_q = \left( \frac{1}{\phi - \psi} \right)^2 (\sigma^2_d + \sigma^2_s) \quad \text{and} \quad \text{var}[p] = \sigma^2_p = \left( \frac{1}{\phi - \psi} \right)^2 (\phi^2 \sigma^2_d + \psi^2 \sigma^2_s)
\]
information on planned and realized investment. Every year in Autumn, firms reveal their amount of planned investment for the coming year, \( I_{t+1} \), investment of the current year, \( I_t \), and investment in the preceding year.\(^4\) The Annual Accounts information is used to construct the capital stock, \( K_t \), sales, \( Y_t \), cash flow, \( CF_t \), and the capital-output ratio.

To construct measures of demand and price uncertainty we employ the Business Cycle Survey database. This survey is conducted every month by the National Bank of Belgium (NBB). It reports qualitative information on firms' own subjective expectations about future demand and prices. Our measure of demand uncertainty is based on the answers to the following question of the Business Survey:\(^5\)

*Do you expect demand for your product, in the next three months (A) to rise, (B) to remain unchanged, (C) to decrease, with respect to its average level at that time of the year?*

The question directly asks for *demand*, not output. We assume that the person answering that question therefore presumably thinks first about external factors that can influence the firm demand, i.e. shocks that shift the demand curve. It seems less plausible that the person thinks about its supply function, hence of input prices, labor costs, technology shocks, taxation, etc.

The construction of the demand uncertainty measure is as follows. For each year \( t \), using the answers of question above we first construct, for industry \( j \), the proportions of the answers (A) and (C).\(^6\) We call these proportions respectively \( \%_{up,j,t} \) and \( \%_{down,j,t} \). Uncertainty is then measured by Theil (1952)'s disconformity index, i.e.: \( \sigma^2_{jt} = a^2 \cdot \left[ (\%_{up,j,t} + \%_{down,j,t}) - (\%_{up,j,t} - \%_{down,j,t})^2 \right] \), with \( a \) set to unity. As shown below, under simplifying assumptions, this disconformity index is proportional to the variance of demand changes of individual firms.

To see that this is the case, assume each firm \( i \) from industry \( j \) at time \( t+1 \) will receive a demand shock \( d_{ij,t+1} \). Assume for simplicity that the demand shock can be written as the sum of two random variables \( d_{ij,t+1} = M_{ij,t} + S_{ij,t+1} \). These two random variables are distributed as follows. Each firm receives an independent (from other firms) draw \( M_{ij,t} \) from the same (industry) distribution \( M_{jt} \), which can take three values: \(+m_{jt} \), \(0\), \(-m_{jt}\) with respective probabilities \( p_{jt}(+)\), \( p_{jt}(0)\) and \( p_{jt}(-)\). Obviously \( p_{jt}(+)+p_{jt}(0)+p_{jt}(-)=1\). The independence assumption implies that the measure of firms in industry \( j \) that have \( M_{ij,t}=+m_{jt} \) is \( p_{jt}(+) \), that have \( M_{ij,t}=-m_{jt} \) is \( p_{jt}(-) \), etc. \( S_{ij,t+1} \) is a random variable.

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\(^4\) We are very confident on this survey because reported realized investment in the survey coincides with investment as reported in the annual accounts in 85% of the cases. Further, the average investment rate from our sample follows a similar time-series pattern as the aggregate macroeconomic series of the investment-GDP ratio.

\(^5\) One difficulty of using this information is that the Business Survey reports information by firms' product and plant rather than by firm. Since the information is qualitative we cannot simply add the information for each product. We select the product that accounts for most of the firm’s turnover to proxy the firm’s total demand changes.

\(^6\) These proportions are calculated over all firms of the industry \( j \), and, since the Business Survey is a monthly survey, over all months of the year \( t \).
independent from $M_j$, with mean zero and variance $\tau_{jt+1}^2$. The mean and variance of $d_{ijt+1}$ are therefore:

1. $E(d_{ijt+1}) = p_{jt}(+)m_{jt} - p_{jt}(-)m_{jt}$
2. $\text{var}(d_{ijt+1}) = \text{var}(M_{jt}) + \text{var}(S_{ijt+1}) = m_{jt}^2[p_{jt}(+) + p_{jt}(-) - (p_{jt}(+)-p_{jt}(-))^2] + \tau_{jt+1}^2$.

Hence, $M_{ijt}$ can be seen as the random variable determining the mean of the demand shock for an individual firm, i.e. the firm's expectation of its future demand shocks. $S_{ijt+1}$ has no effect on the mean and determines the conditional variance of the demand shock (conditional on the mean). Since the $M_{ijt}$ are drawn from the same (industry) distribution $M_j$, this distribution also determines the variance of the mean within the industry. Basically, the variance of the demand shock consists of two parts. The first part $m_{jt}^2[p_{jt}(+) + p_{jt}(-) - (p_{jt}(+)-p_{jt}(-))^2]$ is identical for each firm within industry $j$. The second part $\tau_{jt+1}^2$ is different across firms within the same industry. So $S_{ijt+1}$ allows for heterogeneity in the variance of firms' demand shocks.

The answers to the survey allow us to construct a proxy for $[p_{jt}(+) + p_{jt}(-) - (p_{jt}(+)-p_{jt}(-))^2]$. Given the framework above, the response of each firm to the survey question is as follows. Assume that each firm in industry $j$ receives the information on the value of $M_{ijt}$ to form its expectation of the demand shock. Essentially assume that firm answers the question using the following conditional expectation $E(d_{it+1} | M_{jt})$ (which is equal to $M_{jt}$). The firm will clearly answer (A) (demand is expected to go up) if $E(d_{it+1} | M_{jt}) = +m_{jt}$, (B) if $E(d_{it+1} | M_{jt}) = 0$, and (C) if $E(d_{it+1} | M_{jt}) = -m_{jt}$. Since not all firms, within an industry, have the same expected mean of the demand shock, not all firms provide the same answer to the question above. Above we argued that in industry $j$ with a large (infinite) number of firms, there will be a fraction of $p_{jt}(+)$ firms that have $E(d_{it+1} | M_{jt}) = +m_{jt}$, a fraction of $p_{jt}(-)$ firms that have $E(d_{it+1} | M_{jt}) = m_{jt}$, and a fraction of $p_{jt}(0)$ firms that have $E(d_{it+1} | M_{jt}) = 0$. Hence there will be a fraction $p_{jt}(+)$ of firms that answer the question with (A), a fraction of $p_{jt}(-)$ firms that answer (C) and a fraction of $p_{jt}(0)$ firms that answer (B). The Business Cycle Survey allows us to estimate those fractions. It provides us with independent observations of $N_j$ different firms in industry $j$, where $N_j$ answer (A), $N_0$ answer (B) and $N_0$ answer (C). We therefore can estimate the probabilities of positive (negative) shock, by the industry proportions of firms expecting a positive (negative) shock. The estimate of the variance of $M_{jt}$, $\hat{\sigma}_{jt+1}^2$, is equal to

$$\hat{\sigma}_{jt+1}^2 = m_{jt}^2\left[\frac{N_j}{N_j + N_0} \cdot \frac{N_0}{N_j + N_0}\right] - (\%up - \%down)^2$$

or otherwise said

$$\hat{\sigma}_{jt+1}^2 = m_{jt}^2\left[\%up + \%down\right] - (\%up - \%down)^2$$

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7 Since in the data we never have that all firms give the same answer, it can not be the case that they answer using the unconditional expectation $E(d_{it+1})$.  

6
We drop the unobservable scale factor $m^2_{jt}$ and take $\sigma^2_{jt} = [(\%_{\text{up}} + \%_{\text{down}}) - (\%_{\text{up}} - \%_{\text{down}})^2]$ as our measure of demand uncertainty. This means that using this measure we don’t take into account changes in the “magnitude” of the demand shocks i.e. changes of $m^2_{jt}$. We also don’t take into account differences across firms in the variance $\tau^2_{it+1}$. However, as far as they vary little over time, they will be subsumed in the fixed effect. We do take into account over time shifts in the probabilities of getting a positive, zero, or negative shocks. Essentially our demand uncertainty measure will be higher as more firms disagree about future economic conditions, or if firms change their mind very often during the same year. Our disconformity measure is a qualitative counterpart to disagreement measures. These have been shown to directly reflect variance changes. Using an inflation survey in which forecasters report their forecast together with some probability distribution, Bomberger (1996) and Giordani and Söderlind (2003) show that disagreement, i.e. the cross-sectional variance of forecast, is proportional to individual uncertainty, i.e. the average of each individual’s standard deviation of forecast errors.

This uncertainty measure does not capture entirely heterogeneity across firms and industries if the size of demand shocks vary across firms or industries. Further it understate true uncertainty changes if the magnitude of the demand shocks vary over time. To take heterogeneity into account we include firm fixed effects and time dummies in the estimations. Firm fixed effects capture part of the cross-sectional variation in $m^2_{jt}$. Time dummies accounts for all aggregate fluctuations, including common aggregate fluctuations in the magnitude of the shocks.

Our measure of price uncertainty follows that of demand uncertainty; it is based on the answers to the following question of the Business Survey:

*Do you expect the price of your product, in the next three months (A) to rise, (B) to remain unchanged, (C) to decrease?*

We construct our measure of price uncertainty in the same way as above, i.e. $\sigma^2_{jt} = [(\%_{\text{up},jt} + \%_{\text{down},jt}) - (\%_{\text{up},jt} - \%_{\text{down},jt})^2]$. Here the question ask for *prices* but not for supply. It should be clear from the outset that the answer to this question contains entirely different information for perfectly competitive (price-taking) versus imperfectly competitive (price-setting) firms. For perfectly competitive firms the “price of your product” is set by market forces independently of firm’s actions. Otherwise said, for perfectly competitive firms the question can be interpreted as “*Do you expect your (flat) demand curve to rise, remain unchanged or to decrease*”. In this case, our price uncertainty measure is a proxy for uncertainty as defined in Hartman (1972) and Abel (1983). On the contrary, for an imperfectly competitive firm the answer to the question contains different information. First, the answer to this question may be related to demand shocks as well as

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8 Using sales growth to construct a proxy for the size of demand shocks is not correct since, as already argued above, it is a mix of supply and demand shocks.

9 Percentages are constructed on all monthly surveys of the same year.
to supply shocks. Second, imperfectly competitive firms face a downward sloping demand curve and set prices based on their marginal cost curve (i.e. supply) and the curvature of their demand curve. The price setting strategy is internalised by the firm when she makes other decisions, such as investment plans. Hence, for a price-setting firm the answer to the question above reflect her (known) price setting strategy rather than price uncertainty. Therefore, if our measure of price uncertainty mainly reflect intended (and known) price changes rather than market price uncertainty, it may have no effect on the level of investment. We are convinced that our measure of uncertainty of prices is a correct measure only if firms are price-takers. Since we have no prior on whether the firms in our sample are price-takers or not, we consider both demand and price uncertainty. We predict that, if firms of our sample are perfectly competitive, our measure of price uncertainty will affect investment positively, whereas if they are imperfectly competitive the measure is likely to be insignificant, and demand uncertainty is likely to reduce investment.

Our measures of uncertainty are at the same time forward-looking and time-varying and are therefore well-suited to the analysis of the microeconomic behavior of investment in a changing and uncertain environment. An additional advantage is that they are derived from directly observable firms' subjective expectations rather than being based on an assumption about the firms' expectation formation model. Driver et al (2002) also construct uncertainty from the firms' qualitative expectations about future conditions; they measure uncertainty by an other measure of disagreement, and rely on firms' forecast. To our knowledge, there are only two papers that use directly observable firm-specific demand uncertainty. Guiso and Parigi (1999) and Patillo (1998). They rely on surveys in which the firms report their own subjective probability distribution about their own future demand.

Table 1 below summarizes the variables in our sample. The planned investment rate has a mean of 0.09 and a standard deviation of 0.07. Realized investment rate is close to plans with a mean of 0.09 and a standard deviation of 0.07. It is interesting to note that price uncertainty is lower than demand uncertainty, and this holds over all years and sectors. In most sectors, aggregate demand uncertainty peaked in the first half of the nineties and is negatively correlated with the business cycle, suggesting that firms are more uncertain about the future in downturns.
IV. The empirical framework

The theoretical frameworks of the investment under uncertainty literature generally don’t resolve in estimable closed form solutions for investment. The investment relationships are therefore not directly suited for empirical testing. Bloom et al (2003), Ghosal and Loungani (1996, 2000), Guiso and Parigi (1999) and Leahy and Whited (1996) all use some type of reduced form investment model. We follow this empirical literature. To capture general investment dynamics due to adjustment costs, installation lags, gestation lags etc. we specify investment as an error-correction model. Defining the planned investment rate in period $t$ for period $t+1$ as $I_{Pt+1}/K_t$ and the actual investment rate as $I_{it+1}/K_{it}$, our basic specifications for planned and actual investment are

\[
I_{Pt+1}/K_t = \phi P_t + \delta P_t + \alpha P_{it}/K_{it-1} + \gamma \Delta y_{it+1} + \beta \Delta y_{it} + \theta \sigma_{st} + \lambda (y_{it-1}-k_{it-1}) + \epsilon_{it+1}
\]

\[
I_{it+1}/K_t = \phi i + \delta i + \alpha i_{it}/K_{it-1} + \gamma \Delta y_{it+1} + \beta \Delta y_{it} + \theta \sigma_{st} + \lambda (y_{it-1}-k_{it-1}) + \epsilon_{it+1}
\]

with $\sigma_{st}$ representing demand or output price uncertainty (whereby the subscript s notes that we compute uncertainty of price and demand shocks industry by industry, as explained in section 3). Small cases represent logs. We also experiment with including the cash flow-capital ratio $CF_{it}/K_{it-1}$.

Our specification essentially follows Bond et al (2003) by modeling investment in a dynamic adjustment model. Current output is controlled for by entering sales growth ($\Delta y_{it}$) in the regression. We also include an error correction term and assume, as in Bloom et al (2003), that in the long run, the capital-output ratio is constant, so that deviations from the long-run equilibrium simplify to ($k_{it-1} - y_{it-1}$). When making plans in year $t$ for investment of year $t+1$ firms have to forecast sales growth. Since no quantitative measure of firms' own expectations about future sales growth is available, we assume that they form rational expectations with respect to next-year sales growth. We replace the
expected sales growth in period t+1 by realised sales growth \( \Delta y_{t+1} \) and instrument this by lagged values of all RHS variables. Finally, we include time dummies and fixed effects in the equation. The time dummies (\( \delta_{p}, \delta_{t} \)) capture macroeconomic fluctuations; and together with fixed effects they also proxy for the user of capital. In addition, fixed effects may account for other firm-specific factors such as productivity growth. As argued above, time dummies and fixed effects will also capture across firm differences in the level of uncertainty and aggregate fluctuations in uncertainty.

We estimate equations (3) and (4) using the system-GMM estimator, as in Arellano and Bover (1995) and Blundell and Bond (1998). This simultaneously estimates the equation in level and in first difference. Lagged differences of the RHS variables serve as instruments for the equation in levels, and lagged levels are used as instruments for the equation in first differences. In a sample only slightly larger than ours (140 firms with 7 to 9 annual observations), Blundell and Bond (1998) show that the standard first-differenced GMM estimator suffers from small sample biases and imprecision in the estimates which can be substantially reduced by exploiting the additional moment conditions of the system-GMM estimator. We assume the uncertainty variables to be exogenous and therefore instrument them by themselves. We assume that all variables in period t are predetermined, i.e. the firm knows the realizations of the current period when it makes its plans for the next year. Therefore, RHS variables in t-1 and earlier are valid instruments for the difference equation and differences of the variables in t are additional instruments for the level equation. For the difference equation, we use the instruments \( I_{t-1}/K_{t-2} \) and \( I_{t-2}/K_{t-3} \). For the level equation, we use \( \Delta I/K_{t-1}, \Delta y_{t}, \Delta (y_{t-1}-k_{t-1}) \), and \( \sigma_{v} \) as instruments. By not taking all possible further lags we reduce the number of instruments and thereby avoid potential overfitting problems. We report the second step estimation results with t-statistics corrected for small sample bias, using Windmeijer (2000) ’s correction.

V. Empirical results

We first estimate equations (3) and (4) using the system-GMM estimator including our measure of either demand or price uncertainty. The results are presented in Table 2 for planned and realised investment. The model is correctly specified, as indicated by the standard Sargan test, m1 and m2 statistics.

Our results indicate that the current investment rate is significant and positively related to planned investment, consistent with a dynamic adjustment of the capital stock. Current sales growth is significant and positively related to planned investment. Next years sales growth is also significant. The error-correction term has the right sign but is not significant at traditional levels, although it is significant at the 10% level. Demand uncertainty is statistically significant and negative. This is consistent with Caballero (1991) ’s theoretical results on investment under uncertainty for imperfectly competitive firms. The point estimate is -0.120. A one standard deviation increase in demand uncertainty (0.06) decreases the planned investment-capital ratio by 0.007. With an
average level of the investment-capital ratio of 0.09, this signifies a drop in investment of around 8.4%. This represents almost one half of the cumulative effect of a one standard deviation decrease in sales growth, and one half of the effect of a one standard deviation increase in the error correction term $k_{t-1} - y_{t-1}$. Price uncertainty is insignificant. The results are robust to entering the cash flow-capital ratio (not shown in the table). The cash flow-capital ratio is never significant and the other coefficients hardly change. A nonsignificant cash flow-capital ratio on a Belgian panel was also obtained by Bond et al. (2003).

Table 2: Effect of demand and price uncertainty on planned and realized investment

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Investment plans $I_{t+1}/K_t$</th>
<th>Realized investment $I_{t+1}/K_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coef (i) t-stat (ii)</td>
<td>coef (i) t-stat (ii)</td>
</tr>
<tr>
<td>constant</td>
<td>0.104 4.491 ***</td>
<td>0.062 2.952 ***</td>
</tr>
<tr>
<td>$I_{t-1}/K_{t-1}$</td>
<td>0.167 2.289 **</td>
<td>0.196 2.922 ***</td>
</tr>
<tr>
<td>$\Delta Y_t$</td>
<td>0.075 2.550 **</td>
<td>0.061 1.974 **</td>
</tr>
<tr>
<td>$\Delta y_{t-1}$</td>
<td>0.050 3.802 ***</td>
<td>0.040 3.073 ***</td>
</tr>
<tr>
<td>$(y_{t-1}-k_{t-1})$</td>
<td>0.022 1.843 *</td>
<td>0.013 1.336</td>
</tr>
<tr>
<td>$\sigma^2_t$</td>
<td>-0.126 -2.464 **</td>
<td>-0.120 -2.368 **</td>
</tr>
<tr>
<td></td>
<td>0.023 0.449</td>
<td>0.080 1.124</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>coef (i) t-stat (ii)</th>
<th>p-value</th>
<th>coef (i) t-stat (ii)</th>
<th>p-value</th>
<th>coef (i) t-stat (ii)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sargan (iii)</td>
<td>68.305 0.467</td>
<td>0.65118</td>
<td>0.577</td>
<td>60.401 0.534</td>
<td>66.561 0.323</td>
<td></td>
</tr>
<tr>
<td>m1</td>
<td>-3.755 0.000</td>
<td>-3.568 0.000</td>
<td>-5.077 0.000</td>
<td>-4.909 0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m2</td>
<td>1.417 0.157</td>
<td>1.459 0.144</td>
<td>0.963 0.336</td>
<td>0.636 0.525</td>
<td></td>
<td></td>
</tr>
<tr>
<td># obs # firms</td>
<td>635 114</td>
<td>635 114</td>
<td>764 130</td>
<td>764 130</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


All estimations include time dummies. For the difference equation, we use Arellano-Bond instrument matrix for $I_{t-1}/K_{t-2}$ and $I_{t-2}/K_{t-3}$. For the level equation, we use Arellano-Bond instrument matrix for $\Delta I_{t-1}/K_{t-1}$, $\Delta Y_t$, $\Delta(y_{t-1}-k_{t-1})$, and $\sigma_t$. * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

10 We also experimented with interacting uncertainty with proxies for irreversibility and market power, since these should influence the investment-uncertainty relationship. As proxies we used the fraction of building in investment and a markup measure. We did not find any effect of irreversibility or market power. One reason may be that the proxies we used were bad measures of irreversibility and market power, the other may be that our sample is not heterogenous or large enough.
The conclusions and order of magnitude of the coefficients are similar for realized investment. The error correction term is again significant at the 10% level only. As for investment plans, demand uncertainty is negative and significant. The effect of a one standard deviation increase in demand uncertainty on actual investment is of the same order of magnitude as for investment plans.

If firms investment decisions at the time of planning are fully irreversible, then plans made at time $t$ are simply executed at time $t+1$. In this case, we should expect equality between the coefficients in the planned and the actual investment regressions. Table 3 below reports a test for the hypothesis of equal coefficients in the planned and realized investment equations. We regress investment revisions on all RHS variables. If the hypothesis is true, all coefficients should be equal to zero. Fixed effects should be identical in both planned and realized equations, so that they drop out from the investment revisions equation. This can therefore be estimated by OLS. Differences in fixed effects of the planned and realized investment equation would imply that expectations of future investment (investment plans) have a systematic bias. As a robustness check, we also report the system GMM estimates that allows for this possibility. Results suggest that all coefficients are equal. One possible exception is the coefficient on future sales growth, which is significant at the 10% level in the OLS regression only. The reason may be that $\Delta Y_{t+1}$ is the only variable that is not known with certainty at the time investment plans are made, while when investment is realized, at time $t+1$, $\Delta Y_{t+1}$ is now observed by the firm.

11 At the time of revisions, in $t+1$, $\Delta Y_{t+1}$ is known and must no longer be instrumented.
Table 3: Test of equal coefficients in the planned and realised investment equations

(Dependant variable is investment revisions: \( I_{it+1}/K_t - I_{pt+1}/K_p \))

<table>
<thead>
<tr>
<th></th>
<th>Least Squares</th>
<th>System GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coef(i)</td>
<td>t-stat(ii)</td>
</tr>
<tr>
<td>constant</td>
<td>-0.004</td>
<td>-0.224</td>
</tr>
<tr>
<td>( I_t/K_{t-1} )</td>
<td>0.044</td>
<td>1.201</td>
</tr>
<tr>
<td>( \Delta Y_{t+1} )</td>
<td>0.023</td>
<td>1.635 *</td>
</tr>
<tr>
<td>( \Delta Y_t )</td>
<td>0.002</td>
<td>0.102</td>
</tr>
<tr>
<td>((y_{t-1}-k_{t-1}))</td>
<td>-0.005</td>
<td>-1.316</td>
</tr>
<tr>
<td>( \sigma_{st} )</td>
<td>0.021</td>
<td>0.486</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>0.026</td>
</tr>
<tr>
<td>Sargan(iii)</td>
<td>72.433</td>
</tr>
<tr>
<td>m1</td>
<td>-2.384</td>
</tr>
<tr>
<td>m2</td>
<td>0.332</td>
</tr>
</tbody>
</table>

(i) The system GMM reports second step estimates, (ii) Windmeijer (2000) ‘s corrected t-stat, (iii) and second step Sargan. All estimations include time dummies. The estimation period is 1989-1998. The sample contains 622 observations for 94 firms. In system GMM, the difference equation is instrumented with \( I_{t-1}/K_{t-1}, I_{t-2}/K_{t-3}, \Delta Y_t, \) and \( \Delta Y_{t-1} \). The level equation is instrumented with \( \Delta I_t/K_{t-1}, \Delta \Delta Y_t, \Delta (y_{t-1}-k_{t-1}), \) and \( \sigma_t \).

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level

The real option theory (Dixit and Pindyck, 1994) stresses that, before undertaking investment, firms may have an incentive to wait, so that new information about the uncertain future is disclosed. We now test whether firms revise their investment decision when uncertainty about the future is partly resolved. On average in our sample investment revisions are very small. The sample mean of investment revision amounts to 0.0047, which represents 6% of the mean planned investment rate. However, there is heterogeneity in investment revisions across firms, as the standard deviation of investment revisions is equal to 0.06. Thus, although revisions are small on average, there may be substantial for some firms and years. We therefore investigate the determinants of investment revisions.

Investment plans for \( t+1 \) were decided given the information and uncertainty that existed when the decision was made (in \( t \)). In year \( t+1 \), the firm may revise its investment plans because part of the uncertainty about the future has been resolved (one year has passed since the investment decision). In our framework, at the time firms revise their investment decisions they observe rather than forecasts sales growth, \( \Delta Y_{t+1} \). In addition, they might revise their evaluation of future uncertainty (beyond \( t+1 \)), since uncertainty about period \( t+1 \) is now resolved. We regress the ratio of investment revisions to capital on future sales growth, current and future uncertainty.

\[
(5) \quad \frac{(I_{it+1} - I_{pt+1})}{K_{it}} = \alpha_1 \Delta Y_{it+1} + \alpha_2 \sigma_{st+1} + \alpha_3 \sigma_t + \varepsilon_{it+1}
\]
Equation (5) can be estimated by OLS, provided there is no fixed effects in the investment revisions equation. As a robustness check for fixed effects, we also present the OLS results on first difference. OLS results, reported in Table 4, show that no coefficient is significant at conventional level. Demand growth in $t+1$ is significant at the 10% level. However, allowing for fixed effects and estimating the equation in first difference suggest that firms revise their investment decisions in response to demand growth, which was unobserved at the time the investment decision was made. Demand uncertainty at time $t$ and at time $t+1$ is not relevant for investment revisions at time $t+1$. We conclude that, for investment, firms might find it difficult to deviate substantially from their plans even if uncertainty changes. This suggests that the investment decision in itself is for a large part irreversible. What matters for investment is the level of uncertainty at the time plans are on the drawing board not when the plans are executed. For policy makers this implies that reducing uncertainty will only have lagged effects on investment.

### Table 4: Determinants of investment revisions

<table>
<thead>
<tr>
<th></th>
<th>Least Squares</th>
<th>Least Squares on first differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dependent variable: $I_{t+1}/K_t - I^p_{t+1}/K_t$</td>
<td>dependent variable: $\Delta(I_{t+1}/K_t - I^p_{t+1}/K_t)$</td>
</tr>
<tr>
<td></td>
<td>coef, t-stat</td>
<td>coef, t-stat</td>
</tr>
<tr>
<td>constant</td>
<td>-0.008, -0.411</td>
<td>-0.008, -0.412</td>
</tr>
<tr>
<td>$\Delta Y_{t+1}$</td>
<td>0.023, 1.597</td>
<td>+</td>
</tr>
<tr>
<td>$\sigma^d_{t+1}$</td>
<td>0.027, 0.500</td>
<td></td>
</tr>
<tr>
<td>$\sigma^d_t$</td>
<td>0.002, 0.044</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.021</td>
<td></td>
</tr>
</tbody>
</table>

All estimations include time dummies, The estimation period is 1989-1998, 622 observations for 94 firms

* significant at the 11% level, * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level

Our results show that demand uncertainty reduces the level of investment plans. This is consistent with Caballero (1991) ’s results for imperfectly competitive firms in an uncertain environment. Guiso and Parigi (1999) and Patillo (1998) report a negative effect of demand uncertainty on firms' investment. Driver et al (2002) also find that uncertainty about future business conditions reduces investment authorisations. We find that price uncertainty has no effect on investment. This contrasts with the findings of Ghosal and Loungani (1996) and Henley et al. (2003). But, this confirms our earlier conjecture that firms may not be price-takers. Indeed, if this was the case, price uncertainty would be identical to demand uncertainty (see the discussion in Section 2), and both should be significant in our investment equation. Rather, firms in our sample seem to be monopolistic firms, and our measure may capture price changes that are decided by the firm rather than uncertainty about output prices.
Finally, our results suggest that firms revise their investment plans very little on average. They do not modify their investment decisions due to the fact that part of the uncertainty was resolved between the time the investment was planned and the time investment is realized. This contrasts with the effect of uncertainty on the timing of investment as stressed by the real option theory. At most, firms revise their investment plans according to their revisions of sales growth forecasts, but they do so by a very small amount. Our results indicate that the level of uncertainty affects investment plans, but that plans are not revised following a change in uncertainty. This suggests that a reduction in the level of uncertainty would have lagged effects, since it affects future investment plans but not revisions of current investment.

VI. Conclusions

Empirical investigations of the relationship between investment and demand uncertainty seldom use good empirical proxies that are close to the concept of demand uncertainty for which the theory is developed. Using survey information in which firms reveal their forecasts of future demand changes has proved useful in filling this gap. Our results show that demand uncertainty reduces both planned investment and actual investment, in line with the predictions made by Caballero (1991) for imperfectly competitive firms. We find no evidence of an effect of price uncertainty on investment, which is consistent with the assumption of price-setting firms.

Our results show that the sensitivity of investment to demand uncertainty is the same for both planned and realized investment. Further, investment revisions are driven by sales growth at the time of revision, but not by changes in the level of uncertainty. Investment revisions are very small on average. This suggests that investment plans are generally, by a large extent, irreversible. Firms revise their investment decision based on new information about sales growth, but not on uncertainty reduction. So, although part of uncertainty is resolved one year after investment was planned, firms do not adjust investment. For policy-makers, this implies that reducing uncertainty would only have lagged effects.

APPENDIX:

Sample description

We construct two samples, one for investment plans, $I_{t+1}$, the other for realized investment, $I_{t+1}$. The first is used to analyze firms' investment decisions, the second to compare our results with firms' investment realizations. Initially, the sample of investment plans contains 4551 observations and that of realized investment 5857 observations. We then clean our sample for outliers. Since the distribution is censored at left (investment rates are positive), trimming for outliers was performed by taking investment rates below the 98th percentile. We trim year by year in order to avoid trimming bias due to business cycle fluctuations. Annual accounts data of sales growth and the cash
flow-capital ratio were trimmed symmetrically, by taking the P2-P98 interpercentile range year by year. Both samples were then matched with the Business Survey (to obtain uncertainty and expectation indicators). Then, selecting firms with enough consecutive observations (at least six years) to estimate our ECM equation, our final samples contain 977 observations on 114 firms in the plans sample over the period 1987-2000 and 1154 observations on 130 firms over the period 1987-1999 in the realizations sample.

We focus on six manufacturing sectors: (1) food, (2) textile, (3) wood, (4) paper, (5) non metal, and (6) metal. Firms are more or less evenly distributed among sectors, except for the wood sector.

### Number of firms and observations by sector

<table>
<thead>
<tr>
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<th>Plans sample</th>
<th>Realizations sample</th>
</tr>
</thead>
<tbody>
<tr>
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<td># obs</td>
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<tr>
<td>Food</td>
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<td>242</td>
</tr>
<tr>
<td>Textile</td>
<td>24</td>
<td>192</td>
</tr>
<tr>
<td>wood</td>
<td>5</td>
<td>39</td>
</tr>
<tr>
<td>paper</td>
<td>19</td>
<td>161</td>
</tr>
<tr>
<td>non metal</td>
<td>14</td>
<td>132</td>
</tr>
<tr>
<td>metal</td>
<td>25</td>
<td>211</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>114</strong></td>
<td><strong>977</strong></td>
</tr>
</tbody>
</table>

### Definition of the variables

Investment plans and investment realizations are given in the Investment Survey. In this survey, each Autumn, firms have to give quantitative evaluations of their investment plans for the coming year and their evaluation of investment over the current period. To construct investment capital ratios, we construct series of the capital stock from the Annual Account database. Sales and cash flow are also constructed from this database. Sales are defined by turnover. Cash flow is defined as net profits plus depreciation. We use sector-specific prices to obtain real series.

For the construction of the capital stock, we distinguish between five different types of capital goods: (1) land and buildings, (2) plant and machinery, (3) furniture and rolled material, (4) leasing, and (5) others. For each of these capital goods, and each sector we construct the capital stock in the following way.

We use the perpetual inventory method to construct the real capital stock, i.e.:

---

12 Since the Business Survey is conducted product by product, we consider the product that accounts for the largest part of the firm’s turnover as a proxy for the firm’s output.
\[
\bar{K}_t = K_{t-1}(1-\delta) + p_t I_t / p_t
\]

We use the industry specific price index of investment goods given by National Accounts, where the price index at 1995 is equal to one. Nominal investment is the sum of several factors, each one of which is deflated by the investment price index of the time at which the investment was made. In particular, acquisition of tangible assets in current year are deflated by current prices, but sales and disposals of old capital are deflated by the prices related to the age of this capital.\(^\text{13}\) The initial nominal capital stock at historical prices in \(t\) is equal to the sum of all acquisitions of new capital minus (accumulated) depreciation over the entire history of the firm up to \(t-1\). The real initial capital stock is obtained by deflating the initial nominal capital stock with investment prices related to the age of the capital stock.\(^\text{14}\) We construct depreciation rates by sector and type of capital good, based on the lifetimes of the capital goods reported in the National Accounts.

As explained in section 3, demand (price) uncertainty is defined according to the percentage of firms within industry \(j\) that expect a positive demand (price) change, \(\%_{\text{up}_j}\), and the percentage of firms that expect a negative demand (price) change, \(\%_{\text{down}_j}\), in the Business Cycle Survey. More precisely, uncertainty is defined as \(\sigma^2_{jt} = [(\%_{\text{up}_j} + \%_{\text{down}_j}) - (\%_{\text{up}_j} - \%_{\text{down}_j})^2].\) In the estimations, uncertainty is defined industry-by-industry. To illustrate our uncertainty measures, Figure I reports demand and price uncertainty defined at the aggregate level, together with a business cycle indicator (the National Bank of Belgium business economic conditions index). Although there are important differences across sectors, three main features are shared by most sectors. Demand uncertainty peaked in the first half of the nineties. Price uncertainty is always lower than demand uncertainty. In macroeconomic data: over the period 1987-2000, the coefficient of variation of GDP growth (0.74) was 80% higher than that of consumer price growth (0.41). Finally, both demand and price uncertainty are negatively correlated with the business cycle. This suggests that firms are more uncertain about the future in downturns than in upturns.

\(^{13}\) The average age of sold and used capital is estimated from annual accounts information on depreciation. Details are available from the authors on request.

\(^{14}\) This is again inferred from annual accounts information on depreciation.
Figure I: Aggregate demand and price uncertainty and the business cycle

The business cycle index is the National Bank of Belgium business economic conditions index. Aggregate demand and price uncertainty are the Theil’s disconformity index using the answers to the National Bank of Belgium Business Survey of all firms over all industries and months of the year.
References


