STUDIECENTRUM VOOR ECONOMISCH EN SOCIAAL ONDERZOEK

VAKGROEP MACRO-ECONOMIE

Investment in the EC-countries : does reducing uncertainty matter ?

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report 95/320

April 1995

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We want to thank R. Van Straelen and the participants at the macro-economics workshop of SESO, UFSIA and at the July 1994 Economic Policy Conference in Washington D.C. for their useful comments. All usual disclaimers apply.

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D/1995/1169/07

Abstract

Recent empirical research on development countries with high-uncertainty economic systems and on the U.S. economy shows that the stimulation of investment depends more on stability and credibility than on tax incentives or interest rates. In this paper, we test this hypothesis for 14 European countries. We start from an appropriate model of investment and uncertainty using option theory and stochastic dynamic programming.

In the second part an empirical application is performed. We come to the conclusions that reducing uncertainty by aiming at stable effective exchange rates or interest rates is more important for investment stimulation than reducing the interest rates. These results are much more pronounced for business fixed investment than for public investment.

Keywords: investment, uncertainty, EC

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INTRODUCTION

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

Although investment has always been an important research topic, both theoretically as well as empirically, the results in the latter domain are not very satisfying. A recent survey of Chirinko [1993] gives a clear insight in the different ways researchers have tried to come to a better understanding of investment, and more specific of business fixed investment. One of his important conclusions is that

> "*the weight of the evidence clearly points to a modest response of investment to prices and a much greater response to output*" (p.1898)

If this is indeed the case it has important policy consequences because it implies that the level of prices and interest rates is of minor importance for stimulating investment.

An interesting explanation for this minor role of the interest rate level is given in recent work of a.o. Dixit and Pindyck [1994]. The starting point of their analysis is that the decision to invest is often irreversible. Especially in times of increasing uncertainty about future economic evolutions, this may well result in postponing investment decisions. Hence, in their view, reducing volatility in the economy may be much more important to stimulate investment than reducing interest rates.

To the extent that the economic and monetary unification of Europe reduces the volatility of exchange rates, interest rates and inflation of the individual countries, it may be preferable for a country to stick to the agreement even if it implies giving up the possibility to control the interest rate level. Giving up the agreement reduces the credibility and might result in a higher volatility of exchange rates, interest rates and inflation for the country under consideration.

In this paper we make a first attempt to find out how important volatility is for macroeconomic investment in Western Europe. The first part of the paper gives a summary and a situation of the new investment theory, largely inspired by the recent work of Dixit and Pindyck . In the second part, a first sample of empirical results is presented.

1. A NEW THEORY OF INVESTMENT?

Despite a vast body of literature, and still growing theoretical and empirical research interest, the behaviour of investment in general, and business fixed investment in particular, is yet not well understood, as well on the firm, industry as on the macroeconomic level. Most striking is the fact that a number of theories (and models derived from it), constructed on the basis of sound theoretical underpinnings, that should in theory have very strong explanatory power, in practice do not seem to perform satisfactorily, leaving much of investment spending unexplained. The most prominent example is the (marginal) (Brainard)-Tobin q, based on well-established neo-classical underpinnings. In essence, the q-ratio is the ratio between the observed or computed expected present value of future profits streams of a (marginal) unit of capital over its replacement cost. Although the empirical flaw of the theory has been blamed, amongst other things, on the fact that, since marginal q is unobserved, empirical research has been performed on 'average' q ratio's, more sophisticated approximations of marginal q, incorporating delivery lags and adjustment costs, do not seem to help much[1]. This is the more important since, in fact, the classical and well-accepted 'Net Present Value' (NPV) rule to invest an additional unit of capital when its value, in the following denoted as V, is at least as large as its (investment) cost, denoted as I, is basically equivalent to the q-theory (invest when $q > 1$).

This continuing frustration of economists together with the drive to find an accurate policy answer to worldwide recession and growing unemployment, and the necessities in supporting marked-based transition of major economies in Eastern-Europe, the former Sovjet-Union and the developing countries, has made the quest for better-performing investment theories more than ever open and pressing. A new stand of theory that sets up for fulfilling high hopes has emerged in recent years. This theory is based on the simultaneous existence of three phenomena: uncertainty, irreversibility of investment and some freedom of choice on the timing of investment. It starts from the fact that investment decisions are to a large extent irreversible, i.e. cannot be reversed except at a high

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[1] The copybook example is Abel and Blanchard [1986].

cost (the cost is largely 'sunk'). Combining irreversibility with the existence of uncertainty over the future behaviour of variables that affect the value of the investment (such as future output prices) leads to the following intuitive reasoning: suppose there is some leeway in delaying investment until more information about the uncertain future becomes available; it may then be optimal to wait some time before investing. It is clear that waiting to invest implies risks (e.g. entry of competitors) and foregone profits, but it may prevent from being trapped in an irreversible investment project which turns out to be very costly when the adverse future materializes.

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

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

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[2] See e.g. Bernanke [1983], McDonald & Siegel [1986], Pindyck [1988], Dixit [1992] Ingersoll and Ross [1992], Caballero & Dixit [1992], Pindyck & Solimano [1993], Bertola and Caballero [1994] and Pindyck [1989,1991] for a early review. A comprehensive theoretical treatment is given in Dixit and Pindyck [1994]. See also Dornbusch [1990] and Serven & Solimano [1990,1993] for early applications on FDI and domestic investment in debt-ridden developing countries.

Hence the optimal investment criterion is modified into

$$V < I + F_0 \qquad \text{wait to invest}$$

$$V > I + F_0 \qquad \text{invest}$$

In option pricing jargon, the option is said to be 'out of the money' in the first case (waiting) and 'in the money' when the underlying value of the investment, V, exceeds the option value (price) plus the investment cost. The basic new insight is in fact that one should wait until the 'orthodox' NPV is "very large", with F putting an exact value to it[3]. As such, the basic investment decision to take is not **whether or not** to invest (as indicated by the orthodox NPV-rule), but rather **when** to invest, i.e. determining the optimal moment of exercising the investment option[4].

In the following section 2, we will illustrate how to derive the current option value, F_0 for an individual investment decision. However, this reasoning can be easily extended to a number of other sources of uncertainty, such as interest rates, exchange rates, the government's tax policy, as well as to industry, or aggregate (fixed) investment. As such, real option theory can be a very powerful tool to assess the efficacy and efficiency of certain policy measures with respect to investment. This will be done from section 3 on and will constitute the main focus of the paper.

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

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

2. ON MODELLING THE INDIVIDUAL IRREVERSIBLE INVESTMENT DECISION

The basic assumption is that of future uncertainty, which is standard also in orthodox investment theory: the future is always uncertain. In this example, let the basic source of uncertainty be the future output prices, affecting the value of the investment project, $V_t^{(i)}$, with the subscript denoting time, and the superscript denoting possible scenario's (different future output prices). The decision on the investment can be made 'today' (t=0) or can be postponed to 'next year' (t=1)) . The prices today are known to be P_0. Future output prices are not known with certainty and are assumed to be $P^{(1)}$ for the bad scenario and $P^{(2)}$ for the good scenario, with a given probability distribution and an expected future price equal to today's price P_0 [5].

Today's value of the project, V_0, (noting that the expected future price is the current one) equals

$$V_0 = \sum_{t=0}^{\infty} \frac{P_0}{(1 + r_f)^t}$$

where r_f is the (risk-free) rate.

If V_0 is greater than I, one could go ahead with the investment now, but one could also wait until next year when the uncertainty is resolved, and only invest when the good scenario materializes[6].

Since next year the uncertainty is resolved, next year's decision is simple, depending on which output price is realised: assume that under the bad scenario $(P_1^{(1)})$, $V_1^{(1)}$ will be lower than I and investment is cancelled, while under the good scenario $(P_1^{(2)})$, the NPV

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[5] In this example, all uncertainty is resolved next year. Therefore, the option wait has only value this year, and the decision to wait has only relevance this year.

[6] Here, we explicitely assume that under the bad scenario $(P^1{}_1)$, the value of the project is no longer greater than the investment cost.

is much larger than it would be today. The decision to make is whether today we should invest or wait?

Reformulated using standard option pricing techniques, the value of the investment option under the good scenario, $F_1^{(2)}$, is equal to $V_1^{(2)}$ - I, or

$$F_1^{(2)} = \sum_{t=0}^{\infty} \frac{P_1^{(2)}}{(1+r_f)^t} - I$$

while the option value under the bad scenario, $F_1^{(1)}$, is zero[7]. What one needs to know is today's option value, F_0. This is what one should be willing to pay now to have the option to invest (Dixit & Pindyck [1994,p.30]); for traded options, this should be the price of the option.

2.1. Determining the Value of the Option

The conventional way to solve this problem is to create a hedged (risk-free) portfolio containing the hold of an option to invest (a 'long' position or an 'asset') on the one hand, and the short sale of a certain number of output (the 'liability') on the other hand. Since the portfolio matches an asset with a liability (or a long with a short position), the portfolio can be constructed so that its value is independent of the future, uncertain behaviour of the output price, i.e. is risk-free; this risk-free characteristic of the portfolio is attained from carefully selecting the amount of output, n, that is short-sold. We can do that by calculating the value of the portfolio 'next year', $\Phi_1^{(i)}$ for every scenario i, and solving for n by equalizing these alternative portfolio values. The value of the option is of course F_t, while the value of the short position equals nP, so $\Phi_t^{(i)} = F_t^{(i)} - nP_t^{(i)}$; hence, in order to find n^*,

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[7] In case V < I, the option is worthless, i.e. has zero value.

$$F_1^{(1)} - P_1^{(1)} n = - P_1^{(2)} n$$

This gives us n^*, the amount of output that makes the portfolio risk-free,

$$n^* = \frac{F_1^{(1)}}{P_1^{(1)} - P_1^{(2)}}$$

The next step is to calculate the return on this risk-free portfolio, which is equal to the change in value of the portfolio (the difference between 'next year' and 'today') minus its holding cost, i.e. any payments that must be made to hold the short position. To calculate this holding cost, the following reasoning applies: since the expected rate of capital gain on output is zero (we assumed the expected future output price to be equal to today's price), no investor would be willing to hold the offsetting long position in output unless earning at least the risk-free return on it. Hence, for us holding the portfolio, short-selling output will require an annual payment equal to the risk-free rate times today's output price, per unit of output involved in short-selling. Summarizing, the return from holding the portfolio is then the capital gain on the portfolio (Φ_1 - Φ_0) minus the holding cost, or

$$\begin{aligned} \Phi_1 - \Phi_0 - r_f n^* P_0 &= \Phi_1 - (F_0 - n^* P_0) - r_f n^* P_0 \\ &= \Phi_1 + (1 - r_f) n^* P_0 - F_0 \end{aligned}$$

Because this return is risk-free, it should equal the risk-free return, which is the risk-free interest rate times the initial value of the project. As such,

$$\Phi_1 + (1 - r_f) n^* P_0 - F_0 = r_f \Phi_0$$

where $\Phi_0 = F_0 - n^* P_0$, and the value of the investment opportunity today (the option price), F_0, can be calculated as

$$F_0 = \frac{\Phi_1 + n^* P_0}{1 + r_f}$$

Since every component of the right-hand side of the equation is known today, the current option value, F_0, which is non-negative (as any option value), can be determined from this equation.

A problem arises when it is not possible to construct a risk-free portfolio, based on the possibility of trading (e.g. short selling), the existence of an option market in the output, and there is a tradable asset with a perfect correlation to the price behaviour of the output. In this case, it is always possible to calculate the value of the option by computing the NPV of each scenario (investing now versus waiting) and pick the scenario with the highest NPV. This is essentially what is done using the dynamic programming approach, when acting in a continuous time framework. As such, this dynamic programming route will be followed from 2.2. on.

2.2. The Optimal Individual Investment Problem

The conventional approach of illustrating the problem uses the continuous time model of irreversible investment presented by McDonald and Siegel [1986], under the following formulation: at what point is it optimal to pay a sunk (investment) cost, I, in return for a project whose value is V, given that V evolves according to a geometric Brownian motion

$$dV = \alpha V dt + \sigma V dz \qquad (1)$$

where dz is the classical increment of a Wiener process. This in fact implies that the current value V_0 is known, but future values are uncertain and lognormally distributed with a variance that grows (linearly) with the time horizon (see also e.g. Pindyck [1991]).

For that, there is need to derive an investment rule that maximizes the exact value of the investment opportunity, incorporating the opportunity cost of waiting, or option price, F. The pay-off for investing at time t is V_t-I, so we need to maximize

$$F(V) = \max E\,(V_T - I)\,e^{-\rho T}$$

where T is the (unknown) future time at which the investment decision is made, ρ is the discount rate and the maximization is subject to equation (1)[8]. It can be shown that the solution is a function of a threshold value V^*, such that it is optimal to invest once V is larger than the threshold value. Assuming that investment is indeed taking place only when $V \geq V^*$, the value of the investment opportunity, or the option value, F is equal to

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[8] Another necessary assumption is that $\alpha < \rho$; otherwise one would never invest, with F(V) becoming infinite. For the following, it is useful to denote the difference ρ-α as δ.

$$F(V) = a V^{\beta}$$

with

$$\beta = \frac{1}{2} - \frac{(\rho - \delta)}{\sigma^2} + \sqrt{\left(\frac{\rho - \delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}}$$

and $\beta > 1$. The threshold value V^* and the constant, a, are given by:

$$V^* = \frac{\beta}{\beta - 1} I \ ,$$

$$a = \frac{V^* - I}{(V^*)^{\beta}}$$

F(V) can be used to characterize the optimal timing of individual investment, namely to invest only when $V \geq I + F_0$ [9].

From the viewpoint of the subject of this paper, the most important consequence resulting from this model solution is that uncertainty (and irreversibility) introduces a difference between the minimum-acceptable value of the project in order to invest (V^*) and the cost of investment, I (contrary to the conventional NPV rule): since β is greater than one , V* is greater than I; more important even, since $\partial\beta/\partial\sigma > 0$, the greater the level of uncertainty, the more the value of the investment opportunity must exceed its cost before investment is indeed taking place.

As such, the individual investment decision is, in theory, very dependent on the level of uncertainty, as measured by σ.

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[9] This 'dynamic programming' formulation and solution of the investment is identical to the presentation in Pindyck and Solimano [1993]. A more detailed presentation of the procedure is given in Dixit and Pindyck [1994, chapter 5.2]. The problem can also be presented and solved using contingent claims (option pricing) theory, with identical results (see e.g. Pindyck [1991] or Dixit and Pindyck [1994, chapter 5.3] for details).

3. MACROECONOMIC INVESTMENT FUNCTIONS AND VOLATILITY

For an individual investment project it is clear that an increased volatility of the future returns will drive up the wedge between the cost of investment and the critical value of the project V*. In this study, however, we are interested in the effect of uncertainty and volatility on a macroeconomic level. This brings us to the aggregation problem which is treated in detail by Bertola & Caballero [1994]. Starting from the behaviour of the individual firm, they try to come to a relation between aggregate investment and two types of uncertainty: idiosyncratic or firm-related uncertainty on the one hand, and aggregate or overall uncertainty on the other.

The importance of this distinction between aggregate and idiosyncratic uncertainty is stressed by Caballero & Pindyck [1992]. Whether changes in uncertainty will or will not affect investment depends upon the distribution of the future values of the marginal revenue product of capital. Only when this distribution is asymmetric, higher volatility will result in less investment. In a competitive market, only aggregate shocks will lead to an asymmetric distribution for the marginal revenue product and might, in combination with irreversibility of the investment, lead to a negative relation between uncertainty and aggregate investment. The exact analysis of the interaction between aggregate and firm-specific shocks and irreversibility can be found in Caballero & Pindyck [1992] and Pindyck & Solimano [1993]. Because they are the starting point for our empirical analysis, we will give a brief summary of their main findings.

The economy is assumed to consist of a large number, N, of small production units, i, each having a productivity A_i. At time t the total productivity in the economy is given by

$$Y(t) = \int_0^{N(t)} A_i(t)di$$

The productivity of each unit is decomposed into an aggregate and an idiosyncratic component, or

$$A_i(t) = A(t)a_i \qquad with \quad \int_0^{N(t)} a_i di = N(t)$$

The average productivity in the economy is A(t) and is assumed to follow an exogenous stochastic process representing the aggregate source of uncertainty. The productivity of a single unit relative to that of the economy as a whole is $a_i(t)$ and is also following a stochastic process representing the firm-specific source of uncertainty. It is assumed that a firm only learns its relative productivity after entry, so that there is no selective entry. This means that a firm cannot choose the distribution for its idiosyncratic shock.

Another source of aggregate uncertainty is introduced in the model through the aggregate demand function

$$P(t) = Y(t)^{-1/\eta} M(t)$$

where M(t) represents an exogenous stochastic process.

Irreversibility is introduced in the model by assuming that entry requires a sunk cost, F.

It is shown that free entry implies that

$$F \geq E\left[\int_0^\infty P(t)A(t)e^{-\gamma t}dt\right]$$

where

$$\gamma = r + \theta$$

with r the interest rate (discount rate) and θ is an indicator for the rate at which productive units are removed. The expectation is over the distribution of the future marginal profitability of capital, $P(t)A_i(t)$.

According to Caballero & Pindyck [1992] the marginal profitability of capital for a firm considering entry is the average value of output, B(t) with

$$B(t) \equiv P(t)A(t) = A(t)^{\frac{\eta-1}{\eta}} N(t)^{-\frac{1}{\eta}} M(t)$$

Assuming that A(t) and M(t) follow uncorrelated geometric Brownian motions, then B(t) will follow a regulated geometric Brownian motion:

- when there are no new entries B(t) will follow a geometric Brownian motion

$$dlnB(t) = \beta dt + \sigma dz(t)$$

where dz(t) is a Wiener process

- when there are new entries, the profitability will not increase infinitely and so B(t) will remain below a fixed boundary, U, which is, according to Caballero & Pindyck [1992] given by

$$\frac{U}{F} = \frac{\lambda}{1-\lambda}(r+\theta-\beta-\frac{1}{2}\sigma^2)$$

with

$$\lambda = \frac{-\beta+\sqrt{\beta^2+2(r+\theta)\sigma^2}}{\sigma^2}$$

and

$$\frac{\partial(U/F)}{\partial\sigma} > 0 \quad , \quad \frac{\partial(U/F)}{\partial\beta} < 0$$

This implies that the threshold value for the marginal profitability of capital will increase with a higher volatility of B(t). This is due to the fact that a higher value of σ leads to a higher opportunity cost of investing so that the firm will require a higher return for the sunk cost Figure. The conclusion is similar to the one for a single project on firm level where a higher volatility increases the threshold value V*.

4. EMPIRICAL APPLICATION FOR EUROPE

The previous analysis suggests that uncertainty plays an important role in the investment decision. However, it only gives an idea of how the volatility of the marginal profitability of capital affects the threshold value. The problem when one wants to test empirically this relationship, is that there is no direct information available on this threshold value so that we have to start from an approximation.

In order to be able to build such an approximation, we start from a competitive economy with a Cobb-Douglas production function

$$Y = A\ K^{\alpha} L^{\beta} \tag{2}$$

with Y value added
K capital input
L labour input

Using annual data for 14 European countries, we estimated the coefficients of this function for each of the countries and tested for constant returns to scale (CRS)[10].
For each of the countries we could accept the CRS hypothesis, which implies that (2) can be written as

$$Y/L = A\ (K/L)^{\alpha} \tag{3}$$

Starting from (3) and assuming profit maximization under perfect competition, the marginal profitability of capital is

$$\partial\pi/\partial K = \alpha\ (1-\alpha)^{\frac{1-\alpha}{\alpha}}\ A^{\frac{1}{\alpha}}\ w^{-\frac{\alpha}{1-\alpha}} \tag{4}$$

with w the real labour cost.
According to Caballero & Pindyck [1992] this is the average value of output B.
Substituting A = $Y/(K^{\alpha}L^{1-\alpha})$ in (4) and taking logarithms gives for a certain period t

$$b_t = \ln(B_t) = \ln\alpha + \frac{1-\alpha}{\alpha}\ln(1-\alpha) - \frac{\alpha}{1-\alpha}\ln w_t + \frac{1}{\alpha}\ln Y_t - \ln K_t - \frac{1-\alpha}{\alpha}\ln L_t$$

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[10] More information on the data is given in appendix 1.

We used AR1-estimates for α to calculate annual values for b_t for each of the fourteen countries[11]. These values were used to construct for each country an approximation for the threshold value $u = \ln(U)$ in a similar way as Pindyck & Solimano [1993]. We used extreme values of b_t:

bMAX	the largest value of b_t over the time period
bDEC	the average of the top decile of the values of b_t over the time period
bQUINT	the average of the top quintile of the values of b_t over the time period

These variables are calculated relative to the mean over the time period.

Table 1: Volatility and threshold approximations for 14 European countries

	bMAX	bDEC	bQUINT	sddlnB	meanmax	meandec	meanquint
bel	0.220862	0.201212	0.18835	0.024023	-0.01511	-0.01396	-0.01518
den	0.202160	0.201064	0.180009	0.033980	-0.01097	-0.01173	-0.01136
fin	0.064447	0.058514	0.051005	0.023976	-0.00372	-0.00513	-0.00562
fra	0.094608	0.09061	0.084737	0.016207	-0.00355	-0.00433	-0.00465
ger	0.233621	0.200375	0.166344	0.021358	-0.01097	-0.00965	-0.00897
gre	0.245664	0.243201	0.22025	0.041513	-0.01060	-0.01410	-0.01308
ire	0.202714	0.179318	0.151321	0.045744	-0.00601	-0.00629	-0.01089
ita	0.040264	0.037058	0.033179	0.018649	-0.00251	-0.00299	-0.0031
ndl	0.138101	0.126519	0.114271	0.024268	-0.00986	-0.01039	-0.0089
nor	0.054717	0.052581	0.04512	0.016436	0.003214	0.003007	0.003461
aus	0.422982	0.382786	0.335793	0.029052	-0.02333	-0.02184	-0.02154
spa	0.770184	0.708384	0.630966	0.149302	0.006978	0.00574	-0.00739
swe	0.149076	0.142986	0.128646	0.037427	-0.01146	-0.01505	-0.01794
uk	0.338614	0.305719	0.269917	0.165313	-0.02595	-0.03297	-0.03508

meanmax = average growth rate of b_t over periods that excludes bMAX
meandec = average growth rate of b_t over periods that excludes bDEC
meanquit = average growth rate of b_t over periods that excludes bQUINT
sddlnB = the standard deviation of b_t over the sample period

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[11] The results of the AR1-estimation are reported in appendix 2.

Both Spain and the United Kingdom are characterized by a rather high volatility of the marginal profitability of capital (more than 10 %), where for other countries the standard deviation varies from 1.6% (France and Norway) to 4.6% (Ireland).

Figure 1: Volatility of the marginal profitability of capital

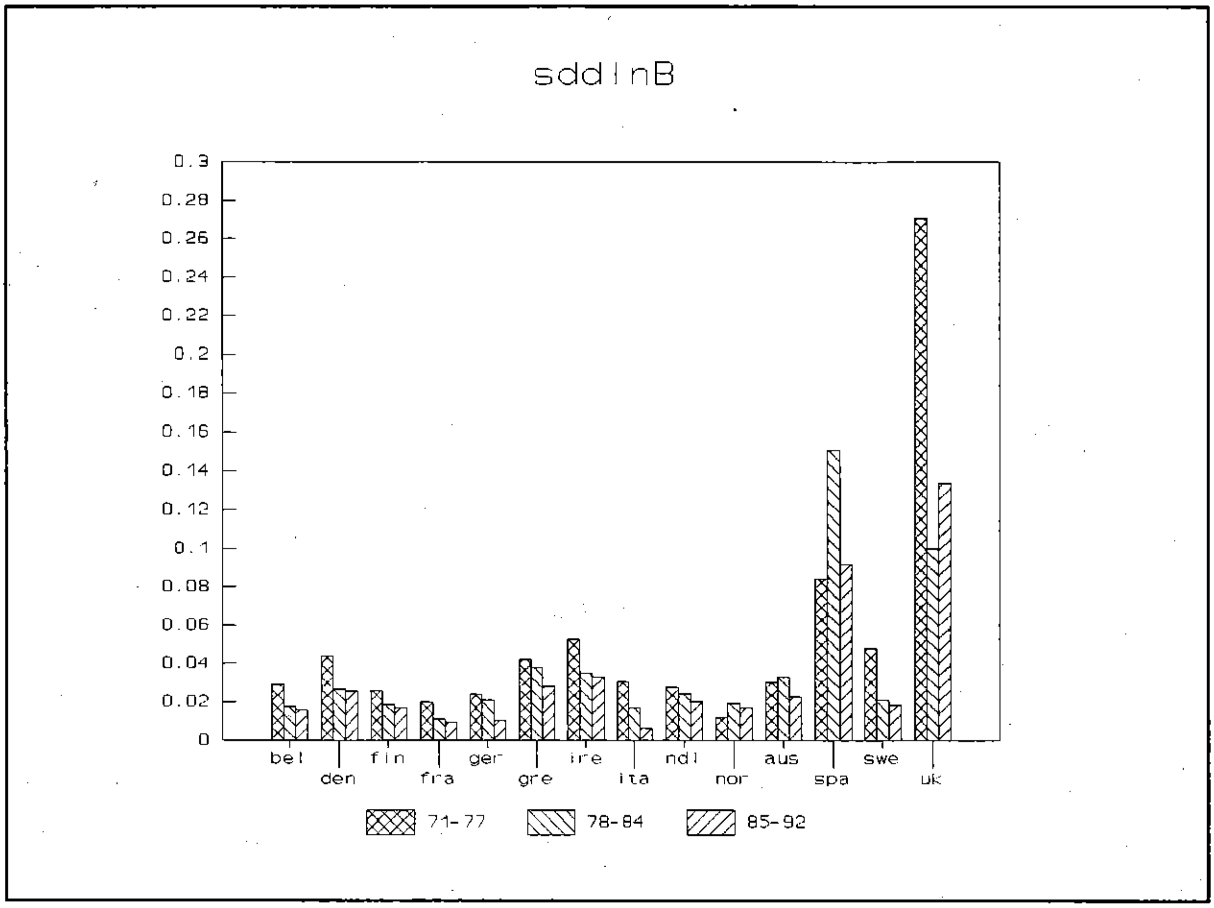


Figure 1 represents the standard deviation of the marginal profitability of capital for three subperiods (1971-77, 1978-84, 1985-92). Once again the high values for Spain and the UK can be observed. For most countries the volatility is reduced in the last periods, with the exception of Spain, the UK, Austria and Norway.

To determine the effect of volatility on the threshold approximations, we ran cross-section regressions with as explanatory variables the standard deviation of b_t over the sample period (sddlnB) and the average growth rate of b_t over periods that exclude the extreme values (meandlnB). The data for the fourteen countries are given in table 1.

The results of the regressions are presented in table 2. It is clear that volatility has a significant positive effect on the approximated threshold value. The higher the standard deviation of the growth rate of the marginal profitability of capital, the higher the critical value.

Table 2: The effect of volatility on the approximated threshold value

Dependent variable	Explanatory variables			R2
	const	sddlnB	meandlnB (*)	
bMAX	0.103 (0.063) (**)	2.918 (0.819)	1.268 (4.357)	0.536
bDEC	0.109 (0.055)	2.785 (0.755)	2.802 (3.677)	0.554
bQUIN	0.086 (0.051)	2.479 (0.795)	1.295 (4.111)	0.533

(*) meandlnB = meanmax if the dependent variable is bMAX
meandec if the dependent variable is bDEC
meanquin if the dependent variable is bQUIN
(**) numbers between brackets are standard errors corrected for heteroscedasticity

Table 3: The effect of volatility on the approximated threshold value

Dependent variable	Explanatory variables			R2
	constant	sddlnB	meandlnB (*)	
bMAX	0.101 (0.062)	2.899 (0.815)	1.052 (4.191)	0.535
bDEC	0.096 (0.057)	2.647 (0.746)	1.102 (3.840)	0.534
bQUIN	0.085 (0.050)	2.351 (0.664)	1.001 (3.416)	0.533

(*) meandlnB is the average growth rate of b over the entire time period

According to Eberly (1993), omitting the extreme values in the calculation of the average growth rate of the marginal profitability of capital might bias downwards the average change if the highest values are associated with large innovations. Therefore we re-estimated the regressions from table 2 replacing the average growth rate of b_t over periods that exclude the extreme values by the average growth rate over the entire sample period. The results are reported in table 3. This does not affect the main findings. Volatility clearly has an effect on the threshold value that is used for deciding whether to invest or not.

The value of the coefficient of sddlnB is in the range of 2.4 to 2.9. This implies that, for example, an increase of the standard deviation of the marginal profitability of capital from .01 to .02 will lead to an increase of the threshold value with 2.4 to 2.9%, which is for most of the countries not overwhelming. For Belgium the volatility (sddlnB) decreased with -.1654% from the period 78-84 to the period 85-92 resulting in an effect on the threshold value of -.4 to -.48%. This means that, if the required return during the period 78-84 was on average 20%, it will remain practically the same in the next period. For the United Kingdom the effect is more pronounced due to the high changes in volatility. It went down with 17% from period 71-77 to period 78-84, resulting in an effect on the threshold value of -40.8 to -49.3%. If the required return would have been 20% in the first period, the reduction of volatility had brought it down to 10.14 to 11.84%.

The previous results clearly show a relation between volatility and the threshold value for investing, but they tell us nothing about the relation between volatility and investment as such. This requires a more detailed analysis of the aggregation problem for which information on the distribution of the marginal profitability of capital over the firms in the economy is needed. In absence of that information little can be said on theoretical grounds about the exact relation between investment and uncertainty. In the short run one can expect that higher volatility will lead, through a higher required return, to a temporary decrease of investment. The long run effects are not that straightforward and we have to rely on empirical results to come to conclusions.

In traditional macroeconomic investment functions two important sets of variables are introduced in order to find a suitable explanation for the investment level. The first set is related to the accelerator principle and contains actual and delayed levels and/or growth rates of real GNP, GDP or value added. The second set is based on the neoclassical analysis of the investment function and contains different prices, amongst others the user cost of capital of which the interest rate is an important component. What we especially want to know is whether the level of the interest rate has a bigger or smaller influence than the volatility of the marginal profitability of capital.

Figure 2: Total fixed investment over GDP

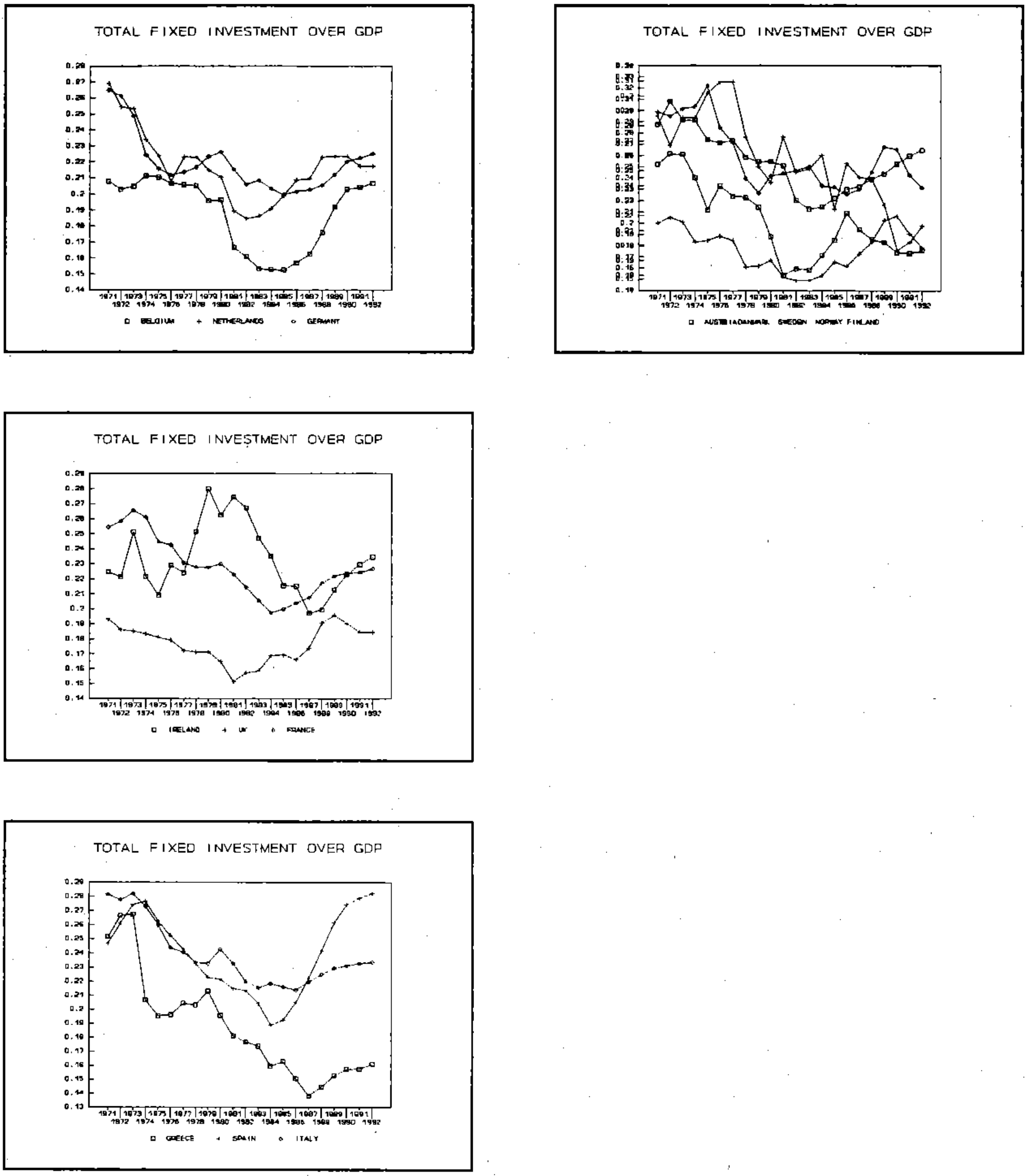
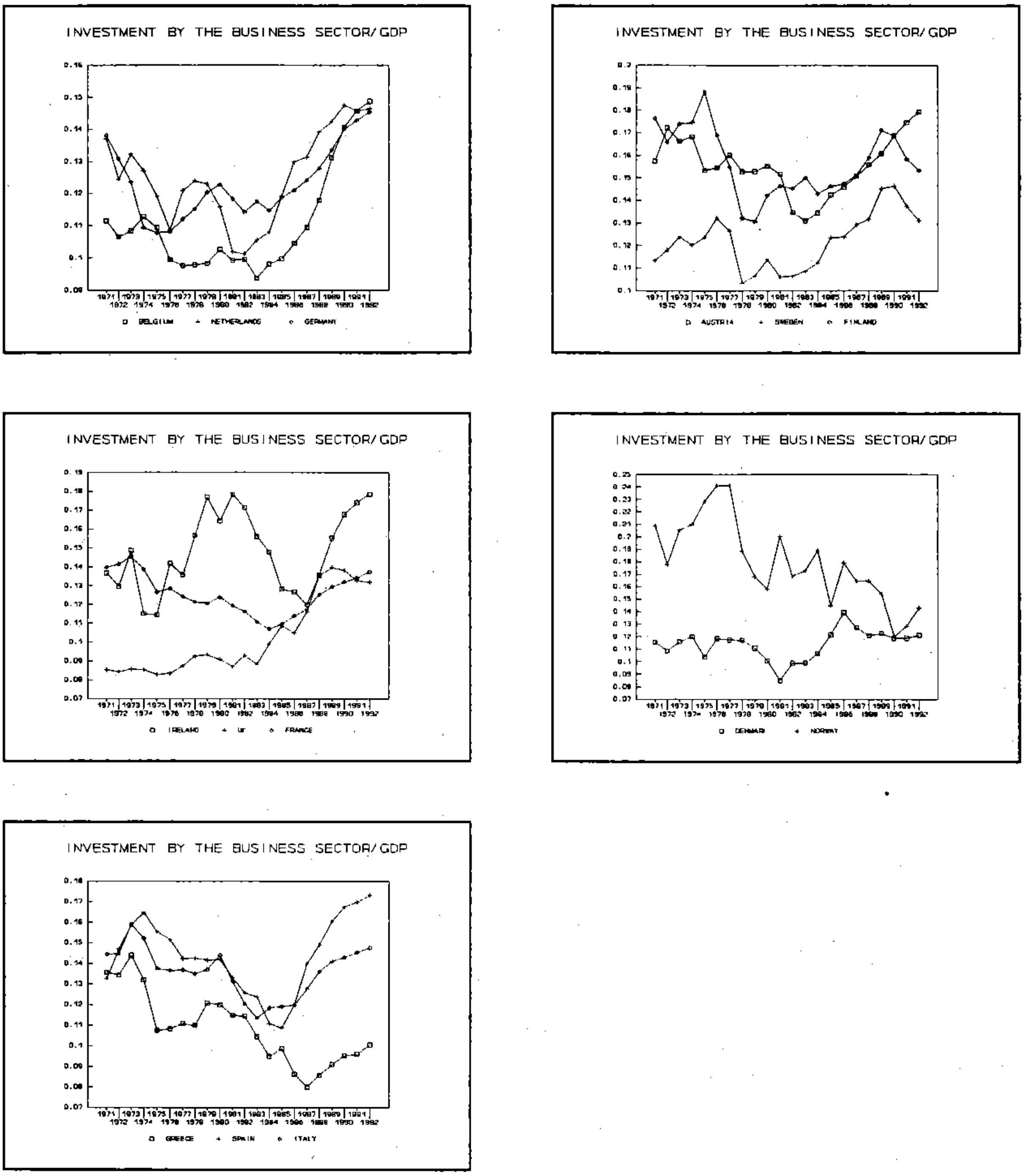


Figure 3: Business fixed investment over GDP



To have some idea of the behaviour over time of the investment function, we considered for each country three subsamples: 1971-77, 1978-84, and 1985-92. From figures 2 and 3 it is clear that in the first period, and to some extend also in the second period, most of the countries were confronted with a downward trend in the investment-output ratio. The third period is characterized by a revival which slowed down or even came to an end at the end of the period. Within this rather general pattern there are some striking exceptions. As an example it is remarkable to see how the investment-output ratio of the business sector in the UK has been going down only during the last years. It is also interesting that the investment-output ratios for Belgium, the Netherlands and Germany seem to converge at the end of the period. The main question is whether differences in uncertainty can help to explain the differences in the evolution of investment amongst the fourteen countries.

Table 4: Relation between investment and the volatility of the marginal profitability of capital

Dep. var.	Explanatory Variables								R^2
	const	lnY	dlnY	RR	RPI	RPIB	dlnB	sddlnB	
I/Y	.349 (.066)		1.492 (.469)	-.0036 (.0014)	-.148 (.062)		.0411 (.119)	-.167 (.087)	.469
IB/Y	.178 (.063)		1.348 (.408)	-.0005 (.0013)		-.075 (.059)	.0018 (.106)	-.111 (.076)	.283
I/K	.047 (.052)		1.606 (.371)	-.002 (.0011)	.028 (.049)		-.079 (.094)	-.107 (.069)	.498
IB/K	.007 (.041)		1.162 (.264)	-.0002 (.0008)		.029 (.038)	-.033 (.069)	-.075 (.049)	.418
lnI	-1.413 (.153)	.983 (.0097)	6.874 (2.248)	-.0125 (.0068)			.145 (.574)	-.923 (.418)	.996
lnIB	-2.050 (.206)	.983 (.013)	9.687 (3.040)	.0018 (.0092)			-.0356 (.777)	-1.146 (.565)	.993

Values between brackets are standard errors

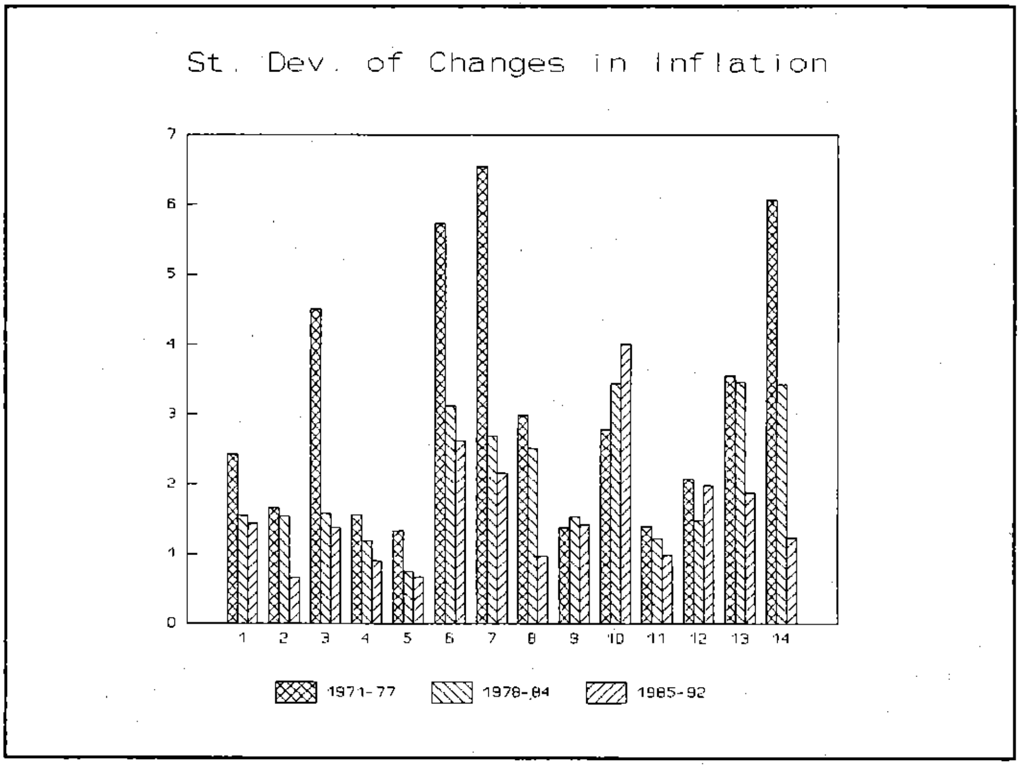
To solve this problem we estimated investment functions on pooled data over the three subperiods. For each subsample we calculated average values of the variables under consideration. As additional explanatory variables we introduced the average growth rate of the marginal profitability of capital, dlnB, and the volatility indicator, sddlnB, each calculated for each subsample. The results of the regressions on the pooled data are reported in table 4.

Allthough the explanatory power of the models differ, we still can come to some striking conclusions which are confirmed by each model. In general the conclusions of Chirinko (1993) are confirmed in as far as prices, in this case the real interest rate, RR, and the price of capital goods, RPI and RPIB, are less important than the growth rate of production, dlnY. Further we find that the average growth rate of the marginal profitability of capital, dlnB, has no effect on investment. This is not surprising given the results from tables 2 and 3 where the average growth rate has no effect on the threshold value. The effect of the volatility, sddlnB, on the other hand, cannot be neglected. It plays an important role in the investment decision and clearly has a negative impact. Increasing the volatility of the marginal profitability of capital will not only increase the threshold value but will also reduce investment.

There are some striking differences between total investment (I) and business fixed investment (IB). Concentrating on business fixed investment it is clear that volatility is much more important than the level of the real interest rate. In none of the equations for IB, the real interest rate had a significant influence. This is not the case for total investment where both the real interest rate and the volatility are important additional determinants of investment.

One of the problems with this type of research is that one has to construct in one way or another the volatility variable sddlnB. This is time consuming, vulnerable to all kinds of criticism, and finally one will allways end up with an approximation for the true values. As an alternative one can try to find other approximations for the aggregate volatility in the economy. In his analysis for the United States Ferderer (1993) used survey data on individual macroeconomic forecasts and assumed that the disperion of these forecasts across forecasters at a point in time provides a good approximation for the uncertainty experienced by the group. In absence of such surveys for all the countries under consideration, we decided to use some other approximations which are relevant for our analysis and which are quite easy to collect.

Figure 4: Volatility of inflation



1	Belgium
2	Denmark
3	Finland
4	France
5	Germany
6	Greece
7	Ireland
8	Italy
9	Netherlands
10	Norway
11	Austria
12	Spain
13	Sweden
14	United Kingdom

Figure 5: Volatility of the real interest rate

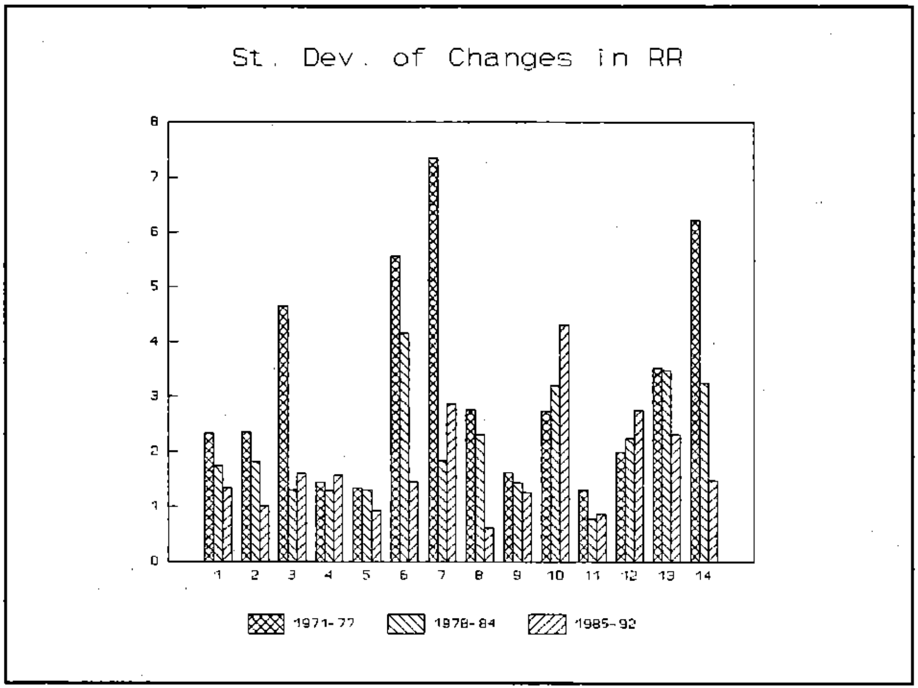
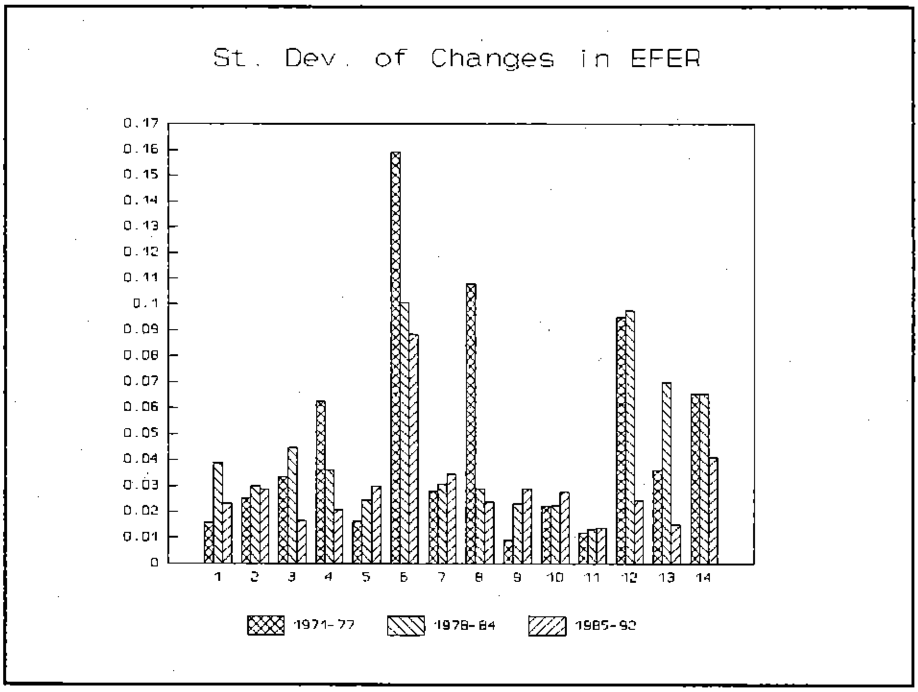


Figure 6: Volatility of the effective exchange rate



As we are interested in the effects on investment of the monetary unification in Europe, we considered for each country the standard deviations of the change in three important target variables: the rate of inflation (figure 4), the real interest rate (figure 5), and the effective exchange rate (figure 6). One might expect that the unification should reduce fluctuations in those variables and hence reduce the volatility in the economy.

Especially Greece, Ireland, Norway and Sweden have been confronted with strong fluctuations in the inflation rate. Most of the countries under consideration have seen a reduction of the standard deviation of the rate of inflation in the last two periods with the exception of Norway. This pattern can also be found in the volatility of the real interest rate. For the fluctuations in the effective exchange rate the situation is somewhat different. Extremely high values for the standard deviation can be observed for Greece, Italy, Spain, Sweden and the United Kingdom. For Greece and the United Kingdom these values remained high even during the last subperiod.

Another important reason for the choice of this variables is their correlation with the volatility of the marginal profitability of capital (table 5).

Table 5: Correlation between macroeconomic variables and the volatility of the marginal profitability of capital

Correlation between sddlnB and	
average inflation rate, INF	0.32
stand. dev. of INF	0.48
stand. dev. of change in INF	0.38
stand. dev. of change in real interest rate, SDRR	0.41
stand. dev. of change in effective exchange rate, SDEFER	0.32

The standard deviation of the inflation rate is a good indicator of the volatility. The problem however is that the correlation between this variable and SDRR and SDEFER is very strong so that we decided to leave the inflation indicators out of the models.

The average value of relative total investment and business fixed investment is represented in figures 7 and 8.

Figure 7: Total investment

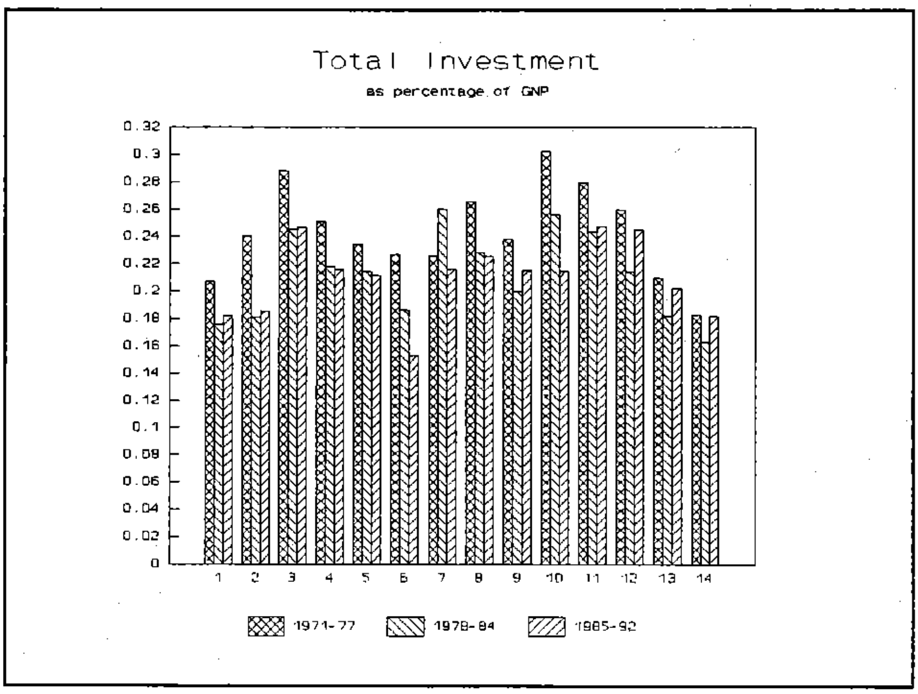


Figure 8: Business fixed investment

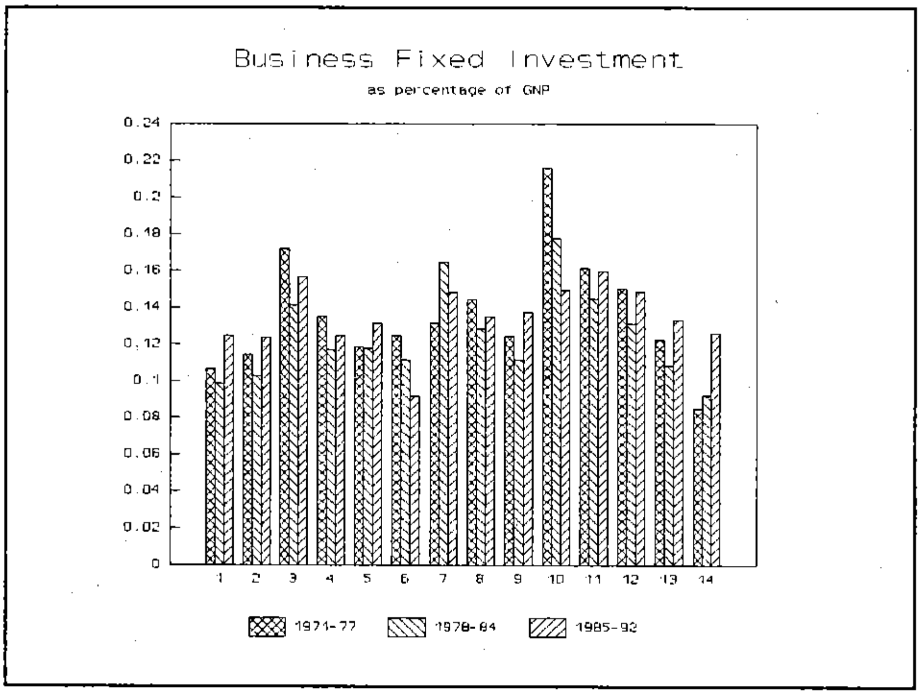


Table 6 represents the results of regressing average investment to traditional accelerator and cost indicators, and to approximations of volatility.

Table 6: Investment and macroeconomic volatility indicators

Explan. Variables	Dependent Variable			
	IY	IBY	lnI	lnIB
constant	0.221 (.017)	0.121 (.018)	-1.233 (.130)	-1.933 (.202)
lnY			0.980 (.008)	0.982 (.012)
dlnY	1.763 (.414)	1.562 (.372)	7.613 (1.783)	10.748 (2.774)
RR	-0.0054 (.0014)	-0.0017 (.0013)	-.024 (.006)	-.008 (.009)
sdefer	-0.409 (.128)	-0.318 (0.131)	-2.131 (.552)	-2.084 (.859)
srr		0.007 (.0051)		
sdrr	-0.006 (.0027)	-.005 (.0036)	-0.029 (.012)	-.025 (.019)
sdlny		-0.918 (.622)		
R^2	0.556	0.379	0.997	0.994
DW	1.75	2.16	1.97	1.92
Sum u^2	0.0189	0.014	0.337	0.816
# obs	42	42	42	42

Values between brackets are standard errors

In each of the equations the indicators of volatility have a considerable effect on investment. An increase of the volatility indicators will, ceteris paribus, result in lower investment. The most striking feature is that it is especially the standard deviation of the change in the effective exchange rate which has, of all the volatility indicators, the most significant contribution. Once again there is a difference between total investment and business fixed investment. For the latter the level of the interest rate is of no importance for the average investment, whereas volatility has a significant influence.

To have some idea of the importance or contribution of each of the explanatory variables, we calculated the so-called beta-coefficients (table 7), allthough we are well aware that in multiple regression there is no relationship between these coefficients and the partial correlation coefficients.

Table 7: Beta-coefficients for investment and macroeconomic volatility indicators

Explan. Variables	Dependent Variable			
	IY	IBY	lnI	lnIB
constant	6.52 (.017)	4.751 (.018)	0.640 (.130)	0.999 (.202)
lnY			0.998 (.008)	0.996 (.012)
dlnY	0.496 (.414)	0.584 (.372)	0.0376 (1.783)	0.053 (2.774)
RR	-0.537 (.0014)	-0.225 (.0013)	-0.042 (.006)	-0.014 (.009)
sdefer	-0.390 (.128)	-0.403 (0.131)	-0.036 (.552)	-0.035 (.859)
srr		0.332 (.0051)		
sdrr	-0.226 (.0027)	-0.295 (.0036)	-0.023 (.012)	-0.019 (.019)
sdlny		-0.245 (.622)		

Values between brackets are standard errors

It is clear that for total investment, apart of the traditional role of accelerator and cost components (here represented by the level of the real interest rate), volatility is an additional determinant. Especially strong and large fluctuations of the effective exchange rate have a negative impact on total investment.

Concentrating on business fixed investment, the results are even more pronounced. Dominating is still the accelerator effect, but the level of the interest rate is not significant any longer. On the contrary, volatility has a much stronger effect. In order to stimulate business fixed investment, the volatility of the effective exchange rate and of of the real interest rate has to be reduced as much as possible.

CONCLUSION

The aim of this paper was to identify to what extent uncertainty is important in explaining investment behaviour. The analysis put forward here has clearly shown that the application of real options theory, not only provides us with a powerful tool to analyze the theoretical relation between investment and uncertainty more rigorously, but also improves the explanatory power of investment models in practice and enables a better assessment of the likely impact of alternative (government) policy measures on macro-economic investment.

The hypothesis put forward in real options theory is largely confirmed on the empirical field by the prelimary results for a sample of Western-European countries, using pooled annual data. The results indicate that the **volatility** of major macro-economic variables such as the real interest rate, the inflation rate or the effective exchange rate (as measured by their standard deviation), tends to be as, or even more, important as their **level**. This is particularly true in explaining business sector investment.

However, these results should be handled with care because they use approximations for the marginal profitability of capital, which itself is calculated using estimated values for the production function. Furthermore, the volatility of this marginal profitability of capital itself is approximated by the standard deviation of some macro-economic indicators, the selection of which remains to some extent arbitrary.

The current lack of monthly data forced us to split up the sample period into three sub-samples with each a rather restricted number of observations. For a more reliable time series analysis of the relation between investment and uncertainty, it would be interesting to use data for interest rates, inflation and exchange rates on a monthly basis. This will also be the next stage in our research.

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APPENDIX

The data used for estimation are from the OECD Economic Outlook Historical Series from 1971 to 1992 for the following countries: Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Austria, Spain, Sweden, and the United Kingdom.

Y	Gross Domestic Product, volume
K	Capital stock, business sector, volume
L	Total Employment
w	Real Labour Cost
I	Total Fixed Investment, volume
IB	Investment by the business sector, volume
RR	Real interest rate, Long-term
RPI	Deflator for total fixed investment over GDP-deflator
RPIB	Deflator for business fixed investment over GDP-deflator
EFER	Effective Exchange Rate, BOP definition
INF	Rate of change of GDP-deflator

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