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Some Normative Implications for European Monetary Policy*

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Summary

In the current low growth environment, accompanied by a high degree of uncertainty, calls for an even easier monetary policy have gained momentum. However, our model approach – which rests on the so-called theory of the "option value of waiting" – shows that the impact of monetary policy on growth and employment is strongly diminished in an environment of high (revenue) uncertainty. This finding is actually based on the existence of sunk investment, e.g. hiring costs. Against the background of the prevailing uncertainty, our model provides three important implications for ECB monetary policy: (1) cutting interest rates is not effective as long as high uncertainty continues to prevail; (2) by cutting rates under high uncertainty, the ECB reduces the option value of waiting, thereby reducing its effectiveness in future periods; and (3) a hectic ECB monetary policy, that is frequent interest rate changes, induces additional uncertainty to the economy which would most likely aggravate the weakness of investment and consumer goods demand.

JEL-codes: D81, E52, E58

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1. Introduction

Pressure on the ECB to cut interest rates has been growing as short-term growth prospects for the euro area deteriorate. The arguments for even lower rates seem to be compelling. Inflation is now below the ECB's upper ceiling. Low growth is expected to cause downward pressure on the price level and ongoing uncertainty is assumed to dampen economic activity even further. However, a closer look at the economic implication of uncertainty suggests that demand monetary policy easing is in fact a poor strategy. This is because in times of uncertainty, as we will show, the effectiveness of monetary policy decreases greatly.

Where does uncertainty come from? It is very popular nowadays to trace uncertainty of revenues back to the events of September 11th and ensuing war against terrorism, which have shaken the hitherto prevailing geopolitical order. In addition, high uncertainty could also stem from certain macro-economic disequilibria such a, for instance, the US current account situation, the strong increase in corporate debt, corporate malfeasance etc.

To deal with the influence of uncertainty on economic decisions, economists have developed the concept of the "option value of waiting". This formalises a common-sense rule: if a decision involves some sunk costs, or any other element of irreversibility, it makes sense to wait until the uncertainty has been resolved. The temptation to postpone investment decisions is particularly strong when the uncertainty is likely to be resolved in the near future.

One can easily imagine investors assessing various investment projects. Some would be slightly profitable under the prevailing degree of uncertainty, but they would be even more profitable if uncertainty were favourably resolved (e.g., a scenario of a relatively short war period in Iraq), and would cause a loss if not (e.g., a scenario of a longer conflict by destabilising a whole region, even after war in Iraq). In such a situation, investors would lose little (in terms of forgone profits) if they postpone investment decisions: Once the uncertainty had been resolved, it would still have the option to proceed if that was to its advantage. An analogous argument applies to the consumers which might delay their decisions to buy a durable consumer good in times of uncertainty. According to the simple models, uncertainty which cannot be hedged raises the variability of revenues and induces the investors to apply a higher discount rate on (expected) future revenues. Dixit (1989) introduces an additional motive why uncertainty should hamper investment: if investments bear an irreversible sunk cost character, there is an incentive to wait until the uncertainty has resolved; this is the "*option value of waiting*".

Some months ago, it was widely believed that a war in Iraq would not have any appreciable direct consequences for the European economy due to its low degree of openness towards the Gulf region. However, the indirect effects could be substantial if the war lasted longer than expected, or if it led to a disruption of oil supplies and wider regional instability and geo-political frictions. Such an outcome could not be ruled out. This uncertainty is likely to be resolved soon, perhaps not in a matter of weeks, as the US administration maintains, but certainly in a matter of months. However, while it remains, you would expect demand – especially investment demand – to remain quite weak in the near future.

Should the ECB then not try to stimulate demand with an interest rate cut? A first argument against this approach would be that the concept of the "option value of waiting" applies to the ECB just as much as it applies to everyone else. Some months ago, it was not clear whether a war might be averted, or it might be short and have little effect on oil prices. Hence, if the ECB would have cut rates, it would have risked having to reverse its decision almost immediately. The ECB should thus cut rates only if it is convinced that such a cut will make sense even if the uncertainty is favourably resolved. A cut as an insurance against a bad outcome does not make sense, since

(1) cutting interest rates is not effective in these days due to large uncertainty,

(2) the ECB itself disposes of an option value of waiting with interest rate cuts. If the ECB cuts today, it kills this option, and

(3) a hectic activity of the ECB, i.e. frequent interest rate changes, induces additional uncertainty which aggravates weakness of investment and consumer goods demand.

The models of decision-making under uncertainty also have further important implications for monetary policy. All economic decisions involve some transaction costs – whether they are about investment, or about hiring and firing. These last are especially important in Europe. This implies that businesses facing only a small change in prices may not respond (immediately). There is always a band of inaction – a price range within which it does not pay to change course. The size of this band of inaction increases as uncertainty increases. And, given the structural rigidities in the eurozone economy, uncertainties probably affect decision-making in Europe more than they do in the US.

So, under present circumstances, a small cut in interest rates on March 6th, 2003, was unlikely to have any effect on demand. If monetary policy is to be effective in these uncertain times, a large cut would have been needed. It does not make sense to cut interest rates by 25 basis points now. Either the ECB should have cut on March 6th by at least 50 basis points, or it should have waited for the uncertainty in Iraq to be resolved. The increasingly apparent structural weakness of the European economy suggests the ECB should stay its hand. But if the ECB is not convinced of this, it should avoid cutting a little today, because that would not be a sensible compromise; in fact, it would just waste an option without helping the economy.

The current world economic climate is still characterised by high uncertainty. The example of the Iraq conflict clearly demonstrated that we even experienced some spikes of very high uncertainty (significant short-term uncertainty about the duration of war on the post-war consequences). Uncertainty can be approximated by, e.g. a high volatility of oil prices. Since there is much *'sluggishness' in labour markets,* this variability has – even the spikes are of only temporary nature – permanent negative investment / employment effects due to the relevance of 'turnover costs'. The central conclusion of this paper will be as follows: the marginal effect of lowering the central bank interest rate as the control variable on the state variables (e.g., investment / employment) is changed if we take uncertainty into account. In other words, the transmission channel of monetary policy is modified which should be taken into account by monetary authorities deciding on monetary policy issues in times of uncertainty. We refer to the current economic performance of the euro area which is characterised by low inflation and high unemployment and illustrate the option value effect based on the example of the question whether or not to lower interest rates.

2. The baseline model

In the following, we focus on the micro level and disregard aggregation issues.[1] Investments are typically characterised by large set-up costs which are often highly irreversible. These set-up costs consist of investment expenditures which cannot be resold (e.g., firm-specific investment) and the hiring and training costs for needed staff. In order to make an investment profitable, the revenues stemming from this investment project have to cover these costs.

The gross profit of an investment project, without consideration of these instalment costs, is:[2]

(1) $R_{a,t} = e_t$ (if active) , otherwise $R_{p,t} = 0$ (if passive).

with: t : time index, and
e_t : present gross revenues if the investment project is executed ("earnings", variable costs subtracted)

It is assumed that the sunk investment/hiring costs H must be spent at the moment the investment is executed.[3] It has to be noted that the parameter H can also be interpreted as anticipated scrapping / firing costs. In case of a one-time non-utilisation, we assume immediate depreciation. If the firm is inactive for only one period, the investment / staff must be completely re-set up and the hiring / investment costs must be paid anew. Since switching the state of activity leads to a complete depreciation of hiring costs, H have to be regarded as sunk costs ex post (Dixit, Pindyck, 1994, p. 8; Bentolila, Bertola, 1990; Dornbusch, 1987, pp.

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1 For an extensive formal treatment of the latter referring to exchange rate instead of revenue uncertainty see Belke, Göcke (2001, 2001a)

2 For a related trade model see Baldwin, Krugman (1989), p. 638, and Göcke (1994). In the current paper we analyse only a single firm. However, heterogeneity effects are especially important for aggregation; see Belke, Göcke (2001, 2001a). For empirical evidence of heterogeneity for Italian manufacturing firms see Guiso, Parigi (1997).

3 Investment in employment that takes 'time to build' (i.e. implementing a lead) magnifies effects of uncertainty. See Pindyck (1988), p. 973, Dixit, Pindyck (1994), pp. 46 ff.

7 ff.).[4] Specific investments in new employees close to the production process may partly be irreversible because of market regulation and institutional arrangements.[5]

The decision as to whether or not the firm should invest / hire is reached by a comparison of the expected present values of the investments with or without being active in the decision period t. In addition to the state of activity in the preceding period, the present revenues and expenditures as well as the influence of the current activity decision on the future returns must be taken into account.

Let us first introduce some important definitions relevant for an assessment of the profitability of an investment. The discount factors are defined as

$$(2) \qquad \delta_0 = \frac{1}{1+i} \quad \text{and} \quad \delta_1 = \frac{1}{1+i_1} \qquad (\text{with: } i, i_1 > 0 \Leftrightarrow \delta_0, \delta_1 < 1).$$

The expected value of long-term interest rate i_1 is assumed to be determined as follows:

$$(3) \qquad i_1 = r + \alpha \cdot (i - r) \qquad (\text{expected value of long-term interest rate } i_1)$$

with:

- i as the short-term interest rate as the "control variable" of monetary policy which is valid until the next period,
- δ_0 as the discount factor until the next period (based on i),
- i_1 as the *expected* long-term interest rate,
- δ_1 as the corresponding long-term discount factor based on i_1 , and
- r as the "base value" for the expected long-term interest rate.

The coefficient α represents the "expectation pass-through parameter" from the short-term interest rate i to the expectation with respect to the long-term interest rate i_1. Within our model of the option value of waiting, we focus on uncertainty with respect to the general revenue performance e. However, uncertainty with respect to future interest rates is not explicitly included in our model. An interesting special case analysed by Belke, Göcke (1999) emerges

$$(4) \qquad \text{for } \alpha = 1 : \quad i = i_1 \quad \text{and} \quad \delta_0 = \delta_1$$

4 We abstract from additional uncertainty over H.

5 However, one has to distinguish between specific investment as analysed in this paper and general investment, which enables the firm to cope with different situations in the future. Thus the latter type is often claimed to be positively correlated with uncertainty about revenues. See e.g. Gros (1987).

3. Decision without the option of waiting (certainty equivalent)

Let us now develop the model *without the option value of waiting* and regard the expected values as equivalents to certainty (i.e. we assume risk-neutrality). Motivated by the current scenario of low inflation in the euro area and in the US accompanied by high unemployment at least in Euroland and the often posed popular question "Why doesn't the ECB follow the Fed with interest rate cuts?", we limit ourselves to the analysis of only one of the two logically possible status quo situations, namely the case of an firm being "*passive in the preceding period*". Hence, we illustrate the main aim of an expansionary monetary policy, i.e, to give a stimulus for investment and employment by lowering financing costs.

3.1 Scenario "passive (unemployed) in the preceding period"

A previously non-active firm has two possibilities to act. Either it remains passive or it starts the investment project in period t. If it stays passive, it earns neither current nor future profits (i.e. no present value of future revenues has to be calculated).

However, a firm which enters / invests will gain the period t gross revenue $R_{a,t}=e_t$. To simplify matters, we assume an infinite horizon of investors. Since, we assume that an investor expects the same revenue for the whole *infinite future* ($e_{t+i}=e_t=e$), the present value of annuity due of future gross revenues under activity from period t+1 to the infinite future has to be calculated. In period t+1, the firm receives, if it is running the investment project, a present value of annuity due $V_{a,t+1}$:

$$(5) \qquad V_{a,t+1} = \frac{e}{1-\delta_1}$$

$(1-\delta_1)=\delta_1 \cdot i_1$ is the *rate of interest costs* in case of the annuity due (i.e., we apply a simple formula for present value of annuity due). Remember that e (without index t) is the certainty equivalent gross revenue without consideration of the interest/financing costs of sunk costs, i.e. the gross revenue per period before financing the sunk costs.

If the firm invests, it has to pay for the sunk instalment costs H to be able to earn current ($R_{a,t}$) and future profits (present value in current period t of annuity due of future revenues under activity from period t+1 on, applying the short-term interest rate i in period t: $\delta_0 \cdot V_{a,t+1}$) using equations (2) and (3):

$$(6) \qquad -H+R_{a,t}+\delta_0 \cdot V_{a,t+1} = -H+e+\frac{\delta_0 \cdot e}{1-\delta_1} =$$

$$= -H+e+\frac{e}{(1+i)\cdot\left(1-\frac{1}{1+r+\alpha\cdot(i-r)}\right)}$$

In order to calculate the entry-trigger revenue under certainty, we have to proceed as follows.[6] The firm is indifferent between remaining passive or entering if the present value of continuing non-activity equals the present value of an instantaneous investment ("entry"):

(7) $$0 = -H + e + \frac{\delta_0 \cdot e}{1-\delta_1} \quad \text{resp.} \qquad \text{(indifference)}$$

$$0 = -H + e + \frac{e}{(1+i)\cdot\left(1-\frac{1}{1+r+\alpha\cdot(i-r)}\right)} \quad \Rightarrow$$

(8) $$e^c_{entry} = \frac{(1-\delta_1)\cdot H}{1-\delta_1+\delta_0} \quad \text{resp.} \qquad (\text{entry if } e > e^c_{entry})$$

$$e^c_{entry} = \frac{H\cdot(1+i)\cdot(r+\alpha\cdot i-\alpha\cdot r)}{2\cdot r+2\cdot\alpha\cdot i-2\cdot\alpha\cdot r+i\cdot r+\alpha\cdot i^2-\alpha\cdot i\cdot r+1}$$

The firm enters if the gross revenues e exceeds e^c_{entry}. The entry decision becomes favourable if the gross revenue e covers at least the interest costs on sunk investment costs. Interest costs of entry become relevant as they have to be interpreted as an opportunity gain of staying passive. Due to the sunk hiring costs, the necessary revenue (after subtracting variable costs, "Deckungsbeitrag") is larger than null. So the required surplus over variable costs, i.e. the required gross revenue e, will be the larger the higher the sunk costs are. Entry will happen, as soon as he gross revenue covers the interest costs (i.e. approximately interest rate i_1 times H).

We now ask how the central bank can impact the profitability calculations of investors. Hence, we have to calculate the short-term interest rate i, which makes investment just worthwhile. In our model we have to differentiate between two effects of the short-term interest rate i: (1) a short-term interest payment effect during the current period t (i.e. between the start of period t and the start of period t+1) and (2) an impact on expectations of the long-term interest rate according to parameter α and, by this, on the present value of annuity due.[7] The same is valid for a monetary authority which uses the interest rate i as a control variable.

The indifference condition results according to eq. (7). If the latter is solved for the short-term interest rate i, the interest rate which triggers investment can be derived as the following root (with an entry if $i < i^c_{entry}$).

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[6] The calculation is the same for a case with certainty and for a situation with uncertainty and risk neutrality, but *without* the option to wait. In this case, the corresponding present value has to be interpreted as expected values.

[7] The long-term interest rate is placed in the denominator of the formula of the present value of the annuity due and, thus, determines the realised present value (if the long-term interest rate moves to zero, the present value converges towards infinity).

$$(9)\qquad i^c_{entry} = \frac{1}{2}\Big(-2e\alpha - er + e\alpha r + H\alpha + Hr - H\alpha r \pm \big(-2er^2H + 6e\alpha Hr - 6e\alpha^2 Hr + 4er^2H\alpha - 2e\alpha^2 r^2 H + e^2\alpha^2 r^2 - 4e^2\alpha + e^2 r^2 + 4e^2\alpha^2 + H^2 r^2 + H^2\alpha^2 - 2H^2\alpha r + 2H^2\alpha^2 r - 2H^2 r^2\alpha + H^2\alpha^2 r^2 - 4e\alpha^2 H - 4e^2\alpha r - 2e^2 r^2\alpha + 4e^2\alpha^2 r + 4H\alpha e\big)^{1/2}\Big)/(-H\alpha + e\alpha)$$

In this section, we illustrate the main aim of an expansionary monetary policy, i.e, to give a stimulus for investment and employment by lowering financing costs. However, our analysis is not complete in all respects. For example we only regard the financing costs of the *sunk* investment costs. We do *not* explicitly consider the need for financing also those fixed capital costs of the whole investment project which are *not* sunk. Implicitly, this could be taken into account in our model by an increase of e (the residual revenue before financing sunk costs). Instead, we feel justified to assume in a simplifying fashion that all investment costs are sunk due to, e.g., irreversibility. The reason is that investments are to a large extent firm-specific and thus have to be considered as sunk from an ex post –perspective.[8]

3.2 Special cases: No and/or complete pass-through of the short-term interest rate on the expected long-term interest rate

We have to consider the following special cases which are highly relevant in our monetary policy effectiveness context:

(A) The first special case consists of the assumption of $\alpha = 1$. This parameter restriction implies static expectations, i.e. a complete identity of the short-term interest rate and the expected long-term interest rate. This exactly corresponds to scenario investigated by Belke, Göcke (1999):

$$(10)\qquad \text{for } \alpha = 1:\quad i^c_{entry} = \frac{e}{H-e} > 0 \qquad\qquad \text{with}\quad H > e$$

According to eq. (10), the interest rate has to be smaller than the "internal return" of the investment project. The "internal return" can be defined as the gross revenue e divided by irreversible investment costs H minus the instantaneous revenues from the first period which instantaneously partly cover the investment costs.

(B) The second scenario is $\alpha = 0$, i.e. the current performance of short-term interest rates is meaningless for the expectation of long-term interest rates. In other words, market participants expect a "mean reversion" towards the base value r after the central bank has

8 The model was augmented by us to take account of this effect. The results become a little weaker. However, the pattern of the results stays the same. The results are available on request.

"shocked" the money market rate (at least on average in the long-run, like for instance in an error-correction model):

$$\text{(11)} \quad \text{for } \alpha = 0 : \quad i^{c}_{entry} = \frac{2e + \frac{e}{r} - H}{H - e}$$

4. The model under one-off uncertainty and the possibility of waiting

Uncertainty about future revenues, like after September 11th 2001 and before the Iraq conflict in early 2003 typically generates an option value of waiting, and therefore introduces a bias in favour of a "wait-and-see"-strategy. Since the firm's investment / employment decision can be understood as irreversible, we follow a *real option approach*. The firm's investment / employment opportunity corresponds to a call option that gives the firm the right to invest and employ, sunk investment / hiring costs being the exercise price of the option, and to obtain a 'project'. The option itself is valuable, and exercising the investment "kills" the option.

We analyse the effects of an expected future stochastic one-time shock. However, assuming a risk-neutral firm, we abstract from risk-aversion. Focusing on the impacts of uncertainty on the effectiveness of monetary policy, we further develop an idea originally proposed by Dornbusch (1987), pp. 8 f., Dixit (1989), p. 624, fn. 3, Bentolila, Bertola (1990), and Pindyck (1991), p. 1111. Option price effects are modelled in a technically sophisticated way in these references. However, based on the model by Belke, Göcke (1999), we model uncertainty effects as simple as possible, since the basic pattern ot the effects of uncertainty are left unchanged.

We assume a non-recurring single stochastic change in the gross revenues, which can be either positive (+ε) or negative (–ε) [with $\varepsilon \geq 0$, mean preserving spread]. This kind of binomial stochastic process was introduced into the theory of option pricing by Cox, Ross and Rubinstein (1979). Both realisations of the change ε are presumed to have the same probability of ½ : $e_{t+1} = e_t \pm \varepsilon$ and $E_t(e_{t+1}) = e_t$. From period t+1 on, the potential investor will be be able to decide under certainty again. The stochastic change between t and t+1 leads to an increase in the gross revenue trigger. If the latter is passed, investment becomes worthwhile. Moreover and even more important in our context, the interest rate i which makes an investment worthwhile becomes lower than in the base scenario without option value effects.

Under certainty, the relevant alternative strategies are to invest immediatetly or not. Under uncertainty and the *feasibility to delay* an investment, a third alternative has to be taken into account: the option to wait and to make the respective investment decision in the future. The option to invest in the future is valuable because the future value of the 'asset' obtained by the investment is uncertain. If its value will decrease, the firm will not need to invest and will only lose what it will have spent to keep the investment opportunity. This limits the risk downwards and with this generates the inherent value of the option.

A *previously inactive firm* has to decide whether to invest now or to stay passive, including the option to invest later. The firm anticipates the possibility of internalising future gains by an investment in t+1 if the future revenue turns out to be favourable (+ε). Besides, the firm foresees that it can avoid future losses if the revenue change will be negative (–ε) by staying passive. Waiting and staying inactive implies zero profits in t. Conditional on a, the firm will use its option to invest in t+1 causing discounted sunk investment / hiring costs $\delta_0 \cdot H$, and gaining an annuity value of $\delta_0 \cdot (e+\varepsilon)/(1-\delta_1)$. Thus, the present value in the case of a (+ε)-realisation is:

$$(12) \quad -\delta_0 \cdot H + \frac{\delta_0 \cdot (e_t+\varepsilon)}{1-\delta_1} \qquad \text{resp.} \qquad \frac{-H}{1+i} + \frac{e_t+\varepsilon}{(1+i)\cdot\left(1-\frac{1}{1+r+\alpha\cdot(i-r)}\right)}$$

For a (–ε)-realisation the firm will remain passive with a present value of inactivity being 0. Consequently, the expected present value of the wait-and-see strategy is given by $E_t(V_t^{wait})$ in eq. (13). Hence, the expected present value of the wait-and-see strategy in period t is defined as the probability-weighted average of the present values of both ±ε-realisations:

$$(13) \quad E_t(V_t^{wait}) = \frac{1}{2}\cdot\left(-\delta_0 \cdot H + \frac{\delta_0 \cdot (e_t+\varepsilon)}{1-\delta_1}\right) = \frac{1}{2}\cdot\left(\frac{-H}{1+i} + \frac{e_t+\varepsilon}{(1+i)\cdot\left(1-\frac{1}{1+r+\alpha\cdot(i-r)}\right)}\right)$$

The expected present value of an immediate investment (without re-exit) is $E_t(V_t^{entry})$:

$$(14) \quad E_t(V_t^{entry}) = -H + e_t + \frac{\delta_0 \cdot e_t}{1-\delta_1} \qquad \text{since} \quad E_t(e_{t+1}) = e_t$$

The option value of having the flexibility to make the investment decision in the next period rather than to invest either now or never, can easily be calculated as the difference between the two expected net present values: $OV(e_t,\varepsilon) = E_t(V_t^{wait}) - E_t(V_t^{entry})$, with: $\partial OV/\partial e_t < 0$, $\partial OV/\partial \varepsilon > 0$. An increase in uncertainty enlarges the value of the option to invest later. The reason is that it enlarges the potential payoff of the option, leaving the downside payoff unchanged, since the firm will not exercise the option if the revenue falls. The firm is indifferent between investment in t and wait-and-see if

$$(15) \quad E_t(V_t^{wait}) = E_t(V_t^{entry}) \qquad \text{i.e. indifference if} \quad OV = 0$$

$$\Leftrightarrow \quad \frac{1}{2}\cdot\left(-\delta_0 \cdot H + \frac{\delta_0 \cdot (e_t+\varepsilon)}{1-\delta_1}\right) = -H + e_t + \frac{\delta_0 \cdot e_t}{1-\delta_1}$$

The revenue entry trigger under uncertainty follows as (investment for $e_t > e^u_{entry}$):

(16) $$e^{u}_{entry} = \frac{2H - 2\delta_1 \cdot H - \delta_0 \cdot H + \delta_0 \cdot \delta_1 \cdot H + \delta_0 \cdot \varepsilon}{2 + \delta_0 - 2\delta_1}$$

From this equation, it becomes obvious that *uncertainty increases the probability that a firm stays passive*; since ε enter the expression in a positive way.

However, some words (and calculations) of *caution* seem to be justified at this stage of analysis. Our assumptions with respect to entry and exit for (+ε) respectively (–ε) are of course only valid, if investors really enter the market in period t+1, if (+ε) is realized and if there is really no entry in t+1 in cases of realisation of (–ε). A firm's entry in period t+1 happens only if the trigger under certainty $e^{c,t+1}_{entry}$ is passed. Since the calculation of the option has to be based on assumptions which are dynamically consistent, an additional condition for the size of the shock ε [see eq. (18) below] becomes necessary. Mathematically, the necessary condition for this can be calculated as follows (assumption):

(17) $$0 = -H + e^{c,t+1}_{entry} + \frac{\delta_1 \cdot e^{c,t+1}_{entry}}{1 - \delta_1} \quad \Leftrightarrow \quad e^{c,t+1}_{entry} = (1 - \delta_1) \cdot H$$

(18) $$\varepsilon > \varepsilon_{min} \qquad \text{with} \qquad \varepsilon_{min} = \frac{(1 - \delta_1) \cdot (\delta_0 - \delta_1) \cdot H}{1 - \delta_1 + \delta_0}$$

This result implies that normally, ε has to be a little bit larger than zero (in fact by not too much, since the difference $(\delta_1 - \delta_0)$ in the numerator is not too large). In the case of the significant kind of uncertainty analysed in this paper (September 11th and Iraq conflict) this assumption should be valid anyway. Approximately this condition implies that ε has to be larger than zero. In the special case $\alpha = 1$ (i.e. $\delta_0 = \delta_1$) the following relation holds exactly:

(19) $$\text{for } \alpha = 1 : \quad \varepsilon_{min} = 0 \quad \Leftrightarrow \quad \varepsilon > 0.$$

In this case ($\alpha = 1$) the profit trigger e^{u}_{entry} under uncertainty and the option of waiting converges to the trigger calculated for the case without the option of waiting e^{c}_{entry} ("c-trigger") if the size of the shock ε converges to zero.[9] Insofar as assumption (18) of a minimum realisation of ε is valid, the following relation holds (which can be shown mathematically, proof is available on request):

(20) $$\text{If } \varepsilon > \varepsilon_{min} \quad \text{then} \quad e^{u}_{entry} > e^{c}_{entry}$$

Hence, uncertainty leads to a *higher revenue entry trigger* which by itself causes a *more resistant investment behaviour* which the central bank has to take into account when

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9 If α is not equal to one, this is valid only approximately. This is due to the following. If we calculate the option value, in the formula of the present value in case of activity (realisation of +ε) only δ_1 is used for discounting, whereas in the case of immediate entry under certainty in the first period t the discount factor δ_0 (i.e., the short-term interest rate i) has to be applied. If α is smaller than one, there is a difference between i and i_1. However, these considerations are not decisive, if ε reaches the minimum level calculated before.

measuring out its intended interest rate changes. However, the final aim of our calculations is to identify the interest rate entry trigger which is of central importance for the central banks as a benchmark for interest rate setting in times of uncertainty.

The short-term interest rate threshold which makes investment worthwhile (and thus triggers off investment activity) under revenue uncertainty can from the indifference condition given in eq. (15) be calculated as follows:

$$(21)\quad i^{u}_{entry} = \frac{1}{2}\Big(H\alpha + 2e\alpha r - 3e\alpha - 2H\alpha r - 2er + 2Hr + \alpha\varepsilon \pm \big(-8er^2H + 16e\alpha Hr - 16e\alpha^2Hr + 16er^2H\alpha - 8e\alpha^2r^2H + 4e^2\alpha^2r^2 - 8e^2\alpha + 4e^2r^2 + 9e^2\alpha^2 + \alpha^2\varepsilon^2 + 4e\alpha r\varepsilon - 4e\alpha^2r\varepsilon + 4H^2r^2 + H^2\alpha^2 - 4H^2\alpha r + 4H^2\alpha^2r - 8H^2r^2\alpha + 4H^2\alpha^2r^2 - 6e\alpha^2H - 6e\alpha^2\varepsilon - 8H\alpha\varepsilon + 2H\alpha^2\varepsilon - 4H\alpha r\varepsilon + 4H\alpha^2r\varepsilon - 12e^2\alpha r - 8e^2r^2\alpha + 8e\alpha\varepsilon + 12e^2\alpha^2r + 8H\alpha e\big)^{1/2}\Big)/\big(-2H\alpha + 2e\alpha\big)$$

The calculation of the interest rate entry trigger is simpler in the special cases of the parameter restrictions $\alpha = 1$ and $\alpha = 0$. Let us start now with the calculation of the interest rate entry trigger when the *first* kind of restriction is relevant (for $\alpha = 1$):

$$(22)\quad \text{for } \alpha = 1: \quad i^{u}_{entry} = \frac{1}{4}\frac{H - 3e + \varepsilon \pm \sqrt{H^2 + 2eH - 6H\varepsilon + e^2 + \varepsilon^2 + 2e\varepsilon}}{-H + e}$$

Like in the case of the revenue trigger for $\alpha = 1$, this result converges towards the result under certainty if ε moves towards zero.

The interest rate entry trigger when the *second* type of restriction is relevant (for $\alpha = 0$) can be calculated as follows:

$$(23)\quad \text{for } \alpha = 0: \quad i^{u}_{entry} = \frac{1}{2}\frac{r(-H + 3e - \varepsilon) + e - \varepsilon}{r(H - e)}$$

Hence, uncertainty leads not only to a higher revenue entry trigger, but also to a ***lower** interest rate entry trigger*.[10] Hence, a central bank has to take an area of non-reaction into account when thinking about lowering its interest rate. In this sense, monetary policy becomes less effective.

Starting for instance with a model with two successive stochastic revenue changes [as conducted by Belke, Göcke (1999) for successive exchange rate changes], our analysis could be extended by adding more periods of uncertainty which induces the calculation of additional option value effects. This implies a repeated backward induction along the lines taken above,

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10 In eq. (23) this will result, if total amount of the sunk investment is higher than one-period profits (H > e). The condition should be valid for a marginal investment project.

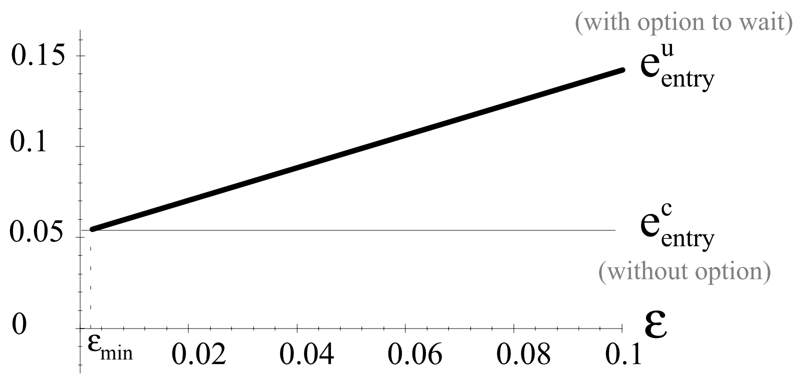
but this would be a hard way to walk. Another possibility is the transition to continuous time models with permanent uncertainty. However, we dispense with the use of the latter, since it implies the application of advanced mathematical tools (e.g. Ito's lemma) without leading to significant additional insights concerning our research purposes.[11]

5. Numerical examples

In order to convey an idea of the impacts of the underlying model and to illustrate our results, we calculate two simple numerical examples. In the first example we let the hiring and firing costs be quite large with an eye on the fact that in the euro area institutional rigidities may lead to such high realisations of H.[12] We take the short-term interest rate given as $i=2\%$ and the "base value" for the expected long-term interest rate as $r=10\%$ per period. The parameter α is set to 0.5, i.e. the expected long-term interest rate corresponds to an arithmetic average of the short-term interest rate and the "base value" r for the expected long-term interest rate. Later on, we compare the results for $\alpha=0.5$ with the special cases of $\alpha=0$ (second example) and $\alpha=1$ (third example).

First scenario: $\boldsymbol{\alpha = 0.5}$ **;** **H = 1** *(normalized)* **;** **r = 0.1**
$e^c_{entry} = 0.05458437389$; $e^u_{entry} = 0.05277401895 + 0.8964817321\,\varepsilon$
$\varepsilon_{min} = 0.002019399700 < \varepsilon$

Fig. 1: Gross profit trigger e^u_{entry} dependent on uncertainty / shock size ε
[first scenario ($\alpha=0.5$), infinite time-horizon, $i=0.02$]

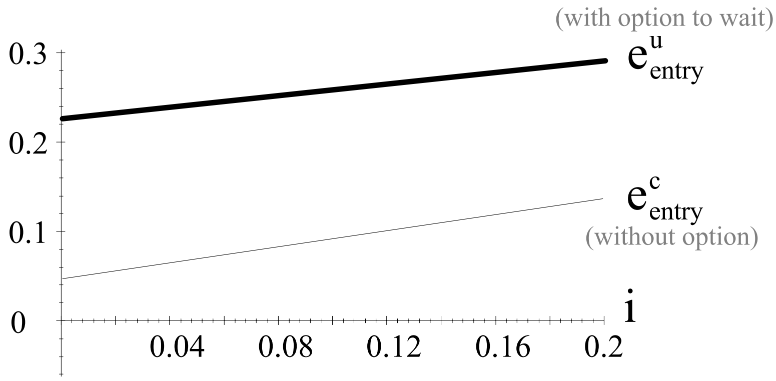


[comment: the higher uncertainty ε,
the higher is the profit e which is necessary for triggering an entry/investment.]

[11] For an application of continuous time models in a related context see Darby et. al. (1997), Calcagnini, Saltari (1998), Dixit (1989), pp. 624 ff., Dixit, Pindyck (1994), pp. 59 ff., and Pindyck (1991), pp. 1118. Adding further periods of uncertainty will lead to a further widening of the band of inaction. However, these additional option value effects will be the smaller the more far in the future the uncertain shocks will occur, since the effects of the shock are discounted more and more. Thus, even in the case of a permanent uncertainty, the option value effect would not be infinitely large, but converges towards an upper bound. See e.g. Dixit (1989) for a model with permanent uncertainty and a limited width of the band of inaction.

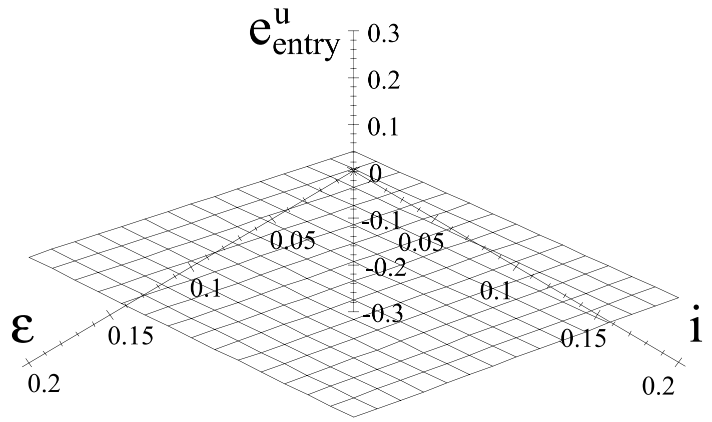
[12] For lower values of H in the US case see Krugman (1989), p. 57.

Fig. 2: Entry trigger profit under uncertainty e^u_{entry} dependent on short term interest rate i [first scenario ($\alpha = 0.5$), and "uncertainty" $\varepsilon = 0.2$]



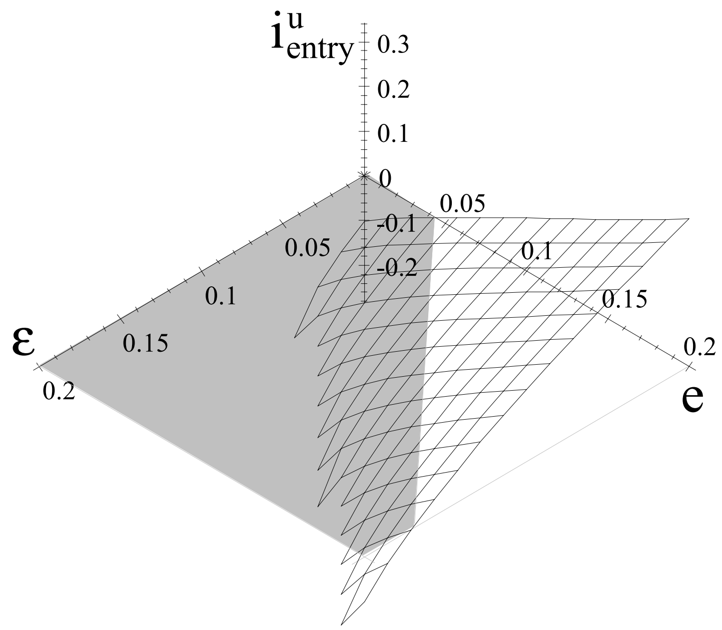
[comment: the higher short term interest rate i, the higher is the profit e which is neccessary for an entry / investment. However, the effect of short term interest rate on trigger profit under uncertainty is relatively weak.]

Fig. 3: e^u_{entry} dependent on ε and i [first scenario ($\alpha = 0.5$)]



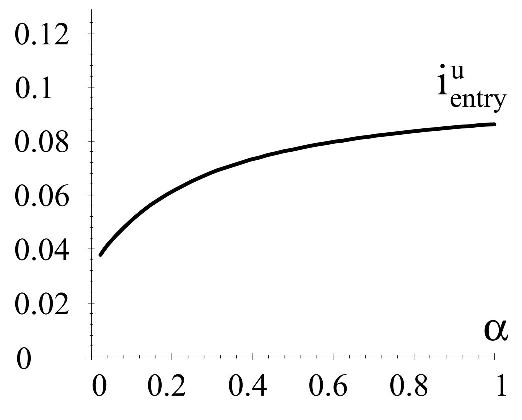
[comment: the lower short term interest rate i and the lower uncertainty ε, the lower is the profit e which leads to an entry/investment.]

Fig. 4: Interest rate entry trigger i^u_{entry} dependent on gross profit e and uncertainty ε
[first scenario ($\alpha = 0.5$)]



[comment: in a situation with high uncertainty and low gross profits,
interest rates have to be very low in order to induce an entry/investment.
***Grey area**: combinations of ε and e, where a non-negative short term interest rate is not compatible with an investment, i.e. monetary policy is not effective in a situation with uncertainty and low profits]*

Fig. 5: Interest rate entry trigger i^u_{entry} dependent on pass-through parameter α
[except α: first scenario and revenue $e = 0.25$, uncertainty $\varepsilon = 0.2$]



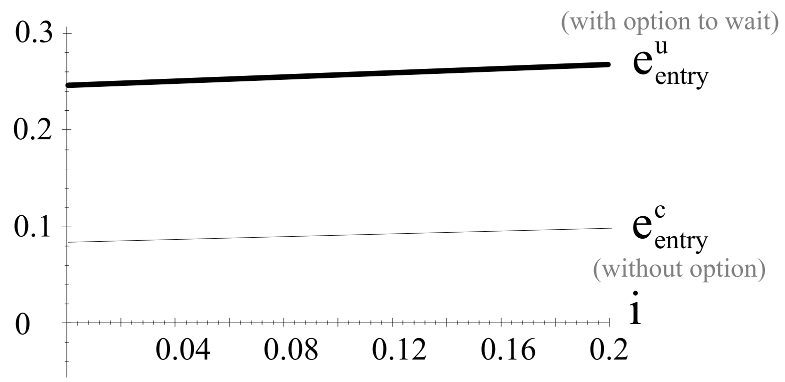
[comment: the higher the pass-through parameter α of short term to long term interest rate,
the lower is a necessary reduction of the short term interest rate i resulting in an entry/investment.
I.e. the higher α, the more effective is an interest rate reduction.]

Second scenario: $\boldsymbol{\alpha} = \mathbf{0}$ (other: see first scenario)

$e^c_{entry} = 0.08485856905$; $e^u_{entry} = 0.07975460122 + 0.8435582822\,\varepsilon$

$\varepsilon_{min} = 0.006050521857 < \varepsilon$

Fig. 6: Entry trigger profit under uncertainty e^u_{entry} *dependent on short term interest rate i [second scenario* ($\alpha = 0$)*, and uncertainty* $\varepsilon = 0.2$ *]*



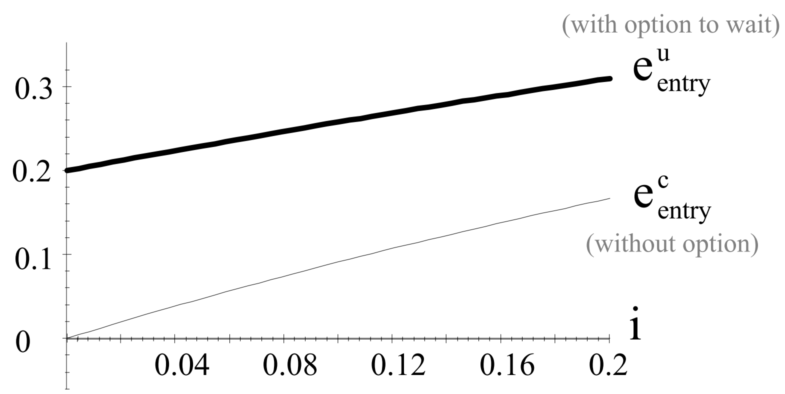
[comment: in a situation without any spill-over of short term interest rate i on expected long term interest rate, the impact of short term interest rate is very weak, i.e. monetary policy is very ineffective.]

Third scenario: $\boldsymbol{\alpha} = \mathbf{1}$ (other: see first scenario)

$e^c_{entry} = 0.01960784314$; $e^u_{entry} = 0.01960784314 + 0.9615384615\,\varepsilon$

$\varepsilon_{min} = 0 < \varepsilon$

Fig. 7: Entry trigger profit under uncertainty e^u_{entry} *dependent on short term interest rate i [third scenario* ($\alpha = 1$)*, and* $\varepsilon = 0.2$ *]*



[comment: in a situation with a complete pass-through of short term rate to long term interest expectation, we have a strong impact of i on the entry-trigger profit. However, this effectiveness is again weakened by uncertainty in a situation with the option to wait.]

Taking into account the option values induced by revenue uncertainty implies an amplification of 'band-of-inaction' / hysteresis effects. Our theoretical results are compatible with recent empirical studies, which show that option values can be large. Hence, monetary policy actions which rely on investment rules that do not take the latter into account can be very misguided.[13]

6. Conclusions

In this paper we model the impact of uncertainty on the effectiveness of monetary policy. We set up a model which leads to hesitant investment / employment decisions due to sunk investment-/ hiring-costs is proposed. This 'weak' relationship ('band of inaction') between investment / employment and the interest rate as its determinant is augmented by revenue uncertainty. As a result of option value effects the relationship between the interest rate and the investment is strongly weakened by uncertainty (as numerical examples demonstrate). Thus, monetary policy may be very ineffective in an uncertain economic environment.

The model proposed before was based on a *risk-neutral single-unit* investment / employment decision under revenue uncertainty induced by revenue (step) volatility and fixed *sunk (i.e. irreversible)* investment and hiring costs. In principle, it can be compared to other models were an irreversible investment decision is analysed. In contrast to similar work in that area we did not rely on the asymmetry of adjustment costs (Caballero, 1991) and on scrapping values (Darby et. al., 1997), since we analysed also 'investments' in employment and did not focus only on real capital investments. Additionally, the degree of competition in the output market and economies of scale (Caballero, 1991) did not play a predominant role since we analyse a single-unit decision.

As an *example*, we felt justified to ascribe revenue volatility solely to the events of September 11th and the Iraq conflict. However, since uncertainty ε was included additively in the revenue function it was straightforward to interpret ε as an all comprising expression of uncertain revenues like, e.g., disequilibria of the US economy since the turn-of-year 2000/01 (current account, consumer financial position, over-investment). Moreover, the relation (including the 'band-of-inaction' characteristic) between investment / employment and all its determinants (not only interest rates but also e.g. the wages and the oil prices) was affected by uncertainty. Thus, the impacts implied by sunk costs and uncertainty are manifold. We only calculated interest rate triggers, holding other determinants of investment / employment constant. Summarising, compared to the prediction of the majority of models of monetary policy transmission, real world investment / employment may appear less sensitive to changes in the interest rate, due to uncertainty.[14]

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13 See e.g. the studies cited by Dixit, Pindyck (1994), p. 7.

14 In order to derive macroeconomic implications which are empirically testable Belke, Göcke (2001, 2001a) deal with the aggregation of the approach proposed in this paper. They assume that the firms have different exit ("disinvestment") and entry ("investment") triggers. Special attention is paid to the problem of aggregation under uncertainty. It is shown that under uncertainty 'bands of inaction' have to be considered even at the macroeconomic level. Due to the similarities of the macro relations under uncertainty to the micro behaviour derived in this contribution our micro-approach can serve as a first base for empirical tests.

How do our formal considerations fit with the monetary policy strategy of the ECB in reality? According to its two-pillar strategy, the rationale for the ECB for taking investment / employment demand functions into account when deciding on interest rate cuts is to support general economic policy in times of low inflation. Moreover, empirical evidence as a stylised fact comes up with the result that Taylor-rule type monetary policy reaction functions describe the actual behaviour of the ECB quite well. Till the unforeseeable future, the ECB will be confronted with an unusually highly uncertain environment. First, many of the underlying causes of world wide uncertainty do not seem to be resolved, although the Iraq conflict itself was terminated unexpectedly early. Second, it cannot be excluded that the effects of the quick termination of war actions in the Gulf region are more than compensated by an increase in uncertainty with respect to the shape of the post-war world order. As long as uncertainty stays relevant, the approach of the option value of waiting should be relevant for the monetary policy of the world's leading central banks.

In the light of the results of the paper, the remarks on the ineffectiveness of monetary policy made in the introduction are corroborated in a subtle sense. Under the presumption of a net reduction of revenue uncertainty, the investment / employment impacts of a lower interest rate level continue to be twofold. A reduction of uncertainty, e.g. after the end of the Iraq conflict, will lead to a contraction of the band of inaction. Thus, the interest rates triggering investments need not to be as low as before. Hence, the effectiveness of expansionary monetary policy via cutting interest rates is increased (lowered) by a low (high) degree of uncertainty.

How do the theoretical results gained in this chapter fit with current issues in European monetary policy? To anticipate the answer, it gives an answer to one important question often addressed in the public: Did the ECB systematically follow the US Federal Reserve in setting interest rates? However, it is difficult to document "conventional wisdom" because it seems so obvious to everybody that few bother to actually provide evidence for it. While many seem to be convinced that the ECB does follow the Fed, few seem to ask the obvious question: why should the ECB follow the Fed? The simplest explanation would be that moves by the Fed provide the ECB with an important signal (about the state of the US economy and financial markets). One implication of this explanation would be that the ECB should follow the Fed almost immediately because it would not have any reason to delay its move once the signal has been given. One could thus account for the episode related above (e.g., Begg et al. 2002, p. 42). The problem with this argument is that it implies that then the Fed should also follow the ECB because the euro area is of a similar size as the US economy. However, nobody seems to suggest that the Fed might also follow the ECB.

Another explanation might be that the US cycle precedes that of the euro area so that the ECB might appear to follow the Fed, but in reality it just reacts to the evolution of the euro area's cycle, which happens to lag that of the US. The problem with this explanation is that leads and lags in macroeconomic variables like output and employment are usually measured in months or quarters (Begg et al. (2002), pp. 41 ff., estimate the lag at 3-5 months), whereas the ECB is usually assumed to follow the Fed within a much shorter time frame (see, e.g., the events after September 11th, 2001). Finally, recent research clearly demonstrated that the impact of the US business cycle has become significantly weaker throughout the nineties as compared to the seventies and eighties. This is mainly due to the emergence of multinational firms which can afford to stick to longer-term strategies independent of business cycle troughs. Hence, this approach is also not well-suited as an explanation for the "leader-follower" pattern.

Perhaps the most popular explanation why the ECB might follow the Fed is that the ECB is simply slow and inefficient. This explanation would roughly run as follows: The world's financial markets were buffeted over the last years by the emergence and then the bursting of an asset price bubble. The leadership of the Fed (Mr. Greenspan in particular) is simply smarter and was quicker to spot the problems. After the Fed's surprise half-point rate cut on 3 January 2001, the markets have clamoured for a cut by the ECB providing numerous unfavourable comparisons between the Fed chairman and his European counterpart. By contrast, so the story seems to go, the ECB is a new institution that still has to find its ways, and its decision making body is too large to come to quick decisions, especially given that it usually tries to forge a consensus before moving (Wyplosz, 2001).

Another explanation which we strongly favour in this paper could be grounded in a fundamental difference between the US and the euro zone economies: namely that the US economy is more flexible. This has important implications especially in times of heightened uncertainty. This can be seen most easily through the concept of the "option value of waiting". This concept formalises a common sense decision rule: if a decision involves some sunk costs, or any other element of irreversibility, it makes sense to postpone the decision until the uncertainty has been resolved. The temptation to postpone investment decisions is particularly strong when sunk costs are high and when the uncertainty is likely to be resolved in the near future. One can imagine in particular enterprises that have to consider normal investment projects, i.e. projects that would be slightly profitable under current circumstances and even more profitable in case the uncertainty is resolved in a positive sense, but would lead to losses if the uncertainty is resolved in a negative sense. In this case the enterprise would loose little (in terms of foregone profits) if it waited with the decision. Once the uncertainty has been resolved it would still have the option to proceed if the outcome is positive.

The concept of the "option value of waiting" has relevance to ECB monetary policy. If, during times of unusual uncertainty, rate cuts today it risks having to reverse its decision soon. The ECB should thus cut today only if it is convinced that such a cut would make sense even if the uncertainty is resolved in a positive way. In this sense, monetary policy is not a game of "follow my leader", but of setting the right policy in the light of domestic inflation and growth prospects (Gros, Belke, 2003).

As transactions costs (which are effectively sunk costs) are more important in the euro area than in the US it follows that for the ECB the option value of waiting for more information should be higher and might thus explain why the ECB is slower to react to signals than the Fed. However, the problem with this explanation is that it should hold only for periods when volatility is temporarily higher than usual because the option value argument is valid only if the uncertainty is resolved (diminished) after a certain period. The option value of waiting argument should thus apply only when financial markets are "excessively" turbulent. We find some evidence for this hypothesis in the sense that we find that it is mainly after September 2001 that the Fed seems to influence the ECB (and not vice versa). Hence, the ECB was right and acted rational in withstanding the pressure for an easier monetary policy for some time.

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