9. MACROECONOMIC UNCERTAINTY AND INVESTMENT – EMPIRICAL ANALYSIS FOR ROMANIA[1]

Corina SÂMAN*

Abstract

From a theoretical point of view, uncertainty may have an impact on investment by different channels and in different directions. Thus, the sign of its overall effect is unknown and could be found only empirically from the historical data. This paper analyzes the relation between macroeconomic uncertainty and total investment in Romania over the period 2000-2008. As a source of uncertainty, it considers different measures of volatility in prices and exchange rate from autoregressive conditional heteroskedastic (GARCH) models. These measures are introduced as a linear and a quadratic term in the investment equation. The results prove a nonlinear effect of uncertainty on investment.

Keywords: investment, uncertainty, irreversibility, economic instability, inflation, exchange rate

JEL Classification: E22, C22

Introduction

The impact of uncertainty and instability on investment was studied from a theoretical point of view through different channels and under various assumptions on risk aversion, costs to acquisition and other factors (Abel and Eberly, 1999, Pindyck and Solimano, 1993, Caballero, 1991).

The conclusions envisage effects in opposite directions depending on the economic assumptions made (such as perfect competition and constant return to scale in Caballero, 1991 or the degree of risk aversion, the convexity of the profit function and the distribution of risk in Zeira, 1990), the source of uncertainty and, also, depending

[1] This paper is part of the program : "Modelling and assessing the impact of direct investments, national and international, on labour market and macroeconomic evolutions of Romania", Contract MEC 91-052/ 10 September 2007

* *Institute of Economic Forecasting, email: csaman@ines.ro.*

on the investment model chosen to test the effect of uncertainty and for the empirical models the data used.

The recent theoretical studies present the effect of uncertainty on investment depending on the value of uncertainty: for low levels of uncertainty the effect is positive and negative for high levels, showing the investment-uncertainty relationship as non-monotonic and, probably, represented as an inverted U-curve.

Empirical studies on uncertainty and investment are mostly single country studies focusing on the U.S. and the U.K., plus some cross-country papers. They are not conclusive in their assessment of the impact of uncertainty on investment, although the majority does find a negative association. Thus, Federer (1993) finds a negative effect of uncertainty on the US equipment investment and Price (1995) finds also a negative impact on the U.K manufacturing investment, Aizenman and Marion (1995) suggest a negative relation between different indicators of economic instability and private investment in a cross-country study.

In most cases, however, these studies see the investment-uncertainty relationship as linear; only some recent works (Lensink, 2002) suggest that this relationship might be non-linear.

This paper intends to evaluate the impact of uncertainty on total investment for Romania, over the years 2000-2008, in the context when some other factors are empirically associated with investment. It derives the uncertainty measure by the conditional standard deviation of inflation and exchange rates from the generalized autoregressive conditional heteroskedasticity (GARCH) specification of Bollerslev (1986).

Investment, Uncertainty and Instability

This paper aims to explore the link between uncertainty and the level of aggregate investment. To do this, it studies the relationship between the monthly conditional variance of some economic indicators of instability and the level of investment. This allows capturing the effect of instability through channels other than the volatility of marginal profitability of capital.

I consider two such indicators of instability: the volatility of prices and those of exchange rates. These instability measures could affect the investment in different ways.

Inflation is often considered as a global measure of macroeconomic state and, therefore, the volatility of its unpredictable component can be seen as an indicator of macroeconomic instability.

A high level of inflation and its volatility could indicate the inability of the government to control the economy (Fischer, 1993), hence, the macroeconomic policies will be perceived by the investors as risky and the level of investment may diminish: inflation and investment will be negatively correlated. Also, a high level of inflation is associated with an increased marginal profitability of capital and volatile relative prices, therefore, the inflation-investment relationship could be positive.

The exchange rate is linked with the profitability of investment in export-oriented activities or in those depending on imports. Under *ceteris paribus*, the increased volatility of exchange rate diminishes the impact of price signals on relative profitability of investment across sectors, affecting the investment decisions.

Uncertainty Measures

It is necessary to separate sample variation from what we want to measure, the real uncertainty that influences the investment decisions. The first measure can overestimate the second by including not only the unpredictable changes in the variables, but possibly also the changes predictable from the variable's recent history.

The principal directions in the evaluating uncertainty (Lensink, 2002) are: (i) standard deviation of the variables, (ii) dispersion of the unpredictable part of a stochastic process, (iii) generalized autoregressive conditional heteroskedasticity model of volatility (GARCH).

The volatility of three key macroeconomic variables as source of uncertainty was considered: prices volatility resulting from log indices of CPI (*Uc_inf*), the volatility of USD/RON exchange rate (*Uc_usd*) and that of EUR/RON (*Uc_euro*), as well as the first principal component of the three volatilities considered (*Uc_pc*).

I constructed the uncertainty measure as the conditional standard deviation of the innovation to each of the variables considered resulting from a GARCH model with no other regressors than lags of the dependent variable. Therefore, the uncertainty could be considered as the variance of the unpredictable part of a GARCH process.

More precisely, a GARCH(1,1) model can be describe by the following equations:

$$Y_t = X_t^{'}\theta + \varepsilon_t \tag{1}$$

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \tag{2}$$

where: Y_t represents the variable whose volatility we want to evaluate and σ_t^2 is its conditional variance at moment t obtained on the basis of past information, a function of three factors:

- the constant term ω ;
- news about volatility from the previous period, the ARCH term given by the volatility from previous period measured as the lag of the square residual from equation (1), ε_{t-1}^2 ;
- The term GARCH, last period's forecast variance, σ_{t-1}^2 .

The GARCH(1,1) model could have some problems:

(i) equation (1) could present serial correlation for residuals;
(ii) some supplementary ARCH effect could be present.

The first problem is solvable by adding more autoregressive terms for Y in (1) if the p-value of the Ljung-Box Q-statistic is below 0.05. Also, from the Lagrange multiplier test LM, if some supplementary ARCH effects exist the equation (2) will be modified accordingly:

$$\sigma_t^2 = \omega + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \sum_{i=1}^{p} \alpha_j \varepsilon_{t-i}^2 \qquad (2')$$

where: q represent the order of the moving average ARCH terms.
Thus, we extend the model to GARCH(q,p).
The $\mathbf{X_t}$ variables are lags of Y.
The data used in the GARCH models are the daily exchange rates from the period November 1999-November 2008 and the monthly inflation rate expressed as the log of the relative consumer price index. Since the data used in evaluating the uncertainty-investment models has a monthly frequency, I construct the volatility measures with the same periodicity, by calculating the arithmetic mean of the conditional standard deviation of the exchange rates.
Table 1 presents the q and p parameters, the values of probability for the residual ARCH effects and the p-values for the Ljung-Box Q-statistic and the mean and standard deviation for entire sample of Uc_ variables.

Uncertainty and Investment: Empirical Analysis

In order to analyze the empirical link between investment and the measures of uncertainty considered I present in Table 2 the correlation between them.
The most striking aspect in this table is the negative correlation of investment with the majority of these measures of uncertainty, except for the volatility of USD/RON exchange rate. The similarity in magnitude and sign between the level of correlation of investment with unpredictable component of volatility of inflation and the EUR/RON exchange rate, the opposite sign in the case of USD/RON exchange rate, respectively, raises the question about the extent to which the latter brings new information and the first contains common information. To observe the global effect of these variables, I constructed a different measure of uncertainty by extracting the first principal component of the three volatilities considered.
One could not evaluate the impact of uncertainty on investment independently of other important factors of investment, as the growth rate of GDP, the real interest rate or the price of capital goods. Ignoring such factors leaves open the question whether the uncertainty has an independent impact on the aggregate investment.
The empirical equation of the evolution of investment considered in this paper is:

$$I_t = f(I_{t-1}, \mathrm{X}_t, \sigma_t) + u_t \qquad (3)$$

where: I is the logarithm of aggregate investment, σ is a vector of the variables measuring the uncertainty, $\boldsymbol{X}$ represents a series of investment determinants, *u* is a random disturbance and f is a linear function.

The vector $\boldsymbol{X}$ includes the log of current GDP, its lags to capture the accelerator effect, lags of I, and two variables measuring the cost of capital goods: the real interest rate IR (log of (1+i)/(1+inf)), where i is the nominal interest rate and inf is the inflation rate).

The equation (3) poses the complication of simultaneity, as some columns of $\mathbf{X}$ may be jointly determined with investment. This is very probable for GDP, but it could occur for the cost of capital variables or the measures of uncertainty.

The standard procedure of estimation requires defining some instrumental variables to correct the problem of endogeneity of the columns of **X** and, also, to correct the correlation between dependent variable and residues. Since the problem of finding instruments strictly exogenous is difficult, there is a common practice to use as instruments the lags of the variables. Particularly, if one considers that $E[u_t \mid \mathrm{X}_t] = 0$, then the second and higher-order lags of columns of **X** can be used as instruments in estimating (3). This condition is likely to be fulfilled if u_t is not serially correlated.

Using these instruments, the GMM estimation procedure (generalized method of moments) is efficient. For estimating the equation of investment, one supposes that all variables have a high-order level of endogeneity (due to the monthly frequency of series) and, therefore, considers as instruments variables lags from interval [-5, -1].

Estimation is made using the Newey-West HAC heteroskedasticity and autocorrelation consistent covariance estimates, which does not change the point estimates of the parameters, but only the estimated standard errors.

The estimated equations (one for each measure of uncertainty) are:

$$I_t = \alpha I_{t-1} + \beta PIB_t + \gamma PIB_{t-1} + \delta IR + \pi_i Uc\_i + \varepsilon_t \tag{3'}$$

where: $i \in \{\inf, usd, euro, pc\}$.

The results presented in Table 3 indicate a robust negative impact on investment (95% statistical significance) for uncertainty derived from inflation and EUR/RON exchange rate and a positive effect of exchange rate USD/RON uncertainty, as expected from the positive correlation between it and investment (Table 2).

In conclusion, the empirical experiments in this section revealed a consistent negative effect of macroeconomic uncertainty on the aggregate investment, after evaluating the effect of some standard determinants of investment. This confirms results in earlier empirical studies.

I considered also an equation with all three primary measures of uncertainty. This model (Table 3, Column 6) shows the simultaneity of the impact of uncertainty of inflation with the measures from exchange rates, more precisely, if adding the influence of uncertainty from exchange rates, the effect of inflation uncertainty on investment has lower relevance (82% statistical significance as against 95%). This fact sustains the assertion that the increase in exchange rate volatility makes the price impact on the relative profitability of investment less important.

The fact that all three indicators share a good deal of common information suggests an alternative empirical approach based on a summary measure of uncertainty encompassing the unpredictable components of all macroeconomic measures of uncertainty. To explore this track, a new equation is constructed using the first principal component of these measures (Uc_pc).

All of the conventional investment determinants carry significant coefficients of the anticipated sign, and their magnitude is in most cases larger than that obtained by the preceding estimation methods.

For all models, the influence of the determinants of relative cost of capital goods is negative and the effect of current GDP and lag –1 of investment is positive, which is consistent with the theory of accelerator.

There is also very interesting to evaluate the nonlinear effect of uncertainty on investment, therefore I estimate a model with a quadratic f with respect to uncertainty and linear with respect to the other assumptions:

$$I_t = \alpha I_{t-1} + \beta PIB_t + \gamma PIB_{t-1} + \delta IR + \pi_i Uc\_i + \tau Uc\_i^2 + \varepsilon_t \qquad (3'')$$

where: $i \in \{\inf, usd, euro, pc\}$.

Upgrading the model from linear to quadratic we test if the relation investment-uncertainty can be described by an inverse U-curve.

From Table 4 one realizes that this hypothesis is only true for the uncertainty of USD/RON exchange rate, when the coefficient of the quadratic term is negative and that of the linear term of uncertainty is significantly positive. This fact was expected from the positive sign (different from the other correlation) of the correlation between investment and the volatility of the unpredictable component of this variable.

The shape of inverse U-curve of this dependence means that for low levels of uncertainty in USD/RON exchange rate the investment-uncertainty relationship is positive, while for high levels of uncertainty this influences negatively the investment. In the interval of the values of uncertainty [0.001489, 0.1237] both positive and negative effects are comprised.

The theoretical explanations for the non-linear investment-uncertainty relationship refer to the presence of the propensity to risk for the low levels of uncertainty.

An alternative explanation considers a threshold, which if exceeded by the current value of the present value of future profits make the firms invest. At the moment of investment, the present value of the project is known, while in time, after this moment the future value is uncertain with a dispersion, which increases in time. The increase in the uncertainty value leads to rise in the investment threshold and, on the other side, increased uncertainty augments the probability of bypassing it and, therefore, the investment becomes profitable. Thus, the increase in uncertainty with moderate levels can augment investment.

Conclusions

The impact of uncertainty on aggregate investment was studied, theoretical models were proposed, but with different predictions in the sense and direction of investment-uncertainty relationship. Also, empirical macroeconomic studies obtained different results. For these reasons, the sense of this relationship is unknown and could be found out only empirically from the history of the process at some moment.

Some empirical models do not consider other investment determinants, trying to explain only the effect of uncertainty on investment. Disregarding these factors leaves open the question whether uncertainty has an independent impact on investment and to what extent.

Some models are linear, but others are quadratic.

In this paper, I tried to analyze the nonlinear effect of uncertainty on investment and in the context of the influence of important investment determinants. I considered four measures of macroeconomic uncertainty, three of them evaluated as conditional standard deviation from GARCH volatility models and one as their first principal component.

These macroeconomic measures of uncertainty were introduced into some linear and quadratic models of investment, solved by the GMM technique.

The best ones harmonizing with theory were those using uncertainty of the USD/RON exchange rate. The linear model shows a significant negative impact of uncertainty on investment, but a non-linear model better described this influence when the function involved was quadratic for uncertainty and linear for the rest of the investment determinant factors. This function was found to be an inverse U-curve consistent with the theory that states that low levels of uncertainty have a positive impact and a negative one above some threshold.

For the other uncertainty measures, the negative effects in the linear case, as well as the accelerator effect of the investment-GDP relation were highlighted.

References

Abel, Andrew B., and Janice C. Eberly, (1994), "A Unified Model of Investment Under Uncertainty", *The American Economic Review,* 84(5): 1369-84.

Aizenman, Joshua and Nancy Marion, (1995), "Volatility, Investment and Disappointment Aversion", *NBER* Working Paper No.5386.

Bollerslev, T. (1986), "Generalized Autoregressive Conditional Heteroskedasticity", *Journal of Econometrics*, 31: 307-327.

Caballero, Ricardo J. (1991), "On the Sign of the Investment-Uncertainty Relationship", *American Economic Review,* 81(1): 279-88.

Federer, J. (1993), "The Impact of Uncertainty on Aggregate Investment Spending", *Journal of Money, Credit and Banking,* 25: 30-48..

Hall, S.G., Yhap, B. (2008), "Measuring the Correlation of Shocks between the UK and the Core of Europe", *Romanian Journal of Economic Forecasting*, 9(1): 17-26

Lensink, R. (2002), "Is the Uncertainty-Investment Link Non-linear?", *Review of World Economics*, 138(1): 131-147.

Pederzoli C. (2006), "Stochastic volatility and GARCH: a comparison based on UK stock data", *The European Journal of Finance*, 12(1): 41-59.

Pindyck, R. and A. Solimano, (1993). "Economic Instability and Aggregate Investment", *NBER Macroeconomics Annual,* 8: 259-303.

Price, S. (1995), "Aggregate Uncertainty, Capacity Utilization and Manufacturing Investment", *Applied Economics,* 27: 147-54.

Miles, William, (2009), "Irreversibility, Uncertainty and Housing Investment", *Journal of Real Estate Finance Economics*, 38:173–182.

Zeira, J. (1990), "Cost uncertainty and the rate of investment", *Journal of Economic Dynamics and Control*, 14(1): 53-63.

Table 1

Alternative GARCH Model Specification for measuring uncertainty

	Regressors in equation (1)	Specification	Residual tests		Mean	Standard deviation
			ARCH(5) p-value	Q(10)-statistic p_value		
Uc_inf (monthly, 104 obs.)	inf(-1),inf(-2)	GARCH(1,1)	0.63	0.418	0.0028	0.0016
Uc_usd (daily, 3655obs)	dlog(usd(-1))	GARCH(1,1)	0.9383	0.679	0.0051	0.0028
Uc_euro (daily, 3655obs)	dlog(euro(-1))	GARCH(2,1)	0.1074	0.14	0.0059	0.0020
Uc_pc		First Principal Component of (*Uc_inf, Uc_usd, Uc_euro)*			0.0074	0.0023

Table 2

Correlation between investment (I) and alternative measures of uncertainty

	I(investment)	***Uc_inf***	***Uc_usd***	***Uc_euro***	***Uc_pc***
I(investment)	1				
Uc_inf	-0.482	1			
Uc_usd	0.187	-0.526	1		
Uc_euro	-0.393	0.371	0.401	1	
Uc_pc	-0.089	-0.144	0.870	0.800	1

Table 3

The impact of uncertainty on investment (linear case)

$I_t = \alpha I_{t-1} + \beta PIB_t + \gamma PIB_{t-1} + \delta IR + \pi_i Uc\_i + \varepsilon_t$ $i \in \{\inf, usd, euro, pc\}$					
I_{t-1}	0.695820 (0.208) 0.0012	0.9563 (0.0798) 0.0000	0.838797 (0.164207) 0.0000	1.572732 (0.16428) 0.0000	0.571605 (0.200231) 0.0053
PIB_t	1.9326 (0.3694) 0.0000	2.01328 (0.138662) 0.0000	2.152218 (0.401756) 0.0000	2.796800 (0.357531) 0.0000	2.011344 (0.327436) 0.0000

PIB_{t-1}	-1.4296 (0.5357) 0.0090	-1.835885 (0.4047) 0.000	-1.819758 (0.192069) 0.000	-3.117900 (0.459127) 0.0000	-1.265719 (0.480253) 0.0099
IR	-1.743466 (0.6536) 0.0090	-1.069187 (0.462193) 0.0229	-1.067787 (0.938313) 0.2581	-1.128784 (0.602534) 0.0642	-2.773763 (0.933053) 0.0038
Uc_inf	-24.7430 (11.9866) 0.0418				-14.99683 (11.08882) 0.1796
Uc_usd		4.849690 (3.244068) 0.1383			22.07302 (11.52197) 0.0586
Uc_euro			-43.29544 (22.32305) 0.0555		-19.93476 (12.90851) 0.1260
Uc_pc				3.752777 (3.306237) 0.2593	
Wald test p_value	H_0 π =0, δ =0 0.0165	H_0 π =0, δ =0 0.0710	H_0 π =0, δ =0 0.1688		H_0 $\pi_{\inf}$ =0, π_{usd} =0, π_{euro} =0 0.0376
Instru-ments	$I_{t-2,...,t.-4}$ $PIB_{t-2,...,t.-4}$ $Uc\_inf_{t-1,...,t-3}$ IR_{t-1}	$I_{t-2,...,t.-4}$ $PIB_{t-2,...,t.-4}$ $Uc\_usd_{t-1,...,t-3}$ IR_{t-1}	$I_{t-2,...,t.-4}$ $PIB_{t-2,...,t.-4}$ $Uc\_euro_{t-4,...,t-}$ $IR_{t-1,t-2}$	$I_{t-2,...,t.-4}$ $PIB_{t-2,...,t.-4}$ $Uc\_pc_{t-1,...,t-3}$ IR_{t-1}	$I_{t-2,...,t.-4}$ $PIB_{t-2,t.-3}$ $Uc\_inf_{t-1,t-2}$ $Uc\_usd_{t-1,t-2}$ $Uc\_euro_{t-1,t-2}$ IR_{t-1}
Adj. R^2	0.855093	0.871570	0.718159	0.675989	0.791744
SE	0.075223	0.072301	0.104907	0.114840	0.090178
Jstatistic	0.104948	0.117820	0.070429	0.108807	0.089875

Note: For each coefficient are presented standard errors, which are heteroskedasticity consistent (in brackets) and p-value of the t-statistic on the next row

Table 4

The impact of uncertainty on investment (non-linear case)

$I_t = \alpha I_{t-1} + \beta PIB_t + \gamma PIB_{t-1} + \delta IR + \pi_i Uc\_i + \tau_i Uc\_i^2 + \varepsilon_t$ $i \in \{\inf, usd, euro, pc\}$				
I_{t-1}	0.883487 (0.451043) 0.0532	1.014513 (0.192640) 0.0000	0.975238 (0.117491) 0.0000	1.342353 (0.201234) 0.0000
PIB_t	2.786763 (0.740555) 0.0003	2.118354 (0.219847) 0.0000	2.274374 (0.238391) 0.0000	3.161168 (0.539211) 0.0000
PIB_{t-1}	-2.349981 (1.172727) 0.0481	-1.920076 (0.306115) 0.0000	-2.008901 (0.298127) 0.0000	-3.081924 (0.650855) 0.0000
IR	-1.765540 (1.236797) 0.1569	-2.113943 (0.514042) 0.0001	-1.257231 (0.430414) 0.0044	-1.883055 (1.022863) 0.0689
i	inf	usd	euro	pc
Uc_i	-351.4919 (166.9640) 0.0381	165.7263 (63.60387) 0.0107	-114.8155 (55.61154) 0.0418	-122.0154 (136.4775) 0.3737
Uc_i^2	53019.23 (27147.61) 0.0539	-14001.68 (5838.772) 0.0185	8659.124 (4772.468) 0.0729	6744.566 (7620.998) 0.3785
Wald test p_value	H_0 $\pi_i = 0, \tau_i = 0$ 0.0097	H_0 $\pi_i = 0, \tau_i = 0$ 0.1801	H_0 $\pi_i = 0, \tau_i = 0$ 0.0091	H_0 $\pi_i = 0, \tau_i = 0$ 0.6678
Instru-ments	$I_{t-2,...,t.4}$ $PIB_{t-2,...,t.4}$ $Ic\_\inf_{t-1,...,t-3}$ $IR_{t-1,t-2}$	$I_{t-2,t.-3}$ $PIB_{t-2,...,t-4}$ $Ic\_usd_{t-1,...,t-3}$ $IR_{t-1,t-2}$	$I_{t-2,t.-3}$ $PIB_{t-2,...,t-4}$ $Ic\_euro_{t-1,...,t-3}$ $IR_{t-1,t-2}$	$I_{t-2,...,t.4}$ $PIB_{t-2,...,t-4}$ $Ic\_pc_{t-1,...,t-3}$
Adj. R^2	0.442811	0.532725	0.816903	0.528670
SE	0.147679	0.135038	0.084530	0.135664
J-statistic	0.026368	0.071400	0.069796	0.043352

Note: For each coefficient are presented standard errors, which are heteroskedasticity consistent (in brackets) and p-value of the t-statistic on the next row